Tone Sandhi Directionality and Relative Markedness Constraints[1]

Te-hsin Liu, UC Berkeley, liu.tehsin@berkeley.edu
Joaquim Brandão de Carvalho, Université Paris 8, joaquim.brandao@univ-paris8.fr

1. The issue

✓ In some Chinese dialects, disyllabic tone sandhi rules must apply from left to right to derive the outputs for some tri-tonal strings and from right to left to account for the others. One common point among them is that morphosyntactic structures play no role, a left-branching string and a right-branching string generating the same surface form.

(1) Tianjin

Input	Output	[x x] x	x [x x]
HL+HL+L	L.H.L	[s.tɕi] tɕ^{h}in "evergreen"	tswɔ [tiæn.tʂʌ] "take a tram"
LH+LH+LH	H.H.LH	[li.fa] swɔ "barber shop"	mu [law.hu] "tigress"
L+L+L	L.LH.L	[twɔ.la] tɕi "tractor"	k^{h}aj [fɛj.tɕi] "pilot a plane"

✓ We examined the trisyllabic sequences of four Chinese dialects: Boshan (Chen 2000), Tianjin (Chen 2000), Sixian-Hakka (Hsu 1996, Hsiao 2000), and Chengtu (Lin 2004). We argue that rule application directionality is primarily determined, in Boshan, Sixian-Hakka and Tianjin, by the lowest number of tonal modulations generated in the output.

2. Boshan (Chen 2000): right-dominant

✓ Three citation tones: /214/, /55/[2], /31/

✓ Disyllabic tone sandhi rules (largely lexicalized):

(2) a. 214+214→55.214
chun fen "spring equinox"
b. 55a+55→53.55
qi ma "horse-riding"
c. 55b+55→214.55
tan bai "to confess, be candid"
d. 214, 55, (31)+31→24.31
xiang xia "countryside" (214+31→24.31)
cheng shi "city" (55+31→24.31)
ban ye "midnight" (31+31→24.31)
dui xiang "target" (31+31→31.31) no change

(3)

1st tone	2nd tone		
	214	55	31
214	55.214	no change	24.31
55a	no change	53.55	
55b		214.55	
31		no change	(24.31)

✓ These sandhi rules govern the realization of tone sandhi in trisyllabic forms.

✓ Nine tonal combinations give rise to tone sandhi in trisyllabic forms:

(4) Rules must apply from left to right:

	a. left-to-right	b. right-to-left
Input	214+214+214	214+214+214
	↓	↓
	55+214+214	214+55+214
	↓	↓ (n/a)
Output	55+55+214	*214+55+214

✓ This is the case with the following sequences:

[1] Our cordial thanks are due to Larry Hyman for his precious suggestions and comments. All inaccuracies and omissions are of course our own responsibility.
[2] The citation tone /55/ comes from two different historical tonal categories: /55a/ derives from Middle Chinese lower register *ping* category, whereas /55b/ is from Middle Chinese *shang* category.

(5) Tone sandhi must apply from left to right (3 = 3 tonal modulations, i.e. pitch changes):

left-to-right ⇨		right-to-left ⇦	
55a+214+214→55.214+214→55.55.$\widehat{214}$	3	55a+214+214→55a+55.214→*$\widehat{53}$.55.$\widehat{214}$	5!
55b+214+214→55.214+214→55.55.$\widehat{214}$	3	55b+214+214→55b+55.214→*$\widehat{214}$.55.$\widehat{214}$	5!
214+214+214→55.214+214→55.55.$\widehat{214}$	3	214+214+214→*$\widehat{214}$.55.$\widehat{214}$	5!
214+214+31→55.214+31→55.$\widehat{24}$.$\widehat{31}$	3	214+214+31→*$\widehat{214}$.$\widehat{24}$.$\widehat{31}$	5!

