Phonological Opacity and Unfaithful Mapping*

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Kim, Jong-Kyoo. 2006. Phonological Opacity and Unfaithful Mapping. *The Linguistic Association of Korea Journal, 14*(2), 241-267. The cases of phonological opacity where a non-surface-apparent intermediate form plays a decisive role in deriving a correct output form raises a serious problem in non-serial mechanism of Optimality-theoretic (OT, henceforth) approaches. In two-level system of OT operating only with underlying inputs and surface-true outputs, such an existence of intermediate form originated from derivational system is an unwanted component of phonology that should not be accepted. The present study analyzes the phonological opacity problem in Korean phonology deriving from the interaction between the process of consonant simplification and the process of tensification can in OT framework, especially based on the mechanisms of candidate-to-candidate faithfulness and unfaithful mapping. In order to handle the opacity problem in non-serial OT framework, *Sympathy Theory* directly resorts to the elaboration of the component CON by positing a constraint with special property, which might be a well-expected move in constraint-based phonology. By the crucial role of the sympathetic constraint in the system of constraint interaction, the influence of a non-surface-apparent, failed candidate on the actual output form, which is the main source of phonological opacity, can be captured in a parallel fashion. As a consequence, the need of intermediate representation no longer exists in phonology, upon which the rule-based approaches are heavily dependent. Phonological opacity is a simple reflection of candidate-to-candidate faithfulness relation.

Key Words: phonological opacity, counterbleeding relation, sympathy, inter-candidate correspondence, unfaithful mapping, cumulativity, sympathetic constraint, tensification

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1. Introduction: Aim and Scope

The main purpose of this study is to discuss how phonological opacity can be handled in OT framework where phonological process is parallel and thus, the mechanism of serial derivation is not allowed (Prince and Smolensky 1993). Since the insightful discussion of Davis (1995) regarding derivational residue in phonology, phonological opacity (Kiparsky 1973, 2000) has emerged as one of the most intriguing problems in the parallel constraint-based system of OT. In the case of phonological opacity, generally detected in the relation of so-called counter-feeding or counter-bleeding between phonological rules (Kenstowicz and Kisseberth 1971, Koutsoudas et al. 1974, Iverson 1995),[1] the actual output includes some phonological elements unmotivated by surface structural harmony. Such effects of phonological opacity have been generally accounted for by the utilization of intermediate representations in the phonological derivation of serial rule-based approaches, as discussed in detail in the following Tiberian Hebrew problem.

A typical example of phonological opacity comes from Tiberian Hebrew (Davis 1997, Itô and Mester 1997, Kager 1999, McCarthy 1999, etc.). In Tiberian Hebrew, two processes are closely interactive in creating phonological opacity. One is a process of epenthesis which inserts a vowel between word-final consonant clusters (/melk/→[melex]). The other is a process of deletion which deletes a glottal stop when it is not in the position of syllable onset (/qaraʔ/→[qārā]). To put it differently, a glottal stop is deleted when it is not prevocalic (Davis 1997). The strict ordering between these two rules, that is, epenthesis before glottal deletion, generates an opaque output form that is crucially dependent on the intermediate form in phonological derivation.

1) Iverson(1995) provides a complete review of rule ordering mechanism in phonology.

(1) Opacity in Tiberian Hebrew[2)]

UR	/dešʔ/	'tender grass'
Epenthesis	dešeʔ	
Glottal Deletion	deše	
SR	[deše]	

Since the later rule of glottal deletion erases the proper environment of the earlier rule of epenthesis, the opacity of the output form [deše] is created. The output form [deše] is opaque in the sense that its phonological realization is heavily relying on the intermediate form like 'dešeʔ' which cannot be detectable as either underlying input form or the actual output form.

The fact that a non-surface-apparent intermediate form plays a decisive role in deriving a correct output form raises a serious problem in non-serial mechanism of OT approaches. In two-level system of OT operating only with underlying inputs and surface-true outputs, such an existence of an intermediate form originated from derivational system is an unwanted component of phonology that should not be accepted.

By the interaction between the process of consonant simplification and the process of tensification, Korean also displays certain phonological opacity in verbal inflection, resulting in unexpected, opaque segmental sequences of 'liquid-tense obstruent' such as [lt'], [ls'], [lc'], and [lk']. The present study will discuss in detail how such phonological opacity in Korean phonology can be analyzed in OT framework, especially based on the mechanisms of candidate-to-candidate faithfulness and unfaithful mapping.

2) If the ordering between these rules is reversed, a transparent, but incorrect output form would be generated.

UR	/dešʔ/
Glottal Deletion	deš
Epenthesis	___
SR	*[deš]

In such a reverse order, Glottal Deletion would bleed Epenthesis. Since the reverse ordering reflects a bleeding relation, the correct ordering of 'Epenthesis before Glottal Deletion' reflects a counter-bleeding relation.

2. Opacity in Optimality Theory

2.1. Opacity Problem

In the perspective of OT, what is most problematic is that constraint interaction system of input-output corresponding relation cannot provide a correct output form in opaque cases.[3] What would be selected as a winning candidate is not an actual output form which is opaque, but a wrong transparent candidate as the following tableau (2) indicates.[4]

(2) Opacity Problem in OT Analysis

	/deš?/	CODA-COND[5]	MAX_{IO}	DEP_{IO}
	a. deš?	*!		
	b. deše?	*!		
transparent	☜ c. deš		*	
opaque	d. deše		*	*!

