Hiatus resolution and opacity in Seoul Korean verbal paradigm*

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Jun, Jongho. 2014. Hiatus resolution and opacity in Seoul Korean verbal paradigm. *Studies in Phonetics, Phonology and Morphology* 20.3. 379-401. The present study explores hiatus resolution patterns in Seoul Korean verbal paradigm. I provide an analysis of the data of hiatus resolution, focusing on phonological opacity and variation. In so doing, I compare rule-based phonology and OT-CC which are expected to explain phonological opacity equally well. It will be shown that rule-based phonology equipped with rule ordering and optionality fails to provide an adequate analysis of the data with variation. In contrast, the same data can be properly analyzed within the framework of OT-CC. **(Seoul National University)**

Keywords: vowel hiatus, opacity, variation, rule ordering, OT-CC

1. Introduction

Phonological opacity has been an important issue in the development of phonological theories. It is somewhat ironic that phonological opacity can be easily explained within the framework of the early rule-based generative phonology (Chomsky and Halle 1968) whereas it can hardly be captured in a more recent mainstream constraint-based theory, i.e., Optimality Theory (Prince and Smolensky 1993/2004). As discussed by McCarthy (2007), most previous constraint-based theories including Sympathy Theory (McCarthy 1999) and Stratal OT (Kiparsky 2000) fail to explain at least some of the attested patterns. Arguing that opaque forms must be derived in a serial fashion as in rule-based phonology, McCarthy (2007) proposes a serial version of Optimality Theory, i.e., OT-CC, to explain opacity within the framework of Optimality Theory. OT-CC is no different from rule-based theories in that a surface form is derived through a sequence of changes from the underlying form, and the ordering of some changes may be fixed (by means of rule ordering stipulation in the rule-based phonology and PREC constraints in OT-CC). It may thus be accepted that OT-CC with PREC constraint and rule-based phonology relying on rule ordering mechanism can explain phonological opacity equally well.

The present study explores hiatus resolution patterns attested in Seoul Korean verb and adjective paradigm (hereafter, verbal paradigm). When vowel-final stems are combined with vowel-initial suffixes, potential vowel hiatus is often avoided through processes like Glide Formation and vowel deletion. In contrast, when potential vowel hiatus results from the application

* I am grateful to three anonymous reviewers for their helpful comments.

of stem-final consonant deletion, the hiatus resolution processes are usually blocked. For the purpose of finding an optimal account of the observed patterns, I will compare the rule-based and OT-CC analysis. (See McCarthy (2007) for discussion of problems of other alternative approaches to opacity.) It will be shown that some observed patterns with variation cannot be explained in rule-based phonology relying on rule ordering and optionality. In contrast, the same data do not cause any problem to the OT-CC analysis which employs PREC constraints and variable constraint ranking.

The structure of this paper is as follows. The next section, section 2, discusses hiatus resolution patterns in Seoul Korean verbal paradigm. Based on this discussion, I present the data which will be analyzed in following sections. Section 3 presents the rule-based analysis of the data. Section 4 provides an OT-CC analysis of the same data. The final section, section 5, concludes the present study.

2. Hiatus resolution in Seoul Korean verbal paradigm

In this section, to provide background information, I begin with a presentation of Seoul Korean phoneme inventory and a brief description of vowel harmony patterns in Korean verbal inflection. I will then discuss how vowel hiatus may be avoided in Seoul Korean verbal paradigm.

2.1 Phoneme inventory and vowel harmony

In this study, I adopt the following consonant and vowel phoneme inventories of Seoul Korean.

(1) Seoul Korean phoneme inventory (based on Kang 2003)

a. Consonant (C^h = aspirated, C' = tense)

	labial	*coronal*	*velar*	*glottal*
stop	p, p^h, p'	t, t^h, t'	k, k^h, k'	
affricate		c, c^h, c'		
fricative		s, s'		h
nasal	m	n	ŋ	
liquid		l		
glide	w	j		

b. Vowel

front		back	
[-round]	[+round]	[-round]	[+round]
i	y	ɨ	u
e	œ		o
ɛ		ʌ	
		a	

There is almost no disagreement among previous studies as to the consonant inventory of Seoul Korean. In contrast, the vowel inventory is somewhat controversial. Controversies include the debates over whether front rounded vowels /y, œ/ are simple vowels or diphthongs, and whether /e/ and /ɛ/ are merged completely or not. None of these debates are relevant to any important aspects of the present study. I adopt the one, shown above, which I think is a conservative option, with no theoretical commitment to it.

Let us now consider vowel harmony. In Korean verbal paradigm, all vowel-initial inflectional suffixes begin with a/ʌ: e.g., -a/ʌ ('declarative and interrogative indicative', 'imperative', and 'adverbial'), -as'/ʌs' ('past tense'), -asʌ/ʌsʌ ('and then'), and -ala/ʌla ('imperative'). In this study, I will be mainly concerned with forms inflected with a single vowel suffix -a/ʌ. Examples are shown below:

(2) Korean verbs and adjectives suffixed with -a/ʌ

suffix V		stem	suffixed form	
a. [ʌ]	i.	/mʌk/	mʌk-ʌ	'eat'
	ii.	/cʌk/	cʌk-ʌ	'little'
	iii.	/mil/	mil-ʌ	'push'
	iv.	/sum/	sum-ʌ	'hide'
	v.	/tɨl/	tɨl-ʌ	'lift'
	vi.	/mɛc/	mɛc-ʌ	'bear'
b. [a]	i.	/c'oc^h/	c'oc^h-a	'chase'
	ii.	/nop^h/	nop^h-a	'high'
c. [a]~[ʌ]	i.	/cap/	cap-a ~ cap-ʌ	'grab'
	ii.	/mac/	mac-a ~ mac-ʌ	'correct, be hit'

The choice of suffix allomorph depends on vowel harmony. As shown in (2a), [ʌ] is chosen after a variety of different vowels. In contrast, the suffix [a] may appear after stem-final /o/, as in (2b), and stem-final /a/, as in (2c). Notice in (2c) that when stems end in a vowel /a/ followed by a consonant, [ʌ] may be adopted as a variant suffixal form. (As will be seen later, [a] is always chosen when the stem ends in /a/ with no following consonant.) Since [ʌ] may occur after all vowels except /o/, it can be considered as a default option. Vowel harmony facts can be summarized as follows:[1]

(3) Vowel harmony in allomorph selection of a/ʌ-initial suffixes
- i. [a]-initial form is chosen if the stem-final vowel is /o/ or /a/;
- ii. Otherwise, [ʌ]-initial form is chosen.
- iii. If the stem ends with a vowel /a/ followed by a consonant, [ʌ]-initial form may be chosen as a variant.

