[text-dist] 8.02

The Paradox of Hakka Tone Sandhi

Matthew Y Chen
City University of Hong Kong

Wee Lian-Hee
Rutgers University

Yan Xiu-Hong
Shantou University

For correspondence:

Matthew Y Chen
Faculty of Humanities and Social Sciences
City University of Hong Kong
Tat Chee Avenue, Kowloon Tong, Hong Kong

Email: fhmychen@cityu.edu.hk)
Tel: (852) 2788-7472

Abstract*

The Hakka dialect of Changting, China, exhibits extraordinarily intricate tone sandhi phenomena that present a formidable analytical challenge for any theoretical model. The problem is not unlike what one encounters in rudimentary arithmetic. The value of 2 + 3 x 4 depends on whether addition or multiplication comes first:

2 + (3 x 4) = 14

(2 + 3) x 4 = 20

The ultimate outcome is determined by the orderly combination of the elementary operations. Likewise, given a tonal sequence /ABC/, the phonetic form is predictable from the elementary sandhi rules that operate on either AB, then BC, or vice versa. In this paper we offer a fair sample of the empirical facts instantiating this “directioality” effect (to use an orthographic metaphor), and investigate the various logistic moves both Optimality Theory and conventional rule-based derivational model could make to render an account of the attested facts.

* Work leading to this paper was supported in part by a Competitive Earmarked Research Grant awarded by the Research Grant Council of Hong Kong, and by a Strategic Research Grant given by the City University of Hong Kong, in both cases with the first author as PI. These grants made it possible for the remaining two co-authors and our Hakka informant to spend extended periods of time at the Institute of Chinese Linguistics, City University of Hong Kong during 2000-2002.

The full range of Hakka data will be reported in a forthcoming monograph.

1. Introduction

The Changting variety of Hakka Chinese displays a complex pattern of contextually conditioned tonal substitutions. While it is patently clear that the sandhi form of a multitonal string like ABC is predictable from the simple rules governing two-tone substrings (AB, BC), it is not at all clear how these elementary operations combine to produce the attested ultimate output. The problem would be trivial if rule application were (a) unidirectional, i.e. consistently from left to right, or from right to left; or (b) cyclic, i.e. with sandhi rules applying to ever-larger morphosyntactic or prosodic constituents; or (c) consistently ordered, extrinsically (by stipulation) or intrinsically (by appeal to some such constraints as transparency, derivational economy, and so forth). It will become apparent that none of the above is consistent with the observed facts of Hakka.

After a brief factual description of the basic facts of Hakka tone sandhi (sections 2-3), we state the crux of the problem more explicit in section 4. In section 5 we note two general observations, namely the logical possibility of chain tonal substitution, in some cases involving infinite recursion and “backtracking”, neither of which actually occur. We can filter out these logically possible but non-occurring cases by means of what we call “Moving Window” constraint. The problem then boils down to what general principles govern the orderly application of sandhi rules to guarantee the attested outputs. Ordering of sandhi rules are demonstrably inadequate (section 6), while attempts at identifying general principles that govern directional rule application have also failed (section 7 and 8). Having shown that all standard rule-based approaches fail to rise to meet the analytical challenge of Hakka tone sandhi, we turn to Optimality Theory (OT) for inspiration -- with equally disappointing results (sections 9-13).

In this paper we sketch the most salient facts, present a number of potential analyses, and point out why none of the latter proves to be satisfactory. Given the state of the art, the case of Hakka tone sandhi appears to stand as an unmet analytical challenge. We invite our readers to use the Hakka data as a testing ground for sharpening, extending, and perhaps radically reconceptualizing linguistic theory.

2. Background

The variety of dialect that is of focal interest to us belongs to the Hakka group (also known as Kejia by its Pinyin transliteration), one of the 10 major dialect groups of the Sinitic family. It is spoken within the urban area of Changting county seat located in southwest Fujian province on the southeastern coast of China (see Chinese Academy of Social Sciences et al. 1987-90). The number of native speakers of the urban variety of Changting is estimated at close to 50,000.[1] For convenience, we will refer to this particular dialect by its generic name of Hakka.

Hakka tone sandhi was first reported in Li (1965). Since then, Luo (1982) and Rao (1987) have added substantially to the store of empirical data. Hsu (1994) offered the first serious analysis, which was further developed in Chen (2000, ch.4)[2]. The data that formed the empirical base of our study was collected during a six months period of intensive fieldwork in 2001 with Luo Meizhen as our informant[3].

Hakka has a 5-tone system given below:

---

1 The Changting county, including the surrounding rural districts, has a population of approximately 480,000. The Hakka group as a whole has roughly 35 million speakers, scattered over a wide geographical area, including the provinces of Jiangxi, Fujian, Guangdong and Taiwan (cf. Chen 2000:3).

2 Hsu (2002) came to our attention as this manuscript reached its final stages.

3 Luo, a pioneer investigator of Changting Hakka, is affiliated with the Institute of Nationality Studies, Chinese Academy of Social Sciences, Beijing.

Table 1

	Level	Rising	Falling
High	H 55		
Mid	M 33	R 24	F 42
Low	L 11		

H, M, L stand for high, mid, low level tones, with the phonetic values [55, 33, 11], where pitch levels are indicated as 1 (low) to 5 (high) on a five-point tonal scale according to the widely accepted notational convention introduced by Y-R. Chao (1930).[4] Correspondingly, R and F signify rising and falling tones respectively.

Aside from inherently toneless morphemes (notably grammatical particles), each syllable is associated with a lexically specified tonal category. Furthermore, as in many Chinese dialects, tonal juxtaposition triggers changes known as tone sandhi.[5] Table 2 encapsulates the sandhi phenomena occurring in two-tone strings.

---

[4] The low level tone [11] is actually low-falling [21]. For our purposes, we ignore this fine phonetic detail, presumably of an intonational nature.

It is worth pointing out that the Chinese notation is exactly the opposite of the convention that prevails in African and Amerindian tonological literature: in the latter, 1 is high, 5 is low.

[5] For an overview, see Chen (2000) and copious references cited therein.

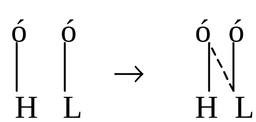
Table 2

2nd / 1st	H	M	L	R	F
H		FM	FL	FR	
M			LL	LR	
L	MH	MM			MF
R		HM	RF		
F	LH; FM	RM	RF	LR	MF

Down the left column and across the top row of Table 2 are specified the underlying forms of the five tonal categories associated with the first and the second syllable respectively. The sandhi forms are given in the cells, where the relevant column and row intersect. Thus the input string /HL/, i.e. where the H-row and L-column meet, the cell gives [FL] as the sandhi output, with H transformed into a falling tone. Cells representing two-tone strings that do not give rise to sandhi change remain blank and are shaded. For instance, /RH, RR, RF/ cells are shaded in Table 2.

The sandhi process /HL/ → [FL] alluded to above instantiates a common regressive tone spread, made more perspicuous in the conventional autosegmental notation of (2.1):

(2.1)



As a matter of fact, many of the attested sandhi processes are amenable to similar treatment. Since our focus of interest lies elsewhere, we will not pursue this line of formal re-statement. Instead, we will let Table 2 stand as a shorthand or synopsis of the two-tone input/output correspondences. For our purposes, suffice it to say that tone sandhi in Hakka is predominantly “backward” or regressive (2.2a,b,c); however, there are two other types, namely “forward” (2.3a,b) and “bidirectional” sandhi (2.4).

(2.2) Backward sandhi

a. M, L $\rightarrow$ M / ___ H, M, F
L / ___ L, R

b. R $\rightarrow$ H / ___ M

c. H $\rightarrow$ F / ___ M, R, L

d. F $\rightarrow$ R / ___ M
L / ___ R, H
M / ___ F

(2.3) Forward sandhi

a. L $\rightarrow$ F / R ___
b. H $\rightarrow$ M / F ___

(2.4) Bidirectional sandhi

FL $\rightarrow$ RF

These sandhi processes are exemplified in Table 3.

Table 3

Base form	***Sandhi form***	***Example***[6]	***Gloss***
HM	FM	*song.shu*	"to give book (as present)"
HR	FR	*xi.jie*	"details"
HL	FL	*ban.ye*	"midnight"
ML	LL	*zhong.xue*	"middle school" (high school)
MR	LR	*fan.shu*	"sweet potato"
LM	MM	*bai.ma*	"white horse"
LF	MF	*mao.xian*	"to take risk"
LH	MH	*jiu.huo*	"old merchandise"
RM	HM	*tao.hua*	"peach blossom"
RL	RF	*bei.ji*	"north pole"
FH	LH	*jian.jia*	"to cut price"
	FM	*hao.xiao*	"funny, laughable"
FM	RM	*huo.che*	"train"
FL	RF	*li.mao*	"courtesy"
FR	LR	*wu.shi*	"noon time"
FF	MF	*xuan.ju*	"to elect"

3. Tritonal sandhi

So far Hakka tells a familiar story that is repeated in any number of Chinese dialects (cf. Chen 2000). But, what happens to longer strings of tone-bearing syllables? To find out, we have systematically investigated the sandhi behavior of multisyllabic expressions in Hakka. In this article, we will focus mainly on three-tone constructions. Given a five-

[6] Examples are transcribed in standard Pinyin rather than IPA, since segmental content exerts no detectable influence on sandhi behavior. Syllables are separated by a dot [.].

tone system, an n-long tonal string, there are 5^n combinatorial possibilities. Thus a trisyllabic sequence can carry any one of the 125 tonal patterns (= 5^3). For each tonal pattern we constructed a dozen or so examples, subdivided into three morphosyntactic configurations (a) right-branching: A[BC] or 1+2; (b) left-branching: [AB]C or 2+1; and (c) flat: ABC or 1+1+1. As it turned out, in our informant's speech, a given tonal pattern may have one to four different sandhi forms, while any particular example may have up to three variant readings. Consider the input form /RML/ in Table 4. It yields four different sandhi forms: [HLL, RFL, HML, RLL]. However, no one example has more than three alternative phonetic forms. Details of the distribution of the sandhi forms among the construction types are given in Table 4.

Table 4. Base form: /RML/

Examples \ Sandhi forms		a. HLL	b. RFL	c. HML	d. RLL
2+1	*[liang.xin] hua* "words from the heart"	x	x	x	
	[chang.ting] hua "Changting dialect"	x	x		
	[yi.jin] dou "one catty of beans"	x	x	x	
	[jue.xin] ban "resolved to do it"	x	x	x	
	[liang.xin] huai "(have) bad conscience"	x	x	x	
	[liu.dong] hui "Liu Dong can"			x	
1+2	*tan [xin.shi]* "speak confidentially"	x	x		x
	nan [kai.ye] "hard to start a business"	x	x		x
	lai [kai.hui] "come to attend a meeting"	x	x		x
	xing [gong.lu] "take the highway"	x	x		x
	liu [kai.hui] "Liu attends a meeting"	x	x		x
1+1+1	ba.san.er "eight-three-two"		x		

'x' indicates that a sandhi form is attested for a particular example.

