Constraint combinations and phonological opacity[*]

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Lee, Yongsung. 2014. Constraint combinations and phonological opacity. *Studies in Phonetics, Phonology and Morphology* 20.2. 187-206. This paper presents an extensive explanation to opacity, which represents one of the most recalcitrant problems in Optimality theory. The research history of opacity in Optimality theory is that of gradual departure from its original proposal. The recent proposal of OT-CC by McCarthy virtually gives up the idea of parallelism and argues for the importance of derivational history. This paper, however, reviews the opacity problems and offers an alternative explanation without abandoning parallelism. This paper makes use of constraint combinations to explain both underapplication opacity and overapplication opacity. It cites various papers to show that the underapplication opacity is the work of disjunctively combined complex constraint. Based on such constraint combinations, it further argues that the overapplication opacity is also the work of a combined constraint. The complex constraint with implicational combination and its interaction with relevant constraints can explain the overapplication opacity. As such, this paper shows that we can deal with opacity issues in Optimality without introducing derivational history or constraints that do not fall into either markedness or faithfulness constraint family. **(Busan University of Foreign Studies)**

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1. Introduction

Optimality theory (=OT), as originally proposed in Prince and Smolensky (1993), McCarthy and Prince (1993a, b), argues against serial derivation and presents the markedness-oriented selection of the optimal form. The great merit of the theory, dispensing with the step-by-step derivation, however, causes explanatory difficulty in phonological opacity. Opacity, in traditional generative phonology, is seen to be the result of serial interactions of phonological rules. Naturally, OT with parallelism faces problems in explaining opaque interaction of phonological rules.

Ever since the beginning of OT, researchers have attempted to put forth proposals to explain the opacity effect within the OT framework. They include local constraint conjunction (Smolensky 1995), base-identity proposal (Kenstowicz 1996), output-output correspondence (Benua 1997),

sympathy theory (McCarthy 1999), paradigm contrast (Łubowicz 2003), comparative markedness proposal (McCarthy 2003) and OT with candidate chains (McCarthy 2006, 2007). A quick overview of these proposals and developments shows that these alternative proposals drive OT away from the original proposal of parallelism and gradually accept derivational stages. The opacity problems, as such, undermine simplicity and consistency of the OT theory, and therefore, disappoint many researchers and followers. Given this murky situation, this paper goes back to the drawing board of OT and sees how the opacity problems can be dealt with in OT without any major surgical operation on the theory itself. The gist of the proposal in this paper is that we can make use of constraint combination in line with the local constraint conjunction proposal (Smolensky 1995) to deal with two different types of opacity, the underapplication opacity and the overapplication opacity. In a nutshell, this paper claims that both of the opaque interactions are the work of the complex constraints formulated by combining faithfulness constraints.

This paper is based on three different types of constraint combinations, conjunctive combination, disjunctive combination and implicational combination, as proposed in Crowhurst and Hewitt (1997), expanded in Crowhurst (2011), and illustrated in Y. Lee (2013). As for the underapplication opacity, it is argued that the opaque result comes from the ban on the violation of two or more faithfulness constraints in a given domain. Accordingly, we propose a disjunctively combined complex constraint. It is an equivalent of the local constraint conjunction, which argues against the radical departure from the input in a given domain. As for the overapplication opacity, the fundamental problem in OT presents itself as the harmonically-bounded one appears on the surface. What we need is to have a constraint that breaks the shackle of harmonic bounding, and we argue the implicational combination of faithfulness constraints does the work of overriding the harmonic bounding effect.

To this end, we will survey the issues in opacity in Section 2. Section 3 introduces three types of constraint combinations and offers explanation on opacity based on the constraint combinations. Section 4 wraps up the discussion and concludes the paper.

2. Theoretical backgrounds and opacity issues

In generative grammar, opacity comes from the extrinsic rule ordering. Consider Kiparsky's (1973: 79) description of opacity in traditional Generative phonology:

(1) A phonological process P of the form A → B / C__D is opaque if there are surface structures with either of the following characteristics:
    a. instances of A in the environment C__D.
    b. instances of B derived by P that occur in environments other than C__D.

Opacity arises when A appears between C and D in a language that has a rule P, A → B / C__D, as in (1a) and when B appears in other environments than between C and D as in (1b). In rule-based approaches, the opacity is explained with the extrinsic rule ordering. For example, the rule P that changes CAD sequences into CBD is not applicable to CAE, but later E is somehow changed into D by another rule Q. But the rule ordering P→Q, the counterfeeding order, prevents the application of P once Q is applied and CAD sequence surfaces as a result. McCarthy (2005) calls it "underapplication opacity." Further, if rule P is applied to CAD sequence and changes it into CBD, and the later rule Q changes either C or D, the environments of rule P is hidden on the surface. This time the ordering, P→Q, the counterbleeding order, is responsible for the surface opacity as in (1b), which McCarthy (2005) calls "overapplication opacity."

