An Optimality Theoretic Analysis of Tonal Realization in Korean*

Mira Oh**

ABSTRACT

This paper investigates edge effects on the relationship between the underlying tonal sequence and its surface realization in the IP-final Accentual Phrase within the Optimality Theoretic framework. I will examine the way in which AP tones are aligned with their associated syllables in IP-final position. In Korean, Jun's (1996) 'see-saw effect' does not allow any two identical tones if they are marking a boundary of a prosodic group. A phonetic experiment conducted in this paper suggests that the 'see-saw effect' only apply to H boundary tones. Furthermore, it will be shown that the timing of tonal peaks is determined through the ranking of a set of violable constraints. The AP tonal realization is achieved through the access to the global intonation in a complicated way. In the course of discussion, pitch patterns in IP-medial Accentual Phrase will also be discussed.

Keywords: Optimality Theory, Constraints, Boundary Tone, Tonal Realization, Laryngeal Consonants

1. Introduction

The Accentual Phrase surfaces as LHLH in Korean (Jun 1993). When the AP is placed in the Intonation Phrase-final position, the AP-final H is replaced by a boundary tone (L%, H%, etc). Hyman (1990) contends the unidirectional effect of boundary tones of a larger domain on to the boundary tonology of a smaller one. However, the tonal realization in Korean cannot be fully accounted for by simple replacement of the AP-final tone by a boundary tone. Rather it requires a computation

* This paper was presented at the 15th International Conference on Phonetic Sciences held in Barcelona, Spain, in 2003. I am thankful to an anonymous reviewer for his/her valuable comments. This work was supported by the Korea Research Foundation Grant (KRF-2002-042-A00026).

** Dept. of English, Chonnam National University

of its detailed phonetic consequences and grammatical information.

Jun (1996) suggests 'see-saw effect' which does not allow any two identical tones if they are marking a boundary of a prosodic group. She proposes two modes of achieving the 'see-saw effect': categorical tone change and phonetic strengthening.

The tonal realizations of the AP also have to do with the number of syllables within the AP. The LHLH underlying tones are realized when the AP has more than 4 syllables. Otherwise, some tones are undershot on the surface. An AP-initial laryngeal consonant triggers the AP-initial H giving rise to HHLH pattern. In interrogatives whose boundary tones are mostly H%, IP-final AP tones are realized quite differently from those in declaratives.

The goal of this study is to determine whether the 'see-saw effect' applies to any identical tones, L or H, and find a number of constraints determining the timing of tonal peaks. It will be investigated how these constraints interact to align underlying tonal sequence and its surface realization. Furthermore, AP-initial consonants' effect on adjacent tonal patterns will also be discussed.

2. Method

All data illustrating the avoidance of the AP-final H and H% sequence in Jun (1996) is of 2 syllable-words. However, tonal realization in the AP can vary depending on the number of syllables within the IP-final AP. Thus, a phonetic experiment will be conducted to see how the 'see-saw effect' is resolved according to the number of syllables within the AP, the AP-initial consonant, and the type of a boundary tone.

Data sets are shown in the appendix. Set 1 has three syllable words in the IP-final AP varying in initial consonant quality: plain including sonorants vs. laryngeal consonants. Sets 2 and 3 include the varying number of syllables, from 2 syllables to 5 syllables, in the IP-final AP with nasal and /s'/ initial consonants. Three sets are all read both in interrogatives and declaratives. The same order of words are employed in interrogatives and declaratives in Korean. Two male and two female Seoul native speakers participated in this experiment. They repeated the sentences 4 times.

Pitch values were measured from the middle of the vowel in each syllable of the IP-final AP using PitchWorks. The types of the boundary tones were defined by the tone types appearing in the last syllable of the IP (Han and Oh 1999).