Tone pattern /RML/ represents a limiting case with a total of 31 readings associated with 12 examples. The majority of tone patterns yield fewer sandhi forms, and each example typically has a single reading or two alternants, especially when optional morphosyntactic blockages are discounted (see below). On average, each tritonal combination has about 16 readings. The subcorpus we have assembled consists of 1,814 recorded tokens of trisyllabic forms.

4. The problématique

What is the relationship between polysyllabic patterns and the disyllabic ones? In principle the sandhi rules that govern tritonal and longer strings may be totally independent of the ditonal processes.[7] However, the most fundamental assertion one can make about the polysyllabic forms of Hakka is that they are derivatives of the more basic disyllabic substrings. Setting aside a handful of exceptions, most of the attested 125 tritonal patterns are derivable from some combination of the more rudimentary processes already established in section 2 (table 2 and rules (2.2-4). Recall the limiting case of /RML/. It has four different sandhi forms [HLL, RFL, HML, RLL]. The remarkable fact is that some orderly application of the 2TS rules generates *all and only* the four attested sandhi forms. Specifically, the tritonal string /R-M-L/ contains two sandhi sites, marked with a hyphen [X-Y]; depending on which pair of tones (R-M or M-L) undergoes 2TS first, the step-wise derivation produces either [HLL] or [RFL] as the output. This is illustrated below:

---

[7] Such is the case of Yantai polysyllabic sandhi, reported in Chen (2000:99f).

(4.1) a. RML (⇨)
|
HML ≺
|
HLL

b. RML (⇦)
|
RLL ≺
|
RFL

Legend: XY = tonal substring being scanned or operated on.
Shaft ("|") connects the target input (top) and the corresponding output (bottom).
⇨, ⇦ left to right; right to left
≺ attested intermediate form

In describing the derivational history of illustrative cases, we employ the following convention. Underlining highlights the substring being scanned by the lementary tow-tone sandhi (2TS) rules. The vertical shaft connects the target input tone(s) and its/their corresponding output(s). Thus, in (4.1a), 2TS rules scan the input from left to right (directionality symbolized by the arrow "⇨"), selecting the first two tones RM as the "local window" of operation. The shaft connects R (input) on the top to H (output) on the next line. The "local window" then moves further to the right, this time focusing on the substring ML and so forth, until it produces [HLL] as the output. Likewise, (4.1b) operates in the opposite direction ("⇦"). We are, therefore using directionality as a metaphor for the orderly sequence of rule application.

How about [HML] and [RLL]? Notice that [HML] and [RLL] are none other than some 'intermediate' outputs of (4.1a) and (4.1b) respectively, marked here with the symbol "≺". Notice further that the distribution of [HML] and [RLL] is structure-sensitive: the former occurs only with left-branching (2+1) expressions, while the latter is attested only with right-branching (1+2) examples. This state of affairs can be expressed quite simply as morphosyntactic blocking: tone sandhi is optionally blocked at morphosyntactically defined junctures specified below:

(4.2) i. $[[AB]_a \# C_b]_{X'}$

ii. $[A_a \# [BC]_b]_{X'}$

where "#" marks potential blockage site. Typically, tone sandhi is blocked in phrasal construction rather than lexical compounds (hence X'), with the internal constituents *a* and *b* standing in subject-predicate or verb-object relation. It is worth noting that blockage in (4.3) is unattested:

(4.3) i. [[A # B] C]

ii. [A [B # C]]

Schematically, therefore:

(4.4) a. [[RM] # L]
 |
HM # L

n/a

b. [R # [ML]]
 |
R # LL

n/a

n/a = 2TS blocked, not applicable

As noted before, /R-M-L/ has two potential sandhi sites (marked with "-"). Since one of them is blocked ("#"), 2TS applies to the remaining two-tone substring, giving rise to (4.4a) and (4.4b).

What does this mean for linguistic theory? In our telling, the Hakka story has been couched in terms of rule-based derivation. But given the paradigm shift of Optimality Theory (OT), rules, let alone orderly rule application,[8] are no longer part of the theoretical vocabulary. How can we then begin to make sense of these facts, and construct a coherent narrative using the concepts and analytical tools of OT? To put the problématique in sharper focus, recall that the input /RML/ can in principle correspond to any tonal string. Assuming that output candidates are restricted by the repertoire of underlying tonal categories, the optimal candidate(s) can be any one or any subset of the 125 combinatorial possibilities (= 5^3). How to pick from this multitude of tonal strings those and only those attested sandhi forms is a daunting task, esp. in view of the fact that the attested outputs [HLL, RFL, HML, RLL] do not necessarily improve on the input /RML/. Let us assume that certain tonal combinations are better than others. The best combinations are those that are given phonetic expression without further alteration – namely /HF, HH, MM, MF, MH…/, the two-tone combinations occupying the shaded cells in Table 2. All other tonal juxtapositions deviate in varying degrees from the input in the interest of more harmonic tonotactic collocation. Viewed in this light, the output [HML], for instance, does not improve on the input /RML/ in any obvious way. The input and the output differ only in the first tone. Both substrings [HM] and /RM/ are illformed in that both are tonotactically restricted, and are expected to turn into [FM] and [HM] respectively, according to Table 2. In this sense, both [HML] and /RML/ are equally

[8] There is, of course, a substantial literature on rule ordering. For a recent survey, see Iverson (1995).

marked. It goes without saying, the problem alluded to above is magnified if outputs are not restricted by the input repertoire.[9]

In sections 9 to 13, we will return to the question of how OT might deal with the Hakka case. The challenge that Changting Hakka tone sandhi throws at classical derivational theory is no less daunting. We have established the generalization that tritonal strings of Hakka can be derived from the some orderly application of the elementary rules operating on ditonal substrings. The expression “orderly application” covers a host of analytical problems, which we now proceed to detail in the subsequent sections.

5. Chains and Loops

5.1. Loops: infinite recursion

Unlike some garden variety phonological rules, tone sandhi rules can, in principle apply persistently (apply whenever applicable) and iteratively (i.e. to their own outputs).[10] As a consequence, one fairly common characteristic of tone sandhi rules is chain substitution, in some cases resulting in a loop, resembling that of the English “great vowel shift” (cf. Chomsky-Halle 1968). The most celebrated case of tonal chain shift is that of Xiamen (see references given in Chen 2000:519f). If anything, the Hakka case is even more complex. For one thing, in the environment __M, R   H, H   F, and F   R (see section 2, rule (2.2b,c,d)), creating a loop:

---

9 It is quite common among Chinese dialects for tone sandhi rules to generate new phonetic tone shapes not attested in citation forms.

10 For iterative rule application, see Howard (1972), Kenstowicz & Kisseberth (1977); for persistent rules, see Chafe (1968) and Myers (1991).

(5.1) RM
|
HM by rule (2.2b)
|
FM by rule (2.2c)
|
RM by rule (2.2d)
|
… > loop

The situation is rendered more complicated by the fact that the environment [__M] can be itself derived from the operation of other sandhi rule. This is exemplified below:

(5.2) /RFF/ → [HMF]

e.g. *[fu.xie] zhi* "carbon paper"
xun [xiao.li] "to look for Xiao Li"

RFF
|
RMF (a) attested in [A # [BC]] structures
|
HMF (b) attested
|
FMF (c) *
|
RMF (d) *
|
… > loop

Symbol: * = not attested

The underlying string /RF-F/ comprises only one sandhi site (marked by hyphen). The substring FF → MF, which in turn creates the (__M) window that triggers the chain reaction. By its nature, this kind of chain substitution potentially entails infinite recursion, and cannot be internally ordered. Notice that neither (c) nor (d) is attested (marked by an asterisk).

5.2. Chain substitutions and backtracking

Even where substitutions forming a loop is not involved, "unregulated" trafficking of sandhi rules can lead to a long chain of derivational steps, wildly over-generating outputs unattested in Hakka. Take /FHL/ as an example.

(5.3) /FHL/ [LFL]

e.g. *[tong.ji] xue* "statistics"
xiao [qi.hou] "micro-climate"

FHL
|
LHL (a) attested in [[AB] # C] structures
|
LFL (b) attested
|
MFL (c) *
| |
MRF (d) *
|
LRF (e) *

Proceeding from left to right, the substring FH → LH. In [[AB] # C] structures, tone sandhi optionally stops at this point, producing output (5.3a) [LHL]. Otherwise, as the two-tone window moves rightwards, HL → FL, resulting in reading (b) [LFL]. At this point, if we "*backtrack*" and move the local window back to the first two syllables [LFL], 2TS in principle can apply to generate [MFL] (c). Scanning again further to the right, 2TS turns [MFL] (c) into [MRF] (d). This back and forth scanning eventually yields [LRF] (e), to which no further rules apply. It is important to note that the theoretically possible forms of (c, d, e) never occurred in our Hakka corpus.

To prevent the overgeneration of unattested forms like (5.3c,d,e) we need to appeal to a powerful global constraint against "backtracking". No-Backtracking basically imposes a “unidirectional” scanning or movement of the “local window” of 2TS. Thus, in a left to right scan, once we reach the end of the line in (5.3b), the derivation stops there. No-Backtracking effectively puts an end to the derivation at step (5.3b), thereby barring (5.3c,d,e) from ever surfacing.

Observationally speaking, No-Backtracking is an extremely robust constraint on phonological processing. We have found not a single counter-example in our subcorpus of 2,000 or so tokens of three-tone patterns. For the moment we state this constraint simply as (5.4) (cf. Chen 2000:116):

(5.4) No-Backtracking

Do not backtrack.

5.3 Moving Window Constraint

Powerful as No-Backtracking may be, it is far from an adequate answer to the problem of over-generation at hand. Derivation (5.3) is by no means the only logically possible path. (5.5) represents an alternative course of events:

```
(5.5)   FHL
         |
        LHL        (a)  =   (5.3a)
          |
        LFL        (b)  =   (5.3b)
         | |
        LRF        (c)  *
```

In particular, the derived substring FL of (5.5b)   RF, with [LRF] as output (c), to which no further rules apply. The predicted reading (c) is unattested. Notice, though, derivation

(5.5) does not violate No-Backtracking. It merely applies further 2TS to the same disyllabic local window at the end of the trisyllabic structure.

One possible way of preventing derivations like (5.5) is to appeal to what Hsu (1994 cf. 2002) calls One Step Principle, which we paraphrase as follows:

(5.6) One Step Principle

Sandhi rules are barred from applying to an input that has been previously altered.