[1] For details of vowel harmony in Korean verbal paradigm including suffix-dependent differences and variation, see H. Kang (2012) and references therein.

2.2 Hiatus resolution

When vowel-final stems are combined with a/ʌ-initial suffixes, the resulting vowel-vowel sequences usually undergo hiatus resolution although specific resolution processes may differ depending on the type of the stem-final vowel. Since the main topic of the present study is phonological opacity, I will discuss the following processes which may potentially interact with deletion of stem-final consonants: (i) Glide Formation, (ii) a/ʌ deletion, and (iii) /ɨ/ deletion.

2.2.1 Glide Formation

When a stem ends in one of /i, u, o/, it undergoes Glide Formation before a/ʌ–initial suffixes, as illustrated below:

(4) Glide Formation in Korean verbal paradigm[2]

stem-final V	stem	applied	not applied	
a. /u/	i. /cu/	[cwʌ]	?[cuʌ]	‘give’
	ii. /tu/	[twʌ]	?[tuʌ]	‘put’
	iii. /tat^{h}u/	[tat^{h}wʌ]	?[tat^{h}uʌ]	‘quarrel’
	iv. /pɛu/	[pɛwʌ]	*[pɛuʌ]	‘learn’
b. /i/	i. /nɨk’i/	[nɨk’jʌ]	?[nɨk’iʌ]	‘feel’
	ii. /kɨli/	[kɨljʌ]	?[kɨliʌ]	‘draw’
	iii. /ki/	[kjʌ]	[kiʌ]	‘crawl’
	iv. /k’i/	[k’jʌ]	[k’iʌ]	‘insert’
c. /o/	i. /po/	[pwa]	?[poa]	‘see’
	ii. /s’o/	[s’wa]	?[s’oa]	‘shoot’
	iii. /o/	[wa]	*[oa]	‘come’

Glide Formation may apply to all verb and adjective stems ending in one of /i, u, o/ when they are combined with a/ʌ–initial suffixes. However, it is somewhat complicated to figure out whether Glide Formation is optional or not. For most stems, it is at least true that forms without Glide Formation are in general less acceptable than those with Glide Formation. But, the extent of acceptability of the forms without Glide Formation varies across words. Glide Formation is obligatory for some stems like /pɛu/ ‘learn’ and /o/ ‘come’: forms like *[pɛuʌ] and *[oa] are completely unacceptable. This is probably due to a ban on a sequence of onsetless syllables.[3] For many other

[2] Some previous studies (for instance, Lee 1997) argue that compensatory lengthening is accompanied by Glide Formation. However, in my own informal survey on several Korean speakers, no one accepted the occurrence of compensatory lengthening. As I (a native speaker of Seoul Korean) agree with them, I decide to exclude compensatory lengthening from the analysis. Its occurrence or absence is probably a generational difference.

[3] Song (2008: 59) states that Glide Formation is also obligatory with a verb stem /i/ ‘put (something) on the head’. But, according to the judgment of the author of this paper, a Seoul Korean speaker, [iʌ] is fully acceptable. If this judgment is correct, the obligatory

stems such as /cu/, /tu/, /nɨk'i/, /po/ and /s'o/, forms without Glide Formation are only marginally (if possible) acceptable, which is denoted by ? in the above table. For stems like /ki/ and /k'i/ which are both mono-syllabic and /i/-final, their suffixed forms without Glide Formation are fully acceptable. Although there are some disagreements among previous studies as to whether Glide Formation is optional or not, and details of Glide Formation patterns are more complex than stated above, an overall pattern of Glide Formation may be summarized as below, and this is sufficient for the purpose of the present study.[4]

(5) Summary: Glide Formation
   a. All stems ending in one of /i, o, u/ may undergo Glide Formation before vowel-initial suffixes.
   b. For some of them, forms without Glide Formation may occur as variants.
   c. The likelihood that such variants will occur differs depending on the word.

2.2.2 a/ʌ deletion

When stems ending in /a/ or /ʌ/ are combined with a/ʌ-initial suffixes, the underlying vowel-vowel sequence across a stem-suffix boundary surfaces as a single vowel which is identical to the stem-final vowel, as can be seen below:

(6) a/ʌ deletion

stem-final V	stem	suffixed form		
a. [a]	i. /ka/	[ka]	*[kaa]	'go'
	ii. /sa/	[sa]	*[saa]	'buy'
b. [ʌ]	i. /sʌ/	[sʌ]	*[sʌʌ]	'stop'
	ii. /kʌnnʌ/	[kʌnnʌ]	*[kʌnnʌʌ]	'cross'

This a/ʌ deletion may be interpreted as degemination which must apply after vowel harmony, as will be discussed in section 3. Additional possibilities include deletion of the stem-final vowel and deletion of the suffix vowel, regardless of whether the stem-final vowel is identical to the following suffix vowel or not. Among these three options, I adopt the degemination interpretation. To see why, consider cases in which vowel deletion occurs when stem-final vowels are clearly different from the suffix –

application of Glide Formation with stems like /o/ and /pɛu/ cannot solely be attributed to a phonological factor.