3. Results and discussion

All data are composed of two APs: IP-initial AP (AP1) and IP-final AP (AP2). The f0 pattern of sonorants is the same as that after plain stops (Jun 1996). Thus AP2-initial sonorants were grouped together with plain stops in data set 1. The AP1-final f0 and the AP2-initial f0 values of plain stops and sonorants vs. other laryngeal consonants in data set 1 are shown in Table 1.[1)]

Table 1. AP1-final and AP2-initial pitch values in data set 1

Speaker	AP2-initial Consonant	Sentence type	AP1-final σ pitch (Hz)	AP2-initial σ pitch (Hz)
Male J	Plain and sonorant C	Declarative	170.75	122.55
		Interrogative	168.2	122.65
	Laryngeal C	Declarative	160.1786	191.3571
		Interrogative	157.1429	212.28
	/s/	Declarative	156.75	191.25
		Interrogative	160.3333	201.6666
Male Y	Plain and sonorant C	Declarative	149.45	109.65
		Interrogative	160.45	114.25
	Laryngeal C	Declarative	139.8929	169.4285
		Interrogative	150.44	190.16
	/s/	Declarative	142.25	167.5
		Interrogative	149	180.75
Female P	Plain and sonorant C	Declarative	282.5789	197.8421
		Interrogative	275	194.3888
	Laryngeal C	Declarative	270.75	329.3333
		Interrogative	252.963	336.222
	/s/	Declarative	282.5	313.75
		Interrogative	243.75	338.25
Female L	Plain and sonorant C	Declarative	251.4	206.75
		Interrogative	236.3158	194.1052
	Laryngeal C	Declarative	247.48	310.16
		Interrogative	225.5926	284.4814
	/s/	Declarative	210.75	282.75
		Interrogative	233.5	282.75

1) The categorization of the fricative /s/ has been controversial. It is sometimes categorized as plain and sometimes as aspirated. In Korean orthography, the /s/ is regarded as plain. However, its phonetic realizations are believed to be similar to the aspirated stops in that it is not likely to become voiced between voiced consonants and it triggers a high tone in the beginning of an Accentual Phrase (Jun 1993). Furthermore, fiberscopic data in Kagaya (1974) showed that /s/ has a glottal opening configuration similar to aspirated stops. Tone rising after /s/ is also observed in Table 1. Thus we categorize /s/ as laryngeal as opposed to as plain.

AP-initial pitch after a laryngeal consonant is significantly higher than that after a plain stop (Jun 1996, Han 1996). Table 1 shows that /s/ and laryngeal consonants behave similary with respect to tone rising after them. Two facts are observed in Table 1. First, AP1-final pitch values are different depending on AP2-initial consonant. Second, tone rising in AP-initial position is also affected by AP-initial consonant. Table 2 illustrates averaged pitch values and t-tests for AP1-final tone depending on AP2-initial consonant.

Table 2. Pitch average and t-tests for AP1-final tones (*: significant)

Gender	AP2-initial consonant	Pich average (Hz)	T-test
Males	Plain C	161.21	P < 0.001*
	Laryngeal C	151.90	
Females	Plain C	261.026	P < 0.001*
	Laryngeal C	247.798	

Table 2 shows that AP-final tones before laryngeal consonants are significantly lower than those before plain consonants for both males and females. Table 3 illustrates averaged pitch values and t-tests for AP2-initial tone depending on AP2-initial consonant.

Table 3. Pitch average and t-tests for AP2-initial tones (*: significant)

Gender	AP2-initial consonant	Pich average (Hz)	T-test
Males	Plain C	117.275	P < 0.001*
	Laryngeal C	190.0242	
Females	Plain C	198.5065	P < 0.001*
	Laryngeal C	313.3361	

Table 3 shows that AP-initial tones after laryngeal consonants are significantly higher than those after plain consonants for both males and females. Tables 2 and 3 suggests that two modes of tonal adjustment are performed to maximize tone rising after a laryngeal consonant. One is AP1-final tone lowering and the other is AP2-initial tone rising.

In data set 1, all declarative sentences show L boundary tones and most interrogative sentences H boundary tones. The pitch values of those boundary tones are shown in Table 4.