The first two candidates cause a fatal violation of a highly-ranked constraint, CODA-COND and thus, are eliminated. The problem lies in the fact that in this constraint system, the winning candidate would be not the last one but the third one. Since the opaque candidate (2d) violates an additional constraint like DEP_{IO}, there is no way of selecting the optimal output form in (2d) as a winning candidate. The reversal of ranking relation between MAX_{IO} and DEP_{IO} cannot improve the situation, since the result would be identical.

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3) A theoretical problem in handling the opacity in another OT approach like the PARSE/FILL theory of faithfulness in the Standard Containment Theory (Prince and Smolensky 1993) is discussed in detail in McCarthy (1999, 2000, 2002a). In Containment Theory, deleted segments are present in the output but syllabically unparsed, while inserted segments are not present in the output but syllabically parsed.

4) The symbol ☜ indicates an unintended winning candidate that is not an actual output form. In the case of phonological opacity, the transparent candidate is usually indicated by ☜.

5) The constraint CODA-COND prohibits glottal stops from coda position. Glottal stops are permitted only in onsets in Tiberian Hebrew.

2.2. Sympathy Theory: Inter-Candidate Faithfulness

As illustrated, what is crucial in the case of phonological opacity is the influence of an intermediate form like 'dešeʔ' in (2b) on the occurring output form [deše] in (2d) in a derivational sense. In a non-serial framework of OT disallowing such an intermediate representation, 'dešeʔ' in (2b) would be hosted as another member of the candidate set, which fails to surface.

Sympathy Theory of McCarthy (1999, 2002b) is mainly based on such kind of faithfulness relation between a winning candidate and a certain failed candidate. What the term *sympathy* indicates is the phonological influence of a particular candidate (that is more faithful to the input) on the winning output, which is mediated by a unique relation of faithfulness.[6] Under such notion of *sympathetic faithfulness*, the reason why an opaque form 'deše' in (2d) is selected as a winning output form over a transparent form 'deš' in (2c) is its closer resemblance to a failed candidate 'dešeʔ' in (2b). That is, there is another type of faithfulness relation which operates between candidates.[7] In this way, the occurring output form 'deše' in (2d) is in sympathy with a particular failed candidate 'dešeʔ' in (2b). The selection of the particular failed candidate, referred to as the sympathetic candidate whose status

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6) In OT, especially in Correspondence Theory adopted in the current analysis, three crucial components of phonological evaluation are constraints (CON), the input, and output candidates. In the treatment of phonological opacity, *Sympathy Theory* resorts to the refinement of the constraint component, providing a constraint with a special property of candidate-to-candidate faithfulness relation. There might be, however, an equal amount of possibility that opacity effects can be explained by altering or reconceptualizing input or output representation. Such input- or output-oriented approaches to phonological opacity are actually advocated by *Enriched Input Model* of Sprouse (1997) and *Turbidity Theory* of Goldrick (2000), respectively. For a more detailed discussion on the possibility of handling phonological opacity in standard OT framework, please refer to Kager(1999) and McCarthy(2002b).

7) In OT, 'dešeʔ' is the most harmonic member of the candidate set obeying the *Input-Output Faithfulness* constraint MAX_{IO}, while in the serial rule-based phonology, it is an intermediate form in the derivation as the main source of opacity.

is indicated by the flower icon, cannot be random, but should be the one which obeys a certain designated faithfulness constraints.[8] In the Tiberian Hebrew case, 'dešeʔ' in (2b) is the sympathetic candidate and the designated faithfulness constraint is an Anchoring constraint like ANCHOR-R_{IO}(Root, σ, Final) that requires the alignment of the right edge of the root with the right edge of the syllable.[9]

Another crucial constraint in the sympathy analysis is the sympathetic faithfulness constraint[10] that directly captures the connection between the sympathetic candidate and the winning candidate. This sympathetic faithfulness constraint requires all the other candidates to be faithful to the sympathetic candidate. In other words, the candidate-to-candidate faithfulness is directly exposed by the role of the sympathetic faithfulness constraint. In Tiberian Hebrew case, the sympathetic faithfulness constraint is ❀MAX. As the following tableau shows, it is the sympathetic ❀MAX that selects the opaque form 'deše' over the transparent form 'deš' as the winning output form.

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8) The designated faithfulness constraints obeyed by the faithfulness candidate, but not by either the transparent candidate or the winning opaque candidate, as will be shown.

9) Anchoring constraints are a refined version of the more well-known Alignment constraints. The definition of the constraint is as follows(McCarthy and Prince 1995).

ANCHOR-RIO (Root, σ, Final)

If $\zeta 1 \in$ Input
$\zeta 2 \in$ Output,
$\zeta 1$ stands in correspondence with $\zeta 2$, and
$\zeta 1$ is final in the root,
then $\zeta 2$ is final in some syllable.

It can be interpreted as follows; If the root-final consonant is preserved in the output, then it must be syllable-final. The actual effect of this Anchoring constraint is to prevent epenthesis after root-final consonants, while allowing deletion of root-final consonants.

10) Note that the role of the designated faithfulness constraint is confined to select the sympathetic candidate. Thus, there still needs another constraint that directly scans the faithfulness relation between the selected sympathetic candidate and the actual output form. This is what the sympathetic faithfulness constraint is needed for.