(6) Rules must apply from right to left:

	a. left-to-right	b. right-to-left
Input	55b+55a+55	55b+55a+55
	↓	↓
	214+55a+55	55+53+55
	↓	↓ (n/a)
Output	*214+53+55	55+53+55

✓ This is the case with the following sequences:

(7) Tone sandhi must apply from right to left:

left-to-right ⇨		right-to-left ⇦	
55a+55a+55→53.55a+55→*$\widehat{53}$.$\widehat{53}$.55	3!	55a+55a+55→55.$\widehat{53}$.55	2
55b+55b+55→214.55b+55→*$\widehat{214}$.$\widehat{214}$.55	4!	55b+55b+55→55.$\widehat{214}$.55	3
55a+55+31→53.55+31→*$\widehat{53}$.$\widehat{24}$.$\widehat{31}$	4!	55a+55+31→55.$\widehat{24}$.$\widehat{31}$	3
55a+55b+55→53.55b+55→*$\widehat{53}$.$\widehat{214}$.55	4!	55a+55b+55→55.$\widehat{214}$.55	3
55b+55a+55→214.55a+55→*$\widehat{214}$.$\widehat{53}$.55	4!	55b+55a+55→55.$\widehat{53}$.55	2

✓ Observation: the winning candidates always have fewer tonal modulations compared with their counterparts generated by the opposite directionality. We propose a constraint MINMOD (minimize modulation) to capture the facts in Boshan.

(8) MINMOD (minimize modulation):

The number of modulations generated by tone sandhi should be minimal.

⇨ Motivation of the constraint: Contour tones are more complicated to produce than level tones because the muscle contraction that is necessary for an articulatory movement needs time to be implemented (Duanmu 1994, Gordon 1998, Zhang 2002). It follows that the increase of number of modulations in one sequence complicates speakers' articulatory task. This constraint is in line with the principle of least effort (Zipf 1949, Martinet 1955, Lindblom 1986, 1990).

⇨ The constraint MINMOD is dramatically confirmed in Sixian-Hakka, a right-dominant language, in which rules apply systematically from left to right.

3. Sixian-Hakka (Hsu 1996, Hsiao 2000): right-dominant

✓ Four lexical tones are observed in CV, i.e. LH, L, ML, H; two tones in CVC, i.e. M?, H?.

✓ Disyllabic tone sandhi rules:

(9) a. LH+LH→L.LH
tsu kon "pork liver"

b. LH+H(?)→L.H(?)
hi mong "hope"
sam sip "thirty"

✓ Tone sandhi must apply from left to right in trisyllabic sequences:

(10)

left-to-right ⇨		right-to-left ⇦	
(P1) LH+LH+LH→L.LH+LH→L.L.$\widehat{LH}$	1	(P1) LH+LH+LH→*$\widehat{LH}$.L.$\widehat{LH}$	3!
(P2) LH+LH+H→L.LH+H→L.L.$\widehat{H}$	1	(P2) LH+LH+H→*$\widehat{LH}$.L.$\widehat{H}$	3!
(P3) LH+LH+H?→L.LH+H→L.L.$\widehat{H}$	1	(P3) LH+LH+H?→*$\widehat{LH}$.L.$\widehat{H}$?	3!

✓ Rules apply consistently from left to right in a right dominant language since the opposite directionality would generate more tonal modulations.

4. Tianjin: right-dominant

✓ Four lexical tones are observed (Shi 1990): 11 (L), 55 (H), 24 (LH), 53 (HL)

✓ Four tone sandhi rules in disyllabic forms (Chen 2000):

(11) Dissimilation

a.	L+ L	→	LH.L	[fɛj tɕi]	"airplane"
b.	LH+ LH	→	H.LH	[ɕi ljan]	"wash one's face"
c.	HL +HL	→	L.HL	tɕiŋ tʂɔŋ]	"net weight"

(12) Tonal absorption

d.	HL+L	→	H.L	[z̩ʌn tʂʌn]	"earnest"

(13) Some tone sandhi must apply from left to right:

left-to-right ⇨		right-to-left ⇦	
(P1) HL+HL+L→L.HL+L→L͡H.L͡	2	(P1) HL+HL+L→*HL͡.H.L͡	3!
(P2) LH+LH+LH→H.LH+LH→H.H͡LH	2	(P2) LH+LH+LH→*LH.H͡.LH	3!