Table 4. Pitch values of boundary tone in data set 1

Speaker	AP2-initial Consonant	Sentence type	Boundary tones (Hz)
Male J	Plain and sonorant C	Declarative	119.95
		Interrogative	213
	Laryngeal C	Declarative	120.892
		Interrogative	224.928
Male Y	Plain and sonorant C	Declarative	117.55
		Interrogative	257.9
	Laryngeal C	Declarative	118.6786
		Interrogative	282.52
Female P	Plain and sonorant C	Declarative	192.947
		Interrogative	312.111
	Laryngeal C	Declarative	190
		Interrogative	311.3704
Female L	Plain and sonorant C	Declarative	177.7
		Interrogative	266.0526
	Laryngeal C	Declarative	176.2
		Interrogative	274.888

Next we will examine how the plain stop-initial and laryngeal consonant-initial AP2s are realized on the surface in the context of interrogatives and declaratives. Table 5 summarizes the tonal patterns exhibited in IP-final AP consisting of the 2 syllables in data sets 2 and 3. Data set 1 has the IP-final AP consisting of 3 syllables, while data sets 2 and 3 have the IP-final AP consisting of 2,3,4, and 5 syllables.

Table 5. Tonal patterns in the IP-final AP consisting of 2 syllables (- indicates the beginning of a boundary tone)

Speaker	AP2-initial C	Declarative	Interrogative
Male J	Plain and sonorant C	L-L%	L-H%
	Laryngeal C	H-L%	**H-LH%**,[2] H-H%
Male Y	Plain and sonorant C	L-L%	L-H%
	Laryngeal C	**H-L%**, L-HL%	H-H%
Female P	Plain and sonorant C	L-L%	L-H%
	Laryngeal C	H-L%	H-LH%
Female L	Plain and sonorant C	L-L%	L-H%
	Laryngeal C	H-L%	H-LH%

2) When there are more than two alternative tone patterns, the bold-faced tone indicates the dominant tone pattern hereafter.

When the IP-final AP consisting of 2 syllables begins with a nasal, tones in declaratives and interrogatives are consistently realized as L-L% and L-H%, respectively, in Table 3. On the other hand, when the IP-final AP begins with a laryngeal consonant, different tonal patterns surface. First, as for the male Y speaker, it is realized as either H-L% or L-HL% in declaratives in Table 3. The AP-initial tone is realized as H when the AP begins with a laryngeal consonant as shown in Table 1. Then we can assume that the HL% boundary tone triggers the tone lowering of AP-initial H tone. Otherwise, *H-HL% tonal pattern violates the 'see-saw effect' which does not allow the identical two tones marking a different prosodic domain.

Second, when the IP-final AP begins with a laryngeal consonant in interrogatives, H-H% (upstepped H boundary tone) or H-LH% surface. These realizations represent two modes of satisfying the 'see-saw effect' suggested by Jun (1996): categorical tone change and phonetic strengthening. Notice that upstepped H only occurs in 2 syllable words beginning with a laryngeal consonant. We can now predict the possibility of LH% in the H-initial IP-final AP consisting of 2 syllables. Jun's (1996) 'see-saw effect' refers to any two identical tones marking a prosodic domain edge. However, table 2 shows that the effect only concerns two adjacent H tones belonging to different prosodic category since LL% does not undergo any change in tonal realization.

Interestingly enough, tonal realizations of the IP-final AP consisting of 3 syllables in data sets 1, 2 and 3 shown in Table 6 are different between male and female speakers.