[4] For a detailed discussion of Glide Formation and other hiatus resolution processes in Korean verbal paradigm, see P. Lee (1979), Huh (1984), Yu (1985), Ki (1989), Ko (1991), Ha (2000), J. Kim (2000), Yun (2004), Cha and Ahn (2004), Song (2008), Park (2011, 2012) and references therein.

a/ʌ.

First, as will be discussed below, deletion of a stem-final vowel occurs when it is /ɨ/, which is considered as a neutral weak vowel in Korean. As far as I know, there are no cases in which vowels /a, ʌ/ behave as a weak vowel in Korean phonology. Thus, a/ʌ deletion can hardly be considered as deletion of the stem-final vowel which targets a weak vowel.

Suffix vowel deletion occurs when the stem-final vowels are /e, ɛ/, as shown below:

(7) Suffix vowel deletion

stem-final V	stem	suffixed form		
a. /e/	i. /se/	[se]	?[seʌ]	'count'
	ii. /t'e/	[t'e]	?[t'eʌ]	'take off'
b. /ɛ/	i. /k'ɛ/	[k'ɛ]	?[k'ɛʌ]	'wake'
	ii. /mɛ/	[mɛ]	?[mɛʌ]	'tie'

Suffixed forms with no suffix vowel deletion are very unlikely to occur with an imperative meaning, and that is why they are marked with ? above. But, they may be used as converb forms:

(8) Converbs suffixed with -a/ʌ

a. /se-ʌ po-ta/ [se pota] ~ [seʌ pota] 'try counting (something)'
b. /t'e-ʌ po-ta/ [t'e pota] ~ [t'eʌ pota] 'try taking off (something)'

In addition, when stems ending in one of /e, ɛ/ are combined with -ala/ʌla ('imperative, formal style'), forms with vowel hiatus such as [seʌla] are possible. In contrast, a/ʌ deletion is obligatory, and forms with geminates like *[kaa] and *[sʌʌ] are impossible with any inflectional meaning and with any a/ʌ-initial suffixes. Thus, it is difficult to consider a/ʌ deletion as deletion of the suffix vowel which is typically triggered by stem-final /e, ɛ/.

Based on the above discussion, I consider a/ʌ deletion as a type of degemination which applies only when the stem-final vowel is identical to the suffix-initial vowel.

2.2.3 /ɨ/ deletion

As mentioned above, when stems ending in /ɨ/ are combined with a/ʌ-initial suffixes, the stem-final vowel /ɨ/ deletes.

(9) /ɨ/ deletion

stem	suffixed form		
a. /s'ɨ/	[s'ʌ]	*[sɨʌ]	'write'
b. /k'ɨ/	[k'ʌ]	*[k'ɨʌ]	'turn off'

This /ɨ/ deletion is obligatory like a/ʌ deletion. In Korean phonology and

morphology, /ɨ/ is usually considered as a neutral weak vowel which corresponds to schwa in many languages including English. It not only deletes but also inserts frequently, for instance, in loanword phonology (e.g., /sinou/ 'snow'). Thus, the stem-final /ɨ/ deletion may plausibly be understood as deletion of a weak vowel.

2.3 Consonant deletion

In the previous section, I have discussed cases where vowel hiatus occurs in the underlying representation. There exist cases where vowel hiatus occurs as a result of applying stem-final consonant deletion. Two consonant deletion processes, h-deletion and s-deletion, are relevant.

Stem-final /h/ deletes between vowels: for instance, /coh-ʌ/ 'good' [coa], *[coha]. This intervocalic h-deletion applies obligatorily, and there are no exceptional stems.

Stem-final /s/ also deletes between vowels: for instance, /pus-ʌ/ 'pour' [puʌ], *[pusʌ]. For the stems which are subject to /s/ deletion, it applies obligatorily. But, not all verbal stems ending in /s/ are subject to /s/ deletion: e.g., /us-ʌ/ 'smile' [usʌ], *[uʌ]. Thus, s-deletion shows lexical variation.

What is important for the present study is whether the derived vowel-vowel sequence is subject to hiatus resolution or not. They may surface as such, not being subject to the hiatus resolution processes, as can be illustrated below:

(10) Application of hiatus resolution with consonant deletion

deleted C	stem	applied	not applied	
a. /h/	i. /coh/	*[cwa]	[coa]	'good'
	ii. /nah/	?[na]	[naa]	'bear'
	iii. /noh/	[nwa]	[noa]	'put'
b. /s/	i. /pus/	?[pwʌ]	[puʌ]	'pour'
	ii. /cis/	?[cʌ][5]	[ciʌ]	'build'
	iii. /nas/	?[na]	[naa]	'recover'
	iv. /kɨs/	?[kʌ]	[kɨʌ]	'draw'

For some stems like /coh/, only the opaque form [coa] is acceptable. For many others, transparent forms are marginally acceptable. For only one stem, /noh/, the transparent form is acceptable with no controversy (Lee 1979, Yu, 1985, Ki 1989, Ko 1991, Song 2008). Notice that opaque forms are well-formed for all stems although their transparent counterparts may vary among never, marginally and fully acceptable.

In the remainder of this paper, I will analyze the patterns, presented thus far, within rule-based phonology and OT-CC.

[5] [cʌ] is derived from [cjʌ] through the application of post-affricate [j] deletion which is an automatic process in Korean (Huh 1984: 264).

3. Rule-based analysis

This section presents an analysis of hiatus resolution patterns, discussed in the previous section, by relying on the rule ordering mechanism. I will first consider the interaction between vowel harmony and hiatus resolution, and then move to the interaction between hiatus resolution and consonant deletion. Finally, I will point out problems with the rule-based analysis.

3.1 Vowel harmony and hiatus resolution

When stems ending in /o/ are combined with a/ʌ-initial suffixes, the resulting forms are potentially subject to both vowel harmony and Glide Formation. As illustrated below, Glide Formation (GF) must apply after vowel harmony (VH) to derive a correct form.