(3) Sympathy Analysis of Tiberian Hebrew
/dešʔ/ → [deše] (*[deš]) 'tender grass'

/dešʔ/	CODA-COND	MAX_{IO}	❀MAX	DEP_{IO}	ANCHOR[11]
a. dešʔ (faithful)	*!		*		√
❀ b. dešeʔ (sympathetic)	*!			*	√
☜ c. deš (transparent)		*	**!		*
☞ d. deše (opaque)		*	*	*	*

By the incorporation of ❀MAX, the constraint system in Tiberian Hebrew can successfully select the opaque candidate 'deše' as the winner. The first two candidates in (3a) and (3b), including the sympathetic one, fatally violate the dominant constraint CODA-COND and thus, are eliminated. The last two candidates in (3c) and (3d) are identical in violating MAX_{IO} once. Consequently, the constraint which plays a decisive role in selecting the winning candidate is the sympathetic faithfulness constraint ❀MAX. The transparent candidate in (3c) violates ❀MAX twice, while the opaque candidate in (3d) does once. The second violation of ❀MAX by the transparent candidate in (3c) is fatal and thus, eliminated, leaving the opaque candidate in (3d) as the winner. The role of low-ranked DEP_{IO} is invisible in this specific case and thus, the violation of DEP_{IO} by the candidate in (3d) does not affect the overall evaluation at all.

11) According to Davis(1997), one question that arises from (3) is that if there is more than one candidate that meets the designated faithfulness constraint, how can it be determined which is the sympathetic candidate. Itô and Mester(1997) suggest that it is the one that best satisfies the rest of the constraint system. In the tableau (3), both(3a) and (3b) satisfy the designated faithfulness constraint. The candidate in (3a) though ends in a sequence of consonants. It thus violates the constraint *COMPLEX. This has the effect of ruling out (3a) as the possible sympathetic candidate since (3b) does not violate this constraint. (3b) then better satisfies the rest of the constraint system.

2.3. Unfaithful Mappings and Cumulativity

Sympathy theory proposed in McCarthy (1999) is crucially based on the role of ❀sympathetic faithfulness constraint regulating candidate-to-candidate faithfulness relation in a direct way. Such a direct utilization of inter-candidate faithfulness constraints is argued against and thus, rejected in McCarthy (2002b), since its descriptive power is excessively rich, even permitting unattested patterns of opacity like the feeding *Duke-of-York* type of quasi-Yokuts.[12] The main source of the original Sympathy Theory's excessive richness lies in the pivotal role of the inter-candidate faithfulness constraints such as ❀MAX in the analysis of Tiberian Hebrew, which allows the direct transmission of any property from the sympathetic candidate to the opaque actual output form.

In replacing such a direct inter-candidate correspondence mechanism, McCarthy (2002b) proposes a more restricted, indirect utilization of candidate-to-candidate comparison in terms of the *unfaithful input-output mappings* that create competing candidates. In the revised Sympathy Theory, the set of unfaithful mappings is the only information that can be transmitted from the sympathetic candidate to other candidates by the sympathy constraint ❀SYM. The basic notion of *unfaithful mapping* which is a tokenized version of faithfulness requires a rather subtle exploration. Unlike general faithfulness constraints which disregards differences in the locus of unfaithfulness in most cases[13] and the type of unfaithfulness in certain cases,[14] the

12) The comprehensive introduction of *Duke-of-York* patterns (Pullum 1976) and their relation to phonological opacity is not provided in the present study. Please refer to McCarthy (2002b).

13) For instance, the constraint DEP is generally indifferent to the specific locus of epenthesis as long as the epenthesized segments are identical. Consequently, both [pa] and [ap] from /a/ incurs the same violation of DEP. The specific cases of positional faithfulness are certainly exceptional, which are displayed by the asymmetry between privileged positions and non-privileged positions (Beckman 1998, Casali 1996 etc.).

14) The type of faithfulness has been very much differentiated from the outset of OT research.

metric of unfaithfulness mappings specifically concerns about not only the type but also the locus of unfaithfulness incurred by output candidates. In the specified unfaithfulness mappings, therefore, two output candidates such as *ap* and *pa* from the input /$p_1a_2p_3$/ incur two distinct unfaithful mappings such as MAX@1 and MAX@3, respectively. Similarly, in the case of epenthesis, the locus of epenthetic segment can also be specified by indexation in correspondence with the input such as /$\varepsilon_{0\text{-}1}a_1\varepsilon_{1\text{-}1}\varepsilon_{1\text{-}2}$/ → [$\delta_{0\text{-}1}a_1\delta_{1\text{-}1}\delta_{1\text{-}2}$].[15] In this way, all the output candidates can be fully characterized by the set of unfaithful mappings that yield them. GEN generates full variety of unfaithful mapping sets as candidates. Distinct candidates are associated with distinct sets of unfaithful mappings, and these sets provide the basic metric of similarity between candidates.