(14) Some other tone sandhi must apply from right to left:

left-to-right ⇨		right-to-left ⇦	
(P3) L+HL+HL→L.HL+HL→L.L.HL→*LH͡.L͡.HL	4!	(P3) HL+HL+HL→HL+L.HL→H͡.L͡.HL	3
(P4) L+L+L→LH.L+L→LH.LH.L→*H͡.LH͡.L	3!	(P4) L+L+L→L.LH͡.L	2

✓ In P1-P4, the correct surface forms always have fewer tonal modulations compared with their counterparts generated by the opposite directionality.

✓ However, there are cases where both directionalities generate the same number of modulations, but rules must apply from right to left.

(15) Some other tone sandhi must apply from right to left:

left-to-right ⇨		right-to-left ⇦	
(P5) LH+L+L→LH.L+L→LH.LH.L[3]→*H.L͡H.L͡	3	(P5) LH+L+L→LH+LH.L→H.L͡H.L͡	3
(P6) L+HL+HL→L.HL+HL→L.L.HL→*LH͡.L͡.HL	4	(P6) L+HL+HL→L+L.HL→LH͡.L͡.HL	4
(P7) HL+L+L→ H.L+L→*H͡.LH͡.L	3	(P7) HL+L+L→HL.LH͡.L	3

✓ Why do rules apply from right to left in P5-P7?

[3] We are assuming that rules apply at every point in the derivation, so that any time their structural description is created, they immediately get changed (*Persistent rules*, Myers 1991).

(16) Default Rule Application[4] (RIGHTPROM, LEFTPROM):

Tone sandhi should apply from the direction of the trigger towards the target.

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

(17)

Phonological rule	Rule application directionality
a. X→Y/__Z	right-to-left ⇦
b. X→Y/Z__	left-to-right ⇨

✓ In a right-dominant language such as Tianjin, the phonological rule should apply from right to left when there is indecidability.

(18) MINMOD >> RIGHTPROM

⇨ RIGHTPROM, in latent state, is activated if the outputs generated by both directionalities have the same number of tonal modulations (or in case of homophony).

5. Chengtu (Lin 2004)

✓ Four lexical tones in citation forms: MH, LM, HM, ML;

(18)

	H register	L register
Rising tones	MH	LM
Falling tones	HM	ML

(19) Disyllabic tone sandhi rules:

	MH	ML	HM	LM
MH	MH.**M**			MH.**L**
ML	ML.**M**			ML.**L**
HM	**H**.**M**	**H**.ML	**H**.HM	**H**.**L**
LM	LM.**H**			LM.**L**

[4] Thanks to Larry Hyman for suggesting this term.

✓ In (19), tone sandhi takes place sometimes on the first syllable and other times on the second syllable.

(20) Some tone sandhi must apply from right to left:

left-to-right ⇨		right-to-left ⇦	
(P1) MH+MH+MH→MH.M+MH→*M͡H.**M͡H**	3!	(P1) MH+MH+MH→MH+MH.MH→M͡H.**M.M**	2
(P2) ML+MH+MH→MH.M+MH→*M͡L.**M͡H**	3!	(P2) ML+MH+MH→ML+MH.M→M͡L.**M.M**	2
(P3) HM+MH+MH→MH.M+MH→*H͡.**M͡H**	2!	(P3) HM+MH+MH→HM+MH.M→H͡.**M.M**	1

✓ The winners all have fewer tonal modulations compared to their counterparts.

✓ But in P4-P7, the outputs generated by both directionalities have the same number of tonal modulations, and tone sandhi must apply from left to right:

(21) Some other tone sandhi must apply from left to right:

left-to-right ⇨		right-to-left ⇦	
(P4) MH+LM+MH→MH.L+MH→M͡H.**L͡M**	3	(P4) MH+LM+MH→MH+LM.H→*M͡H.**L͡H**	3
(P5) ML+LM+MH→ML.L+MH→M͡L.**L͡M**	2	(P5) ML+LM+MH→ML+LM.H→*M͡L.**L͡H**	2
(P6) HM+LM+MH→HM.L+MH→H͡.**L͡M**	2	(P6) HM+LM+MH→HM+LM.H→*H͡.**L͡H**	2
(P7) LM+LM+MH→LM.L+MH→L͡M.**L͡M**	3	(P7) LM+LM+MH→LM+LM.H→*L͡M.**L͡H**	3

✓ Taking a closer look at the outputs, we observe that all illicit forms have farther-apart pitch targets compared with the attested surface forms.

