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Directional Rule Application and Output Problems in Hakha Lai Tone*

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In this paper we discuss some rather interesting tonal facts from Hakha Lai, a Tibeto-Burman language spoken in Burma and Mizoram State, India, in which words are generally monosyllabic. In the first part of the paper, we show that a single conspiracy underlies all of the tonal alternations occurring in two-word sequences, which can be elegantly captured within Optimality Theory. In the second part we show that this "elegance" appears to dissipate once sequences of three or more words are taken into consideration; in particular, a serious problem arises in predicting the right-to-left directionality of rule application, which produces opaque outputs violating the very conspiracy that motivates the tonal alternations in the language. In the last part of the paper we show how this problem is wholly dependent on the view one takes on how to represent the input-output relations in question.

Key words: directionality, counterfeeding, counterbleeding, conspiracy, direct mapping, tone, Optimality Theory

1. Introduction

Within the past decade or so, much of phonological theory and practice has consisted of a major shift from a serial, derivational conception of phonological rules to a static, constraint-based version of input/output relations. Within OT (Optimality Theory, Prince & Smolensky 1993), the mainstream version of non-derivational phonology, phonologists who pursue the "richness of the base" hypothesis, assume that phonological differences between languages derive from differences in their ranking of the

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universal, violable constraints—or "ideals"—which characterize outputs. This has led in turn to a wide range of activities designed to characterize the functional bases of these ideals in terms of phonetic, structural, or conceptual grounding. A major question facing our field is whether all phonology can be done this way.

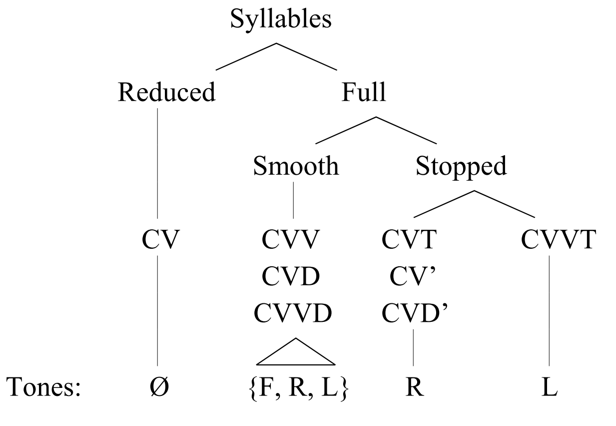
In this context we take a close look at the tone sandhi in Hakha Lai, a Kuki-Chin language spoken in Chin State, Burma, and parts of Mizoram State, India. We show that output-driven phonology runs into serious problems in capturing the input-output tonal relations. After attempting a constraint-based analysis, we conclude that Hakha Lai tone should be analyzed in terms of language-specific rules which directly map specific inputs onto their corresponding outputs.

We begin in §2 by presenting the relevant properties of the Hakha Lai tone system, followed in §3 by an interim OT analysis.[1] In §4 we expand the discussion to consider difficulties posed by the application of the constraints (or rules) to longer sequences. A direct mapping analysis is presented in §5, followed by discussion of alternatives in §6, and a brief conclusion in §7.

2. Hakha Lai tones

As documented in Hyman & VanBik (2002a), the potential for tonal oppositions varies according to the different syllable types in Hakha Lai, schematized in (1):

(1) Syllable structures of (largely monosyllabic) Hakha Lai words (and their tones)[2]



[1] See Hyman & VanBik (2002a, b) for previous work on Hakha Lai tone.

[2] The following abbreviations are adopted: VV = long vowel, T = stop /p, t, k/, ' = [ʔ], D = sonorant /m, n, ŋ, l, r, y, w/, D' = glottalized sonorant, F = Falling, R = Rising, L = Low (level) tones.

The syllable-structure generalizations are indicated in (2).

(2) Syllable-structure generalizations
   a. Hakha Lai syllables require an onset and can be open or closed
   b. Coda consonants can be voiceless stops, sonorants, or glottalized sonorants
   c. Underlying vowel length is contrastive only in syllables closed by a sonorant or voiceless stop
   d. Vowels are short before a glottal stop or glottalized sonorant coda

The tone-syllable generalizations are indicated in (3):

(3) Tone-syllable generalizations
   a. F, R, and L tones contrast only on smooth syllables; there is no H(igh) tone
   b. Short stopped syllables (CVT, CV’, CVD’) are underlyingly R
   c. Syllables with a long vowel and stop /p, t, k/ coda are underlyingly L
   d. reduced CV syllables (e.g., 1sg ka ‘my’) are toneless (Ø)

Concerning the fact that reduced CV syllables consisting of an onset and a short vowel are toneless—vs. all other syllable types—we assume that a syllable needs to have two moras to be a tone-bearing unit.

In this paper we shall be concerned only with smooth syllables, where the full contrast between F, R, and L tone can be realized. Examples are given in (4) of the three tones, F, R, and L, occurring on each of the three smooth syllable types CVV, CVD, and CVVD:

(4) Illustration of F(`), R(´), and L tones on smooth syllables (as realized after *ka* = ‘my’)

CVV		**CVD**		**CVVD**	
ka hmaà	‘my wound’	ka lùŋ	‘my heart’	ka tlaàŋ	‘my mountain’
ka zuù	‘my beer’	ka làw	‘my field’	ka raàl	‘my enemy’
ka keé	‘my leg’	ka hróm	‘my throat’	ka koóy	‘my friend’
ka ʔoó	‘my voice’	ka tsál	‘my forehead’	ka tsaán	‘my time’
ka saa	‘my animal’	ka raŋ	‘my horse’	ka koom	‘my corn’
ka hnii	‘my skirt’	ka kal	‘my kidney’	ka boor	‘my bunch’

Note that we mark the F tone with a grave accent, e.g., *hmaà* ‘wound’, and the R tone with an acute accent, e.g., *keé* ‘leg’. The lack of an accent should be interpreted as a L if the syllable is bimoraic, e.g., saa ‘animal’, but as toneless if the syllable is monomoraic (CV), e.g., *ka* 'my'.[3]

The forms in (4) are all presented as they are realized after the toneless pronoun *ka* 'my'. This is because of a rule, tentatively formulated as in (5), which converts an underlying R tone to F in phrase-initial position:

(5) Initial R rule : (tentative)

$$\phi[\ \ \begin{array}{c}\sigma\\ |\\ \mathrm{R}\end{array} \to \mathrm{F}$$

As seen in (6), what this means is that underlying F and R tones will be realized identically as a F when occurring at the beginning of a phrase:

(6) Phrase-initial /R/ is realized [F] phrase-initially (merging with /F/)

a. /F/	:	hmaà	'wound'		ka hmaà	'my wound'
b. /R/	:	keè	'leg'	vs.	ka keé	'my leg'

For the moment, we shall ignore this fact, but return to it in §3.

The table in (7) shows each of the three tones being plotted against each other in the productive noun compound and possessive construction:

(7) 3×3 tone patterns plotted in N1-N2 combinations after *ka* 'my' (so (5) will not apply)

		F		**R**		**L**	
a.	**F**	tlaàŋ	zuu	tlaàŋ	tsaán	tlaàŋ	saa
b.	**R**	thlaán	zuù	thlaán	tsaàn	thlaan	saa
c.	**L**	koom	zuu	koom	tsaán	koom	saa
	ka +	'mountain beer'		'mountain time'		'mountain animal'	
	'my'	'grave beer'		'grave time'		'grave animal'	
		'corn beer'		'corn time'		'corn animal'	

As indicated by our underlining, four out of these nine combinations undergo a tone change. As seen in (8), to produce these changes, three rules appear to be needed which are conveniently referred to by their input/output relations:

[3] The pitch of such toneless syllables is interpolated from surrounding tones, with the major exception that it takes a preferred H pitch before a L syllable.

(8) Three rules are needed (conveniently referred to by their input/output relations)
   a. FL rule : $F \rightarrow L / \{ F, L \}$ __ (a F tone becomes L after either a F or a L)
   b. RF rule : $R \rightarrow F / R$ __ (a R tone becomes F after a R tone; i.e., R-R → R-F)
   c. RL rule : $R \rightarrow L /$ __ L (a R tone becomes L before a L tone)

The rule in (8a) takes care of the tone changes in the left-most box in (7): A F tone becomes L when preceded by either another F or a L tone. The rule in (8b) takes care of the tone change in the second box in (7): a R tone becomes F after another R tone. Finally, the rule in (8c) takes care of the tone change in the third box in (7): a R tone becomes L before a L tone. A schematic summary of these changes is provided in (9).

(9) Schematic summary of tone sandhi

	F	R	L
F	F - <u>L</u>		
R		R - <u>F</u>	<u>L</u> - L
L	L - <u>L</u>		

The natural question to ask is, why should it be exactly these four combinations that change, rather than the other five?

In order to answer this question, let us first decompose the F and R contour tones into H(igh) and L(ow) tone features and restate the tonal realizations as in (10), where the changed tones are again underlined:

(10) Restatement in terms of H(igh) and L(ow) tone features

	HL	LH	L
HL	HL - <u>L</u>	HL - LH	HL L
LH	LH - HL	LH - <u>HL</u>	<u>L</u> - L
L	L - <u>L</u>	L - LH	L - L

The inputs which do not change are listed in (11a), while those which do change are those in (11b).