In the comparison of unfaithful mappings between candidates *cumulativity* is a significant notion to be explained. If a candidate (Cand1) has a superset of unfaithful mappings of another candidate (Cand2)'s, then Cand1 and Cand2 stand in a cumulative relation, since Cand1 accumulates all of Cand2's unfaithful mappings and may add some more of its own. If Cand1 does not have a superset of Cand2's unfaithfulness mappings, the relation between Cand1 and Cand2 is non-cumulative.[16] The following is more comprehensive illustration of the comparison of the sets of unfaithful mappings U_{cand1} and U_{cand2} associated with the candidates Cand1 and Cand2, respectively, where cumulativity is defined in terms of a subset relation over unfaithful mappings.

(4) Subset Relation over Unfaithfulness Mappings

a. U_{cand1} = U_{cand2}: Cand1 and Cand2 are identica (except for properties like syllabification). Each is *cumulative* with respect to the other.

15) The symbol 'ε' indicates the null character.

16) When the relation between two candidates are non-comparable or, equivalently, non-cumulative, it is indicated by the symbol '⊥'.

b. $U_{cand1} \subsetneq U_{cand2}$: Cand1 and Cand2 are different but comparable. Cand2 is cumulative with respective to Cand1, since Cand2 accumulates Cand1's unfaithful mappings, and adds some more of its own.

c. $U_{cand1} \supsetneq U_{cand2}$: Cand1 and Cand2 are symmetrically comparable. Cand1 is cumulative with respective to Cand2.

d. $U_{cand1} \not\subset U_{cand2}$: Cand1 and Cand2 are non-comparable. There is no relationship of cumulativity between them.

Such unique unfaithful mapping-based inter-candidate relation can be more clearly understood, when a partial ordering among candidates is diagrammatically considered. For the case of Tiberian Hebrew opacity, the input /dešʔ/ that is most faithfully mapped stands at the top of the partial ordering, and below it is a rank of candidates each of which has a single unfaithful mapping. Below that is a rank of candidates each of which combines two of the unfaithful mappings from the first row, and so on.

(5) Partial Ordering Diagram for Tiberian Hebrew /d$_1$e$_2$š$_3$ʔ$_4$/

The candidate 'dešʔ' which is identical to the input is comparable with all other candidates, since it has no unfaithful mappings and thus, all other candidates vacuously accumulate its unfaithful mappings. Candidates '☜deš' and '❀dešeʔ' on the first tier display a single unfaithful mapping with deletion of /ʔ/ and epenthesis of /e/, respectively. The actual output candidate '☞deše' on the next tier includes both of these unfaithful mappings. Accordingly, the opaque output '☞deše' is comparable with all the relevant candidates shown, and more significantly, it is in a cumulative relation with the sympathetic candidate '❀dešeʔ'. In contrast, however, the transparent candidate '☜deš' is not cumulative with respect to the sympathetic candidate '❀dešeʔ', since '☜deš 'does not accumulate the unfaithful mappings of '❀dešeʔ'. Such non-cumulativity of '☜deš' incurs the fatal violation of the sympathetic constraint ❀SYM by which the similarity of candidates to the sympathetic candidate is evaluated as follows.

(6) The Sympathetic Constraint

❀SYM: Given a sympathetic candidate ❀-Cand, to evaluate a candidate E-Cand, derived from the same input:

● If $U_{❀\text{-Cand}} \subseteq U_{E\text{-Cand}}$, then E-Cand's performance on ❀SYM is proportional to the cardinality of the set $U_{E\text{-Cand}} - U_{❀\text{-Cand}}$.

● If E-Cand and ❀-Cand are *non-comparable* in their unfaithful mappings, then E-Cand's performance on ❀SYM is worse than that of any candidate that is comparable.

As seen in (7), the opacity problem in Tiberian Hebrew can be accounted for in a neat way by the crucial role of the sympathetic faithfulness constraint ❀SYM.

(7) Sympathy Analysis of Tiberian Hebrew[17]

/dešʔ/ → [deše] (*[deš]) 'tender grass'

/dešʔ/	CODA-COND	❀SYM	MAX_{IO}	DEP_{IO}	★ANCHOR[18]
a. dešʔ (faithful)	*!		*		√
❀ b. dešeʔ (sympathetic)	*!			*	√
☜ c. deš (transparent)		**!	*		*
☞ d. deše (opaque)		*	*	*	*

17) In the present Tiberian Hebrew case, all the presented candidates are in the cumulative relation.

The tableau in (7) can successfully evaluate the opaque candidate as the desirable optimal output. Candidates (7a) and (7b) are eliminated due to the violation of undominated CODA-COND. Both (7c) and (7d) violate MAX_{IO} because of the deletion of the underlying /ʔ/. The choice between the remaining candidates (7c) and (7d) is crucially dependent upon the role of the key constraint ❀SYM requiring faithfulness to the sympathetic candidate, (7b). The opaque candidate (7d) has only one violation of ❀SYM due to the lack of the final [ʔ], whereas the transparent candidate in (7c) violates this constraint twice because it lacks the last two segments of the sympathetic candidate. The second violation is the fatal one. Even though (7c) satisfies DEP_{IO} while (7d) does not, (7c) still eliminated because of its fatal violation of the sympathetic faithfulness constraint, ❀SYM.

In order to handle the opacity problem in non-serial OT framework, *Sympathy Theory* directly resorts to the elaboration of the component CON by positing a constraint with special property, which might be a well-expected move in constraint-based phonology. By the crucial role of the sympathetic constraint in the system of constraint interaction, the influence of a non-surface-apparent, failed candidate on the actual output form, which is the main source of phonological opacity, can be captured in a parallel fashion. As a consequence, the need of intermediate representation no longer exists in phonology, upon which the rule-based approaches are heavily dependent. Phonological opacity is a simple reflection of candidate-to-candidate faithfulness relation.