✓ Sundberg (1973, 1979) has remarked that a complicated tonal contour involving more pitch targets would involve more complicated muscle state change. In other words, the principle of least effort is also the major criterion in governing the rule application directionality, the output with farther-apart pitch targets being eliminated. Hence:

(22) MINAMP: *Minimize amplitude of contour tones*.

✓ Challenge: both MINAMP and MINMOD can be shown to be satisfied in P1-P3. These two constraints appear to be in competition.

✓ Solution: MINAMP is sufficient in selecting the winning candidates in all cases, MINMOD being trivially satisfied in P1-P3.

✓ Contrary to Boshan, Sixian-hakka and Tianjin, Chengtu has distinctive tonal register (falling HM *vs* ML, rising MH *vs* LM). Hence, though this will not be discussed here, MINAMP dominates MINMOD.

6. The case for relative markedness

6.1 Can markedness be reduced to constraint violation?

✓ In OT, markedness is built into grammars in the form of universal *output constraints* which directly state marked or unmarked patterns (i.e. *CODA, *COMPLEX ONSET) before candidates are submitted to EVAL (*categorical constraints*, McCarthy 2003).

✓ Markedness existed before OT. In structuralist linguistics (Hjelmslev 1935, [1939] 1970, Trubetzkoy 1939, Jakobson 1941), markedness was defined in terms of contrastive specification based on privative oppositions:

> *« Les oppositions* privatives *sont celles dans lesquelles un des termes de l'opposition est caractérisé par l'existence d'une marque : par ex. « sonore »-« sourd », « nasalisé »-« non nasalisé », « arrondi »-« non arrondi ». Le terme de l'opposition caractérisé par la présence de la marque s'appellera « terme marqué » et celui qui est caractérisé par l'absence de la marque « terme non marqué ». Ce type d'opposition est pour la phonologie d'une extrême importance. »* (Trubetzkoy [1939] 1976, p. 77)

✓ A marked linguistic element is not (un)marked in itself, but only in comparison to other linguistic elements: /b/ is marked w.r.t. /p/ (it has [voice]), but unmarked w.r.t. /b^h/ in Hindi (it lacks [spread gl]) ; /i/ and /u/ are marked w.r.t. /a/ (they have tonality features plus [high]), but unmarked w.r.t. /y/ (they have only one tonality feature, while /y/ has two) (Carvalho 2004).

✓ Privative features have been explicitly reintroduced in the 1980's by several phonological frameworks: Dependency phonology (Anderson & Ewen 1987), Government phonology (Kaye, Lowenstamm & Vergnaud 1985), and Particle phonology (Schane 1984).

✓ Various amounts of privativity have also been introduced into binary feature geometric approaches by underspecification theories (Kiparsky 1982a,b, Steriade 1987, Clements 1987, Archangeli 1988, Pulleyblank 1988, Mester & Itô 1989) and implemented in OT (Kiparsky 1994, Itô *et al.* 1995, Inkelas 1995).

- ✓ Structuralist thinking is also found in functionalist theories (Padgett 2001, Flemming 2004).
- ✓ In the present analysis, MINAMP and MINMOD cannot be said to be violated (nor satisfied) before EVAL takes place:

(23) a. Classic OT

$cand_1$ $cand_2$... $cand_n$

↘ | ↙

Markedness/Faithfulness constraints

↓

EVAL

↓

Output

b. Our analysis

$cand_1$ $cand_2$

↘ ↙

EVAL

↓

MINMOD/MINAMP

↓

Output

- ✓ Markedness constraints proposed here are *relative*: an output having three tonal modulations does not, *per se*, violate MINMOD, but only in comparison to the output generated by the opposite directionality.
- ✓ A winner may have more tonal modulations compared to its input, but fewer modulations compared to its counterpart generated by the opposite directionality, as in (24), where * = tonal modulation, not constraint violation:

(24) a. P7 (Tianjin)

H͡L+L+L	MINMOD	RIGHTPROM
☞ H͡L+L͡H+L͡ (⇦)	***	✓
H͡+L͡H+L͡ (⇨)	***	

b. P4 (Tianjin)

L+L+L	MINMOD	RIGHTPROM
☞ L+L͡H͡+L (⇦)	**	✓
H͡+L͡H+L͡ (⇨)	***!	