(11) Rule ordering: vowel harmony must precede Glide Formation.

a.	/po+ʌ/	b.	/po+ʌ/
VH	a	GF	w
GF	w	VH	n/a
	[pwa]		*[pwʌ]

(n/a = not applicable)

Under the reverse ordering, as shown in (11b), the stem-final vowel /o/ first becomes a glide [w] due to Glide Formation, and there remains no stem vowel which determines the choice of the suffix-initial vowel. The underlying suffix vowel /ʌ/ would then surface as such, deriving a wrong output form, *[pwʌ]. Consequently, vowel harmony must precede Glide Formation, in order to explain the fact that the stem /po/ 'see' undergoes both vowel harmony and Glide formation when it is combined with a vowel-initial suffix.

Here, I have taken /ʌ/ as the underlying form of the suffix-initial vowel, based on the fact that [ʌ] occurs across the board, as shown in section 2.1. But, the conclusion would not be different even if the underlying form of the suffix-initial vowel is assumed to be underspecified.[6] This point can be seen in the following derivations:

(12) Rule ordering when suffix vowel is underspecified: same as above.

a.	/po+A/	b.	/po+A/
VH	a	GF	w
GF	w	VH	n/a
	[pwa]	default V	ʌ
			*[pwʌ]

(A = underspecified vowel)

[6] The underlying form should be underspecified for the harmonic feature in Korean vowel harmony. Not knowing for now what it is, we may simply assume the underlying form is underspecified for the feature [low] which can differentiate [a] and [ʌ].

In (12a), underspecified vowel /A/ first undergoes vowel harmony, becoming [a]. Then the intermediate form [poa] undergoes Glide Formation, becoming a correct surface form [pwa]. In contrast, in (12b) with the reverse rule ordering, the stem vowel /o/ first undergoes Glide Formation before the underspecified suffix-initial vowel /A/, becoming a glide [w]. Then, vowel harmony cannot apply to the resulting intermediate output form, since the stem does not have a vowel that would determine the quality of the suffix vowel. Instead, the default vowel [ʌ] is adopted for the underspecified vowel, yielding a wrong output form *[pwʌ].

In conclusion, regardless of whether the underlying suffix-initial vowel is underspecified or not, vowel harmony must precede Glide Formation.

A similar conclusion can be made when we consider cases in which vowel harmony interacts with some other hiatus resolution process. When stems ending in /a/ are combined with the suffix -a/ʌ, both vowel harmony and a/ʌ deletion may potentially apply to the suffixed forms. As illustrated below, if vowel harmony applies before a/ʌ deletion, a correct form may be derived.

(13) Rule ordering: VH precedes a/ʌ deletion.

	/ka+ʌ/
VH	a
a/ʌ del	∅
	[ka]

In the above, the suffix-initial vowel /ʌ/ first undergoes vowel harmony, becoming [a]. Then a/ʌ deletion applies to the intermediate form [kaa]. As a result, a correct surface form [ka] can be derived.

In the reverse rule ordering, shown in (14), a/ʌ deletion cannot apply to the underlying form since different vowels abut across a stem-suffix boundary. Recall from section 2.2.2 that a/ʌ deletion is a type of degemination. Thus, only vowel harmony applies to the underlying form, deriving a wrong output *[kaa].

(14) Rule ordering: a/ʌ deletion must not precede VH.

	/ka+ʌ/
a/ʌ del	n/a
VH	a
	*[kaa]

In summary, in the rule based analysis of hiatus resolution patterns in Korean verbal paradigm, vowel harmony must precede hiatus resolution processes, such as Glide Formation and a/ʌ deletion.

3.2 Consonant deletion and hiatus resolution

As discussed in section 2.3, when consonant deletion interacts with hiatus

resolution processes, all verb and adjective stems may be realized at least as opaque forms although transparent variants are acceptable for some stems. This section focuses on how to derive opaque forms which are at least the main variants of the suffixed forms, postponing the analysis of transparent variants which are usually less frequent and less acceptable.

Let us begin with an interaction between consonant deletion and Glide Formation. As shown in (15a), if Glide Formation precedes consonant deletion, opaque forms can be derived successfully. In contrast, with the reverse rule ordering as shown in (15b), opaque forms cannot be derived.

(15) Rule ordering: GF must precede C deletion.

a. Opacity if GF precedes C deletion.

	/coh+ʌ/	/noh+ʌ/	/pus+ʌ/
VH	a	a	ʌ
GF	n/a	n/a	n/a
h/s del	∅	∅	∅
	[coa]	[noa]	[puʌ]

b. No opacity if C deletion precedes GF.

	/coh+ʌ/	/noh+ʌ/	/pus+ʌ/
VH	a	a	ʌ
h/s del	∅	∅	∅
GF	w	w	w
	*[cwa]	[nwa]	?[pwʌ]

Here, I am only concerned with how to derive correct opaque forms, ignoring whether their transparent counterparts are acceptable or not. What is suggested from the derivations shown above is that Glide Formation must apply before consonant deletion to derive opaque output forms.

A similar conclusion can be drawn if we consider cases in which consonant deletion interacts with a/ʌ deletion. As shown in (16a), if a/ʌ deletion precedes consonant deletion, opaque forms can be derived successfully since identical vowels are not adjacent to each other, and thus a/ʌ deletion cannot apply. With the reverse rule ordering as shown in (16b), opaque forms cannot be derived.

(16) Rule ordering: a/ʌ deletion must precede C deletion.

a. Opacity if a/ʌ deletion precedes C deletion.

	/nah+ʌ/	/nas+ʌ/
VH	a	a
a/ʌ del	n/a	n/a
h/s del	∅	∅
	[naa]	[naa]

b. No opacity if C deletion precedes a/ʌ deletion.