18) In the revised Sympathy Theory in McCarthy(1999), the selector, that is, the designated constraint which selects ❀sympathetic candidate is directly incorporated into the constraint ranking system, indicated by the symbol '★'.

3. Opacity Problem in Korean Tensification and a Sympathy Analysis

3.1. Opacity in Tensification[19]

Korean displays the phonological process of tensification in which lax(plain) consonants such as /p/, /t/, /s/, /c/, and /k/ are changed into tense(glottalized) consonants such as [p'], [t'], [s'], [c'], and [k'], respectively under certain phonological or non-phonological(morphological or syntactic) conditions. As the following data in (8) show, the most regular pattern of consonant tensification can be found in the phonological environment where the lax consonant is preceded by another obstruent, that is, in the post-obstruent position.[20]

(8) Post-Obstruent Tensification

/cap-ta/	→	[capt'a]	'to hold'[21]
/tat-so/	→	[tats'o]	'to close'
/u:s-ci/	→	[u:tc'i]	'to laugh'
/ca:k-ko/	→	[ca:kk'o]	'be small'

Such tensification of lax obstruents in verbal inflection also occurs in the post-nasal position, that is, after nasals articulated with nasal resonance and oral occlusion, as in data (9).

19) For the convenience of analysis, the activity of some phonological processes that are not directly related to the present study are ignored. All the Korean data used in this study is based on Bae(2003).

20) We will not discuss in detail on the issue of the phonetic motivation of tensification.

21) Glossary includes only the lexical meaning of the stem, but not the grammatical meaning of the suffix.

(9) Post-Nasal Tensification

/ka:m-ta/ →	[ka:mt'a]	'to wind'
/nə:m-so/ →	[nə:ms'o]	'to cross'
/a:n-ci/ →	[a:nc'i]	'to embrace'
/si:n-ko/ →	[si:nk'o]	'toputon'

Unlike oral obstruents and nasals, liquid /l/, the genuine sonorant consonant cannot trigger tensification of following lax obstruents in general verbal inflection, as the data in (10) show. In other words, liquid /l/ cannot provide the canonical phonological environment for tensification at least in verbal inflection.

(10) Absence of Post-Liquid Tensification in Verbal Inflection

/u:l-ta/ →	[u:lta]	'to cry'
/tɨl-ta/ →	[tɨlta]	'to hold up'
/a:l-ci/ →	[a:lci]	'to know'
/no:l-ko/ →	[no:lko]	'to play'

Related to the post-liquid position, the comprehensive aspect of tensification in Korean is a little subtle and complicated. Under certain non-phonological conditions, tensing the lax consonant is allowed after liquid /l/, as in the data (11)-(13). In Korean, the native-Korean 'noun + noun' compounds provide extensive morphological environment for tensification by so-called 'sait sori', a morphologically epenthesized element which literally means 'intervening sound'. It is a well-attested fact in Korean phonology that such tensification in compounds is not restricted to the specific phonotactic condition, since it is heavily dependent upon the semantic relation between the compounded nouns. As a consequence, tensification in compounds provides the actual case of post-liquid tensing, as the data in (11) indicate.

(11) Post-Liquid Tensification in Compounds

/tɨl-kil/	→	[tɨlk'il]	'field + path → a field path'
/mul-paŋul/	→	[mulp'aŋul]	'water + drop → a waterdrop'
/mil-karu/	→	[milk'aru]	'wheat + powder → wheat flour'
/mal-sori/	→	[mals'ori]	'speech + sound → voice'
/pyəl-cari/	→	[pyəlc'ari]	'star + seat → a constellation'

Another case of morphologically-conditioned tensification in the post-liquid position can be found in Sino-Korean compounds as in the data (12). In this case, an interesting property of tensification comes from the fact that only coronal consonants such as /t/, /s/, and /c/ are correct targets of tensing, but not labial /p/ and dorsal /k/.[22]

(12) Post-Liquid Tensification in Sino-Korean Compounds

/paltal/	→	[palt'al]	'development'
/palsæŋ/	→	[pals'æŋ]	'occurrence'
/palcən/	→	[palc'ən]	'expansion'

Korean also displays the case of tensification in the post-liquid position that is syntactically conditioned. The syntactic environment of post-liquid tensing involves relative clauses. When the head noun in a relative clause is preceded by a modifier clause ending in prospective modifier ending '-ɨl', tensification occurs as the data in (13) show.[23]

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22) As the following data show, /p/ and /k/ cannot be tensified after liquid /l/ in Sino-Korean compounds. Rather, they are voiced in this case.

/palpyəŋ/	→	[palbyəŋ]	'an attack (of a disease)'
/palpal/	→	[palbal]	'outbreak'
/palkyən/	→	[palgyən]	'discovery'
/palkul/	→	[palgul]	'excavation'

The aspect of tensification in Sino-Korean compounds is rather complex than we discuss in this study. Since the analysis of the present study focuses on tensification in native Korean cases, more detailed discussion on Sino-Korean cases is not presented.

23) Other modifier endings such as '-nɨn'(processive), '-ɨn'(past), and '-tən'(retrospective) do not trigger tensing of the initial obstruent of the following head noun as in the data below.