6.2 Objection I: constraints like *MOD, *AMPLEMOD do the job.

- ✓ Just as *[voice], *[spread gl] or *[front], *[round] account for /b/ : /b^h/ and /i/ : /u/ :: /y/ oppositions, MINMOD and MINAMP could be replaced with *absolute* constraints such as *MOD and *AMPLEMOD, which would be more often violated by marked candidates.
- ✓ However, this would be empirically false. *MOD implies that contour tones are more marked than level tones. Yet, there is *no* language with only level tones in Chinese, but there are languages with *only* contour tones:

(25)

Dialect	Tonal system
Shanghai (Chen 2000)	HL, LH
Zhenhai (Rose 1990)	HM, ML, LM, MH
Pingyao (Hou 1980)	LM, MH, HL
Dalian (Liu, in prep.)	HL, LH, HLH
Chengtu (Chang 1958, Lin 2004)	HM, ML, LM, MH
Longquan (Steed 2006)	HLH, HM, ML, LM, MH
Yencheng (Yu 2005)	HL(51), HLH(213), HHL(554), LH(24)
Wuxi (Chan & Ren 1986)	HL, LH, HLH[5]

- ✓ Beyond Chinese, according to a database of 448 languages of Hyman[6], 159 languages have only level tones, whereas 289 languages have at least one contour tone. This finding suggests that most languages have a contour tone. Moreover, not counting Chinese, 12 languages have only contour tones without level tones: nine in the Southeast of Asia, two in New Guinea, and one in South America.
- ✓ Assuming *MOD-like constraints, what happens in Chinese would, then, run counter to the claims of markedness theory, according to which the presence of any single marked element without its unmarked counterpart is ruled out in phonological systems (Jakobson 1969, Clements 2005, 2007).

[5] Chan & Ren (1986) consider that there are six tones in open syllables in Wuxi. However, since tonal register is conditioned by the laryngeal state of the onset, we propose that there are only three phonological tones.

[6] Data obtained as of July 22, 2008.

6.3 Objection II: Positional constraints *MOD/-STRESS, *AMPLEMOD/-STRESS do the job.

✓ Just as vowel reduction processes which often involve *effort minimization*[7], there is tonal reduction in tone sandhi processes, hence *MOD/-STRESS, *AMPLEMOD/-STRESS. However:

- ✧ The crucial trigger of tone sandhi is not positional; sandhi does not only follow from –stress, but also from certain *combinations* of tones. Hence, tone sandhi does *not* occur in most cases.
- ✧ Even when it does, the unstressed syllables do not always have fewer tonal modulations compared to their input, as shown in (26). Modulation and amplitude of contour tones are minimized in unstressed syllables compared to their counterparts generated by the opposite directionality, not compared to input.

(26)

Language	Input	modulations	Output	modulations
Boshan	55a+55a+55	**0**	55.5$\widehat{3}$.55	**2**
	55b+55b+55	**0**	5$\widehat{5.214}$.55	**3**
	55a+5$\widehat{5+31}$	**2**	5$\widehat{5.24}$.$\widehat{31}$	**3**
	55a+55b+55	**0**	5$\widehat{5.214}$.55	**3**
	55b+55a+55	**0**	55.5$\widehat{3}$.55	**2**
Tianjin	L+L+L	**0**	L.$\widehat{LH}$.L	**2**
	$\widehat{HL}$+L+L	**1**	$\widehat{HL}$.$\widehat{LH}$.L	**3**

6.4 Conclusion

✓ *Phonological objects are not intrinsically marked.*

⇨ MINMOD/MINAMP suppose that more modulations are more difficult to produce than fewer modulations, but this does not imply that tonal modulation is in itself a marked object; clearly, this is not the case in Chinese.

✓ Why are lexical contour tones unmarked in Chinese languages, contrary to what happens in African languages?

- ✧ Lass (1975) claims that 'naturalness' can only be judged on language-specific grounds, not universal statistical ones, and proposes *family universals*, i.e. specific well-formedness conditions in phonological inventories which do not have any (necessary) universal or "intrinsic" motivations.
- ✧ Contour tones are not intrinsically (un)marked in world's tonal languages, and should be judged on *language-specific* grounds.