	/nah+ʌ/	/nas+ʌ/
VH	a	a
h/s del	∅	∅
a/ʌ del	∅	∅
	?[na]	?[na]

So far, I have shown that consonant deletion must apply at least after two hiatus resolution processes, Glide Formation and a/ʌ deletion, to derive correct opaque forms.

Let us now consider cases in which consonant deletion interacts with /ɨ/ deletion. As shown in (17a), if /ɨ/ deletion precedes consonant deletion, opaque forms can be derived successfully since stem-final vowel /ɨ/ is not adjacent to the suffix-initial vowel, and thus /ɨ/ deletion cannot apply. With the reverse rule ordering as shown in (17b), opaque forms cannot be derived.

(17) Opacity if /ɨ/ deletion precedes C deletion.

a.

	/kɨs+ʌ/
VH	ʌ
/ɨ/ del	n/a
h/s del	∅
	[kɨʌ]

b.

	/kɨs+ʌ/
VH	ʌ
h/s del	∅
/ɨ/ del	∅
	?[kʌ]

In conclusion, to explain the occurrence of opaque forms, hiatus resolution rules must precede consonant deletion rules. The following summarizes the orderings found so far.

(18) Summary: rule ordering

VH
↓
Hiatus resolution (GF, a/ʌ deletion, /ɨ/ deletion)
↓
C deletion (h/s deletion)

3.3 Variation

In the previous subsections of section 3, I have provided rule-based analyses of the data of hiatus resolution which consist only of canonical output forms. In this subsection, I additionally consider variation data. Notice that variation, where more than one output form are attested, is usually captured by adopting rule optionality in rule based theories. Dealing with variation data, I will attempt to revise the rule-based analysis, presented above, by adopting the rule optionality.

3.3.1 Variation in vowel harmony

Recall that when stems ending in /a/ followed by a consonant are combined

with a/ʌ-initial suffixes, the suffix vowel may vary between [a] and [ʌ]: e.g. /cap/ [cap-a] ~ [cap-ʌ] 'catch'. As mentioned above, variation is typically captured in terms of the rule optionality within the rule-based phonology, and this variation can in fact be attributed to the optionality of a vowel harmony rule which only consonant-final stems with /a/ in the final syllable are qualified to undergo, as can be seen below:

(19) Optional vowel harmony rule: /ʌ/ → [a] / aC + __ (optional)

	/cap+ʌ/
VH: optional	a ~ ʌ
	[cap-a] ~ [cap-ʌ]

However, this revision would cause a problem to the rule-based analysis of the interaction between a/ʌ deletion and consonant deletion, shown in (16) above. If we incorporate the revision of a vowel harmony rule into that analysis, the resulting revised analysis would be as follows:

(20) Interaction between a/ʌ deletion and C deletion (revision: VH = optional)

	/nah+ʌ/	/nas+ʌ/
VH: optional	a ~ ʌ	a ~ ʌ
a/ʌ del	n/a	n/a
h/s del	∅	∅
	[naa]~*[naʌ]	[naa]~*[naʌ]

Notice that incorrect output forms such as *[naʌ] would be derived as optional variants.

Therefore, given that variation in vowel harmony exists, the interaction between a/ʌ deletion and consonant deletion cannot be properly captured within rule-based theories.

3.3.2 Variation in opacity

In this section, I consider how rule-based theories can explain the fact that transparent forms may occur along with opaque forms when consonant deletion interacts with hiatus resolution processes. The relevant forms can be seen under "applied" in table (10), repeated below:

(10) Application of hiatus resolution with consonant deletion

C deletion	stem	applied	not applied	
a. /h/	i. /coh/	*[cwa]	[coa]	'good'
	ii. /nah/	?[na]	[naa]	'bear'
	iii. /noh/	[nwa]	[noa]	'put'
b. /s/	i. /pus/	?[pwʌ]	[puʌ]	'pour'
	ii. /cis/	?[cʌ]	[ciʌ]	'build'
	iii. /nas/	?[na]	[naa]	'recover'
	iv. /kɨs/	?[kʌ]	[kɨʌ]	'draw'

Recall that for most stems, transparent forms are only marginally acceptable, denoted by ? above. But, I want to emphasize that they are not as bad as impossible forms, marked with *. Moreover, the transparent form of /noh+ʌ/, i.e., [nwa], is perfectly acceptable. Notice that transparent forms cannot simply result from gestural overlap in phonetic implementation since their acceptability differs depending on the stem (cf. Ko 1991). It would be difficult to understand why phonetic gestural overlap applies to /noh+ʌ/, producing [nwa], whereas it does not apply to /coh+ʌ/, which would yield *[cwa]. Thus, it seems that any optimal (morpho-)phonological account of hiatus resolution in Korean verbal paradigm must be able to derive transparent forms.

As mentioned above, variation is typically explained by adopting the rule optionality in the rule-based approach. In the analysis shown in (15a), two rules, vowel harmony and h/s deletion, apply whereas Glide Formation does not apply since the output of vowel harmony does not meet the condition of Glide Formation. Thus, even if Glide Formation is redefined as optional, its effect cannot be seen with the data we have.

We may then consider only vowel harmony and h/s deletion rules as candidates for optional rules. With optional vowel harmony, a new, unattested, output *[noʌ] would result. With optional h/s deletion, a new, unattested, output *[noha] would result. Neither of them are transparent forms. Consequently, there is no way to derive transparent forms like [nwa] by adding rule optionality to the analysis, presented above in (15a).

In conclusion, given that variation exists in vowel harmony and opacity, there is no plausible way to explain all hiatus resolution patterns in Korean verbal paradigm within rule-based theories.

4. OT-CC Analysis

In this section, I analyze hiatus resolution patterns in Seoul Korean verbal paradigm within the framework of OT-CC (McCarthy 2007). I begin with analysis of cases in which the derivational ordering is not crucial. In so doing, I present some OT constraints and their relative rankings. With this basic OT analysis as background, I will provide an OT-CC analysis of more complicated patterns in which opacity and variation are involved.