/ka-nɨn-saram/ → [kanɨn saram] 'a person who goes'

(13) Syntactically-Conditioned Post-Liquid Tensification

/ka-ɨl-saram/	→	[kal s'aram][24]	'a person who will go'
/mək-ɨl-kəs/	→	[məgɨl k'ət]	'a thing that somebody will eat'
/po-ɨl-caŋmyən/	→	[pol c'aŋmyən]	'a scene that somebody will see'

Even though post-liquid tensification can actually occur in certain non-phonological conditions as in (11)-(13), such morphologically or syntactically conditioned tensings are not concerned in the present study. As illustrated, their motivations cannot be detected in the phonological perspective and thus, they are out of the range that this study can cover. Related to tensification in the post-liquid position, the main focus of this study is set upon the phonological fact that liquid /l/ cannot trigger tensing, as discussed on the data (10).

There is, however, a case in which unexpected post-liquid tensification occurs seemingly in verbal inflection as in the following data (14).

(14) Post-Liquid Tensification in Verbal Inflection

/nəlp-ta/	→	[nəlt'a]	'to be wide'
/yalp-ci/	→	[yalc'i]	'to be thin'
/halt^h-so/	→	[hals'o]	'to lick'
/ɨlp^h-ko/	→	[ɨlk'o]	'to recite '
/malk-ke/	→	[malk'e]	'to be clear'
/kulk-ko/	→	[kulk'o]	'to be thick'

Remembering the absence of post-liquid tensification in general verbal inflection as in (10), actual output forms(surface forms) in (14) allowing segmental sequences like [lt'], [ls'], [lc'], and [lk'] need a more scrutinized investigation. Regarding the data in (14), one thing obvious

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/mək-in-kəs/	→	[məgɨn kət]	'a thing that somebody ate'
/po-tən-caŋmyən/	→	[podən caŋmyən]	'a scene that somebody saw'

24) The vowel 'ɨ' is deleted through hiatus resolution. For a more comprehensive discussion on the general patterns of hiatus resolution in Korean, please refer to J-K Kim(2000).

is that two phonological processes are closely related to each other in deriving surface forms from underlying forms in serial rule-based approaches. One is the process of consonant simplification, and the other is tensification. The phonological motivation of consonant simplification is to prevent the occurrence of a possible consonant cluster in the coda position of a syllable.[25] Therefore, when a verbal root ending in a consonant cluster like C_1C_2 is concatenated with a consonant-initial ending, consonant simplification of C_1C_2 is a necessary phonological process as in (14).

Concerning the general patterns of tensification in Korean verbal inflection, what is most important fact is that all the surface forms in (14) are phonologically opaque, since they include unexpected segmental sequences of 'liquid-tense obstruent'. With a more careful comparison between underlying forms and corresponding surface forms, it is not difficult to understand that the existence of such opacity is a natural result of the ordering relation between the process of consonant simplification and the process of tensification. As pictured in (15), consonant simplification and tensification in Korean provide a typical example of counterbleeding relation between phonological rules like the Tiberian Hebrew case in (1).

(15) Counterbleeding Rule Order and Opacity in Korean

UR	/nəlp-ta/	'to be wide'
Tensification	nəlpt'a	
Consonant Simplification	nəlt'a	
SR	[nəlt'a]	

The strict ordering relation between tensification and consonant simplification, that is, tensing before simplifying consonant clusters, derives an opaque surface form that is crucially dependent on an intermediate form in a derivational mechanism. Since the later rule of

25) Analyzing which consonant of the root-final C_1C_2 is deleted is a rather complicated issue in Korean phonology. We will not discuss this issue in detail, except pointing out the fact that sonority and place of articulation are co-related.

consonant simplification obliterates the proper environment(post-obstruent) of the earlier rule of tensification, the opacity of the output form [nəlt'a] is created. The output form [nəlt'a] is opaque in the sense that its phonological realization is heavily relying on the intermediate form like 'nəlpt'a' which cannot be detectable as either the underlying input form or the actual surface output form. Consequently, it can be argued that there is no post-liquid tensification in Korean verbal inflection as in (14). What is responsible for the realization of a tense consonant in the output form is the general process of post-obstruent tensification.

If the ordering between these rules is reversed, a transparent, but incorrect output form would be generated as in the following (16).

(16) Reverse Rule Order, Transparency, and Incorrect Output form

UR	/nəlp-ta/	'to be wide'
Consonant Simplification	nəlta	
Tensification	____	
SR	*[nəlta]	

In such a reverse order, consonant simplification would bleed tensification, deriving an incorrect output, *[nəlta]. Since the reverse ordering reflects a bleeding relation, the correct ordering of 'tensification before consonant simplification' directly reflects a counter-bleeding relation between these two phonological processes.

3.2. Sympathy Analysis of Tensification in Korean

As discussed above, phonological opacity can be rather easily handled in serial rule-based approaches, based on the basic rule-ordering mechanism. In non-serial mechanism of OT approaches, however, phonological opacity that involves a decisive role of non-surface-apparent intermediate form in deriving a correct output form raises a serious problem. In two-level system of OT operating only with underlying inputs and surface-true outputs, such an existence of an intermediate form originated from the derivational system is an unwanted component of phonology that should not be accepted. The tableau (18) clearly indicates that the account of the counterbleeding type of opacity shown in (14) and (15) is problematic for OT analyses. For a detailed discussion on (18), the relevant constraints for the present OT analysis is presented in (17).