✓ How can (Chinese) unmarked contours be compatible with MINMOD and MINAMP? At any event, it seems that phonological markedness can hardly be accounted for in terms of constraint violation by surface forms.

[7] Vowel contrasts are often neutralized to schwa in unstressed syllables in English (Hayes 1995), Southern Italian dialects (Maiden 1995) and Dutch (Booij 1995). Van Bergen (1994) and Kondo (1994), working respectively on Dutch and English, indicate that schwa can be analyzed as the result of *effort minimization* predominating where vowel contrasts are neutralized (Flemming 2004).

7. References

Anderson, John M. & Colin J. Ewen (1987) *Principles of dependency phonology*. Cambridge: Cambridge University Press.

Booij, Geert (1995) *The Phonology of Dutch*. Oxford University Press, Oxford.

Carvalho, Joaquim Brandão de (2004) *From binary features to privative element: Issues for markedness theory and language acquisition*. Unpublished manuscript, http://www.umr7023.cnrs.fr/IMG/pdf/From_binary_features_to_privative_elements.pdf

Chan, Marjorie & Ren, Hongmao (1986) Wuxi tone sandhi : from last to first dominance. *UCLA Working Papers in Phonetics* 63 :48-70.

Chang, Nien-Chuang (1958) Tone and Intonation in Chengtu Dialect, in Dwight Bolinger (edi.), *Intonation*, Penguin Books Ltd., Middlesex, 391-413.

Chen, Matthew (2000) *Tone Sandhi*, Cambridge, Cambridge University Press.

Clements, George N. (2005) The role of features in speech sound inventories. In Eric Raimy & Charles Cairns, eds. *Contemporary Views on Architecture and Representations in Phonological Theory*. Cambridge, MA: MIT Press.

Clements, George N. (2007) L'Evitement de la Marque : vers un nouveau modèle des inventaires phonologiques. In E. Delais-Roussarie & L. Labrune (eds.), *Des sons et des sens : données et modèles en phonologie et en morphologie*. Paris & London : Hermès.

Duanmu, San (1994) Against Contour Tone Units, *Linguistic Inquiry*, 25:4, 555-608.

Flemming, Edward (2004) Contrast and perceptual distinctiveness. In B.Hayes, R.Kirchner, and D.Steriade (eds.), *Phonetically-Based Phonology*. Cambridge University Press, 232-276.

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

Hjelmslev, Louis (1935) *La catégorie des cas: Étude de grammaire générale* I. København: Munksgaard [Jutlandica: Aarsskrift for Aarhus Universitet 7.1].

Hjelmslev, Louis ([1939] 1970) Notes sur les oppositions supprimables in *Travaux du Cercle linguistique de Copenhague*, 8, 51–57. Republished in his *Essais linguistiques* (Travaux du Cercle linguistique de Copenhague, 12), 82–88 (Second edition), Copenhagen: Nordisk Sprog- og Kulturforlag.

Howard, Irwin (1972) *A Directional Theory of Rule Application in Phonology*. PhD Dissertation, MIT.

Hou, Jingyi (1980) Pingyao fangyan de liandu biandiao (Tone sandhi in the Dialect of Pingyao). *Fangyan*, 260-274.

Hsu, Kuei-Ping (1996) *Hakka Tone Sandhi: the Interface between Syntax and Phonology*. MA thesis. National Tsing Hua University.

Hsiao, Yuchau (2000) Trisyllabic and Quadrasyllabic Tone Sandhi in Sixian Hakka: An Optimality Theory Perspective. In *Proceedings of the 2000 NCCU Teachers Conference on Linguistics Research*, 101-124.

Hyman, Larry & VanBik, Kenneth (2002) Directional Rule Application and Output Problems in Hakha Lai Tone, *Language and Linguistics. Proceedings of the 8th International Symposium on Chinese Languages and Linguistics.* Institute of Linguistics, Academic Sinica, November 8-10, 2002.

Inkelas, Sharon (1995) The consequences of optimization for underspecification. In Beckman, J.N. (Ed.), *Proceedings of the North East Linguistic Society* 25: 287–302.