4.1 Basic OT analysis

The present study does not aim to provide a complete analysis of each of the processes observed in Seoul Korean verbal paradigm. The main purpose of this study is to find an optimal mechanism for the analysis of the interaction of those processes. For this reason, in this section, I mostly employ descriptive and stipulative OT constraints which are intended to be

theoretically neutral.[7]

4.1.1 Vowel Harmony

For an OT analysis of vowel harmony patterns in Korean verbal paradigm, I adopt the following constraints:

(21) Constraints for vowel harmony

a. *o(C)ʌ	The suffix vowel is not [-low] when the stem-final vowel is [o].
b. *aCʌ	The suffix vowel is not [-low] when the stem ends in [a] followed by a consonant.
c. *aʌ	The suffix vowel is not [-low] when the stem ends with [a].

Note that in the above definitions of harmony-triggering constraints, I use the feature [low] to differentiate alternative surface forms of the suffix vowel, [a] and [ʌ].[8] The first VH constraint, *o(C)ʌ, is adopted to capture the fact that the suffix-initial vowel is [a] if the stem-final vowel is /o/. The second VH constraint, *aCʌ, captures the fact that the suffix-initial vowel is [a] if the stem ends in a vowel /a/ followed by a consonant. The final VH constraint, *aʌ, captures the fact that the suffix-initial vowel is [a] if the stem ends in a vowel /a/. The reason, why two separate /a/-triggering VH constraints are posited, is that /a/-triggering vowel harmony is optional only when the stem ends in a consonant: e.g., /mac-ʌ/ [maca] ~ [macʌ] 'correct, be hit' vs. /ka-ʌ/ [ka], *[kaʌ] 'go'. To capture this optionality, I propose that the ranking between *aCʌ and ID(low) be not fixed. (See Coetzee and Pater 2011 for a recent review of OT approaches with variable constraint rankings.) Under such variable ranking, vowel harmony may and may not occur. When *aCʌ outranks ID(low), vowel harmony occurs. Under the reverse ranking, vowel harmony is blocked. (This point will be illustrated in section 4.3.1.) In contrast, two VH constraints, *o(C)ʌ and *aʌ, must always outrank ID(low), to explain the obligatory application of relevant vowel harmony processes. These adopted rankings are summarized as below:

(22) Constraint ranking for vowel harmony
*o(C)ʌ, *aʌ >> *aCʌ, ID(low)

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[7] For OT analyses of hiatus resolution processes in Korean verbal paradigm, see Y. Lee (1997), H. Kang (1998), O. Kang (1999a,b), J. Kim (2000, 2010), Y. Kim (2003), Ha (2000) and Park (2011, 2012).

[8] As I mentioned above, given that it is not known yet what the right harmonic feature in Korean vowel harmony is, the feature [low] is here taken as a theory-neutral descriptive option.

4.1.2 a/ʌ deletion

I define a constraint triggering a/ʌ deletion as follows:

(23) Constraint for a/ʌ deletion
*V_iV_i: Identical vowels are not adjacent across a stem-suffix boundary.

This constraint has the effect of prohibiting [a-a] and [ʌ-ʌ] sequences. It may be considered as a type of OCP constraint. The occurrence of a/ʌ deletion suggests the ranking of *V_iV_i above the faithfulness constraint blocking deletion, i.e., MAX-V, as shown below:

(24) Constraint ranking for a/ʌ deletion
*V_iV_i >> MAX-V

4.1.3 Glide Formation

For the analysis of Glide Formation, I adopt a following descriptive constraint.

(25) Constraint for Glide Formation
*uoi-V: /u, o, i/ do not occur before a suffix-initial vowel.

Glide Formation may occur with all Korean verbs and adjectives suffixed with vowel-initial suffixes. This suggests that *uoi-V normally outranks the faithfulness constraint ID(syllabic) which prevents the change in the value of the feature [syllabic], as stated below.

(26) Constraint ranking for Glide Formation
*uoi-V >> ID(syllabic)

Recall that forms without Glide Formation are marginally acceptable for many stems and fully acceptable for a small number of stems. To explain this minor variation pattern, the constraints given above need to rank in a variable way, as mentioned above. Nonetheless, forms with Glide Formation are mostly main variants, and thus *uoi-V should outrank ID(syllabic) frequently. (See Boersma and Hayes (2001), Hayes and Londe (2006), Zuraw (2010) for details of how to implement the relevant stochastic constraint rankings.)

4.1.4 Consonant deletion

For the analysis of intervocalic /h/ and /s/ deletion, I adopt the following constraints as deletion-triggering constraints:

(27) Constraints for consonant deletion
   a. *VhV: /h/ does not occur intervocalically across a stem-suffix boundary.
   b. *VsV: /s/ does not occur intervocalically across a stem-suffix boundary.

Among these two, *VsV must be lexically-specific since /s/ deletion does not apply to all verbs and adjectives ending in /s/: e.g., /nas-ʌ/ [naa] 'recover' vs. /us-ʌ/ [usʌ] 'smile'. If we follow lexically-indexed constraint approach (Pater 2000) to explain such lexical variation, *VsV would be divided into two separate lexically-indexed constraints, *VsV$_{\{nas\ldots\}}$ and *VsV$_{\{us\ldots\}}$. Since this study is concerned with s-final stems which are subject to /s/ deletion, only *VsV$_{\{nas\ldots\}}$, not *VsV$_{\{us\ldots\}}$, is relevant. Thus, *VsV should be understood as *VsV$_{\{nas\ldots\}}$ in the remainder of this paper.