Table 6. Tonal patterns in the IP-final AP consisting of 3 syllables

Speaker	AP-initial C	Declarative	Interrogative
Male J	Plain and sonorant C	LL-L%	LL-H%
	Laryngeal C	HL-L%	HL-H%
Male Y	Plain and sonorant C	LL-L%	LL-H%
	Laryngeal C	HL-L%	HL-H%
Female P	Plain and sonorant C	LH-L%	LL-H%
	Laryngeal C	HH-L%	HH-LH%
Female L	Plain and sonorant C	LH-L%	LL-H%
	Laryngeal C	HH-L%	HH-LH%

First, AP-initial tonal rising is not observed in male speakers: LL-L% and HL-L% for male speakers but LH-L% and HH-L% for female speakers. We suppose that AP-initial rising is a crucial cue for female speakers. Second, when H% is employed in interrogatives, laryngeal initial APs are realized as HL-H% for male speakers, while they are realized as HH-LH% for female speakers. As for female speakers, AP-initial tonal rising is important and 'see-saw effect' is resolved by way of the LH% boundary

after HH. In other words, HH-H% is never allowed for both males and females. This result suggests males and females make use of the different tonal realization modes.

When the IP-final AP has 4 syllables as shown in Table 7, it does not incur the two identical H tone conflict.

Table 7. Tonal patterns in the IP-final AP consisting of 4 syllables

Speaker	AP2-initial C	Declarative	Interrogative
Male J	Plain and sonorant C	LHL-L%	LLL-H%
	Laryngeal C	HHL-L%	HHL-H%
Male Y	Plain and sonorant C	LHL-L%	LHL-H%
	Laryngeal C	HHL-L%	HHL-H%
Female P	Plain and sonorant C	LHL-L%	LHL-H%
	Laryngeal C	HHL-L%	HHL-H%
Female L	Plain and sonorant C	LHL-L%	LHL-H%
	Laryngeal C	HHL-L%	HHL-H%

Thus males and females produce the same tonal patterns both in declaratives and interrogatives when the phrase begins with a laryngeal consonant. However, when the phrase begins with a plain consonant, AP-initial tonal rising is consistently observed for female speakers, while male speaker J does not show the phrase-initial rising in interrogatives. Notice that various boundary tones are not attested when there are more than 4 syllables in the IP-final AP. Table 8 shows that all 4 speakers exhibit the same tonal patterns when the IP-final AP has 5 syllables except for the fact that AP-initial rising takes place in the third syllable as opposed to the second syllable (Lee and Kim 1997). We suggest that laryngeal consonant triggered H tone, Phrase-initial rising, and H% can be realized when the IP-final AP is long enough.

Table 8. Tonal patterns in the IP-final AP consisting of 5 syllables

Speaker	AP2-initial Consonant	Declarative	Interrogative
Male J	Plain and sonorant C	LHLL-L%	LHLL-H%
	Laryngeal C	HHLL-L%	HHLL-H%
Male Y	Plain and sonorant C	LHLL-L%	LHLL-H%
	Laryngeal C	HHLL-L%	HHLL-H%
Female P	Plain and sonorant C	LHLL-L%, LLHL-L%	LHLL-H%
	Laryngeal C	HHLL-L%	HHLL-H%
Female L	Plain and sonorant C	LHLL-L%	LHLL-H%
	Laryngeal C	HHLL-L%	HHLL-H%

Tables 5-8 suggest that the constraints in (1) are working for tonal realization.

(1) a. No L: Tone in an AP-initial laryngeal consonant should be realized as H.
b. Domain edge effect: A boundary tone in a prosodic domain is replaced by one in a larger prosodic Domain
c. *HH: A sequence of two H tones is not allowed when they belong to a different prosodic domain.
d. AP-second H: The second syllable in an AP is realized as H.
e. AP-penultimate L: The penultimate syllable in an AP is realized as L.
f. No contour tone in non-IP-final syllable

In optimality theoretic term, a number of constraints conspire to determine the timing of tonal peaks through constraint ranking. The following constraint ranking is suggested for tonal realization.

(2) Domain edge effect, No contour tone, No L >> *HH >> AP-second H, AP-penultimate L

The constraint ranking in (2) indicates that the edge tone assignment takes precedence over the nonedge tone assignment. That is to say, the domain edge syllables (AP-initial syllable aligned with the AP-initial tone and AP-final syllable aligned with the AP-final or IP-final tone) are aligned with a tone before the domain-internal syllables are aligned with a tone. I would posit LHLH or HHLH for the AP depending on the AP-initial consonant: HHLH when the AP begins with a laryngeal consonant but LHLH, otherwise. The default boundary tone for declaratives is L%, while that for interrogatives is H%.[3)]

Tableaux in (3) illustrate how the suggested constraints in (1) interact to yield optimal tonal realization in the IP-final AP.