(11)

	Inputs which do not change:		*Inputs which do change:*			*Outputs they change to:*
a.	LH-HL	b.	HL-HL	c.	→	HL-L
	HL-LH		LH-LH		→	LH-HL
	L-LH		LH-L		→	L-L
	HL-L		L-HL		→	L-L
	L-L					

By comparing the two sets of inputs, we see a clear difference: In (11a) the first tone ends at the same level at which the second tone begins. In (11b), on the other hand, the second tone begins at the opposite tone level with which the first tone ends. This suggests that there is a conspiracy at work, stated in (12):

(12) CONSPIRACY: The end-tone of one syllable should be the same as the beginning tone of the next (i.e., do not change tone levels between syllables!).

In Hakha Lai there is a prohibition against changing tone levels between syllables. Instead, tone levels change WITHIN syllables. We formulate this conspiracy as a constraint in (13), which we call the No Jumping Principle, or NOJUMP:[4]

(13) No Jumping Principle (NOJUMP) : $* \begin{array}{cc} \sigma & \sigma \\ | & | \\ \alpha H & -\alpha H \end{array}$

i.e., Hakha Lai, a contour tone language, likes tone changes to take place <u>within</u> syllables

This constraint is thus a syllable-contact phenomenon driven by an articulatory tendency to minimize tonal ups and downs (Hyman 1978:261). Although we are not aware of any other language with this exact property, we are at least a little reassured to find it among the Southeast Asian "contour tone systems" rather than among African languages which instead have "tone clusters" (Yip 1989).

To summarize, we have thus far established the three rules in (8) affecting tone sequences which violate NOJUMP in (13). In addition, something needs to be said about the realization of an underlying R as F in phrase-initial position. An OT analysis is attempted in §3.

[4] Our thanks to Martine Mazaudon, who suggested to call this "no jumping". In the oral version of this paper we referred to the constraint as the Intersyllabic No Contour Principle, or NoCP.

3. An OT analysis of Hakha Lai tone thus far

Based on what we have seen thus far, there is good reason to suppose that the Hakha Lai tone rules are driven by output constraints. In fact, three such pervasive constraints can be identified as in (14):

(14) Constraints that are active in identifying inputs-for-change, as well as their outputs

a. NOJUMP: drives all tone sandhi in Hakha Lai; only tones which violate NOJUMP change! Hence, in OT terms: NOJUMP >> IDENT(T)
   Output effect: R-R → R-F, not *R-L, because the latter still violates NOJUMP

b. MARKEDNESS scale (phonetically grounded): *R >> *F >> *L
   Output effect: F-F → F-L, not *F-R
   N.b.: No output tone is more marked than its corresponding input, hence: R → F, {F,R} → L; markedness is irrelevant unless NOJUMP is violated, hence IDENT (T) >> MARKEDNESS

c. LEFT PROMINENCE: three out of the four above changes affect the tone on the right
   Output effect: R-R → R-F, not *F-R
   N.b.: Violated by R-L → L-L; but L is immutable because of markedness scale; hence, MARKEDNESS >> LEFTPROM

The first of these is NOJUMP. Since only tone sequences which violate NOJUMP change, we can say that NOJUMP drives all tone sandhi in Hakha Lai. In OT terms, NOJUMP >> IDENT(T). NOJUMP also determines in part how certain offenders will be "repaired". Consider the input R-R, which violates NOJUMP. As seen in (14a), R-R becomes R-F, a process that Bao (1999) refers to as "contour metathesis". Although it is the second R tone that changes, the sequence does not become *R-L, because this would still violate NOJUMP.

The second output constraint in (14b) concerns markedness. As indicated, in the tone sandhi there is a strict adherence to the universal, phonetically grounded, markedness scale: *R >> *F >> *L. We know that rising tones are more complex than falling tones, which, in turn, are more complex than level tones (Ohala 1978:30-1). It is therefore significant that the sandhi rules never output a tone which is more marked than its input, as measured along this scale. The rules we posited in (8) convert F to L, R to F, and R to L. No other tone change occurs, specifically, F ↛ R, L ↛ F, L ↛ R. As indicated in (14b), the sequence F-F becomes F-L, rather than *F-

R, where the change from F to R would have represented an increase in markedness. We propose a constraint, MARKEDNESS, which is violated only if an output tone is more marked on the above scale than its input. We do not want this constraint to have an effect unless a tone has to change, which, as indicated in (14a), will happen only if there is a NOJUMP violation. Since an input such as /ka keé/ 'my leg' must not change to either **ka keè* or **ka kee* to derive a less marked tone, the ranking IDENT (T) >> MARKEDNESS is adopted in (14b).

The third output constraint in (14c) is Left Prominence (LEFTPROM). In three out of the four changes in (8), it is the tone of the syllable on the right that changes: F-F → F-L, L-F → L-L, R-R → R-F. The effect of LEFTPROM is that R-R becomes R-F, not *F-R, although either output would have satisfied NOJUMP. However, consider the fourth change, R-L → L-L. In this case it is the first tone that is changed, in violation of LEFTPROM. The reason for this should be clear. The input R-L violates NOJUMP. There are two ways this might be repaired. First, we might change the L, the second tone, to a F tone, in which case R-L would become *R-F. This would be a violation of MARKEDNESS, since the output F is more marked than its input /L/. The second way would be to change the first tone of the R-L input, in violation of LEFTPROM. This is what happens when R-L is realized L-L. Hence we conclude the partial ranking MARKEDNESS >> LEFTPROM in (14c).

The constraint hierarchy we arrive at in this way is stated in (15).

(15) Constraint hierarchy
NOJUMP >> IDENT (T) >> MARKEDNESS >> LEFTPROM

In (16) we provide tableaux for each of the four T1-T2 sequences that violate NOJUMP. In each case we consider as candidates the nine T1 + T2 input sequences to determine if the hierarchy in (15) successfully generates the correct output:[5]

[5] It would of course be possible to consider a richer set both of inputs and of outputs, the most obvious being simple H, which we assume to be prohibited by a high-ranking constraint *H. In these tableaux we limit ourselves to an underlying inventory /F, R, L/, and respect structure preservation in outputs.

(16) Tableaux for each of the four T1-T2 sequences that violate NOJUMP

a.

/ka F-F/	NOJUMP	IDENT (T)	MARKEDNESS	LEFTPROM
F-F	*!			
F-R		-*	-*!	
☞ F-L		-*		
R-F		*-	*!-	*
R-R	*!	*-*	*-*	*
R-L	*!	*-*	*-	*
L-F	*!	*-		*
L-R		*-*!	-*	*
L-L		*-*!		*

b.

/ka L-F/	NOJUMP	IDENT (T)	MARKEDNESS	LEFTPROM
F-F	*!	*-	*-	*
F-R		*-*!	*-*	*
F-L		*-*!	*-	*
R-F		*-	*!-	*
R-R	*!	*-*	*-*	*
R-L	*!	*-*	*-	*
L-F	*!			
L-R		-*	-*!	
☞ L-L		-*		

c.

/ka R-R/	NOJUMP	Ident (T)	MARKEDNESS	LEFTPROM
F-F	*!	*-*		*
F-R		*-		*!
F-L		*-*!		*
☞ R-F		-*		
R-R	*!			
R-L	*!	-*		
L-F	*!	*-*		*
L-R		*-		*!
L-L		*-*!		*

d.

	/ka R-L/	NoJump	Ident (T)	Markedness	LeftProm
	F-F	*!	*-*	-*	*
	F-R		*-*!	-*	*
☞	F-L		*-		*
	R-F		-*	-*!	
	R-R	*!	-*	-*	
	R-L	*!			
	L-F	*!	*-*	-*	*
	L-R		*-*!	-*	*
☞	L-L		*-		*

The violations indicated by the asterisks in (16a-d) are self-explanatory, except perhaps those seen under MARKEDNESS. An asterisk appears in the MARKEDNESS column if the output tone is more marked than its corresponding input tone. In other words, the constraint could be viewed as *MARKEDNESS INCREASE, a concept which has also recently been proposed for closely related Zahao (Yip 2004). Since this constraint is interpreted as all or nothing in these tables, it would be an equal violation for an input /L/ to have either a F or R as its corresponding output tone. Note also that a constraint DEP(H) seems unimportant here, given MARKEDNESS.

As seen, the correct outputs are generated in (16a-c), but there is an undesirable tie in (16d): F-L and L-L are equally good outputs for the input /R-L/. This result relates to the general issue of how to evaluate the different realizations of /R/: When an input R violates NOJUMP, should the grammar choose F as a better output than L, or vice-versa? Both slide down the markedness scale in (14b). It might, however, be possible to view L as preferable, because it is lower on the markedness scale than F.[6]

Given that both R → F and R → L are acceptable input-output relations, the question is what determines which one will obtain? The advantages and disadvantages of each, taken in isolation, are summarized in (17):

[6] We tried a gradient system of evaluation whereby an output R had two markedness violations, and an output F had only one markedness violation (output L would have no violation), but this created other problems. Specifically, still assuming the constraint ranking in (15), the best output for /R-R/ came out as *L-R, rather than R-F. (Reranking LEFTPROM higher than MARKEDNESS to fix this created other problems.)

(17)

		advantages	disadvantages
a.	R → F	preserves both H and L feature of input /LH/ (vs. LH → L)	violates LINEARITY (LH → HL); F is more marked than L
b.	R → L	L is less marked than F	violates MAX(H)

There thus appear to be at least two possible reasons for /R-L/ to be realized L-L instead of *F-L, as in (18a).