One Step Principle effectively blocks not only loops of infinite recursion like (5.1-2), but also backtracking cases like (5.3) and long chains of serial applications like (5.5). However, it would also wrongly rule in cases like (5.7) and rule out cases like (5.8).

(5.7) /FH/ → [FM]

e.g. *hao.xiao* "funny, laughable"

FH
|
FM (a)
|
RM (b) *

(5.8) /RML/ → [RFL]

e.g. *[chang.ting] hua* "Changting dialect"
xing [gong.lu] "take the highway"

RML
|
RLL (a)
|
RFL (b)

In (5.7), /FH/ → [FM] by progressive tone sandhi, which in turn creates the appropriate environment that triggers a regressive sandhi, whereby [FM] → [RM] (see table 2). This chain of events in no way contravenes One Step Principle. This principle is therefore powerless in preventing 2TS from overapplying to generate the unattested output [RM]*.

As for (5.8), notice that the tone occupying the middle position changes from /M/ to [L], then to [F], as instantiated by the attested ultimate output [RFL]. As stated, One Step Principle fails to discriminate (5.8) from other superficially similar cases. What is crucial in (5.8) is that no 2TS rule applies to the same two-tone window. Notice in particular, the tone in the middle position /M/ first turns into L by virtue of 2TS rule that applies within the /ML/ window; this intermediate L further changes into F by virtue of another 2TS that focuses on it in a different two-tone window consisting of RL.

We can combine No-Backtracking and One Step Principle into one single constraint, which we may refer to as the Moving Window constraint:

(5.9) Moving Window Constraint

2TS may not apply to the same local window more than once.

To better discriminate between Moving Window and other related constraints, we distinguish four different cases, schematically represented below:

(5.10) AB (a)
 |
AC (b)
|
DC (c)

(5.11) ABC (a)
|
DBC (b)
|
EBC (c)
|
ABC (d)

(5.12) ABC (a)
|
DBC (b)
|
DEC (c)
|
FEC… (d)

(5.13) ABC (a)
|
ADC (b)
|
AEC (c)

The Moving Window constraint prohibits (5.10), because two different 2TS rules apply to the same two-tone window. Notice that (5.10) violates neither One-Step Principle nor No Backtracking. Likewise Moving Window forbids (5.12), because tone sandhi (not necessarily the same rule) scans the same two-tone window twice, once at step (a), again at step (c). It is clear that the sameness or difference of the local window is defined *positionally*, not in terms of the identity of the constituent tones. Crucially, Moving Window Constraint correctly makes allowance for (5.13), which is wrongly excluded by One Step Principle. In (5.13) the middle tone B first changes to D by backward sandhi operating on the last two tones (5.13b). The local window then moves leftwards to the first two positions; accordingly, forward sandhi turns D into E.

Note that (5.7) and (5.8) instantiate cases (5.10) and (5.13) exactly; (5.14) differs from (5.13) only trivially in that the "bidirectional" 2TS rule operating on the FL window changes both constituent tones:

(5.14) /FML/ [RFL]

e.g. *[pu.tong] hua* "putonghua" (lingua franca)
zong [si.ling] "commander in chief"

```
FML
  |
FLL        (a)
||
RFL        (b)
```

The Moving Window Constraint has essentially the same effect as "bracket erasure": once a rule or rules apply to a bracketed string, the brackets disappear, and no rules may further apply.[11] In this sense, the moving local windows (annotated by underlining) may be seen as a notational variant of bracketing. More fundamentally, Moving Window Constraint (whether or not expressed as bracket erasure) is clearly derivational in nature: its sole purpose is to "*monitor*" and keep track of "*derivational history*", and to prevent phonological rules from operating on previously scanned local windows.

In what follows we will assume the Moving Window principle as a controlling constraint on rule application. This effectively limits the scope of the problem to the following: given a three tone sequence, tone sandhi may apply at most twice, to two distinct substrings (local windows). The question is which of the two substrings undergoes tone sandhi first.

---

[11] Bracket erasure is related to cyclic rule application and lexical phonology. Cf. Mohanan (1986, 1995), Cole (1995). For subtle differences between bracket erasure, strict cyclicity and Moving Window, see discussioin in Chen (2000:114-8).

6. Directionality

To the fundamental question just posed above, directionality seems to hold the key.[12] This line of inquiry is strongly suggested by the following examples[13].

(6.1) /MRM/ → [LHM]

e.g. *[jin.yu] gang* "gold fish tank"
xin [bei.jing] "new Beijing"

a. <u>MR</u>M
| by MR rule
L<u>RM</u>
| by RM rule
LHM

b. M<u>RM</u>
| by RM rule
<u>MH</u>M
MR rule not applicable
MHM*
(no further rule applies)

By ordering MR rule before RM rule, we insure the attested output [LHM] (6.1a) and exclude the unattested [MHM]* (6.1b). But once we change the tonal configuration, the opposite rule ordering must prevail. In order to guarantee (6.2a) while barring (6.2b), we must reverse the precedence relation between MR and RM.

---

12 The best known cases of directional processes are syllabification (cf. discussion and overview in Kenstowicz 1994, Mester & Padgett 1993, Blevins 1995) and metrification (footing, cf. Hayes 1995, Crowhurst & Hewitt 1995). With respect to directional tone sandhi, see Chen (1999, 2000).

13 For expository convenience, we refer to an elementary 2TS rule by naming the input substring. Thus MR rule stands for: MR → LR, in accordance with the correspondence Table 2.

(6.2) /RMR/ $\rightarrow$ [HLR]

e.g. *[yu.gan] you* "cod liver oil"
zhuo [xin.xie] "wear new shoes"

a. RMR
| by RM rule
HMR
| by MR rule
HLR

b. RMR
| by MR rule
RLR
| RM rule not applicable; by RL rule
RFR*

The Hakka case is reminiscent of Tianjin, a northern Mandarin dialect. Having grappled with a similar analytical problem, Chen (1985, 1986) concluded that Tianjin represented a true paradox, where no known ordering relation among the sandhi rules was capable of yielding all and only attested results (cf. Chen 1987, Hung 1987, Tan 1987, and Zhang 1987).

Examples of the type given in (6.2) can be multiplied readily. We will cite only one additional instance of two rules in mutual bleeding order. (6.3a) argues for LM >> ML (where ">>" stands for "precede"), while (6.4a) demonstrates ML >> LM, both in a bleeding relation.

(6.3) /MLM/ $\rightarrow$ [MMM]

e.g. *[yi.shu] gao* “(to possess) excellent medical expertise”
wo [shi.zhai] “I am a vegetarian”

a. MLM
| by LM rule
MMM
ML rule not applicable; no further rules apply
MMM

b. MLM
| by ML rule
LLM
| by LM rule
LMM*

(6.4) /LML/ $\rightarrow$ [LLL]

e.g. *[ren.zhen] du* “seriously study”
jiu [she.hui] “old society”

a. LML
| by ML rule
LLL
LM rule not applicable; no further rules apply
LLL

b. LML
| by LM rule
MML
| by ML rule
MLL*

Table 5

Example	***Input***	***Output***	***Rule order***	***Direction***
(1)	/MRM/	[LHM]	MR rule >> RM rule	⇨
(2)	/RMR/	[HLR]	RM rule >> MR rule	⇨
(3)	/MLM/	[MMM]	LM rule >> ML rule	⇦
(4)	/LML/	[LLL]	ML rule >> LM rule	⇦

Note: “X >> Y” = X precedes Y

Table 5 summarizes the apparent ordering paradoxes inherent in the data. The paradox disappears when we look at the matter from the point of view of directionality. In (1,2) tone sandhi scans the input from left to right (indicated by “⇨”), and applies whichever relevant rule (MR or RM rule) in the order dictated by the constituent tonal configurations. The same procedure takes place in (3,4) – except that tone sandhi scans the trisyllabic string in the opposite direction, from right to left (“⇦”). In this light, rule ordering is merely a side effect of directional rule application. Therein lies the biggest challenge: how to ferret out the hidden principles that determine the temporal sequence (metaphorically “directionality”) in which elementary 2TS processes combine to generate the more complex tritonal patterns documented in our corpus.

7. Factors in determining directionality

We now turn our discussion to the fundamental issue of what principle or principles determine the directionality of rule application. A priori, here are some prime candidates as factors that may bear on the directionality of rule application:

(7.1)
- Structural Affinity (SA)
  Rules operate successively from the innermost bracketed morphosyntactic constituents to the outermost bracketed strings.

- Temporal Sequence (Temp)
  Rules apply from left to right, i.e. in sync with speech production.

- Transparency (Transp)
  Apply sandhi rules in transparent order.

- Wellformedness (WF)
  Select the derivation that produces tonotactically wellformed sequences, in accordance with Table 2.

- Derivational Economy (Econ)
  Pick the shortest derivational path.

- Markedness (Mark)
  Favor the directional rule applicaton that yields least marked tonal structures. Contour tones are more marked than level tones.

We will refer to these principles as derivational constraints, since they are either output constraints (WF, Mark) or constraints on the derivation itself (SA, Temp, Econ, Transp).

SA (Structural Affinity) is tantamount to cyclic application, with sandhi rules cyling on morphosyntactic structures. From the sample examples already alluded to above and many more to be cited below, we see that the same sandhi form holds for both [[AB]C] as well as [A[BC]] structures. We conclude therefore, SA is for the most part irrelevant, and will be ignored in the ensuing discussion.

Temp (Temporal Sequence) favors a uniform left to right directionality. As Chen (2000:119) puts it, “This bias for left to right directionality accords with common sense… It stands to reason that, other things being equal, phonological processing ideally coincides with the temporal sequencing of the planning and execution of articulatory events. A right to left processing, on the other hand, would require buffering of long stretches of speech in order to make current decisions dependent on materials many syllables away (cf. Levelt 1989).” Although strong supporting psycholinguistic evidence from speech encoding is still lacking,[14] we find suggestive typological evidence, for instance, in the predominantly left to right parsing of syllables into feet (cf. Hayes 1995).[15]

On the other hand, (tonotactic) WF (Wellformedness) and Transp (Transparency) favor, in principle, a right to left directionality. As pointed out above, tone sandhi in Hakka is, for the most part, regressive, with the target on the left, and the environment on the right. It follows that what process, if any, A undergoes depends on what, if anything, happens to its neighbor B on the right. Transp therefore clearly privileges a right to left directionality. Likewise, to the extent that sandhi rules turn a tonotactically illformed sequence into a wellformed one, WF also gives preference to the right to left directionality. WF and Transp are, of course, conceptually different constraints. This is illustrated below:

(7.2) /FFF/ [MMF, RMF]

a. FFF
|
M FF
  |
MMF

e.g. *[zong.tong] fu* “presidential palace”
zhi [yu.san] “paper umbrella”

---

[14] However, see Meyer (1990, 1991).
[15] For evidence of rightward footing in Shanghai, see Duanmu (1995, 1997).

b. FFF
|
FMF
|
RMF

e.g. *zhi [yu.san]* "paper umbrella"
(no example of [[AB] C] constructions)

In (7.2a) the output [MMF] is tonotactically wellformed, in that both [MM] and [MF] occupy the shaded cells of Table 2, and trigger no sandhi process. However, the output [MMF] is opaque in the sense that the initial F surfaces as M rather than R as expected, when F precedes the M tone (see Table 2). In other words, the F:M correspondence crucially depends on the intermediate output [MFF], no longer observable on the surface. In contrast, the final output [RMF] of (7.2b) is tonotactically illformed, because the substring [RM] is expected to turn into [HM]. On the other hand, the order of rule application is transparent in that the first F surfaces as R before (the surface) M, exactly as expected.[16]

Econ (Derivational Economy) and Mark (Markedness) could have a rightward or leftward bias depending on the specific tonal configuration. Thus, Econ favors bleeding and counterfeeding relations over feeding and counterbleeding order, regardless of directionality.