(17) Relevant Constraints in the Present Analysis

- MAX_{IO}

  Every segment of the input has a correspondent in the output

- IDENT[cg]

  Corresponding segments are identical in feature [constricted glottis]

- *COMPLEX-CODA

  Codas must consist of no more than one consonant.

- TENSE

  Obstruents followed by another obstruent are tense ones.

MAX_{IO} is a basic faithfulness constraint that accesses the corresponding relation of segments between input and output forms. Regulating a segment-mediated correspondence, the constraint MAX_{IO} militates against the actual deletion of a segment. Accordingly, consonant simplification definitely incurs a violation of MAX_{IO}. Another familiar faithfulness constraint, IDENT[cg] assures featural identity between corresponding segments in the input and the output. That is, it requires the same featural specification of [constricted glottis]. The process of tensification would incur the violation of IDENT[cg]. Two markedness constraints, *COMPLEX-CODA and TENSE, provide phonological motivations of consonant simplification and tensification, respectively. *COMPLEX-CODA is a sub-constraint of the constraint family *COMPLEX which prohibits any complex sequence of segments in all the positions of a syllable. To be more specific, *COMPLEX militates against the occurrence of consonant cluster in both onset and coda positions and the occurrence of diphthong in nucleus position. Thus, *COMPLEX-CODA requires consonant deletion through consonant simplification, forming a competing relation with MAX_{IO}. The constraint that is crucially relevant to tensification is presented as TENSE in the present analysis.26) The constraint TENSE requires tensification, forming a competing relation with IDENT[cg].

As previously discussed, in the perspective of OT, what is most problematic is that constraint interaction system of input-output corresponding relation cannot provide a correct output form in the opaque case. What would be selected as a winning candidate is not an actual output form that is opaque, but a wrong transparent candidate as the following tableau (18) indicates.

(18) General OT Analysis of Korean Tensification
/nəlp-ta/ → *[nəlta] ([nəlt'a]) 'to be wide'

	/nəlp-ta/	*COMPLEX	TENSE	MAX_{IO}	IDENT
	a. nəlpta	*!	*		
	b. nəlpt'a	*!			
transparent	☞c. nəlta			*	
opaque	d. nəlt'a			*	*!

As seen in (18), the constraint ranking wrongly selects the transparent candidate *[nəlta] in (18c) as the winner. The actual output, however, is the opaque candidate [nəlt'a] in (18d). Both (18c) and (18d) violate MAX_{IO} because of the deletion of underlying consonant /p/. However, the candidate in (18d) additionally violates IDENT[cg] because of the featural change of [constricted glottis]. A strategy of reranking IDENT[cg] over MAX_{IO} would clearly not alter the outcome.

The tableau in (18) is indicative of a difficulty for OT that a surfacing opaque output presents especially in the case where an opaque output is the result of a counterbleeding relationship in a serial

26) A more detailed discussion on the constraint regulating tensification requires the clarification of the phonetic and phonological nature of tense consonants in Korean.

rule-based approach. The transparent candidate violates fewer constraints than the opaque candidate, but more crucially, the transparent candidate has a subset of the opaque candidate's violations. This means that the opaque candidate would always be the loser in the OT analysis like (18), since it will necessarily have one additional constraint violation(McCarthy 1999).

In order to overcome such shortcoming in the theoretical framework of OT, Sympathy Theory provides additional corresponding mechanism of inter-candidate correspondence.[27] The basic rationale behind the notion 'sympathy' lies in the fact that an opaque candidate like (18d) wins because it resembles a failed candidate in a certain way that the transparent candidate like (18c) does not. That is, there is faithfulness of one candidate to another in a single candidate set. Through such candidate-to-candidate faithfulness, the actual output form(the opaque candidate) is in sympathy with a particular failed candidate(McCarthy 1999). As discussed in detail in Section 2, the sympathetic candidate cannot be any random failed candidate but one that obeys some designated faithfulness constraint. For the analysis of opacity problem in Korean tensification, the sympathetic candidate is 'nəlpt'a' in (18b) that is the intermediate form on which the actual output [nəlt'a] is based in the counterbleeding relationship in (15). In the mechanism of correspondence, 'nəlpt'a' in (18b) is a possible output candidate and it obeys a specific faithfulness constraint that both the transparent candidate in (18c) and the opaque candidate in (18d) violate, namely ANCHOR-R_{IO}(Root,σ,Final).[28] This constraint calls for the alignment of the right edge of the root with the right edge of the syllable. Deletion of root-final consonant through consonant simplification would incur the violation of ANCHOR-R_{IO}(Root,σ,Final). Therefore, the constraint ANCHOR-R_{IO} (Root, σ, Final) is the designated faithfulness that selects the

27) Following McCarthy(2002b), the revised version of Sympathy Theory relying on the notions of unfaithful mappings and cumulativity is adopted in the present analysis, A detailed discussion on unfaithful mappings and cumulativity has already been presented in Section 2.