(18) Realizations of R as L or F

a. /ka koóy raŋ/ → ka kooy raŋ 'my friend's horse'
R L → L L (*ka koòy raŋ)

b. /ka koóy zaán raŋ → ka koóy zaàn raŋ 'my friend's night horse'
R R L → R F L (*ka koóy zaan raŋ)

First, it could be because L is less marked than F. Or, it could be because the R → F, which appears to involve tonal metathesis, constitutes a linearity violation. However, consider the example in (18b). In this case the second R tone could undergo R-R → R-F or R-L → L-L. As indicated, a F tone is outputted. Let us assume that the constraint distinguishing R → F from R → L is LINEARITY. The correct outputs can then be generated as in (19):

(19) Tableaux accounting for the two realizations R → L and R → F

a.

	/ka koóy raŋ/	NOJUMP	IDENT (T)	LINEARITY
☞	ka kooy raŋ		*	
	ka koòy raŋ		*	*!

b.

	/ka koóy zaán raŋ/	NOJUMP	IDENT (T)	LINEARITY
	ka koóy zaan raŋ	*!	*	
☞	ka koóy zaàn raŋ		*	*

As seen, L is outputted in (19a) because of the LINEARITY violation. If, however, a L were outputted in (19b), a R-L sequence would obtain which violates NOJUMP. As could already have been inferred from the change of R-R to R-F generally, the LINEARITY violation of R → F is of less consequence than NOJUMP. The generalization appears therefore to be that /R/ will become L unless F is needed to avoid violating NOJUMP.

This, then, naturally raises the question of why an input /R/ is realized as F at the beginning of a phrase, exemplified earlier in (6). In (20), we propose that there is a %H (or, alternatively, %R) boundary tone at the beginning of every phonological phrase in Hakha Lai:

(20) Proposal: Phrase-initial %H boundary tone (could also be %R)
i.e., σ is a NoJump violation
|
%H R

As shown, if the R tone is not changed to F, there will be a NoJump violation. It is natural that the lexical R tone would be changed rather than the phrasal boundary tone. Note that a change of %H-R to %H-F respects LeftProm in a way that, say, %H-R → %L-R would not. With this move, the two processes, %H-R → F and R-R → R-F become one.

In the next section we examine NoJump effects in longer phrases where there are different potential outputs.

4. Directionality and its consequences

At the end of the preceding section we proposed that the initial R rule in (5) is the same as the RF rule in (8b). Both rules convert R to F, the former after a %H boundary tone, the latter after another R. In this section we take a closer look at the R → F correspondence.

We begin with a phrase-initial input /R-R/, which, as seen in (21a), is realized F-F:

(21) RF rule appears to precede Initial R rule (but cf. below)

a.			*RF rule*		*Initial R Rule*	
	zaán + tsaán	→	zaán tsaàn	→	zaàn tsaàn	'night time'
	R R		R F		F F	
	koóy + hróm	→	koóy hròm	→	koòy hròm	'friend's throat'
	R R		R F		F F	
b.			*Initial R rule*		*RF rule*	
	zaán + tsaán	→	*zaàn tsaán		n.a.	
	R R		F R			
	koóy + hróm	→	*koòy hróm		n.a.	
	R R		F R			

If for the moment we go back to our first position and assume that the RF rule is separate from the Initial R rule (whether the latter is conditioned by a %H boundary tone or not), the two rules would have to apply in this order. As seen in (21b), the reverse order incorrectly converts /R-R/ to *F-R.

We see in (22), however, that rule ordering is not sufficient to explain the F-F outputs, since the RF rule itself may apply iteratively to a string of R* tones which become F*:

(22) Iterative application of the RF rule

a.	ka +	koóy +	zaán +	tsaán	→		ka	koóy	zaàn	tsaàn		‘my friend’s night time’
		R	R	R				R	F	F		
b.	%	koóy +	zaán +	tsaán	→			koòy	zaàn	tsaàn		‘friend’s night time’
	H	R	R	R				F	F	F		

We can make the following three observations concerning the opaque outputs in (21) and (22). First, as shown in (23a), the RF rule must either apply right-to-left or simultaneously:

(23) RF rule must apply right-to-left or simultaneously (and is “self-counter-bleeding”):

a. Right-to-left: ka R-R-R → ka R-R-F → ka R-F-F
% R-R-R → % R-R-F → % R-F-F → % F-F-F

b. Left-to-right: ka R-R-R → *ka R-F-R
% R-R-R → % F-R-R → *% F-R-F

If the RF rule had applied left-to-right, as in (23b), we would have instead gotten alternating R and F, which is incorrect. Since the left-to-right application would have produced alternating and hence fewer F tones, the RF rule is “self-counterbleeding”. Second, note in (24) that the right-to-left iterative application of the RF rule counter-feeds the FL rule:

(24) Output F-F does not undergo FL rule

a. ka R-R-R → ka R-R-F → ka R-F-F ↛ *ka R-F-L

b. % R-R-R → % R-R-F → % R-F-F → % F-F-F ↛ *% F-L-L

It can be noted in this context in (25) that when the FL rule applies to multiple sequences of F tone, all but the first F becomes L, and there is no directionality problem:

(25) No directionality problem when FL rule applies to F-F-F (→ F-L-L)

a.	kàn + tlaàŋ + zuù	→	kàn tlaaŋ zuu	'our mountain beer'
b.	raàl + làw + hmaà	→	raàl law hmaa	'enemy field time'
	F F F		F L L	

As shown in (26), this is because F is lowered to L after either a F or L tone:

(26) FL rule can apply right-to-left, left-to-right or simultaneously (no self-interaction)

a.	Right-to-left:	F-F-F	→	F-F-L	→	F-L-L		
		F-F-F-F	→	F-F-F-L	→	F-F-L-L	→	F-L-L-L
b.	Left-to-right:	F-F-F	→	F-L-F	→	F-L-L		
		F-F-F-F	→	F-L-F-F	→	F-L-L-F	→	F-L-L-L

The third and final observation in (27) is perhaps the most significant:

(27) Output F-F violates conspiratorial NoJump, the driving force of tone sandhi in Hakha Lai!

While it is not surprising for input-output relations to produce opacities, output F-F violates the conspiratorial NoJump, which we have seen to be the driving force of tone sandhi in Hakha Lai! In other words, when a sequence of R tones, which violates NoJump, becomes F-F, the chosen "repair" violates the same very constraint. This is indicated by the asterisks in (28a).

(28) Right-to-left iterative (or simultaneous) application of RF rule violates NoJump

a. right-to-left

	ka= R- R- R	% R- R- R
	↓ ↓ ↓	↓ ↓ ↓
	R F F	F F F
	*	* *

b. left-to-right

	ka= R- R- R	% R- R- R
	↓ ↓ ↓	↓ ↓ ↓
	R F R	F R F

This result is rather surprising, since, as seen in (28b), a left-to-right application would produce no surface NoJump violations. So, the question is: Why does the RF rule apply right-to-left? Does this have to be stipulated, or can it follow from general principles?

The most comprehensive treatment of the issue of directional tone sandhi is to be found in Chen (2000), which devotes two chapters to this question as it pertains to Chinese dialects. Chen presents six general principles which may contribute to determining directionality, depending on their relative ranking:

(29) Chen's (2000, 2004) six principles determining directionality of tone sandhi in Chinese
a. Temporal Sequence
b. Well-Formedness Conditions
c. Derivational Economy
d. Transparency
e. Structural Affinity
f. Simplicity (= Markedness)

We now show that five of Chen's constraints incorrectly lead to a left-to-right directionality in Hakha Lai, no matter what their ranking, and the sixth runs into conceptual difficulties.

The first of these is Chen's Temporal Sequence constraint in (30).

(30) *Temporal Sequence* (TS): "apply rules left to right" (p.111)
"… 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). For psycholinguistic evidence showing a left-to-right bias in speech organization (phonological encoding), see Meyer (1990, 1991)."

This states that in the unmarked case rules should be applied left-to-right, that is, as forms are met in the temporal sequence. As seen in the quote, Chen cites psycholinguistic evidence in favor of a left-to-right default, which is said to aid "the planning and execution of articulatory events". Hakha Lai obviously does not follow Temporal Sequence.

As cited in (31), Chen indicates that default left-to-right application may be overridden and the direction of operation reversed if this results in fewer violations of his second principle, Well-Formedness Conditions:

(31) *Well-Formedness Conditions*
"By default, rules apply from left to right—unless such a mode of application produces an ill-formed output, in which case the direction of operation is reversed." (p.111)

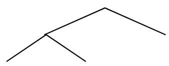
However, if we compare the outputs we saw in (28a), we see that right-to-left application produces serious WFC violations in Hakha Lai, as indicated by the asterisks. On the other hand, left-to-right application in (28b) produces no NOJUMP violations. By the criterion of well-formedness, Hakha Lai tone rules should again apply left-to-right—and not right-to-left.

Chen's third principle is Derivational Economy, which is measured "by simply counting the number of steps…" (p.171). An input-output relation which involves fewer steps, or perhaps fewer changed tones is, thus, to be preferred, other things being equal. In our case it should be clear that this criterion would also favor a left-to-right rule application: (28a) involves more steps (more tone changes, more unfaithfulness to input tones) than (28b). It also violates Chen's fourth principle, Transparency, in that it produces opaque F-F sequences that should have become F-L by the FL rule, but do not.[7] It should be clear from (28) that this criterion would as well favor a left-to-right rule application: (28a) involves more steps (i.e., more tone changes, more unfaithfulness to input tone) than (28b); it also produces opacity, which (28b) does not.