---

[16] Recall, as noted earlier, in certain cases acceptability of the output of directional application is structure-sensitive. Thus the output [RMF], result of right to left application, is attested only for right-branching structures like *zhi [yu.san]* "paper umbrella" (7.2b), but not for left-branching constructions like *[zong.tong] fu* "presidential palace".

8. Ranking paradox

As pointed out earlier, these derivational constraints potentially work at counter-purposes, forcing a rightward scan in some cases, while predicting a leftward sandhi process in others. Therein lies a potential source of explanation for the choice of direction of tone sandhi application given any tritonal sequence. By the same token, in order to render a satisfactory account of the Hakka facts before us, we need to establish an internally *consistent* hierarchy of dominance relations among these derivational constraints that holds across the entire body of data. This is the toughest challenge confronting us.

8.1 Contradictory rank order

Given five derivational constraints,[17] we have 10 pairs of rankable constraints. We have exhaustively tested the rank order holding between these 10 pairs of constraints, including transitive relations, against the 39 critical cases given below in Table 6[18].

---

17 That is the six principles listed in (7.1), minus Structural Affinity.

18 We omit other irrelevant or insignificant cases, which include: (a) tritonal patterns that do not contain any sandhi site (17 cases); (b) direction-neutral cases, i.e. where sandhi rules yield the same output regardless of directionality of application (49 patterns); (c) the singular case of /RML/, which is ambidirectional in the sense that it yields two equally acceptable sandhi forms ([HLL, RFL]) as predicted by sandhi rules operating in two opposite directions; (d) irregular patterns, i.e. tritonal forms not derivable from 2TS (12 out of 125).

Notice that there are very few /A-BC/ patterns because, as we have mentioned before, tone sandhi in Hakka is by and large regressive, this means that sandhi operation on the only sandhi site available (namely /A-B/ string/) will produce XBC output, without creating new sandhi sites in the BC substring. Hence, /A- BC/ is, by its nature, direction-neutral in most cases (29 out of 33).

Table 6

	A-B-C	AB-C	A-BC	Total
Left to Right	16	5	1	22
Right to left	11	11	2	24
Total	27	16	3	46

Legend: hyphen (“-”)indicates sandhi site

What became immediately obvious is that no consistent ranking is possible. This conclusion is easy to demonstrate. Before we proceed, let us delimit the realm of logically possible alternatives. First recall that the Moving Window constraint is inviolable. We can therefore eliminate from consideration all competing derivational paths that violate this peremptory constraint. Second, we ignore all truncated derivations attributable to morphosyntactic blocking: since there is only one single sandhi site in either [[AB]#C] or [A#[BC]], the question of directionality cannot in principle arise (see discussion in section 4). This limits competing derivations to exactly two: from left to right, or from right to left. Third, for expository simplicity, let us assume that the default directionality is Left to Right, consistent with Temp. The question then boils down to what constraints, singly or jointly, override Temp, thereby imposing a right to left direction in a subset of configurations.

It is easy to show a ranking paradox by simply showing that X >> Y in some cases, but Y >> X in others (X, Y = constraints; “X >> Y” means “X outranks Y”). In tableau (8.1a), a left to right application yields [RRM] as output, which is opaque in the sense that /F/ surfaces as R despite the fact that, according to the correspondence rules of Table 2, this /F/ is expected to turn into L before R. Sandhi operation proceeding in the opposite direction generates (8.1b), which is transparent since the input /F/ indeed turns into R before the surface M to the right, exactly as expected from Table 2. Transp therefore dictates a leftward rule application, overriding Temp.

(8.1) Transp >> Temp

/FLM/ → [RMM]

e.g. *[da.zi] ji* “typewriter”
xiao [di.fang] “small place”

			Transp	Temp
a.	⇨	FLM | | RFM | RRM	*	
b.	⇦	FLM | FMM | RMM ☜		*

The problem is that exactly the opposite ranking must prevail in order to guarantee the attested output of tableau (8.2a). Notice that (8.2a) is opaque in that the initial /F/ surfaces as M before R, whereas /F/ is expected to emerge as L in such an environment, pursuant to the correspondence rules of Table 2. (8.2) instantiates a case where Temporal Sequence prevails at the expense of Transparency.

(8.2) Temp >> Transp

/FFM/ → [MRM]

e.g. *[bao.xian] xiang* “safety box”
si [huo.shan] “extinct volcano”

			Temp	Transp
a.	⇨	FFM | MFM | MRM ☜		*
b.	⇦	FFM | FRM | LRM	*	

Other pair-wise ranking paradoxes are not hard to find. Consider the relationship between Econ and Temp. (8.3b) is derivable from a right to left application. Nonetheless, it wins over (8.3a) on account of derivational economy: it takes one single step to get from /MLM/ to [MMM], to which no further rules apply. (8.3b) carries only one * under Econ: we mark each derivational step with one asterisk *. (8.3a), on the other hand, entails two derivational steps, as signaled by two asterisks under the Econ column. By ranking Econ over Temp, we insure that the right candidate, in this case (8.3b), is picked.

(8.3) Econ >> Temp

/MLM/ → [MMM]

e.g. *[si.ling] guan* “commanding officer”
xin [di.fang] “new place”

			Econ	Temp
a.	⇨	MLM | LLM | LMM	**	
b.	⇦	MLM | MMM ☜ n/a	*	*

However, Econ >> Temp makes the wrong prediction in (8.4). Only by reversing the rank order can we guarantee the correct reading of (8.4a).

(8.4) Temp >> Econ

/MRM/ → [LHM]

e.g. *[jin.yu] gang* “goldfish tank”
xin [bei.jing] “new Beijing”

			Temp	Econ
a.	⇨	MRM | LRM | LHM ☜		**
b.	⇦	MRM | MHM n/a	*	*

8.2. Conjoint constraints

To get out of this quandary, one might conceivably explore the possibility of appealing to the notion of *conjoint* constraints (Alderette (1998), Fukazawa (1999), Moreton and Smolensky (2002) and many others). That is, some appropriate combination of derivational constraints may band together to override Temp. For instance, one might hypothesize that while Temp outranks both Transp and Econ, taken singly (see (8.2) and (8.4)); taken jointly, these two latter constraints may dominate Temp. In other words: (Transp + Econ) >> Temp >> Transp, Econ, etc.

While such a ranking order is in principle conceivable, the move to introduce conjoint constraints is unlikely to succeed in the case of Hakka. Consider the tonal configuration in (8.5).

(8.5) /HRM/ → [FHM]

e.g. *[jian.zhu] shi* “architect”
ban [yuan.yin] “semi-vowel”

			Temp	Transp	WF	Econ	Mark
a.	⇨	HRM │ FRM │ FHM ☜		*	**	**	*
b.	⇦	HRM │ HHM n/a	*		*	*	

Crucially, derivation (8.5a), which produces the attested output is worse off on every count except for Temp. Firstly, (8.5a) is opaque in that the initial /H/ changes to F, despite the fact that it is adjacent to a surface H: HH is not expected to undergo sandhi at all. Secondly, the output of (8.5a) [FHM] is doubly illformed (hence two asterisks under WF column), because both FH and HM are potential sandhi sites, whereas (8.5b) contains only one sandhi site, namely the substring HM. Thirdly, (8.5a) requires two derivational steps, while (8.5b) calls for only one. Finally, the ultimate output of (8.5a) contains a marked contour tone (i.e. F), while (8.5b) consists of only unmarked level tones. In short, in order for candidate (8.5a) [FHM] to prevail, one must posit a rank order Temp >> {Transp, WF, Econ, Mark}, i.e. Temp outranks all the other constraints not only taken individually but also as a set of conjoint constraints. That being the case, there is no conceivable subset of Transp, WF, Econ or Mark that could outrank Temp, singly or jointly.

At this point, it should be clear that though surface forms are derivable, it is crucial that the direction of rule application be ascertained. However, direction of application appears to be totally random, neither reducible to any of the factors conceived in (7.1) nor to a combinatory interaction of these factors[19].

9. Foundations of an OT model

Up to this point, we have basically exhausted the descriptive resources of a rule-based model, and have resorted to powerful derivational constraints that do not form part of the standard analytical tools of classical generative phonology. Even such an extended framework is far from succeeding in rendering a satisfactory account of Hakka tone

[19] As we were about to finalize this manuscript, Hyman and Vanbik (2002) came to our attention. By appeal to direct-mapping, they provide an account for directionality effects created by a combination of counterfeeding and counterbleeding effects. As we see it, direct-mapping runs into trouble with Hakka for two reasons: (a) a target tone may undergo sandhi twice in a derivation (see section 5.3), as permitted by Moving Window constraint; (b) Hakka exhibits directionality effects not reducible to feeding and bleeding orders (see section 9, on “preferentiality”). We have considered and rejected two-level and multi-level accounts. For lack of space, we have decided to omit a detailed discussion on this point (cf. Chen (2000), ch.3 and references cited therein).

sandhi. We now turn to Optimality Theory to see if it is capable of shedding light on the matter. In order to construct a working OT model, we shall start by considering the rudimentary ditonal sandhi.

(9.1) /FL/ → [RF]

e.g. *li.mao* "courtesy"

Given (9.1), it is clear that constraints that trigger the alternation, presumably markedness constraints (*MARK), must outrank all the faithfulness constraints (FAITH). In this particular case, constraint *FL that disfavors the ditonal collocation FL must outrank faithfulness. Thus, an OT model would schematically look like this:

(9.2) *MARK >> FAITH

However, we also have alternation of the following type,

(9.3) /HL/ → [FL]

e.g. *ban.ye* "midnight"

where the output of another string is exactly the string that needs to be undone in the first place. This means that one needs to separate marked strings that are derived from those that are not. Hence we must revise (9.2) as (9.4).