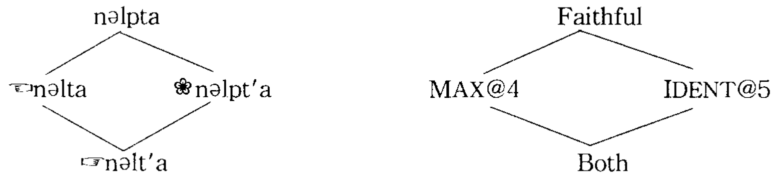
28) Detailed properties of the constraint ANCHOR-R_{IO} (Root, σ, Final) are presented in footnote 9.

sympathetic candidate 'nəlpt'a' in (18b).

As discussed in Section 2, a direct utilization of inter-candidate faithfulness constraints in McCarthy(1999) has excessively rich descriptive power, allowing the direct transmission of any property from the sympathetic candidate to the opaque actual output form. A revised Sympathy Theory in McCarthy(2002) is based upon a more restricted, indirect utilization of candidate-to-candidate correspondence in terms of the unfaithful input-output mappings that create competing candidates. The set of unfaithful mappings is the only information that can be transmitted from the sympathetic candidate to other candidates by the sympathy constraint ❀SYM.[29]

For the sympathy analysis of the present study, inter-candidate unfaithful relations can be more clearly pictured in the partial ordering diagram in (19).

(19) Partial Ordering Diagram for Korean $/n_1ə_2l_3p_4t_5a_6/$



The one that is most faithfully mapped(identical to the input), 'nəlpta', stands at the top of the partial ordering, and below it is a rank of candidates each of the unfaithful mappings form the first row, and so on. Underlying /nəlp-ta/ is mapped onto surface [nəlt'a] by two unfaithful mappings, tensing of /t/ and deletion of /p/.

Such an aspect of unfaithful mappings among candidates can be summarized as follows.

29) The activity of the sympathetic constraint ❀SYM is discussed in (6).

(20) Unfaithful Mappings Relative to Input /n$_1$ə$_2$l$_3$p$_4$t$_5$a$_6$/

		Candidate	$U_{Candidate}$
Faithful Candidate		nəlpta	Faithful
Sympathetic Candidate	❀	nəlpt'a	IDENT@5
Transparent Candidate	☜	nəlta	MAX@4
Opaque Candidate	☞	nəlt'a	MAX@4, IDENT@5

In solving opacity problems in OT framework, the decisive role of the sympathetic constraint ❀SYM regulating candidate-to-candidate correspondence can be clearly detected in the tableau (21).

(21) Sympathy Analysis of Korean Tensification[30]
/nəlp-ta/ → [nəlt'a/ (*[nəlta]) 'to be wide'

/nəlp-ta/	*COMPLEX	TENSE	❀SYM	MAX$_{IO}$	IDENT(cg)	★ANCHOR
a. nəlpta (faithful)	*!	*	*			√
❀ b. nəlpt'a (sympathetic)	*!				*	√
☜ c. nəlta (transparent)			**!	*		*
☞ d. nəlt'a (opaque)			*	*	*	*

The tableau in (21) correctly evaluates the opaque candidate as the optimal output. Relatively faithful candidates with no segmental deletion such as (21a) and (21b) are eliminated because they each violate undominated *COMPLEX-CODA. The choice then is between (21c) and (21d). Both (21c) and (21d) violate MAX$_{IO}$ because of the deletion of the underlying /p/. The key constraint in this analysis is ❀SYM which requires faithfulness to the sympathetic candidate in (21b). The sympathetic candidate '❀nəlpt'a' is chosen for its obedience to the selector, the designated faithfulness constraint, ANCHOR-R$_{IO}$(Root, σ,

30) As seen in (19) and (20), all the presented realistic candidates in (21) are in the comparable, that is, cumulative relation.

Final). In comparison with 'nəlpta' in (21a) that also obeys the selector, '❀nəlpt'a' is more harmonic, since it does not violate another highly-ranked constraint TENSE. The actual output form is the opaque candidate, [nəlt'a] in (21d). Its transparent competitor, *[nəlta] in (21c) lacks the sympathetic effect of tensification, and it is not optimal, because of relatively high-ranking ❀SYM. The opaque candidate in (21d) has only one violation of ❀SYM due to the lack of [p]. On the other hand, the transparent candidate in (21c) violates ❀SYM twice because it lacks both [p] and the feature [+constricted glottis] in [t] of the sympathetic candidate in (21b). Even though (21c) respects IDENT(cg) while (21d) does not, (21c) is still eliminated because of its fatal violation of the sympathetic faithfulness constraint, ❀SYM.

4. Conclusion

The cases of phonological opacity where a non-surface-apparent intermediate form plays a decisive role in deriving a correct output form raises a serious problem in non-serial mechanism of OT approaches. In two-level system of OT operating only with underlying inputs and surface-true outputs, such an existence of an intermediate form originated from derivational system is an unwanted component of phonology that should not be accepted.

In order to handle the opacity problem in non-serial OT framework, *Sympathy Theory* directly resorts to the elaboration of the component CON by positing a constraint with special property, which might be a well-expected move in constraint-based phonology. By the crucial role of the sympathetic constraint in the system of constraint interaction, the influence of a non-surface-apparent, failed candidate on the actual output form, which is the main source of phonological opacity, can be captured in a parallel fashion. As a consequence, the need of intermediate representation no longer exists in phonology, upon which the rule-based approaches are heavily dependent. Phonological opacity is a simple reflection of candidate-to-candidate faithfulness relation.

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