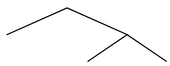
Chen's fifth principle is Structural Affinity. In some Chinese dialects tone sandhi follow the syntactic bracketing, applying within smaller constituents before moving on to larger ones. In the case of left-bracketing in (32a), this could produce left-to-right directionality, while in the case of right-bracketing in (32b), it could result in right-to-left directionality.

(32) *Structural affinity*: following the syntactic bracketing (as optionally in Standard Mandarin)

a. left-to-right



b. right-to-left

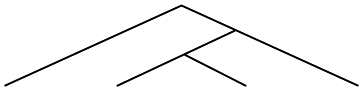


However, as seen in the examples in (33), in Hakha Lai, bracketing is irrelevant. Indeed, the R → F rule always applies right-to-left, whether the bracketing is mixed, as in (33a), or even consistently left-branching, as in (33b).

[7] Chen includes "backtracking" as a subcase of derivational economy. This is the prohibition against a derivation which begins in one direction and then shifts to the other direction, with the usual result that a sandhied tone undergoes a second sandhi. We return to this notion as well as Hsu's (1994, 2002) "one-step principle" below.

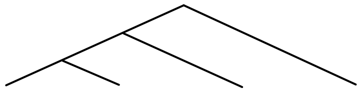
(33) In Hakha Lai, bracketing is irrelevant: RF always applies right-to-left, e.g.:

a.



ka zaán tsaán koóy → ka zaán tsaàn koòy 'my night-time friend'
R R R → R F F

b.



it is NEG if

ʔa sií láw leé → ʔa sií làw leè 'if it isn't (the case)'
R R R → R F F

Chen's last principle, Simplicity, refers to the relative markedness of the output tones: One directionality may be preferred because it produces less marked tones than the other. Superficially this may appear to be relevant in Hakha Lai: The incorrect right-to-left application in (28b) produces cases of R tones, which are more marked than the F tones in the left-to-right application in (28a). The only hope, therefore, of a general principle driving F-F outputs is the avoidance of R tones. However, we see two major problems with this explanation:

The first problem is how to explain why F-F-F outputs, which violate NOJUMP, are preferred over F-R-F, which do not. As we have seen, only the input tonal sequences which violate NOJUMP change. However, if NOJUMP is so important, as we claim, why are F-F outputs tolerated which violate it? If it is because R tones are avoided, then we have to ask why all R tones do not change to F, i.e., even when not preceded by another R? The ranking NOJUMP >> MARKEDNESS which we proposed in (15) suggests that considerations of tonal markedness are subordinated to the need to avoid NOJUMP violations. The second problem has to do with how R tones are avoided. If MARKEDNESS is so important, why does R-R-R become R-F-F rather than *R-F-L (where L is less marked than F)? Obviously, this is not what is going on in Hakha Lai. We conclude, then, that MARKEDNESS alone is not likely to get us out of our bind.

The concepts Chen invokes to account for directional rule application in Chinese thus appear not to work for Hakha Lai. It is interesting that the mostly forgotten work by Howard (1972) is not cited by Chen or in most recent work on directionality (but see Halle & Idsardi 1995:419). Howard's theory of directional iterative rule application, cited in (34a), states that rules should be applied from the direction of the trigger (or determinant) towards the target (or focus) of the rule:

(34) Directional iterative rule application

a. Howard (1972:30): "A rule is applied across a string from the side corresponding to the location of the determinant to the side corresponding to the focus."

i. X → Y / __ Z should apply right-to-left

ii. X → Y / Z __ should apply left-to-right

b. Note that all but one of Chen's directional tone sandhi rules in chapters 3 & 4 involve right-prominence (vs. left-prominence in Hakha Lai)

i. right prominence: T → T' / __ T Tianjin, Changting, Standard Mandarin, Boshan

ii. left prominence: T → T' / T __ Hakha Lai

In each of the schematized rules in (34a), the direction should go (and keep going) in the direction from the trigger Z towards the target X. Note now in (34b) that all but one of Chen's directional tone sandhi rules in his chapters 3 & 4 involve right-prominence vs. the left-prominence which we have seen in Hakha Lai. If Howard's generalization applied to tone sandhi, we would expect directionality to be right-to-left in Chinese, but left-to-right in Hakha Lai. That is, we would expect just the opposite of what we actually find.

Still there seems something rather intriguing about the mirror-image consistency with which Hakha Lai and Chinese violate Howard's theory. Why should this be? It may be that directionality is not predictable. Or, as some scholars have pointed out (e.g., Davy & Nurse 1982), theories of directional rule application established for assimilatory processes may simply not be generalizable to dissimilatory processes. An assimilatory process which follows Howard's predicted direction of application will have the potential for being iterative, e.g., [-nasal] → [+nasal] / __ [+nasal], applying right-to-left. If the same rule applies in the opposite direction, only one target segment will be affected. The question that arises in this case is whether the relevant parametric variation is one of directionality (right-to-left/left-to-right) or of iterativity (bounded/ unbounded). On the other hand, as we have seen, when an input string R* is inputted to a dissimilatory process such as R-R → R-F, either directionality can produce multiple effects.[8] As seen in the comparision in (28), if the rule applies right-to-left (as it does in Hakha Lai), the output will be R-F*. If it applies left-to-right, the output will be (R-F)*.

As an alternative, let us consider the possibility that the direction of dissimilation is "prominence-driven": A prosodically weaker element dissimilates to a stronger one. In this sense, dissimilation is like reduction. Recapitulating a line of research that was

[8] Suzuki (1998) limits these by determining the domain within which dissimilation occurs.

popular in the early 1980s, based on Halle & Vergnaud (1978), let us consider the prominence clines in (35).[9]

(35) Directional Prominence Clines

a. left-prominence (Hakha Lai, Wu)   b. right-prominence (Mandarin, Min)

```
      x                                     x
      x  x                               x  x
      x  x  x                         x  x  x
      x  x  x  x                   x  x  x  x
   %  σ  σ  σ  σ  ... %         %  σ  σ  σ  σ  ... %
      |  |  |  |                   |  |  |  |
      T  T  T  T                   T  T  T  T
```

As seen in (35a), Hakha Lai has left-prominence, which means that there is a gradual decline in prominence in going from left to right within the phonological phrase. This is indicated by the grid marks. Within Chinese, it shares this property with the Wu dialects. The mirror-image of this is right-prominence in (35b), which characterizes the Mandarin and Min dialects of Chinese. In this case there is a gradual rise in prominence as one goes from left to right within the phonological phrase.

With these "prominence clines" established, we can attempt to derive the directionality of iterative tone rules by adopting in (36) a relativized version of Beckman's (1997) notion of positional faithfulness:

(36) Directional Faithfulness

Given two contiguous tones, T1 and T2, where T1 is in a stronger position than T2 and both violate a constraint C, IDENT (T1) cannot be violated unless IDENT (T2) also is

To see how this might work, we return in (37) to the right-to-left application of R-R → R-F.

---

[9] Such research typically represented relative prominence in terms of metrical trees. For example, Zubizarreta (1979:6) proposed left-branching trees for left-to-right harmony, right-branching trees for right-to-left harmony, and multibranching trees for bidirectional harmony. This would make depth of embedding a mark of prominence. Discussing the decrescendoing of nasality in Guaraní, Poser (1982), on the other hand, rejects depth of embedding and refers directly to distance from the designated terminal element (DTE), or trigger.

(37) Right-to-left application of R-R → R-F follows from Left Faithfulness in Hakha Lai

a. right-to-left   b. left-to-right

```
                       x                                x
      x                x   x               x            x   x
      x  x             x   x  x            x  x         x   x  x
      x  x  x          x   x  x  x         x  x  x      x   x  x  x
ka=   R- R- R          %   R- R- R     ka= R- R- R      %   R- R- R
      ↓  ↓  ↓              ↓  ↓  ↓         ↓  ↓  ↓          ↓  ↓  ↓
      R  F  F              F  F  F         R  F  R          F  R  F
                                              *             *
```

The correct outputs are seen in (37a), where R → F has applied to all but the most gridded tone. (The % boundary stands for the boundary H, which, being on the left, is the most prominent tone of the sequence.) This is, of course, what is obtained by right-to-left rule application. In (37b), on the other hand, left-to-right directional application produces incorrect outputs. What is wrong about these is that they each involve an instance where an input /R/ has become F without the following, weaker /R/ doing likewise. These are, then, violations of Left Faithfulness (LEFTFAITH). Of course, LEFTFAITH will have to be ranked higher than NOJUMP, which is violated in (37a).

There is one final problem, however, seen in (38).

(38) Respect for LEFTFAITH

a. correct: violating NOJUMP   b. incorrect: no violations of NOJUMP

```
ka= R- R- R     % R- R- R        ka= R- R- R      % R- R- R
    ↓  ↓  ↓       ↓  ↓  ↓            ↓  ↓  ↓        ↓  ↓  ↓
    R  F  F       F  F  F            R  F  L        F  L  L
```

Both (38a) and (38b) respect Left-Prominent Positional Faithfulness.[10] The correct outputs in (38a) violate NOJUMP, while the incorrect ones in (38b) do not. So, how is (38b) to be ruled out?

Besides LEFTFAITH, it is clear that MARKEDNESS and LEFTPROM, as conceived in §3, are irrelevant, so they are omitted from the tableaux in (39) which compare the outputs in (38a, b).[11]

---

[10] The output *ka* R-F-L in (38b) also nicely reflects a descent down the markedness scale *R >> *F >> *L.