(9.4) $*_{O}M$ >> FAITH >> $*_{N}M$

where $*_{O}M$ mark underlying (inherited) environments

$*_{N}M$ mark derived (non-inherited) environments

The separation of the markedness constraints allows tone sandhi to target only underlying offending tonal sequences. Thus, with the set of faithfulness constraints wedged between them, it is possible to get chain-shift effect[20], as illustrated below.

(9.5) /FL/ → [RF]

e.g. *li.mao* "courtesy"

/FL/	$*_O$FL	FAITH	$*_N$FL
i.☞ RF		**	
ii. FL	*!		

(9.6) /HL/ → [FL]

e.g. *ban.ye* "midnight"

/HL/	$*_O$HL	FAITH	$*_N$FL
i. HL	*!		
ii. ☞FL		*	*
iii. RF		**!	

Legend: ☞ = attested, optimal

Though chain shifts have been successfully described in (9.5) and (9.6), we cannot generalize comparative markedness to cover other cases. To demonstrate this, consider [LL] as one of the competing candidates.

[20] For details on this idea of comparative markedness, see McCarthy (2002).

(9.7)

/FL/	$*_{O}$FL	FAITH	$*_{N}$FL
i.⚐ RF		**!	
ii. FL	*!		
iii.💣LL		*	

/HL/	$*_{O}$HL	FAITH	$*_{N}$FL
i. HL	*!		
ii. ⚐FL		*	*!
iii. RF		**!	
iv.💣LL		*	

Legend: ⚐ = attested candidate 💣 = predicted optimal

In (9.7), the inclusion of [LL] among the candidate pool turns the spotlight on a fundamental problem with a constraint-based analysis. By all accounts, [LL] is more harmonic than the actual attested form: it satisfies perfectly both the inherited and non-inherited markedness constraints by incurring no more faithfulness constraints than the winner candidate (flagged). For now, we will set aside this problem and take (9.8) as a point of departure, to be referred to as Model A.

(9.8) Model A: $*_{O}$M >> FAITH >> $*_{N}$M

Given (9.8), there are only two areas where we may make accommodations for tritonal sandhi patterns. Firstly, we can play with the detailed internal ranking of each “chunk” of constraints. Secondly, we can introduce other constraints into this hierarchy without changing the relative rank order of these constraints. In any case, it would be useful to first lay out the crucial kinds of effects our OT model must accommodate, not that OT must necessary mimic them. They are feeding, counterfeeding, bleeding, counterbleeding and preferentiality. These are illustrated below.

(9.9) Feeding: /MML/ → [LLL]

e.g. *[guan.yin] miao* “Guanyin temple”
jiao [zhong.xue] “teach in a secondary school”

	a.	b.
	MML	MML
	|	(no sandhi rule applies)
	MLL	MML
	|	|
	LLL	*MLL
	(feeding)	(counterfeeding)

(9.10) Counterfeeding: /MFH/ → [MLH]

e.g. *[tian.zhu]jiao* “catholic church”
xin [shou.tao] “new gloves”

	a.	b.
	MFH	MFH
	(no sandhi rule applies)	|
		MLH
	MFH	|
	|	*LLH
	MLH	
	(counterfeeding)	(feeding)

(9.11) Bleeding: /MLM/ → [MMM]

e.g. *[yi.shu]gao* “(to possess) excellent medical expertise”
wo [shi.zhai] “I am a vegetarian”

	a.	b.
	MLM	MLM
	|	|
	MMM	LLM
	(no further sandhi rule applies)	|
		*LMM
	(bleeding)	(counterbleeding)

(9.12) Counterbleeding: /MRM/ → [LHM]

e.g. *[jin.yu]gang* “gold-fish tank”
xin [bei.jing] “new Beijing”

a.		b.
MRM | LRM | LHM (counterbleeding)		MRM | *MHM (no further sandhi rule applies) (bleeding)

(9.13) Preferentiality: /FML/ → [RFL]

e.g. *[pu.tong] hua* “putonghua” (lingua franca)
zong [si.ling] “commander-in-chief”

a.		b.
FML | FLL | | RFL (right to left)		FML | RML | *RLL (left to right)

(9.9a) to (9.13a) give the derivational descriptions of various effects observed in Hakka. Non-attested derivations are provided for reference, under (9.9b) to (9.13b). It should be clear that Hakka exhibits all four kinds of rule-ordering effects. We use the term “preferentiality” to refer to the kind of ordering effect exemplified by (9.13). Here the elementary 2TS rules do not stand in a (potentially) feeding or bleeding relation; rather 2TS rules generate different outputs depending on the directionality (i.e. relative order) in which they apply.

10. Improving the model with sympathy

We are now ready to apply the rudimentary Model A (9.8) to tritonal patterns with particular reference to rule-ordering effects summarized above. For the purpose of illustration, we limit the candidate pool to forms that appear at some derivational stage schematized in (9.9) to (9.13). For clarity's sake, in what follows, we repeat for each case under discussion the derivational steps at which the competing candidates appear.

First off, given the way Model A is set up, for any tritonal input, the optimal form should correspond to that obtained by counterfeeding application rather than that obtained by feeding application. This is so because no prior rule application can create a low ranking $*_{N}$M violation, that is capable of triggering further change at the expense of a higher ranking FAITH. This is illustrated by (10.1).

(10.1) /MML/ → [LLL]

e.g. *[guan.yin] miao* "Guanyin temple"
jiao [zhong.xue] "teach in a secondary school"

a.	MML	candidate (i)	b.	MML
	|			(no sandhi rule applies)
	MLL	candidate (ii)		MML = candidate (i)
	|			|
	LLL	candidate (iii)		MLL = candidate (ii)

/MML/	$*_{O}$ML	FAITH	$*_{N}$ML
i. MML	*!		
ii.💣 MLL		*	*
iii.⚐ LLL		**!	

Legend: ⚐ = attested candidate 💣 = predicted optimal

Tableau (10.1) shows that Model A erroneously prefers the results of counterfeeding application. Notice that candidate (iii) is harmonically bound by candidate (ii). Under Model A, there is no ranking such that candidate (iii) will emerge as optimal. The only way out is to introduce another constraint before FAITH that will eliminate candidate (ii) from competition.

Model A also favors forms corresponding to the output of bleeding application over those corresponding to the output of counterbleeding application. This is evidently so because counterbleeding application incurs more violations of faithfulness than necessary to undo the markedness violations. An example is given in (10.2).

(10.2) /MRM/ → [LHM]

e.g. *[jin.yu]gang* "gold-fish tank"
xin [bei.jing] "new Beijing"

a. MRM candidate (i)
|
LRM candidate (ii)
|
LHM candidate (iii)

b. MRM
|
*MHM candidate (iv)

/MRM/	$*_{O}$MR	$*_{O}$RM	FAITH	$*_{N}$HM	$*_{N}$LH
i. MRM	*!	*			
ii. LRM		*!	*		
iii. ⚐LHM			**!	*	*
iv. 💣MHM			*	*	

Legend: ⚐ = attested candidate 💣 = predicted optimal

Again, the attested candidate is harmonically bound. Like the ditonal case, this points to the need for a constraint to dominate FAITH, such that the constraint (or set of constraints) would favor the attested candidate. Since it is derivational effects that we are dealing with, sympathy theory comes to mind as a potential solution. This allows us to appeal to sympathetic constraints, which could dominate the faithfulness constraints.

Sympathy Theory (hereafter ST) allows for derivational effects through the influence of a (set of) sympathetic candidate(s) (see McCarthy (1998, 2000) and also Walker (1998), Jun (1999), Kiparsky (2001)). The sympathetic candidate corresponds to the intermediate form of a derivation. With the exception of /FLR/, all other two-step derivations of Hakka tritonal sequences have an intermediate form where either the initial tone or the medial tone is stable relative to the input. Neither position is uniformly stable for all tritonal sequences. Thus to employ ST, we shall need to appeal to the faithfulness of both positions as selectors (see Beckman (1998) for discussion on positional faithfulness).

(10.3) FAITH-1 Input tone at the initial position must surface in the output.
FAITH-2 Input tone at the second position must surface in the output.

The appeal to positional faithfulness constraints as selectors would guarantee that at least one of the sympathetic candidates would correspond to the intermediate form of a derivation. Specifically, FAITH-1 as selector would prefer a sympathetic candidate with initial tone stability, thus exerting a leftward (i.e. right to left) derivation effect. Likewise, FAITH-2 as selector would prefer a sympathetic candidate with medial tone stability, thus exerting a rightward (i.e. left to right) derivation effect.

Sympathetic constraints such as ❀CUMUL and ❀DIFF require the output candidate to share the derivational history of the sympathetic candidate and must outrank the faithfulness constraints. Following McCarthy (1998), counterbleeding effects (referred to as “non-surface apparent opacity” in McCarthy (1998)) are attributed to ❀CUMUL >> FAITH, while counterfeeding effects (referred to as “non-surface true opacity” in McCarthy (1998)) are attributed to ❀DIFF >> FAITH. Together, the sympathetic constraints will disfavor the candidates that do not share the derivational histories (faithfulness violations) of the sympathetic candidate. Recall from (10.1) and (10.2) that the attested candidate is the one with more faithfulness violations. The only way for that candidate to win is for there to be a constraint (or set of constraints) favoring it ranked above the faithfulness constraints. With ST, this is done with sympathetic constraints. The revised model now becomes Model B.

(10.4) Model B:

$*_{O}$M

|

❀CUMUL >> ❀DIFF

|

★FAITH-1; ★FAITH-2; FAITH-3

|

$*_{N}$M

Legend: ★ = selector; ❀=sympathetic constraint

The ranking of ❀CUMUL over ❀DIFF is assumed to be universal (McCarthy (1998)). We will stick to it for now, perhaps revising it if it turns out to be necessary.

A grammar such as Model B by its nature favors counterfeeding and counterbleeding effects. The preference for counterfeeding stems from the low ranking $*_{N}$M, crucially below faithfulness constraints. By definition, feeding requires derived environments. Since $*_{N}$M is lowly ranked, candidates corresponding to feeding order would have incurred more faithfulness violations than necessary. In a ST model, candidates corresponding to feeding derivation amounts to excessive violations of DIFF too, which follows from the excessive faithfulness violations. This is illustrated in (10.5) and (10.6).