The occurrence of consonant deletion can be captured by the following ranking of the deletion-triggering constraints above the faithfulness constraint MAX-C, as stated below:

(28) Constraint ranking for consonant deletion
   *VhV, *VsV >> MAX-C

4.2 Opacity

With the above basic OT analysis at hand, this section presents an OT-CC analysis of opacity in Seoul Korean verbal paradigm. OT-CC is a serial version of Optimality Theory. Unlike in standard Optimality Theory, in OT-CC, constraints evaluate not just output forms, but their derivational steps, called candidate chains. Each candidate chain is composed of initial fully-faithful form, intermediate forms and the final surface form. The initial fully-faithful form is the one which satisfies all basic faithfulness constraints and prosodic markedness constraints. The final surface form is no different from the output candidate forms in standard Optimality Theory. The intermediate forms between them in the candidate chain may correspond to intermediate forms in the rule-based derivational analysis. Each candidate cell includes not only a sequence of derived forms but also the information about violations of basic faithfulness constraints incurred by each of them, as can be seen in tableau (30) below, which shows an OT-CC analysis of the interaction of /h/ deletion and a/ʌ deletion. Adjacent forms within each chain differ by a single violation of a single basic faithfulness constraint (gradualness requirement), and a form must be more harmonic than its immediately preceding form (harmonic improvement requirement). A new constraint, called PREC, specifies the ordering of faithfulness constraint violations, explaining the occurrence of opacity. (Details of PREC will be illustrated below.)

For an OT-CC analysis of opacity effects as well as hiatus resolution patterns in Seoul Korean verbal paradigm, I add PREC constraints to the set

of OT constraints, presented in the previous section, and propose the following ranking of the resulting set of constraints:

(29) Ranking for the analysis of opacity and hiatus resolution in Korean verbal paradigm
*VhV, *VsV
>> *o(C)ʌ, *aʌ, MAX-C
>> PREC(MAX-V, MAX-C), PREC(ID(syl), MAX-C)
>> *V_iV_i, *uoi-V
>> MAX-V
>> ID(syl), *aCʌ, ID(low)

Note that constraint rankings presented in the previous section are maintained here.

With the above constraint set and ranking, I first consider how to derive [naa] from /nah-ʌ/ 'recover' where /h/ deletion interacts with a/ʌ deletion. In tableau (30), where only relevant constraints are shown to save space, all constraints except PREC evaluate the final surface form in each candidate chain. If we exclude PREC from the tableau, candidate (30d), which has a transparent final form, would be optimal since the opaque final form in (30c) violates *V_iV_i, but the transparent final form in (30d) does not violate it and a constraint ranked above it, i.e., *VhV. Notice that this is why standard OT cannot explain opacity in general.

(30) OT-CC analysis: /nah-ʌ/ [naa] 'recover'

		*VhV	MAX	PREC	*V_iV_i	FAI
a.	nahʌ	*!				
b.	nahʌ, naha ID(low)	*!				*
c. ☞	nahʌ, naha, naa ID(low), MAX		*	*	*	*
d.	nahʌ, naha, naa, na ID(low), MAX, MAX-V		*	**!		*

(PREC = PREC(MAX-V, MAX-C); MAX = MAX-C; FAI = MAX-V, ID(low))

Let us now consider how PREC can capture the rule ordering effect of the rule-based phonology. In this analysis, I adopt PREC(MAX-V, MAX-C). This constraint requires that if there is a violation of MAX-C, it should follow a violation of MAX-V. The candidate chain with the opaque form (30c) violates PREC(MAX-V, MAX-C) because there is no violation of MAX-V before a violation of Max-C. But, according to the definition of PREC shown in (31), the violation of PREC(Max-V, Max-C) by the chain with the opaque output (30c) is less severe than the violation of the same constraint by the one with the transparent output (30d). In (30c), no violation of MAX-V precedes the violation of Max-C, and thus this candidate chain incurs a single violation of

PREC(MAX-V, MAX-C) according to (31i). The candidate chain in (30d) violates PREC(MAX-V, MAX-C) twice since no violation of MAX-V precedes the violation of Max-C, and a violation of MAX-V follows the violation of Max-C. Since PREC is ranked above $*V_iV_i$, the opaque output in (30c) is selected as an actual output.

(31) PREC(A, B) (simplified from McCarthy 2007: 98, (3-23))
Let A' and B' stand for LUMs (Localized Unfaithful Mappings) that violate the faithfulness constraints A and B, respectively.
(i) If B' is not preceded by A', assign a violation mark.
(ii) If B' is followed by A', assign a violation mark.

A similar analysis can be proposed for the interaction between consonant deletion and Glide Formation. The tableau below illustrates an OT-CC analysis of derivation of [coa] from /coh-ʌ/ 'good'.

(32) OT-CC analysis: /coh-ʌ/ [coa] 'good'

		*VhV	MAX	PREC	*uoi-V	FAI
a.	cohʌ	*!				
b.	cohʌ, coha ID(low)	*!				*
c. ☞	cohʌ, coha, coa ID(low), MAX		*	*	*	*
d.	cohʌ, coha, coa, cwa ID(low), MAX, ID(syl)		*	**!		**

(PREC = PREC(ID(syl), MAX-C); MAX = MAX-C; FAI = ID(syl), ID(low))

Here I adopt PREC(ID(syl), MAX-C), which requires that if there is a violation of MAX-C, it should follow a violation of ID(syl). The candidate chain with the opaque form (32c) incurs a single violation of PREC(ID(syl), Max-C). The candidate chain in (32d) violates it twice since no violation of ID(syl) precedes the violation of MAX-C, and a violation of ID(syl) follows the violation of MAX-C. Since PREC is ranked above *uoi-V, the opaque output in (32c) is selected as an actual output form.

Consequently, I have successfully explained opacity effects in Seoul Korean verbal paradigm within the framework of OT-CC.

4.3 Variation

In this section, I will consider how the OT-CC analysis proposed in the previous section can deal with variation in vowel harmony and opacity in Seoul Korean verbal paradigm.