[11] We believe there is a non-arbitrary relationship between LEFTFAITH and LEFTPROM, but like the relationship between MARKEDNESS (= no I/O markedness increase) and general marked-

(39) Tableaux comparing outputs in (38a, b)

a.

	/ka R-R-R/	NoJump	Ident (T)	Linearity
	R-F-F	*!	-*-*	-*-*
💣	R-F-L		-*-*	

b.

	/% R-R-R/	NoJump	Ident (T)	Linearity
	F-F-F	*!*	*-*-*	*-*-*
💣	F-L-L		*-*-*	

As seen, NoJump and Linearity violations rule out the correct outputs, with no obvious constraint able to choose the desired outputs over the unfortunate winners. Assuming derivationality, the incorrect winning candidates in (39) are achieved as in (40).

(40) Derivation of *R-F-L and *F-L-L

a. (ka)	/R-R-R/	b. /% R-R-R/	
	R-F-F	F-F-F	(by RF rule)
	R-F-L	F-L-L	(by FL rule)

As seen, these outputs are produced by first applying the RF rule, followed by the FL rule. Note that both are ruled out by Hsu's (1994, 2002) One-Step Principle (OSP), which says that a sandhied tone (T') cannot be sandhied a second time (*T"). Both outputs are also ruled out by Chen's prohibition of "backtracking", if the RF rule is assumed to apply right to left; if it applies simultaneously, it is not clear if these outputs are ruled out. Chen's (2000:104) rules in (41a-c) produce the derivation in (42a).

(41) Rules potentially producing backtracking (Chen 2000:104)

a. A → X / __B	But if:	e. X → Y / A __
b. B → Y / __C		f. Y → Z / __ B
c. X → Z / __Y		

ness, it is hard to capture this in terms of a single constraint with a consistent ranking.

(42) Illustration of backtracking

a.	$\underline{\text{A B}}$ C		b.	$\underline{\text{A X}}$ B	
	↓	(by 41a)		↓	(by 41e)
	X $\underline{\text{B C}}$			A $\underline{\text{Y B}}$	
	↓	(by 41b)		↓	(by 41f)
	$\underline{\text{X Y}}$ C			A Z B	
	↓	(by 41c)			
	Z Y C				

As seen, the derivation proceeds left-to-right. First A is converted to X, and then B to Y. The backtracking comes in the last stage of the derivation, where X becomes Z before the derived Y. It is, then, as though the directionality began left-to-right, but then shifted direction and became right-to-left.

Compare this with our hypothetical rules in (41e, f). As seen in the derivation in (42b), X first becomes Y after A, and then Z before B. It is clear that this violates Hsu's OSP, since the input tone X has been the focus of one sandhi and then another. But does it constitute backtracking? This depends on how one views the algorithm for applying rules to strings, something which Howard (1972) discusses at great length.[12]

Two points, then, regarding prohibiting the outputs in (40). First, there is the question of whether the rules in question apply directionally, as in derivational phonology, or simultaneously, as in constraint-based or declarative phonology. Second, there is the question of whether intermediate representations are required, as in derivational phonology in (40), or whether the tableaux in (39) can be interpreted as direct mapping between input and output. In other words, we face the fundamental question of whether phonology is derivational or not.

Before presenting our preferred solution, let us bring in one more fact. As seen in the examples in (43), a F tone is preserved not only after a surface R, as in (43a), but also after a surface F which derives from an input /R/, as in (43b, c):

(43) Another source of F-F

a.	ka	koóy	hmaà	'my friend's wound'
		R	F	

[12] There is a potential difference between the two principles. If a language has AX $\rightarrow$ AY and YB $\rightarrow$ ZB, then, it might be possible for /AXB/ to become AYB, then AZB without violating Chen's backtracking principle. This would, however, violate Hsu's OSP. If both left- and right-prominent tone sandhi occurred more often in the same dialect, perhaps such situations would arise more commonly.

b.	ka	koóy	keè	hmaà	‘my friend’s leg wound’ (cf. ka keé ‘my leg’)
		R	R	F	
			↓		
			F		
c.		koòy	hmaà		‘friend’s wound’
	%	R	F		
		↓			
		F			

In (43b), the R of /keé/ ‘leg’ becomes F by the RF rule, while in (43c), the R of /koóy/ ‘friend’ becomes F after the %H boundary tone. In both cases a /R-F/ sequence is realized F-F. We therefore have two sources of NoJump violations, shown in (44): (i) right-to-left application of the RF rule, such that /R-R-R/ surfaces as R-F-F; (ii) interaction of the RF rule with a following /F/ tone, such that /R-R-F/ surfaces as R-F-F. As this comparison shows, the last F of a F* sequence can, thus, derive from either /R/ or /F/.

(44) Two sources of NoJump violations

a. right-to-left application of RF rule: e.g., /R-R-R/ → R-F-F

b. interaction of RF rule with following F: e.g., /R-R-F/ → R-F-F

N.b.: The last F of a F* sequence can derive from either /R/ or /F/.

As indicated in (45), two different statements are needed in a derivational framework to capture the input-output relations in (44).

(45) Two different statements needed in a derivational framework

a. rule ordering: FL rule ⊃ RF rule

b. directionality: RF rule must apply right-to-left

In the next section we present an analysis that captures the Hakha Lai facts in (44) without having to stipulate either the above rule ordering or directionality.

5. A direct-mapping analysis

All of these problems that have just been discussed skirt around the following basic observation: Hakha Lai does not like feeding and bleeding. It does not allow one rule to feed another. Thus, when /R-R-R/ becomes R-F-F by the RF rule, the latter is not allowed to undergo the FL rule. It also does not allow the RF rule to bleed itself, which would be the case if R-R-R → *R-F-R by left-to-right application. The one place where there is bleeding was seen in (18b). An /R-R-L/ meets the structural description of both the RF and RL rules, hence one or the other must apply. Since /R-R-L/ surfaces as R-F-L (and not *R-L-L), it is clear that the RF rule takes precedence. In the discussion of (18b) this was attributed to the fact that *R-L-L still violates NoJump.

Consider, however, the longer example in (46a).

(46) RF rule takes precedence over RL rule

a.	ka koóy zaán tsaán raŋ R R R L	→	ka koóy zaàn tsaàn raŋ R F F L	'my friend's night-time horse'
b.	ka koóy zaán tsaán raŋ R R R L	→	*ka kooy zaan tsaan raŋ L L L L	
c.	ka koóy zaán tsaán raŋ R R R L	→	*ka koóy zaàn tsaan raŋ R F L L	

In this case the /R-R-R-L/ input has a sequence of three R tones. The correct output is produced in (46a) by applying the RF rule to both /zaán/ 'night' and /tsaán/ 'time', as shown. If the RL rule applies first as a right-to-left iterative rule as in (46b), it successively targets not only /tsaán/ and /zaán/, but also /koóy/, incorrectly producing the output *L-L-L-L. If the RL rule is non-iterative, it would apply only to /tsaán/, and the RF rule would apply to /zaán/, resulting in the equally incorrect *R-F-L-L output in (46c). Since neither of the incorrect outputs in (46b, c) violates NoJump, and since they involve fewer Linearity violations than (46a), there seems no way to generate (46a) other than by extending the rule ordering statement of (45a) to include the RL rule, as in (47a).[13]

(47) Final Stipulations

a. rule ordering: FL rule ⊃ RF rule ⊃ RL rule

b. directionality: RF rule must apply right-to-left

We would still need to stipulate in (47b) that the RF rule applies iteratively, right-to-left. However, we would at least not need to say anything about the application of the FL rule, which as was seen in (26) can apply left-to-right, right-to-left, or simultaneously, with the same results. We also do not have to stipulate the non-iterativity of the RL rule,

[13] We considered adding the constraint Max(H), which would be violated by R → L, but not by R → F. However, this would not explain why the input /ka koóy raŋ/ 'my friend's horse' becomes ka kooy raŋ by the RL rule in (18a), rather than *ka koòy raŋ, where the H of /LH/ is preserved.

since, given the rule ordering in (47a), an /R-R-L/ input will automatically be first subject to the RF rule, which will bleed the RL rule.

To recapitulate what we have seen, an output-driven account runs into serious complications, while a serial derivational approach can handle the Hakha Lai facts with the stipulations in (47). Given the belabored discussion of the above complexities, it is quite striking to note in (48) how simply all of the Hakha Lai facts can be captured by a direct mapping, cross-level analysis:

(48) Ranked, direct mapping, I → O statements

	FL rule	=	**RF rule**	>>	**RL rule**
I:	{F, L} - F		{%, R} - R		R - L
	↓		↓		↓
O:	L		F		L

Three input/output correspondence rules are needed: The FL rule says that an input /F/ tone corresponds to an output L if it is preceded by an input /F/ or /L/. The RF rule states that an input /R/ corresponds to an output F if it is preceded by an input /R/ or %H (which we could alternatively have set up as %R). Finally, the RL rule says that an input /R/ tone corresponds to a L if it is followed by an input /L/.