(10.5) Model B favors counterfeeding (wrongly)

Feeding: /MML/ → [LLL]

e.g. *[guan.yin] miao* “Guanyin temple”
jiao [zhong.xue] “teach in a secondary school”

a. MML candidate (i)
|
MLL candidate (ii)
|
LLL candidate (iii)
(feeding)

b. MML
(no sandhi rule applies)
MML = candidate (i)
|
*MLL = candidate (ii)
(counterfeeding)

/MML/	$*_{O}$ML	⊛CUMUL	⊛DIFF	★FAITH-1	★FAITH-2	$*_{N}$ML
i. $_{⊛faith\text{-}2}$MML	*!	$*_{⊛MLL}$				
ii. 💣 $_{⊛faith\text{-}1}$MLL			$*_{⊛MML}$		*	*
iii. ⚐LLL			$*_{⊛MLL}$*!$*_{⊛MML}$	*	*	

Legend: ⚐ = attested candidate 💣 = predicted optimal
$_{⊛FAITH\text{-}1,2}$ABC = sympathetic candidate selected by FAITH-1,2
$*_{⊛ABC}$ = violation in reference to sympathetic candidate ABC

(10.6) Model B favors counterfeeding (rightly)

Counterfeeding: /MFH/ → [MLH]

e.g. *[tian.zhu]jiao* “catholic church”
xin [shou.tao] “new gloves”

a. MFH candidate (i)
(no sandhi rule applies)
MFH
|
MLH candidate (ii)
(counterfeeding)

b. MFH
|
MLH = candidate (ii)
|
*LLH candidate (iii)
(feeding)

/MFH/	$*_{O}$FH	❀CUMUL	❀DIFF	★FAITH-1	★FAITH-2	$*_{N}$ML	$*_{N}$LH
i. $_{❀faith\text{-}2}$MFH	*!	$*_{MLH}$					
ii. ☞ $_{❀,faith\text{-}1}$MLH			$*_{MFH}$		*	*	*
iii. LLH			$**_{MFH}$!	*	*		*

Legend: ☞ = optimal and attested candidate
$_{❀FAITH\text{-}1,2}$ABC = sympathetic candidate selected by FAITH-1,2
$*_{❀ABC}$ = violation in reference to sympathetic candidate ABC

The preference for counterbleeding stems from the intervention of ❀CUMUL which outranks faithfulness. By definition, bleeding better preserves the identity between input and output, but ❀CUMUL requires identity between output and an intermediate form. Since ❀CUMUL outranks FAITH, Model B disfavors bleeding. This is demonstrated in (10.7) and (10.8).

(10.7) Model B favors counterbleeding (wrongly)

Bleeding: /MLM/ → [MMM]

e.g. *[yi.shu]gao* "(to possess) excellent medical expertise"

wo [shi.zhai] "I am a vegetarian"

a. M<u>LM</u> candidate (i)
|
MMM candidate (ii)
(no sandhi rule applies)

(bleeding)

b. <u>ML</u>M
|
L<u>LM</u> candidate (iii)
|
*LMM candidate (iv)
(counterbleeding)

/MLM/	$*_{O}$ML	$*_{O}$LM	❀CUMUL	❀DIFF	★FAITH-1	★FAITH-2	$*_{N}$LM
i. MLM	*!	*	$*_{❀}$LLM $*_{❀}$MMM				
ii. ⚐ $_{❀faith\text{-}1}$MMM			$*_{❀}$LLM	$*_{❀}$LLM		*	
iii. $_{❀faith\text{-}2}$LLM		*!	$*_{❀}$MMM	$*_{❀}$MMM	*		
iv. 💣 LMM				$*_{❀}$MMM $*_{❀}$LLM	*	*	*

Legend: ⚐ = attested candidate 💣 = predicted optimal
$_{❀FAITH\text{-}1,2}$ABC = sympathetic candidate selected by FAITH-1,2
$*_{❀ABC}$ = violation in reference to sympathetic candidate ABC

(10.8) Model B favors counterbleeding (rightly)

Counterbleeding: /MRM/ → [LHM]

e.g. *[jin.yu]gang* “gold-fish tank”
xin [bei.jing] “new Beijing”

a. MRM candidate (i)
|
LRM candidate (ii)
|
LHM candidate (iii)
(counterbleeding)

b. MRM
|
*MHM candidate (iv)
(no further sandhi rule applies)
(bleeding)

/MRM/	*$_O$MR	*$_O$RM	❀CUMUL	❀DIFF	★FAITH-1	★FAITH-2	*$_N$HM	*$_N$LH
i. MRM	*!	*	*❀MHM *❀LRM					
ii. ❀faith-2 LRM		*!	*❀MHM	*❀MHM	*			
iii. ☞LHM				*❀MHM *❀LRM	*	*	*	*
iv. ❀faith-1 MHM			*❀LRM!	*❀LRM		*	*	

Legend: ☞ = attested optimal candidate
❀FAITH-1,2ABC = sympathetic candidate selected by FAITH-1,2
*❀ABC = violation in reference to sympathetic candidate ABC

In other words, Model B consistently favors counterfeeding and counterbleeding effects over competitions derived from feeding and bleeding order. Since Model B is not compatible with feeding and bleeding, it follows that it would run afoul also with preferentiality. This is because preferentiality could have feeding-like effects (and in fact, any other of the four rule-ordering effects) as seen with /FML/. Further, the appeal to both FAITH-1 and FAITH-2 as selectors make it possible for there to be two sympathetic candidates, each exerting its influence. Since FAITH-1 selection would produce a leftward derivation effect, while FAITH-2 would produce a rightward derivation effect, their simultaneous activity would wrongly predict indeterminacy with preferentiality cases.

(10.9) Preferentiality: /FML/ → [RFL]

e.g. *[pu.tong] hua* “putonghua” (lingua franca)
zong [si.ling] “commander-in-chief”

a. F<u>ML</u> candidate (i)
|
<u>FL</u>L candidate (ii)
| |
RFL candidate (iii)

b. <u>FM</u>L
|
R<u>ML</u> candidate (iv)
|
*RLL candidate (v)

/FML/	$*_{O}$FM	$*_{O}$ML	❀CUMUL	❀DIFF	★F-1	★F-2	$*_{N}$RL	$*_{N}$RM	$*_{N}$FL
i. FML	*!	*	$*_{❀FLL}$ $*_{❀RML}$						
ii. $_{❀faith\text{-}1}$FLL			$*!_{❀RML}$	$*_{❀RML}$		*			*
iii. ☞RFL				$*_{❀FLL}$ $*_{❀RML}$	*	*			*
iv. $_{❀faith\text{-}2}$RML		*!	$*_{❀FLL}$	$*_{❀FLL}$	*			*	
v. 💣RLL				$*_{❀FLL}$ $*_{❀RML}$	*	*	*		

Legend: ☞ = attested optimal 💣 = predicted optimal
$_{❀FAITH\text{-}1,2}$ABC = sympathetic candidate selected by FAITH-1,2
$*_{❀ABC}$ = violation in reference to sympathetic candidate ABC

Mode B wrongly predicts that both candidates (iii) and (v) would surface as optimals. Notice that with /FML/, there are two optimal candidates though only one is attested. This is because the two selectors exert equal influence on determining the direction of derivation (to use convenient derivation metaphors).

To capture feeding and bleeding, one might conceivably appeal to a ranking where the derived markedness constraints outrank the faithfulness constraints. Crucially, they must be on par with the $*_{O}$M constraints for this effect to be obtained (cf. (10.9)). High-ranking markedness constraints favor repairs at the expense of faithfulness. The logic is that feeding is possible when markedness constraints are highly ranked, inherited or otherwise. Model C incorporates this logistic move.

(10.10) Model C: $*_{O}$M; $*_{N}$M >> ❀CUMUL >> ❀DIFF >> F

The problem is that Model C defeats the purpose of separating the two kinds of markedness constraints in the first place. Moreover, it will never favor counterfeeding since all the markedness constraints are ranked high up.

With the "preferentiality" case, the example at hand could be addressed by internally ranking the $*_{N}$M constraints. Specifically, if $*_{N}$RL >> $*_{N}$FL, then the optimal candidate would be the attested candidate. In the next section, we explore this line of thinking by looking into the internal ranking of the $*_{N}$M constraints.

11. The influence of non-inherited markedness constraints

We now turn to the question of the internal ranking of markedness constraints, starting with $*_{N}$M. There are two issues concerning the $*_{N}$M chunk. The first relates to its internal ranking. By simply looking at closed loops involving ditonal sequences /RM/, /FM/ and /HM/, we can construct a comparative tableau[21] like (11.1) that clearly demonstrates that no permutation will produce a ranking where every L is dominated by some W to the left.

[21] C.f. Prince (1999).

(11.1)

	input	W ~ L	$*_N$FM	$*_N$RM	$*_N$HM
i.	/FM/	RM ~ HM		L	W
ii.	/RM/	HM ~ FM	W		L
iii.	/HM/	FM ~ RM	L	W	

Legend : W = constraint prefers attested candidate
L = constraint prefers non-attested competing candidate

The unrankability of $*_N$M constraints is by no means a peculiar property of closed loops. We can illustrate this point by juxtaposing two ditonal patterns that dramatically demonstrates the paradox.

(11.2) Tritonal cases

i. /RLM/ → [HMM]

e.g. *[liu.xue] sheng* “foreign student”
hong [la.jiao] “red chilli pepper”

a. RLM
|
RMM
|
HMM

b. RLM
|
RFM
|
*RRM

ii. /RLF/ → [HMF]

e.g. *[wen.xue] shi* “literary history”
lan [mo.shui] “blue ink”

a. RLF
|
RMF
|
HMF

b. RLF
|
RFF
|
*RMF

	input	W ~ L	$*_N$RM	$*_N$HM
i.	/RLM/	HMM ~ RRM	W	L
ii.	/RLF/	HMF ~ RMF	L	W

In (11.2), we limit the candidates under consideration to the final forms corresponding to a leftward and a rightward derivation. We follow this practice in constructing subsequent comparative tableaux.

In the cases of (11.2) under consideration, $*_{O}$M are irrelevant because neither forms in comparison retain any underlying sandhi sites. Further each pair also incurs the same number of faithfulness violations, and consequently has the same sympathetic violations. As may be seen from the comparative tableau, ranking the $*_{N}$M constraints so that the correct output surfaces as optimal is impossible. From (11.1) and (11.2), it appears that the pursuit for internal ranking of $*_{N}$M is doomed to failure, at least with respect to $*_{N}$RM, $*_{N}$FM and $*_{N}$HM despite its apparent usefulness in (10.9).

The second issue relating to $*_{N}$M has to do with their influence, regardless of their ranking (internally or relative to other sets of constraints). Consider (11.3).