4.3.1 Variation in vowel harmony

I will first consider how to explain vowel harmony variation (e.g., /cap-ʌ/ [capa] ~ [capʌ] 'catch'), and then see whether it will cause any problem to the OT-CC analysis of opacity, presented above.

When consonant deletion does not occur, PREC constraints adopted above should not be active, and thus the variation of vowel harmony can simply be captured by the variable ranking between *aCʌ and ID(low), as already discussed above. This is illustrated by the following tableaux:

(33) OT-CC analysis: /cap-ʌ/ [capa] ~ [capʌ] 'catch'

a. Possible ranking 1: *aCʌ >> ID(low)

		*VhV	PREC	*aCʌ	ID(low)
i.	capʌ			*!	
ii.☞	capʌ, capa ID(low)				*

b. Possible ranking 2: ID(low) >> *aCʌ

		*VhV	PREC	ID(low)	*aCʌ
i. ☞	capʌ				*
ii.	capʌ, capa ID(low)			*!	

Notice that vowel harmony occurs with the ranking of *aCʌ >> ID(low) whereas it is blocked with the reverse ranking. Thus, both attested variants may occur according to the proposed analysis.

Let us now consider how this variable ranking may affect the OT-CC analysis of the interaction between a/ʌ deletion and C deletion, presented above. Among the two possible rankings, the ranking *aCʌ >> ID(low), has been adopted in the analysis shown in (30) above although this is not explicitly shown there. The effect of this ranking can be seen by the fact that vowel harmony applies to [nahʌ] in most candidate chains. Since the analysis in (30) with the ranking *aCʌ >> ID(low) derives a correct output form successfully, we are left with the question of whether the reverse ranking, i.e., ID(low) >> *aCʌ, will cause any problem. The analysis with this reverse ranking is illustrated in the following tableau:

(34) OT-CC analysis (ID(low) >> *aCʌ): /nah-ʌ/ [naa] 'bear'

		*VhV	*aʌ	MAX	PREC	*V_iV_i	FAI
a.	nahʌ	*!					
b.	nahʌ, naʌ MAX		*!	*			
c.☞	nahʌ, naʌ , naa MAX, ID(low)			*	*	*	*
d.	nahʌ, naʌ, naa, na MAX, Id(low), MAX-V			*	**!		*

(PREC = PREC(MAX-V, MAX-C); MAX = MAX-C; FAI = MAX-V, ID(low))

In the above tableau, no harmony applies to [nahʌ] in any candidate chains, which is due to the ranking of ID(low) >> *aCʌ, not shown in the tableau. But, as in (34c, d), [naʌ] may undergo vowel harmony, due to the VH constraint *aʌ which is ranked above ID(low). Notice that candidate (34c) with the opaque surface form is optimal, and thus the opaque form is selected as an actual output like in (30) above.

Consequently, variation involving vowel harmony does not cause a problem to the proposed OT-CC analysis of opacity. This may be considered an advantage of OT-CC analysis over the rule-based analysis.

4.3.2 Variation in opacity

OT-CC analyses presented thus far always select opaque output forms as optimal. But, as discussed in section 2, transparent surface forms of at least some stems are acceptable. Recall that this variation is lexically-specific. For instance, transparent forms *[cwa] (/coh-ʌ/ 'good'), ?[na] (/nas-ʌ/ 'recover') and [nwa] (/noh-ʌ/ 'put')) are impossible, marginally acceptable and perfectly acceptable, respectively. As mentioned above, lexically-specific effects may be captured by adopting lexically-indexed constraints (Pater 2000). For the analysis of the variation under consideration, I adopt lexically-indexed PREC constraints, which are ranked variably with respect to hiatus resolution constraints such as *uoi-V and *V_iV_i. The derivation of [nwa] from /noh-ʌ/ is illustrated below:

(35) OT-CC analysis: /noh-ʌ/ [nwa] ~ [noa] 'put'

		*VhV	MAX	$PREC_{\{noh\}}$	*uoi-V	FAI
a.	nohʌ	*!				
b.	nohʌ, noha ID(low)	*!				*
c. ☞	nohʌ, noha, noa ID(low), MAX		*	*	*	*
d. ☞	nohʌ, noha, noa, nwa ID(low), MAX, ID(syl)		*	**		**

($PREC_{\{noh\}}$ = PREC(ID(syl), MAX-C) specific to /noh/ 'put'; MAX = MAX-C; FAI = ID(low), ID(syl))

In this tableau, variable ranking is denoted by a dotted line, as adopted in Hayes and Londe (2006). When $PREC_{\{noh\}}$ is ranked above *uoi-V, an opaque form [noa] would be selected as an optimal output. In contrast, under the reverse ranking, a transparent form [nwa] would be optimal. To explain the stems where transparent forms are only marginally acceptable, I assume that PREC constraints for them outrank hiatus resolution constraints most of the time. Finally, PREC constraints for stems like /coh/ must always outrank hiatus resolution constraints. In summary, the lexical variation between opaque and transparent forms can be explained by adopting

lexically-indexed PREC constraints and variable constraint ranking although the current analysis cannot be completed until the detailed distribution of variants of each relevant word is fully investigated.

In conclusion, the analyses, just presented, along with those presented in the previous section suggest that not only opacity but also variation patterns in Seoul Korean verbal paradigm can be analyzed within the framework of OT-CC.

5. Conclusion

I have first discussed hiatus resolution processes in Seoul Korean verbal paradigm, which interact with consonant deletion processes, exhibiting phonological opacity and variation. I have shown that rule-based analysis cannot explain both opacity and variation properly. In contrast, OT-CC can analyze them correctly. Results suggest that OT-CC provides a more adequate analysis of vowel hiatus patterns in Seoul Korean verbal paradigm, compared to rule-based phonology.

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received: September 12, 2014
revised: November 6, 2014
accepted: November 13, 2014