A number of linguists have proposed such declarative statements of input-output relations (see, for example, the papers and references in Goldsmith 1993a, also McCarthy's 1995 discussion within OT). What is different about the analysis in (46) is that the proposed language-specific rules are ranked. Both the FL rule and the RF rule are ranked higher than the RL rule. As indicated in (49), what this means is that both directionality and rule ordering effects fall out from these rule formulations and their ranking:

(49) Consequences of RF rule as direct mapping

a. the right-to-left directionality, which needs to be stipulated in other analyses, automatically falls out: /R-R-R/ → *R-F-R has a violation of the RF rule, while /R-R-R/ → R-F-F does not; hence (right-to-left) R-F-F is the correct output

b. the failure of RF rule to feed FL rule automatically falls out, since there is only direct mapping; /R-R-F/ → R-F-F, not *R-F-L, etc.

c. the ordering of RF rule ⊃ RL rule automatically falls out from ranking: /R-R-R-L/ → *R-F-L-L has a higher ranked RF rule violation, while /R-R-R-L/ → R-F-F-L has a lower ranked RL rule violation.

First, in (50a), if /R-R-R/ is realized *R-F-R, the RF rule is violated in the sense that the final input /R/ which is preceded by another /R/ is not realized F:

(50) Evaluating the RF rule (R tones meeting the input condition are underlined)

a. incorrect: violating RF rule		b. correct: no violations of RF rule	
ka= R- $\underline{\text{R}}$- $\underline{\text{R}}$	% $\underline{\text{R}}$- $\underline{\text{R}}$- $\underline{\text{R}}$	ka= R- $\underline{\text{R}}$- $\underline{\text{R}}$	% R- $\underline{\text{R}}$- $\underline{\text{R}}$
↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓	↓ ↓ ↓
R F R	F R F	R F F	F F F
*	*		

On the other hand, if /R-R-R/ is realized R-F-F, as in (50b), there is no violation. Hence (right-to-left) R-F-F is correct output.

Second, note in (49b) that the failure of the RF rule to feed the FL rule also falls out, since there is only direct mapping. There is hence no possibility of feeding or bleeding, of backtracking, or of violating the OSP.

Finally, in (49c), the apparent ordering of the RF rule before the RL rule falls out from their relative ranking. An input /R-R-R-L/ will not become *R-F-L-L, where the higher ranked RF rule is violated, but will rather become R-F-F-L, where the lower ranked RL rule is violated.

In short, the analysis in (48) seems to say exactly what is going on in Hakha Lai. The three rules capture in a one-to-one way the knowledge which Hakha Lai speakers can be assumed to have at their disposal, which in turn guides them in producing the observed tonal alternations. The FL, RF, and RL tone rules which we have adopted throughout this study are exceptionless, applying within phonological phrases whenever their structural description is met.[14]

6. Discussion

We have shown that the direct mapping analysis in §5 is of great simplicity. It of course does not explain why we should get opaque F-F outputs from the so-called rule ordering and directionality effects. Since accounting for surface F-F in functional terms would be a central concern of an output-driven approach, it stands to reason that the opacity cannot be ignored in an OT analysis. Quite clearly, something more would be

[14] Hakha Lai is an SOV language where each argument or adjunct may be a separate phonological phrase. In addition, the verb forms a phonological phrase with all of its pre- and postpositions (cf. Peterson 1998).

needed to parlay the opaque F-F outputs into winning candidates.[15]

In order to see whether an output-driven account is really hopeless, it is incumbent on us to raise the following question not addressed by the direct mapping analysis: Why does Hakha Lai have this F-F opacity? Why is it tolerated, and how did it develop it in the first place? Is there some advantage to F-F opacity that we have overlooked?

In attempting to address this last question, Elan Dresher (pc) has reminded us of Kaye's (1974) demonstration that opacity can serve as an aid in the recoverability of input forms. To illustrate this point, we oversimplify and consider only the input-output pairs in (51).

(51) Opacity preserves recoverability (Kaye 1974)

a. with opacity			b. without opacity				
% F-F	→	F-L	% F-F			→	F-L
% R-R	→	F-F	% R-R	→	F-F	→	F-L

With direct mapping (or proper rule ordering), the correct outputs are derived as in (51a). The failure of derived F-F to become F-L constitutes what Kiparsky (1971) terms a type 1 opacity. In this case, the F-L output allows speakers to infer that the second input tone was /F/. With opposite rule ordering (or an unviolated output constraint *F-F) in (51b), the F-F derived from % R-R is allowed to become F-L. As a result, the two sequences would both surface as F-L, and speakers would not be able to recover the input tone corresponding to the output L.

In fact, (51) is a simplification. The output F-L in (51a) could also have been derived from either % F-L or % R-L. The F-F output could also have been derived from % R-F. The question is whether opacity is much of a help at all in the current Hakha Lai context. To determine this, the two tables (52) represents the neutralizations of the nine two-tone sequences in the following three contexts:

(52) a. Context: After toneless CV

Inputs:	F-R	F-F	R-F	L-R	R-L
		F-L	R-R		L-F
					L-L
Outputs:	F-R	F-L	R-F	L-R	L-L

[15] Specifically, one would have to adopt at least one of the possible approaches to opacity discussed by McCarthy (1999). The most likely strategy to succeed is one which treats the RF rule as a R → H process, as discussed below.

b. Context: After %H or R

Inputs:	R-F	F-R	F-F	L-F	L-R
	R-R		F-L	L-L	
			R-L		
Outputs:	F-F	F-R	F-L	L-L	L-R

c. Context: After F or L

Inputs:	R-F	F-R	F-F
	R-R	L-R	F-L
			R-L
			L-F
			L-L
Outputs:	R-F	L-R	L-L

In (52a) we see that the nine disyllabic input sequences are realized with one of five possible outputs after a toneless CV syllable. Of these nine inputs, only two, /F-R/ and /L-R/, have (unchanged) outputs that do not represent a neutralization. Two cases, [F-L] and [L-R], represent a neutralization of two different inputs, while one case, [L-L], neutralizes three different inputs. There is no opacity.

In (52b), the realizations are provided when the nine disyllabic input sequences occur after either the %H boundary tone or after a /R/. Although distributed differently, the number of neutralizations is identical: /F-R/ and /L-R/ are realized without neutralization (or change); [F-F] and [L-L] each represent a neutralization of two input sequences, while [F-L] neutralizes three input sequences. This time, however, opacity does occur when the output F-F in the first column fails to become *F-L. If the two inputs, /R-F/ and /R-R/ had been realized as [F-L] instead of F-F, F-L would in this case realize five different inputs. Is this a sufficient reason to block derived F-F from becoming F-L?

We don't think so. To see why, consider (52c), which shows that after a /F/ or /L/ tone, the nine input sequences have only three possible outputs. As seen, one of these outputs, [L-L], realizes five different input sequences. We therefore infer that since a recoverability factor of 1-to-5 already exists in (52c), it should not have been too taxing for the same to exist in (52b).[16] In fact, if we total up all 27 input sequences in (52), we get the following neutralization facts in (53).

(53) Total number of inputs (out of 27) for each of the following outputs in (52)

F-F	F-R	F-L	R-F	R-R	R-L	L-F	L-R	L-L
2	2	5	4	Ø	Ø	Ø	4	10

[16] Note that there is no opacity in the outputs in (52c).

Two facts are striking in (53). First, 10 out of the 27 underlying sequences are realized L-L. Second, the opacity problem in the F-F output in the first column only affects 2 out of these 27 inputs. It does not seem likely, therefore, that the failure of output F-F to become F-L is due to problems of recoverability.

As we have seen, there are two sources of F-F. The first is from direct mapping or ordering of the FL and RL rules: /R-R-F/ becomes R-F-F, but not *R-F-L. The second is from the right-to-left directionality of the RF rule: R-R-R → R-F-F. If the RF rule had applied left-to-right, /R-R-R/ would have been realized R-F-R, i.e., without opacity. As shown in (54), directionality has the following effects on recoverability:

(54) Realizations of R* sequences after toneless CV, e.g., *ka* 'my'

a.	trisyllabic input:	/R-R-R/	could also have come from:
	right-to-left:	R-F-F	/R-R-F/
	left-to-right:	R-F-R	/R-F-R/
b.	tetrasyllabic input:	/R-R-R-R/	could also have come from:
	right-to-left:	R-F-F-F	/R-R-R-F/
	left-to-right:	R-F-R-F	/R-F-R-F/, /R-R-R-F/, /R-F-R-R/

In the trisyllabic input in (54a), both the (correct) right-to-left application of the RF rule, as well as the (incorrect) left-to-right application, yield outputs that neutralize with exactly one other possible input. Recoverability is therefore not affected by directionality. However, in (54b), where there is a tetrasyllabic input, the right-to-left application has a definite advantage. As indicated, opaque R-F-F-F can only be derived from two possible inputs, while "transparent" R-F-R-F can be derived from four. In other words, the longer the stretch of surface F* sequences, the more there is a recoverability advantage in applying the RF rule right-to-left.

This having been said, we still are not convinced that this would be enough of an advantage to warrant the unusual right-to-left application of the RF rule. Rather, we will consider that we have not yet shown any synchronic advantage to surface sequences of F-F in Hakha Lai. If there is none, why does [F-F] occur in the language? Diachronically, we suspect that the current Hakha Lai tone system represents a restructuring of an earlier one with a slightly different tonal inventory which included a fourth proto-tone *H. Synchronically, as we shall now demonstrate, everything hinges on the interpretation of the processes that bring about the FL, RF, and RL input-output relations on which our study has focused.

Let us illustrate this with respect to the RF rule, which creates all of the F-F opacity, either by counterfeeding ordering with the FL rule, or by self-counterbleeding.