(11.3)

	input	W ~ L	$*_{N}$LH	$*_{N}$RM	$*_{N}$LF	$*_{N}$MR
i.	/MRM/	LHM ~ MHM	L			
ii.	/FHM/	LFM ~ MFM			L	
iii.	/FHR/	LFR ~ MFR			L	
iv.	/FHL/	LFL ~ MFL			L	
v.	/FFM/	MRM ~ LRM				L
vi.	/FFF/	MMF ~ RMF		L		
vii.	/FFL/	MRF ~ LRF				L

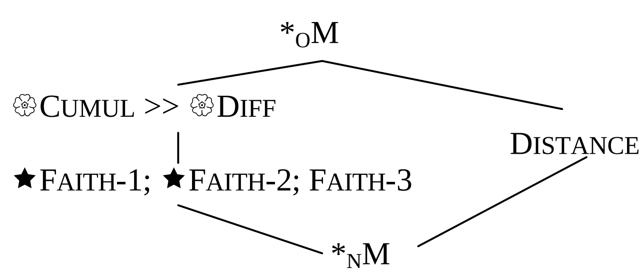
Legend: W = constraint prefers attested candidate
L = constraint prefers non-attested competing candidate

In (11.3), we consider seven “preferentiality” cases - cases that cannot be classified derivationally as feeding, counterfeeding, bleeding or counterbleeding. Thus, for each input, the attested form and a competing form, both derivable from some stepwise application of ditonal sandhi. Neither of these forms incur any $*_{O}$M violation, since there are no underlying sandhi sites left. Further, both forms share the same number of faithfulness violations, and consequently the same number of sympathetic violations. This allows us to zero-in only on the $*_{N}$M violations. However, notice that in all these cases, the attested candidate is harmonically bound. There are no constraints that prefer them to the competing candidate. While it is true that the $*_{N}$M chunk can influence "preferentiality (cf. (10.9)), (11.3) shows that it exercises them in the wrong way.

As may be seen from (11.3), the existence of the $*_{N}$M chunk poses a potential threat to the correct application of Model B. As long as they are there, they could exert an influence, no matter how low they rank. They will cause Model B to wrongly prefer over-application (contra Moving Window) and could cause an error in "preference" for direction of sandhi application (cf. (11.3)).

A partial solution to the problems introduced by $*_{N}$M would be to suppress its influence with a set of faithfulness constraints that do not allow for a tone to undergo more than one alternation, i.e. DISTANCE (set)[22]. This gives us Model D.

(11.4) Model D:



[22] Cf. the derivational constraint (One-Step Principle) presented earlier in section 5. See also Hsu (2002).

The DISTANCE constraint, functionally analogous to One Step Principle, is meant to insure that a given tone X is mapped onto tone Y rather than tone Z, if X is closer to Y than Z – on some language specific scale. For instance, given the scale [R-H-F…], R → H, but not R → F (cf. RM → HM, not *FM). Needless to say, this raises the non-trivial question of how to determine this scale of distance. But suppose we fudge (a little or a lot) and assume that somehow we can determine the internal workings of this constraint set. The introduction of DISTANCE duplicates the work of the separation of the markedness constraints. Both devices produce the effects of chain-shifting. Furthermore, depending on how one includes context sensitivity into ditonal sandhi patterns, there may be an additional problem in having one tone mapped onto a variety of tones, e.g. /F/ → R, L, M. (Note that a one-to-many mapping is not a function).

If we can live with all that fudging about DISTANCE, it buys us a new possibility. Since it replicates the work of $*_{N}M$, one can revive Model C and envisage a model such as the following.

(11.5) Model E: DISTANCE >> $*_{O}M$; $*_{N}M$ >> ❀CUMUL >> ❀DIFF >> F

Model E is Model C with DISTANCE. Because there are no instances where Moving Window is not obeyed (cf. section 5.3), DISTANCE ranks highest. The problem is that, unlike Model C, Model E will not yield feeding. This is because by definition, feeding operates on derived environments. High-ranking DISTANCE will block it. In addition, there is motivation to rank DISTANCE low, at least lower than the markedness constraints.

Notice that in (11.6), the medial tone undergoes two alternations. If DISTANCE is understood as "not undergoing more than one alternation", then (11.6) would constitute such a violation. Because such situations do exist in Hakka, DISTANCE must be ranked fairly low, crucially, it must be ranked below all the markedness constraints, $*_{O}$M and $*_{N}$M. But such a move would make the appeal to DISTANCE vacuous because one would still be left with no way to prevent the situation in (11.3).

(11.6) /RML/ → [RFL]

e.g. *[chang.ting] hua* "Changting dialect"
xing [gong.lu] "take the highway"

RML
|
RLL
|
RFL

In a nutshell, the paradox is as follows. On the one hand, (11.3) dictates the need for some DISTANCE chunk of constraints to dominate $*_{N}$M, thus motivating Model D. On the other hand, examples like /RML/ in (11.6) strongly argues for DISTANCE to be dominated by all the markedness constraints. Furthermore, reranking DISTANCE does not help in providing an account for feeding (cf. Model E). In any case, DISTANCE >> $*_{N}$M makes the internal ranking of $*_{N}$M redundant. This is because there is no longer any motivation for internally ranking the markedness of derived sandhi environments: All derived environments will be blocked by DISTANCE (Model D). In any case, the $*_{N}$M chunk also makes Model D incapable of addressing "preferentiality".

12. Ranking the inherited markedness constraints

We now turn to the inherited markedness constraints. Since we have separated the inherited markedness constraints from the non-inherited ones, an argument for the ranking of markedness (of each ditonal sequence) cannot be made based upon the target of alternation. That is, though /HL/ → [FL], one may not extrapolate *HL >> *FL. In any case, such an approach would be doomed to failure given that there are circular chain shifts (cf. section 5).

The argument for ranking the markedness of ditonal sequences must rest on competition. For example, given a sequence /ABC/ such that both AB and BC are sandhi sites, the site that is more marked will undergo sandhi first. There are two reasons why such an approach would fail. Firstly, the order of sandhi application is inconceivable in a parallel OT framework. Being output-oriented, there is no notion of order of sandhi application. A candidate either violates a constraint or it does not. It is impossible to tell if one alternation is ordered before or after another. Secondly, even if one grants that there are serial OT models (Prince and Smolensky (1993:79f) and McCarthy (2000)) where the ranking of markedness could be determined by order of alternation, there are examples such as /MRM/ & /RMR/ and /MLM/ and /LML/. Take for instance the first pair, /MRM/ and /RMR/, repeated below (cf. section 6).

(12.1) /MRM/ → [LHM]

e.g. *[jin.yu] gang* "gold fish tank"
xin [bei.jing] "new Beijing"

<u>MR</u>M
|
L<u>RM</u>
|
LHM

(12.2) /RMR/ → [HLR]

e.g. *[yu.gan] you* “cod liver oil”
zhuo [xin.xie] “wear new shoes”

RMR
|
HMR
|
HLR

With /MRM/, MR undergoes sandhi first. Under a harmonic serialism conception of OT, *MR >> *RM. With /RMR/, RM undergoes sandhi first, hence, by the same reasoning *RM >> *MR, in direct contradiction to /MRM/. With /MLM/ where derivationally sandhi applies leftwards, *LM >> *ML. /LML/ requires the reverse. Incidentally, this ranking paradox also makes it pointless to explore harmonic serialism as an account for Hakka[23].

In short, there is no way to motivate the ranking of the markedness constraints. Furthermore, under a parallel conception of Model B/D, ranking them would not produce any meaningful results. This is because given that the entire $*_{O}M$ chunk outranks faithfulness, all underlying sandhi sites must undergo alternation.

---

23 Another reason why harmonic serialism will not work for Hakka is that it would require a way of figuring out the random directionality. Essentially, that was the insurmountable obstacle we encountered in our attempt to render a derivational account.

13. Faithfulness constraints

To complete the picture, a brief comment on the FAITHFULNESS chunk of constraints. We begin by noting the relative strengths of positional faithfulness: of the 108 tritonal sequences that undergo tone sandhi, 98 keep the final tone unchanged, 36 maintain the medial tone unaltered, and only 18 exhibit stability at the initial position. Thus, one would expect the ranking to be FAITH-3 >> FAITH-2 >> FAITH-1[24].

Since the final position is quite stable, we will set FAITH-3 aside so as to focus on the other two positional faithfulness constraints. A careful look at all the tableaux given so far reveals that though FAITH-1 and FAITH-2 have not been ranked with respect to each other, ranking them will not contribute to solving the problems at hand. This is because the problems with models B/D stem from the effect high-ranking markedness has on favoring feeding and bleeding in combination with ST. As long as $*_{O}M$ outranks faithfulness and faithfulness outranks $*_{N}M$, feeding and bleeding are not possible under ST, no matter how the faithfulness constraints are ranked internally.

14. Concluding Remarks

Our failure at finding a satisfactory solution to the Hakka problem does not necessarily mean that current theories are inherently incapable of handling attested natural language phenomena, just that we have exhausted the descriptive devices known to us in both classical generative and OT frameworks. For this reason, we have chosen a title for this article that harks back to a paper that appeared 16 years ago (Chen 1986). In

[24] This pristine form will predict that the tone at the final position never alternates, contrary to fact. However, since cases where the final tone alternates invariably involves non-regressive sandhi where it appears that H tones are spreading to the right. To get this effect, one may envisage a set of assimilation-related constraints dominating the FAITH-3.

that article the author tackled a similar problem in Tianjin, and concluded that no conceivable rule ordering could predict the attested sandhi phenomena. Some years later it became obvious that rule ordering was the wrong approach; instead what mattered in the Tianjin case was directionality, which can be stated quite simply as:[25]

(14.1) By default rules apply from left to right – unless such a mode of application produces an illformed output, in which case reverse the direction of operation.

Likewise, it is entirely possible that some theoretical extension or radical reconceptualization of the problem would eventually provide us a key to the Hakka puzzle. Linguistic theories advanced by documenting relatively little known facts that lie just beyond the reach of current frameworks as much as by marshalling empirical arguments in support thereof. In this spirit, we offer the rich array of data we have gathered from Hakka, and invite linguists of all persuasions to exploit them in their own theorizing.

---

[25] We ignore certain details, such as the Preemptive clause (see Chen 1999 and 2000, chapter 3).

Appendix

Having failed at rendering a satisfactory account for the Hakka data, we are faced with the following immediate problem at hand: if Hakka tone sandhi is not reducible to an ordered set of elementary rules or constraints, how do Hakka speakers master their grammar? The rule vs. list dichotomy leaves us with no obvious alternative but to resort to long term memory. In other words, Hakka speakers need to store a long list of tonal "templates" of the form /ABC/   [XYZ], where ABC and XYZ stand for underlying and sandhi tones respectively. For two- or three-tone sequences, this brute force approach presents no problem: given the five-tone system as the base, there are only 25 ditonal and 125 tritonal combinations (= 5^2 and 5^3), well within the limits of long term memory. It goes without saying, the numbers grow exponentially as the syllable string increases in length. For instance, there are 3,125 (= 5^5) combinatorial possibilities for a pentasyllabic string. At this point a list approach begins to stretch the limits of plausibility.