Itô, Junko, Mester Armin & Padgett Jaye (1995) Licensing and Underspecification in Optimality Theory, *Linguistic Inquiry* 26, 571–613.

Jakobson, Roman (1941) *Kindersprache, Aphasie, und allgemeine Lautgesetze. Uppsala, Almqvist & Wiksell* (Child Language, Aphasia and Phonological Universals) The Hague: Mouton.

Kaye, Jonathan D., Jean Lowenstamm & Jean-Roger Vergnaud (1985) The internal structure of phonological elements: a theory of charm and government. *Phonology yearbook* 2. 305-328.

Kiparsky, Paul (1982a) Lexical morphology and phonology. In I.-S. Yang (ed.), *Linguistics in the Morning Calm*. Seoul : Hanshin. 3-91.

Kiparsky, Paul (1982b) From cyclic phonology to lexical phonology. In H. van der Hulst & N. Smith (ed.), *The structure of phonological representations.* Dordrecht : Foris, vol. 1, 131-175.

Kiparsky, Paul (1994) Remarks on markedness. Trilateral Phonology Weekend II. University of California, Santa Cruz.

Kondo, Yuko (1994) Targetless schwa: is that how we get the impression of stress timing in English? *Proceedings of the Edinburgh Linguistics Department Conference'94*, 63-76.

Lass, Roger (1975) How Intrinsic is Content? Markedness, Sound Change and 'Family Universals', In D. Goyvaerts & G. Pullum (eds.) *Essays on the Sound Pattern of English*, 475-504. Ghent: Story-Scientia.

Lin, Hui-shan. (2004) *Directionality in Tone Sandhi and the Effect of Identity Preservation*. Doctoral Dissertation, National Tsing Hua University.

Lindblom, Björn (1986) Phonetic universals in vowel systems. In J.J. Ohala and J.J. Jaeger (ed.) *Experimental Phonology*. Academic Press.

Lindblom, Björn (1990) Phonetic content in phonology. *PERILUS* 11, 101-118.

Liu, Te-hsin (In prep.) *Dalian Tone Sandhi: the Emergence of Lost Tone in Disyllabic Sequences*. Ms., UC Berkeley.

McCarthy, John (2003) OT constraints are categorical. *Phonology* 20, 75-138.

Maiden, Martin (1995) Vowel systems. Martin Maiden and Mair Parry (eds.) *The Dialects of Italy*. Routledge, London, 7-14.

Martinet, André (1955) *Economie des changements phonétiques*, 2nd edition, Berne : Francke.

Mester, Armin & Junko Itô (1989) Feature predictablilty and underspecification: palatal prosody in Japanese mimetics. *Language* 65, 258-293.

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

Padgett, Jaye (2001) Contrast Dispersion and Russian Palatalization. In Elizabeth Hume & Keith Johnson (ed.), *The Role of Speech Perception in Phonology*, 187-218. New York: Academic Press.

Rose, Phil (1990) Acoustics and phonology of complex tone sandhi. *Phonetica* 47: 1-35.

Schane, Sanford A. (1984) The fundamentals of particle phonology. *Phonology yearbook* 1. 129-155.

Shi, Feng (1990) *Hanyu he Dong-Tai yu de Shengdiao Geju* (*Tone Paradigms in Chinese and Kam-Tai languages*). Ph.D dissertation, Nankai University

Steed, William (2006) Phonation type and tone sandhi as evidence of Chinese stress in Longquan Wu. In Paul Warren & Catherine I. Watson (ed.), *Proceedings of the 11th Australian International Conference on Speech Science & Technology*, Australian Speech Science & Technology Association Inc.

Troubetzkoy, Nikolaï Sergueevitch (1939) *Principes de phonologie*. Paris : Klincksieck.

Van Bergen, Dick R. (1994) A model of coarticulatory effects on the schwa. *Speech Communication* 14, 143-162.

Yu, Dominic (2005) *The Phonology of Yengchen*. Ms., UC Berkeley.

Zipf, George K. (1949) *Human Behavior and the Principle of Least Effort.* Addison-Wesley, Cambridge.

Zhang, Jie (2002) *The effects of duration and sonority on contour tone distribution*, New York: Routledge.