As listed in (55), there are at least four ways to conceptualize the change of a R to a F after another R:

(55) Four ways to conceptualize R-R → R-F

a. tonal substitution: R-R → R-F

b. tonal metathesis: L_iH_i-L_jH_j → L_iH_i-H_jL_j

c. tonal delinking: L_iH_i-L_jH_j → L_iH_i-H_j → L_iH_i-H_jL_k

d. tonal spreading: L_iH_i-L_jH_j → L_iH_i-$H_iL_jH_j$ → L_iH_i-H_iL_j

Up until now we have been conceptualizing the FR rule as a single-step change from R to F. This can be effected by an arbitrary substitution of one tone (F) for another (R), as in (55a). Or it may be viewed as contour metathesis, as in (55b). Yip (1989) proposes that dissimilation of this sort is due to the obligatory contour principle (OCP) forbidding identical contours in sequence, something which is taken up also by Chen (2000). Both the latter and Bao (1999) cite a number of dissimilatory processes of this sort in Chinese dialects, the latter invoking such phenomena as evidence for a contour tonal node.[17] However, this is not the only way we might regard this process.[18] In particular, it is possible to view the resulting tonal metathesis as resulting from a two-step process.

First, we might consider that the output of the RF rule is not R-F, but rather R-H, as shown in (56a).

(56) Possible way of avoiding the whole problem by assuming H is output of RR rule

a. LH → H / H __ i.e., LH-LH → LH-H

b. H → HL i.e., LH-H → LH-HL ("later", e.g., by phonetic implementation)

This could be accomplished by delinking the L of a LH contour when the latter is preceded by another [H].[19] Since there is no H tone syllable in Hakha Lai, the resulting

[17] Arguing against Bao, Duanmu (1994:578), however, downplays the phenomenon: "A quick look through Chinese languages provides ample evidence that dissimilation between contour tones is a sporadic phenomenon. It cannot be attributed to any general principle, but reflects idiosyncrasies of particular languages."

[18] In OT terms each interpretation in (55) makes a different assumption about which of the /LH/ tone features is faithfully realized in the HL output: with tonal substitution neither feature corresponds; with tonal metathesis, both do; with tonal delinking only the output H corresponds (and the L is inserted); and with tonal spreading only the output L corresponds.

[19] This would make the Hakha Lai rule the opposite of the Tianjin rule R-R → H-R, which applies left-to-right (or simultaneously): R-R-R → H-H-R (Chen 2000:107).

H would then become F [HL], as in (56b), perhaps even by phonetic interpretation.[20] What this does, in effect, is introduce a third level, where, as in (57), a fourth tone, H, exists only in intermediate representations:

(57) The system at three levels:

L1:	R	F	L	
L2:	R	F	L	H
L3:	R	F	L	

With this move, no directionality is needed to express the RF rule: (*ka*) R-R-R will become R-H-H by left-to-right, right-to-left, or simultaneous rule application—i.e., exactly the same as when F-F-F becomes F-L-L. In fact, all three rules can be reformulated to involve deletion of a tonal feature, as in (58).[21]

(58) Reformulation of rules in terms of tonal deletion

a. RF rule	b. FL rule	c. RL rule
σ σ	σ σ	σ σ
[H] [L] [H]	[L] [H] [L]	[L] [H] [L]
↓	↓	↓
Ø	Ø	Ø

In other words, all three tone sandhi become rules of contour simplification. Note that the RF rule in (58a) must still take precedence over the RL rule in (58c).[22]

20 This is, no doubt, the historically correct analysis. We know from comparison with nearby Falam (a.k.a. Zahao and Laizo), which contrasts the four tones H, F, R and L, that there was originally a four-way opposition. Both Falam H and R regularly corresponds to Hakha F, e.g., Falam *kúa* H, Hakha (*pà-*)*kûa* F 'nine'; Falam *thǔm* R, Hakha (*pa-*)*thûm* F 'three'. In Hyman & VanBik (2002a) we even considered starting with a different underlying inventory of tones, e.g., where R is underlyingly /H/. Not only would this obscure NOJUMP, but, if the richness of the base hypothesis is adopted, we would still have to consider what the fate would be of an input /R/ in Hakha Lai.

21 The H of the first syllable in (58a) is, of course, part of the R tone, whose initial L is not needed in the formulation.

22 The rules in (58) have the effect of simplifying a R tone in either the first or second syllable and a F tone in the second syllable. What is missing is the simplification of a F tone in the left-most syllable. This is because an input such as HL-HL will become HL-L by the FL rule in (58b), not *H-HL.

The rules in (58) simplify a R tone in either the first or second syllable and a F tone in the second syllable. However, to get this result, it is tempting to generalize over the rules in (58) and provide a single rule in (59).

(59) A single rule for tonal deletion

$$\%[\ \dots\quad \alpha H \quad \underset{\displaystyle \varnothing}{\underset{\downarrow}{-\alpha H}} \quad \alpha H \quad \dots\ ]\%$$

This says that within a phonological phrase, a single [-αH] wedged between two [αH] features will be deleted. One might even try to state this as a negative output constraint: *[... αH -αH αH ...]. With the right additional constraints, HL-HL will simplify as HL-L, not as *H-HL, LH-L-HL will not become LH-Ø-HL by deletion of the only (L) tone of the middle syllable, and so forth. One would still need a later change of *H-H to HL-HL, which then violates (59).[23]

The fourth possible interpretation of the RF rule in (55d) is tone spreading. In (60) we show how each of the rules can be conceived as involving the spreading of a tone from one syllable to the next:

(60) Reformulation of rules in terms of tone spreading

a. RF rule	b. FL rule	c. RL rule
σ σ	σ σ	σ σ
[H] [L] [H]	[L] [H] [L]	[L][H] [L]

In (60a) the [H] of a %H boundary tone or R [LH] tone spreads onto a syllable that has a R [LH] tone. Since the result of such spreading would be a complex HLH tone, not permitted in Hakha Lai, the H of the R tone delinks, thereby giving the impression of tonal metathesis. The FL rule in (60b) spreads the [L] of an underlying /L/ or /F/ [HL] tone onto a following F syllable. As seen, the [H] of this latter F is delinked. Finally, in (60c), a [L] spreads onto a preceding R [LH] syllable, delinking the H. As seen, each of the spreading rules results in the delinking of a H tone.[24]

In effect, the tone-sandhi-as-spreading approach in (60) reinterprets all three rules as assimilatory. This may or may not be a good result. It is not clear if we should com-

[23] One could invoke sympathy (McCarthy 1999) or use a targeted constraint (Bakovic & Wilson 2000) to treat the appropriate [H] candidates as having a special relation to the successful [HL] outputs.

[24] It would, of course, be equally possible to conceptualize the rules in (60) as tone copying.

pare Hakha Lai with African tone systems, where left-to-right spreading is rampant (Hyman & Schuh 1974), or with Chinese, about which Chen (2000:80) writes: “It is worth noting that while contour *assimilation* is quite rare, its converse, contour *dissimilation* is extremely common among Chinese dialects. It is so productive that L. Chang (1992:256) quite rightly characterizes contour dissimilation as the primary sandhi process…”

Two results are, we think, potentially interesting. First, rather than requiring the abutting tone features of two syllables to be identical, as in (61a), NOJUMP can now be seen as requiring successive syllables within a phonological phrase to share a [H] or [L] tone feature, as in (61b).

(61) Two formulations of NOJUMP

a. prohibition against unlike tones

```
    * σ     σ
      |     |
      αT    -αT

OK:   σ     σ
      |     |
      αT    αT
```

b. prohibition against separate “crisp” tones

```
    * σ     σ
      |     |
      T     T

OK:   σ     σ
       \   /
         T
```

The constraint in (61a) is identical to what we set up in (13), which states a prohibition against changing tones from one syllable to the next. The restatement in (61b) says that Hakha Lai requires there to be a single H or L tone spanning two successive syllables, thereby constituting an obligatory violation of Itô & Mester’s (1999) CRISP-EDGE constraint, as applied to tone. For this to go through, we need only add that there should be a single output L feature in HL-L and L-L sequences, as per the OCP.

Neither statement in (61) accounts, however, for the violation observed when R* produces F-F [HL-HL] outputs. In fact, such NOJUMP violations are accounted for in entirely different ways, depending on which of the three conceptions in (55) is adopted to describe the RF rule, as follows:

First, both tone substitution (55a) and contour metathesis in (55b) produce complications for a strictly output-driven account, e.g., the necessity to invoke special mechanisms such as sympathy, conjoined or targeted constraints. In §5 we saw that the most straightforward analysis is a direct mapping one.

Second, contour simplification in (55c) gets us out of the problem by positing three levels. In this case, the outputs could still be obtained by direct mapping between the three levels (as in Goldsmith 1993b, Lakoff 1993) or derivationally.

Finally, tone spreading in (55d) provides an unexpected dividend: a constraint that can be ranked higher than NOJUMP! In order to see this, consider the output of R-R-R → R-F-F looks like, geometrically in (62).