3) A reviewer points out that the OT analysis is based on Richness of the Base and it is not appropriate to set up the underlying tonal pattern. For expository purpose, I posit either LHLH or HHLH for the AP depending on the AP-initial consonant. However, the No L constraint will effectively rules out L after an AP-initial laryngeal consonant with the underlying tonal pattern LHLH.

(3) a. Tonal realization of the 3 syllable IP-final AP beginning with a laryngeal consonant in interrogative

/HHLH-H%/	Domain effect	No L	*HH	AP-second H	AP-penultimate L
HHH%			*!		
☞ HLH% (male)				*	
☞ HHLH (female)					*
LLH%		*!			

b. Tonal realization of the 3 syllable IP-final AP beginning with a laryngeal consonant in declarative

/HHLH-L%/	Domain effect	No L	*HH	AP-second H	AP-penultimate L
HHH%	*!		*		*
☞ HLL% (male)				*	
☞ HHL% (female)					*
LHL%		*!			*

c. Tonal realization of the 3 syllable IP-final AP beginning with a plain consonant in interrogative

/LHLH-H%/	Domain effect	No L	*HH	AP-second H
LHH%			*!	
☞ LLH%				*
LHL%	*!			

d. Tonal realization of the 3 syllable IP-final AP beginning with a plain consonant in declarative

/LHLH-L%/	Domain effect	No L	*HH	AP-second H	AP-penultimate L
☞ LHL% (female)					*
☞ LLL% (male)				*	
LHH%	*!		*		*

The optimal output is marked as ☞. For the 3 syllable-AP, there will be two

possibilities for the second syllable to be aligned—either H or L since it is also the penultimate syllable in an AP. This is why we have HLL% or HHL% in declaratives as shown in (3b). That also explains why we have LLH or LHH variation for IP-medial AP. It can be accounted for by the tie ranking between AP-rising and AP-penultimate L in the OT framework as shown in (3b). As examined in Tables 5-8, female speakers obey the AP-rising tonal pattern, while male speakers do not. In contrast, males and females produce the same tonal patterns in interrogatives regardless of whether the AP begins with a laryngeal consonant or not as in (3a) and (3c) due to the higher ranked *HH. Likewise, the constraint ranking in (2) explains the different realizations of AP tones depending on the sentence type. Their different behavior with respect to AP-initial rising suggests that different gender make use of different constraint ranking. The OT account for phonetic realization represents the degree of probability. The least optimal candidate is not likely to occur, while the less optimal candidates may surface.

4. Conclusion

The tonal patterns take various forms in the IP-final AP in contrast to in the IP-medial AP. Above all, IP-final boundary tones affect the tonal realization. Jun (1993) contends that the IP-boundary tone preempts the AP-final H tone. Then we would expect that the tonal patterns in IP-medial AP and those in IP-final AP are the same except for the IP-final boundary tone. Jun (1996) proposed the 'see-saw effect' to account for the mismatch between the tonal patterns in the IP-final AP and those in the IP-medial AP. This study showed that the 'see-saw effect' only applies to a H tone sequence belonging to a different prosodic category through a phonetic experiment. Furthermore, this study maintained that the tones and their associated syllables were differently aligned depending on three factors: the boundary tones, the size of the syllables in the phrase, the initial segment of the phrase.

This study showed that the optimality theory could provide the tool to get the optimal tonal patterns. In OT, the ranking of a set of violable constraints gives rise to the optimal output. The constraints include No L in an AP-initial laryngeal consonant, Domain edge effect, *HH, and AP-initial rising. It also discussed tonal realizations in IP-medial AP depending on AP-initial consonants.

References

Han, J.-I. 1996. The Phonetics and Phonology of "Tense" and "Plain" Consonants in Korean. Ph.D. dissertation, Cornell University.