However, a simple exponential extrapolation (5^n, where n = number of syllables or tones in a string) is only a worse case scenario. Various memory-saving devices are available. Notice that there are only 15 elementary ditonal sandhi rules (see Section 1, Table 2).[26] The learner needs to remember only these rules rather than all 25 ditonal patterns.

As for the 125 tritonal patterns, the Hakka speaker could simply adopt the strategy, for example, of applying the 15 elementary sandhi rules consistently in the default left to right direction. This would take care not only of the 22 left to right patterns, but also the 49 directional neutral cases (i.e. where sandhi rules applying in either direction converge

---

[26] For simplicity, we consider each ditonal correspondence of the form /AB/ → [XY] as one rule.

on the same output, see footnote 18). Essentially, the Hakka speaker needs only to remember a total of 24 right to left patterns, plus 1 ambidirectional cases (where one underlying tritonal form yields two readings depending on whether the rules apply from left to right or right to left). Finally, recall that there are 12 exceptional cases not derivable 2TS. The remaining cases are neutral, i.e. not subject to tone sandhi.[27]

How about longer strings? A few examples below would suffice to give a flavor of what they look like.

(A.1) Quadritonal alternations

a. Left to right

/FFMR/ → [MRLR]

e.g. *[si.huo.shan] qian* "in front of the extinct volcano"
lao [zu.shi.ye] "old grandmaster"

```
FFMR
 |
MFMR
   |
MRMR
     |
MR LR
```

27 Actually, further reduction in memory load is possible. For instance, all /TLT/ (except /FLR/) require a right to left sandhi. This and other purely inductive generalizations can further shorten the list of "marked" patterns. Since such ad hoc rules as memory aid would leave a residue of cases that must be listed any case, we will not pursue this matter further.

b. Right to left

/LMMR/ → [LLLR]

e.g. *[me.xi.ge] cheng* “Mexico city”
da [jin.si.hou] “large golden-haired monkey”

LMMR
|
LMLR
|
LLLR

c. Edge-in

/FFLM/ → [MRMM]

e.g. *[lao.shu.dong] bian* “by the mouse hole”
xiao [da.zi.ji] “small typewriter”

FF LM
| |
MFMM
|
MRMM

As is evident from (A), the problem of directionality persists. Tone sandhi applies left to right in (A.2a); the direction is reversed in (A.2b). Moreover, a new, edge-in pattern is instantiated in (A.2c). It turns out that out of the 625 possible quadritonal correspondences (= 5^4), only 68 sequences require either an edge-in or a right to left order of sandhi operation. However, there are 130 sequences that are not inferable from 2TS rules. All the rest are derivable by applying ditonal sandhi rules in the default left to right directionaliy. This means that out of 625 four-tone sequences, the Hakka speaker need to memorize only 198 marked cases. In summary, for 2 to 4 tone sequences, a total of 249 sets of tonal correspondences need to be committed to memory. The remaining cases are either sandhi-free, or derivable from the default left to right sandhi application.

(A.3) Number of correspondences to memorize

Ditonal sequences	15
Tritonal right-to-left	24
Tritonal ambidirectional	1
Tritonal exceptional	12
Quadritonal sequences	198

Total	250

At present, we do not have sufficient data to make calculations on pentatonal (5-tone) sequences. While one expects the numbers to grow, it appears that up to this point, learning by memory does not seem to an umsummountable Herculean task.

Beyond five syllable strings, tone sandhi in Hakka appears to be constrained by syntactic constituencies, such that either tone sandhi applies from the lowest branching constituent upwards, or else a multisyllabic string is broken up into several sandhi domains. Since each prosodic domain is generally not longer than 4 or 5 syllables, no significant burden is added to learning. However, a full investigation of long polysyllabic strings remains to be undertaken.

References

Alderete, John. *Dissimilation as local conjunction*. ROA#175.

Beckman, Jill. 1998. *Positional Faithfulness*. PhD dissertation, UMASS, Amherst. MA: Graduate Linguistic Student Association. ROA#234.

Blevins, Juliette. 1995. *The syllable in phonological theory.* In John Goldsmith (ed) *The Handbook of Phonological Theory*. pp. 206-243. Blackwell..

Chafe, Wallace. 1968. The ordering of phonological rules. *International Journal of American Linguistics* 24:115-136.

Chao, Y-R. 1930. A System of Tone Letters. *La Maître phonétique* 45:24-27.

Chen, Matthew Y. 1985. *Tianjin tone sandhi: erratic rule application?* Ms., Univ. of California, San Diego.

Chen, Matthew Y. 1986. The paradox of Tianjin tone sandhi. *CLS* 22:98-154.

Chen, Matthew Y. 1987. Introductory remarks to a symposium on Tianjin tone sandhi. *Journal of Chinese Linguistics* 15:203-227.

Chen, Matthew Y. 1999.Directionality constraints on derivation. In Ben Hermans and Marc van Oostendorp (eds.) *The derivational residue in phonological optimality theory*. pp. 105-128. Linguistik Aktuell/Linguitsics Today vol 28. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Chen, Matthew Y. 2000. *Tone Sandhi: Patterns across Chinese dialects*. Cambridge Univ. Press.

Chinese Academy of Social Sciences, Beijing and Australian Academy of the Humanities, Canberra. 1987-90. *Language Atlas of China*. Hong Kong: Longman (Far East) Limited.

Chomsky, Noam and Morris Halle. 1968. *The Sound Pattern of English*. New York: Harper and Row

Cole, Jennifer. 1995. The cycle in phonology. In John Goldsmith (ed) *The Handbook of Phonological Theory*. pp. 70-113. Blackwell.

Crowhurst, Megan and Mark S. Hewitt. 1995. Directional footing, degeneracy, and alignment. *NELS* 25.

Duanmu, San. 1995. Phonology of compounds in two Chinese dialects. *Language* 71:225-259.

Duanmu, San. 1997. Recursive constraint evaluation in optimality theory: evidence from cyclic compounds in Shanghai. *Natural Language and LinguisticTheory*. 15:465-507.

Fukazawa, Haruka. 1999. *Theoretical implications of OCP Effects on Features in Opotimality Theory*. PhD dissertation, Univ. of Maryland. ROA # 307.

Goldsmith, John. 1993. Harmonic Phonology. In John Goldsmith ed. *The last phonological rule* pp.21-60. Chicago: Univ. of Chicago Press.

Hayes, Bruce. 1995. *Metrical Stress Theory: Principles and Case Studies*. Univ. of Chicago Press.

Howard, Irin. 1972. *A directional theory of rule application in phonology*. PhD dissertation, MIT.

Hung, Tony. 1987. Tianjin tone sandhi: towards an unified approach. *Journal of Chinese Linguistics* 15-274-305.

Hsu, Huichuan. 1994. *Constraint-based phonology and morphology: a survey of languages in China*. Ph.D dissertation, Univ. of California, San Diego.

Hsu, Huichuan. 2002. *More on One Step Principle in Tonal Derivation*. Ms., National Chiao Tung Univ.

Hyman, Larry and Kenneth Vanbik. 2002. *Output problems in Hakka-Lai – or What's (not) Chinese about tone sandhi?* Draft of paper prepared for the 8th International Symposium on Chinese Languages and Linguistics. Institute of Linguistics, Academia Sinica. November 8-10, 2002.

Iverson, Gregory. 1995. Rule Ordering. In John Goldsmith (ed) *The Handbook of Phonological Theory*. pp.609-614. Blackwell.

Jun, Jongho. 1999. Generalized Sympathy. In *Proceedings of NELS 29*. ROA #297.

Kenstowicz, Michael. 1994. *Phonology in Generative Grammar*. Blackwell.

Kenstowicz, Michael and Charles Kisseberth. 1977. *Topics in Phonological Theory*. New York: Academic Press.

Kiparsky, Paul. 2001. *Paradigmatic Effects*. Cambridge Univ. Press.

Levelt, Willem J.M. 1989. *Speaking: from Intention to Articulation*. Cambridge, Mass.: MIT Press.

Li, Rulong. 1965. Changtinghua liangyinjie, sanyinjie de liandu biandiao. [Disyllabic and trisyllabic tone sandhi in Changting] *Xiamen Daxue Xuebao*. Xiamen University, Fujian.

Luo, Meizhen.1982. Fujian Changting Kejiahua de liandu biandiao [Tone sandhi in the Hakka dialect of Changting, Fujian]. *Yuyan Yanjiu* pp. 188-197.

McCarthy, John. 1998. *Sympathy and Phonological Opacity*. ROA#398.

McCarthy, John. 2000. Sympathy, cumulativity and the Duke-of-York gambit. In Caroline Féry and R. van der Vijver eds., *The optimal syllable* Cambridge: Cambridge Univ. Press.

McCarthy, John. 2002. *Comparative Markedness*. ROA#489.

Mester, R. Armin and Jaye Padgett. 1993. *Directional syllabification in generalized alignmen*t. Paper presented at Rutgers Optimality Workshop, Rutgers Univ.

Meyer, Antje S. 1990. The time course of phonological encoding in language production: the encoding of successive syllables of a word. *Journal of Meaning and Language*. 29:524-545.

Meyer, Antje S. 1991. The time course of phonological encoding in language production: phonological encoding inside a syllable. *Journal of Meaning and Language* 30:69-89.

Mohanan, K.P. 1986. *The Theory of Lexical Phonology*. Dordrecht: Reidel

Mohanan, K.P. 1995. Organization of the Grammar. In John Goldsmith (ed) *The Handbook of Phonological Theory*. pp. 24-70. Blackwell.

Moreton, Elliot and Paul Smolensky. 2002. *Typological Consequences of Local Constraint Conjunction*. ROA#525.

Myers, Scott. 1991. Persistent Rules. *Linguistic Inquiry* 22:315-344.

Prince, Alan. 1999. *A Proposal for the Reformation of Tableaux*. Ms., Rutgers Univ. ROA#376

Prince, Alan and Paul Smolensky. 1993. *Optimality Theory: Constraint Interaction in Generative Grammar*. Technical Reports of the Rutgers Center for Cognitive Science TR-2.

Rao, C-R. 1987. Fujian Chanting (Kejia) fangyan de liandu biandiao [Tone sandhi in the Kejia dialect of Changting, Fujian]. *Zhongguo Yuwen* pp. 191-200.

Tan, F. 1987. Tone sandhi in the Tianjin dialect. *Journal of Chinese Linguistics* 15:228-246.

Walker, Rachel Leah. 1998. *Nasialization, neutral segments, and opacity effects*.

PhD dissertation. Univ.of California, Santa Cruz.

Zhang, Z-S. 1987. The paradox of Tianjin: another look. *Journal of Chinese Linguistics* 15:247-273.