(62) Spreading analysis of (ka) R-R-R → R-F-F

a. input	b. spreading	c. delinking
σ σ σ	σ σ σ	σ σ σ
/\ /\ /\	/\ /\ /\	/\ ⁄ \ /\
L H L H L H	L H L H L H	L H L H L H

Starting with a sequence of three LH tones in (62a), spreading creates two HLH contours in (62b). Since three-tone contours are not permitted in Hakha Lai, we shall assume Chen's constraint *COMPLEX to rule these out. As was indicated in (60), assuming that the tone rules are to be accomplished by spreading—and that spreading in turn is driven by NOJUMP—illicit HL$\underline{\text{H}}$ and L$\underline{\text{H}}$L contours are repaired by delinking the underlined H tone. This yields the final representation in (62c).[25]

Once we adopt spreading as the response to NOJUMP, we obtain a rather interesting result: LH-LH-LH will be realized LH-HL-HL whether the RF rule is applied right-to-left, simultaneously, *or* left-to-right. Since the other rules interact in a left-to-right way (e.g., the RF rule takes precedence over the RL rule, when they conflict in a /R-R-L/input), we can allow all of the tonology to proceed according to Temporal Sequence.[26] However, no matter which of the two views we adopt of NOJUMP in (61), outputs such as (62c) will violate the constraint because of concomitant delinking. There are two responses we might take to this.

First, we might introduce additional constraints which can be ranked higher than NOJUMP: *COMPLEX, which rules out tritonal contours, and MAX(L), which rules out delinking of an input [L]. But can these even generate the right outputs? Consider again the input (*ka*) /LH-LH-LH/. The desired output LH-HL-HL has one violation of NOJUMP which, as seen in (62c) is motivated by *COMPLEX. However, the incorrect output *LH-LH-HL also has one violation of NOJUMP and is more faithful to the input. Why, then, is the latter not the correct output?

---

[25] Note that this would mean that when /LH/ is realized [HL], there is no LINEARITY violation, as we supposed in (19b). LINEARITY would be violated if /LH-L/ were to become *HL-L vs. the correct L-L.

[26] An anonymous reviewer proposes a similar analysis whereby "tri-tonal strings at the surface in Hakha Lai derive from simultaneous application of the disyllabic sandhi rules following temporal sequence." Crucially, this analysis requires one of the interpretations of tone sandhi in (55c, d).

A second strategy then would be to reframe Hakha Lai tonology as being motivated not by NOJUMP, but by an I/O interpretation of SPREAD: an input tone must link to the following syllable in the output. Viewed this way, the LH-HL-HL output in (62c) incurs no SPREAD violations, while the competing output *LH-LH-HL would. By ranking MAX(L) higher than MAX(H) we get the right output in the tableau in (63):

(63) (ka) /LH-LH-LH/ → LH-HL-HL (via spreading)

	LH-LH-LH	SPREAD	MARKEDNESS	MAX(L)	MAX(H)
a.	LH-LH-HL	*!			*
b.	LH-HL-LH	*!			*
c.	LH-HLH-HLH		*!*		
d.	LH-H-HL			*!	*
☞ e.	LH-HL-HL				*

As seen, the first two candidates violate SPREAD: the H of the first LH fails to spread in (63a), while the H of the second LH fails to spread in (63b). (63c) is ruled out because of the HLH contours: These could be ruled out by *COMPLEX or, since these outputs are more marked than their inputs, by the MARKEDNESS constraint we set up in §3. MAX(L) rules out (63d), and so a *H constraint may not be needed.

The ranking of the constraints in (63) is largely based on what was seen in earlier sections. MAX(L) >> MAX(H) because L is never lost, while H frequently is, e.g., when HL-HL and L-HL are realized HL-L and L-L, respectively. A H is also lost via the RL rule: LH-L → L-L. Recall that this is the only case where an earlier tone is modified. We attributed this to Markedness. However, we have a problem. If *LH-L is an impossible output because it violates SPREAD, and if SPREAD cannot apply because it violates Markedness, then why do we get the output L-L (rather than faithful *LH-L)? It would seem that we would need a mirror-image view of SPREAD which could be divided into two parts: (i) an input tone should be realized on an adjacent syllable; (ii) left-to-right spreading >> right-to-left spreading (cf. Hyman & Schuh 1974). We have tried other alternatives, and there are doubtless other possibilities. However, we are still struck by the simplicity of the direct mapping analysis.

7. Summary and conclusion

In the preceding sections we have presented the basic tone sandhi system of Hakha Lai, as well as several possible analyses and interpretations. We started by considering two syllables in isolation, which suggested that the identified alternations could be accounted for by means of a small set of output constraints. When longer sequences were considered, however, the OT account ran into difficulties. First, a right-to-left application of the RF rule, which converts /R-R-R/ to R-F-F, was shown to be self-counterbleeding. Second, the realization of /R-R-F/ as R-F-F, rather than *R-F-L, revealed a counterfeeding relation between the FL rule and the RF rule. In both cases opaque F-F sequences are produced which fail to become *F-L by the FL rule.

After demonstrating the difficulties faced by a strictly output-driven account, we proposed a direct mapping analysis in §5, which has none of these difficulties. In §6 we then considered different interpretations of the tone rules. Up until this point we had assumed that both of the changes F → L and R → L involved the deletion of a H tone feature (HL, LH → L), and that R → F involved tonal metathesis (LH → HL). In §6 we considered two possibilities involving intermediate stages: (i) input /LH/ first becomes H by delinking the L, and then HL by insertion of L on the other side of the H (since Hakha Lai does not permit H level tone); (ii) all three tone sandhi are spreading rules that produce HLH and LHL contours, which then simplify by H-delinking to HL and L, respectively. We stipulate that a three-level approach can certainly be made to work, whether by rules, direct mapping, or output constraints (whose ranking could vary between levels 1,2 vs. levels 2,3). If correct, NoJump stands out as the most interesting new constraint found in Hakha Lai. However, with (bidirectional) I/O Spread as an alternative, the resulting two-level OT analysis comes much closer to the direct-mapping analysis—which has the drawback of not explicitly referencing general constraints such as NoJump, Spread, Markedness, etc.

Although we found no alternative that was more revealing or simple than the direct mapping analysis in §5, by considering the different interpretations in §6 we are struck by the following two observations, which have wider implications:

First, the metathesis approach to the RF rule led us to posit right-to-left (or simultaneous) rule application. This seemed an obvious fact, beyond question, and it would certainly have been cited as a prime example of a right-to-left directional iterative rule by Howard (1972). On the other hand, the alternatives in (55c, d) come out the same whether applied simultaneously or whether one scans left-to-right or right-to-left. On the other hand, given either of the approaches in (55c, d), if we were to assume, following Chen (2004), that Temporal Sequence (left-to-right) is the main force, we could do quite well—accounting not only for the RF rule, but also the fact that /R-R-L/ is realized R-F-L (alternative outputs such as *L-L-L or *F-L-L would require right-to-left application of tone sandhi). One thus has to be careful before drawing “obvious” conclusions that are, in fact, based on implicit assumptions regarding how I/O relations should be represented.

The second observation concerns the vastness of the enterprise of describing the tone system of just one language. While this may always have been true, the enterprise is even more daunting within OT. On the one hand, an analysis following the richness of the base hypothesis may not rely on limitations on underlying representations. On the other hand, the analyst must in advance think of all potential output candidates and make sure that the ranked constraints do not accidentally produce an undesirable output. In our view, the inventory of available constraints alone vastly overwhelms the simplicity of the Hakha Lai system.[27] It is not even clear that the native speaker or the linguist can tell whether L cannot become HL or LH because of the constraint against an I/O markedness increase—or because of a possibly undominated constraint DEP(T)? Is the failure of /HL-HL/ to become *HL-LH because of the same markedness constraint, or because of LINEARITY? Or, if L-tone spreading is assumed, could the failure of HL-HL → *HL-LH be due to its violation of MAX(L)?

As anyone reading the above description can tell, particularly when dealing with tone, there is lots of room for interpretation, and one small move here is likely to have large consequences there. As a result, there is enormous indeterminacy associated with describing a tone system such as that of Hakha Lai. Should the description of a language be held hostage to resolving perhaps impossible meta-questions such as in the preceding paragraph? These may ultimately have more to do with typology or with explaining historical developments than characterizing what is going on in a synchronic system. As the analysis in §5 shows, a very straightforward account involving very few assumptions is possible if we do not insist on some of the basic tenets of output-driven phonology. True, we do not incorporate into the direct mapping analysis *why* the input/output relations are the way they are. But we do account in a very direct way for what speakers are likely to know about their tone system, and how it works. In other words, simplicity ought still to be a criterion in evaluating phonological analyses.

The test case for our approach may be whether a two-level approach can account for other tone sandhi phenomena, indeed for phonological systems in general.[28] Some languages have feeding and bleeding. Some show cyclic effects. Some are more consistent than Hakha Lai in demanding that their generalizations be surface-true. As we have seen, the NOJUMP constraint is more effective in identifying offending inputs than it is in ruling out surface violations.

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[27] For a partial inventory of constraints which have been proposed in OT accounts of tone, see Akinlabi & Mutaka (2001:352-356).

[28] Note that a two-level approach seems to predict Hsu's OSP, if it allows the trigger to be stated either at the input and/or output level (cf. Goldsmith 1993b, Lakoff 1993).

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哈卡倈語聲調規律應用方向與輸出的問題

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本文探討哈卡倈語的聲調現象。哈卡倈語是緬甸和印度米佐藍州的一種藏緬語，她的語詞大都屬單音節。本文首先指出，出現在雙音節詞中的聲調交替，係出於單一共設，可以用優選理論漂亮地掌握。其次，我們也指出，一旦涉及三個音節以上的語詞，這種“漂亮”立即消失。特別是由右至左的規律應用方向將會出現嚴重的問題，這個問題將導致輸出含混，並從而與聲調交替的理據相抵觸。最後我們將指出，這個問題的解決完全取決於要如何表現輸入輸出關係而定。

關鍵詞：方向性，反增饋，反減饋，共設，直接映照，聲調，優選理論