Han, S. & M. Oh. 1999. "The boundary tones in Korean Intonational Phrases." *Speech Sciences,* 5(1), 109-130.

Hyman, L. 1990. "Boundary tonology and the prosodic hierarchy." *The Phonology-Syntax Connection,* 109-126.

Jun, S.-A. 1992. *The Phonetics and Phonology of Korean Prosody.* Ph.D. dissertation, The Ohio State University.

Jun, S.-A. 1996. "The Influence of the Microprosody on the Macroprosody: a Case of Phrase Initial Strengthening." *UCLA Working Papers in Phonetics,* 92. 97-116.

Kagaya, R. 1974. "A fibersopic and acoustic study of the Korean stops, affricates and frivatives." *Journal of Phonetics,* 96. 43-68.

Lee, H.-J. & H.-S. Kim. 1997. "Phonetic realization of Seoul Korean Accentual Phrase." *Harvard Studies in Korean Linguistics.*

Received: July 29, 2003.
Accepted: September 5, 2003.

▲ Mira Oh
Department of English, Chonnam National University
300 Yongbongdong, Bukgu, Kwangju 500-757
Tel: +82-62-530-3165
E-mail: mroh@chonnam.ac.kr

Appendix

Set 1.

{ige} {paraya} 'This is 'para'.' 'Is this 'para'?'
{ige} {p'araya} 'This is 'p'ara'.' 'Is this 'p'ara'?'
{ige} {p^haraya} 'This is 'p^hara'.' 'Is this 'p^hara'?'
{ige} {taraya} 'This is 'tara'.' 'Is this 'tara'?'
{ige} {t'araya} 'This is 't'ara'.' 'Is this 't'ara'?'
{ige} {t^haraya} 'This is 't^hara'.' 'Is this 't^hara'?'
{ige} {karaya} 'This is 'kara'.' 'Is this 'kara'?'
{ige} {k'araya} 'This is 'k'ara'.' 'Is this 'k'ara'?'
{ige} {k^haraya} 'This is 'k^hara'.' 'Is this 'k^hara'?'
{ige} {maraya} 'This is 'mara'.' 'Is this 'mara'?'
{ige} {raraya} 'This is 'rara'.'.'Is this 'rara'?'
{ige} {saraya} 'This is 'sara'.' 'Is this 'sara'?'
{ige} {haraya} 'This is 'hara'.' 'Is this 'hara'?'

Set 2.

{ajumɔniɨl} {midɔ} 'I believe my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {midɔyo} 'I believe my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {midɨlleyo} 'I will believe my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {midɨryɔguyo} 'I am going to believe my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {s'wayo} '(He) shoots my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {s'olleyo} 'I will shoot my aunt. (Declarative and Interrogative)'
{ajumɔniɨl} {s'ollyɔguyo} 'I am going to shoot my aunt. (Declarative and interrogative)'
{ajumɔniɨl} {s'oniŋgɔeyo} 'I am shooting my aunt. (Declarative and interrogative)'

SET 3.

{paŋgogumaɨl} {nalla} 'I carry sweet potatoes. (Declarative and interrogative)'
{paŋgogumaɨl} {nallayo} 'I carry sweet potatoes. (Declarative and interrogative)'
{paŋgogumaɨl} {naɨlleyo} 'I will carry sweet potatoes. (Declarative and interrogative)'
{paŋgogumaɨl} {naɨryɔguyo} 'I am going to carry sweet potatoes. (Declarative and interrogative)'
{paŋgogumaɨl} {s'ɔyo} 'I use sweet potatoes. (Declarative and interrogative)'

{paŋgogumarɨl} {s'ɨlleyo} 'I will use sweet potatoes. (Declarative and interrogative)'

{paŋgogumarɨl} {s'ɨllyəguyo} 'I am going to use sweet potatoes. (Declarative and interrogative)'

{paŋgogumarɨl} {s'ɨnɨngəeyo} 'I am carrying sweet potatoes. (Declarative and interrogative)'