But in OT, we have neither the rules nor the derivational stages and we are forced to see the opacity from a different perspective. In OT, opacity arises when the usual evaluation fails to select the actual surface form as optimal and therefore we need some additional devices to select the actual surface form. Let's first look at the typical data of the underapplication opacity or the opacity due to counterfeeding ordering:

(2) Bedouin Arabic vowel raising and epenthesis (McCarthy 2006: 4)[1]
  a. Raising of [a] in an open syllable
    /katab/ → ki.tab 'he wrote' (⟦*aCV ≫ IDENT(low)⟧)
  b. Epenthesis
    /himl/ → hi.mil 'load' (⟦NOCOMPLEX ≫ DEP(V)⟧)
  c. Interaction: raising → epenthesis
    /gabr/ → ga.bur (*gi.bur) 'a grave'

Bedouin Arabic has a raising rule that changes /a/ in an open syllable into [i], and an epenthesis that inserts a vowel between two consonants. The ordering, Raising → Epenthesis, changes the underlying /gabr/ into [ga.bur]. If the reversed ordering is applied, we may get the wrong output *[gi.bur]. Now consider the following unfortunate evaluation in OT.

(3) Wrong evaluation of /gabr/ → [ga.bur]
  *aCV, NOCOMPLEX ≫ IDENT(low), DEP(V)

gabr	*aCV	NOCOMPLEX	IDENT(low)	DEP(V)
? surface ga.bur	*!			*
✓chosen gi.bur			*	*

(3) dramatizes the problem of underapplication opacity in OT. The actual surface form is [ga.bur], an opaque output, while the transparent form, or the chosen form is actually non-surface-true as McCarthy (1999) puts it. The only way to choose the surface form is to rank IDENT(low) over *aCV. But as shown in (2a), the ranking, ⟦*aCV ≫ IDENT(low)⟧, is already given and as long as we keep this ranking, there is no direct way to resolve the conflict in evaluation. What we see here is that the chosen form shows radical departure from the input as it violates more faithfulness constraints than the surface form.

Even more serious problem is witnessed in overapplication opacity. Consider the Tiberian Hebrew example given in (4):

(4) Tiberian Hebrew Epenthesis and [ʔ]-deletion (McCarthy 1999: 333)
    a. Epenthesis into the final cluster
        /melk/ → melex 'king' (⟦NOCOMPLEX ≫ DEP(V)⟧)
    b. [ʔ]-deletion outside onsets
        /qaraʔ/ → qara_ 'he called' (⟦CODACOND ≫ MAX(C)⟧)
    c. Interaction : epenthesis → [ʔ]-deletion
        /dešʔ/ → dešeʔ → deše_ (*[deš]) 'tender grass'

Again, Epenthesis must precede [ʔ]-deletion to get the correct result. The reversed ordering will lead to the wrong output *[deš]. In OT, the evaluation fails to pick up the right surface form. Consider the following unfortunate evaluation:

(5) Problematic evaluation of /dešʔ/ → deše_

dešʔ	NO COMPLEX	CODA COND	DEP(V)	MAX(C)
? surface deše			*!	*
✓ chosen deš				*

(5) shows the typical case of harmonic bounding in Samek-Lodovici and Prince (1999). As the actual surface form violates all the constraints that the chosen form violates (MAX(C)) and it has further violation of DEP(V) which the chosen form satisfies, no ranking permutations can select the actual surface form. One observation we can make here, though, is that the actual surface form violates two faithfulness constraints while the wrongly chosen one violates one faithfulness constraint to satisfy both of the markedness constraints, CODACOND and NOCOMPLEX. As such, satisfying two (or more) markedness constraints with a single faithfulness violation results in radical harmonic improvement, which may serve as a key to solving the opacity problem in OT.

So far, we have shown that opacity may not be easily explained in the traditional OT and observed that the chosen form in the underapplication

opacity has the radical divergence from the input, while that in the overapplication form has radical harmonic improvement on the surface. Now we have two diverging roads before us. We may give up the direct mapping from the input to the output and adopt multiple evaluation stages as in Stratal OT (Kiparsky 2000) or Harmonic Serialism (McCarthy 2010). Or we may try to find a way to patch up the theory so that we can dispense with multiple evaluations. The first option may be a viable way to deal with opacity, but this paper pursues the possibility of keeping parallelism and a single evaluation with minimum or no change in the basic OT frameworks. Now consider some of the representative proposals to deal with opacity in OT:

(6) Proposals to deal with opacity in OT
    a. Local Constraint Conjunction (Smolensky 1995, Moreton and Smolensky 2002)
       The locally conjoined faithfulness constraint can block the radical divergence in underapplication opacity. But it cannot explain overapplication opacity.
    b. Base Identity (OO-Correspondence) (Kenstowicz 1996, Benua 1997)
       A constraint which requires identity to the base (or output) serves to explain overapplication opacity. But it may not deal with underapplication opacity.
    c. Paradigm Contrast (Łubowicz 2003)
       A constraint that prohibit the surface neutralization of the distinct inputs may serve to explain overapplication opacity. It may have the potential to explain underapplication opacity as well.
    d. Sympathy (McCarthy 1999)
       Setting up a sympathetic candidate and sympathy constraint can explain both overapplication and underapplication opacities.
    e. Comparative Markedness (McCarthy 2003)
       By dividing markedness constraints into New Markedness and Old Markedness, the comparative markedness theory can deal with overapplication opacity as well as underapplication opacity.
    f. OT-CC with Prec (McCarthy 2006, 2007)
       This introduces the derivational history and the constraint on the order of violation, PREC, can deal with both types of opacities.

Previous research gives ample evidence that (6a) is a very good way to deal with underapplication opacity. It should be the most favorable way as we don't have to change anything in the assumptions or principles in OT. But it is rejected, as it fails to explain overapplication opacity. (6b), (6c) and (6d) introduce additional constraints other than input faithfulness and output markedness, which are criticized by McCarthy (2007) with illustrations. (6e) and (6f) virtually introduce the intermediate stages. (6e) says that the markedness violations should be divided into old markedness violations (the

markedness applicable to input) and new markedness violations (the markedness violation which is absent in the input). The division virtually means that there should be derivational stages to check whether a markedness violation is an old one or a new one. (6f), OT-CC, unmistakably introduces the derivational history as the chain records the history of faithfulness violations. Some of the major changes in OT-CC from the conventional OT are given under:

(7) Major changes in OT-CC
    a. Restriction on GEN
       GEN cannot produce candidates that do not show any harmonic improvement. (GEN must refer to the constraint ranking to check the harmonic improvement.)
    b. Candidate Chain
       The candidate must have the record of chronological faithfulness violations. (Candidates are the end result of serial derivation.)
    c. Precedence constraint
       This constraint evaluates the derivational history. (We need a new kind of constraint other than input faithfulness and output markedness.)
    d. FFC
       The first faithful candidate comes with full prosodic parsing. (There is no evaluation on structure building, because the prosodic parsing does not incur any faithfulness violation.)

   As such, OT-CC shows the radical departure from the conventional OT theory in that it changes the function of GEN (7a) and introduces the derivational stages (7b) and a new type of a constraint family, PREC, which evaluates the derivational history (7c). And it does not say anything about well-formed syllable or foot structures (7d).

   The discussion so far shows that except for (6a), the rest of the proposals introduce either new types of constraints or derivational stages, or both as in the case of (6f). Having observed that (6a) makes use of the constraint conjunction, this paper extends the constraint conjunction to see if it can solve the issues in overapplication opacity.

3. Constraint combinations and their application to opacity

In this section, we argue that the opacity phenomena found in natural languages can be explained with constraint combinations. As for the underapplication opacity, we have already hinted that the local constraint conjunction can deal with the opacity issue and the conjoined constraint, interacting with other constraints, correctly picks the opaque output as optimal. We will further extend the constraint combination and show that the overapplication opacity is the result of the interaction of another type of

constraint combination.

3.1 Three types of constraint combinations

Three different constraint combinations are introduced by Crowhurst and Hewitt (1997) based on Boolean operations in formal logic. Boolean operation is a way to build up a complex proposition by combining simple propositions using logical connectives:

(8) Boolean operations
      a. Conjunction: $X \cap Y$ X and Y
      b. Disjunction: $X \cup Y$ X or Y
      c. Implication: $X \rightarrow Y$ if X then Y

These Boolean operations can also be used to form complex constraints by combining simple constraints. Y. Lee (2013), based on Crowhurst and Hewitt (1997), extends the use of connectives to form the following three types of constraint combinations:

(9) Constraint combinations
      a. Conjunctive combination (Cap-junction): $[X \cap Y]_D$
      b. Disjunctive combination (Cup-junction): $[X \cup Y]_D$
      c. Implicational combination (If-junction): $[X \rightarrow Y]_D$

(9) represents the three possible constraint combinations. The subscript D in the complex constraint represents the domain where the constraint is applicable. We will use the name of connectives, $\cap$ (cap), $\cup$ (cup) and $\rightarrow$ (if (then)) to tell the different combinations apart. Now consider first the following violation tables of combined constraints in (10):

(10) Violation tables
      a. Cap-joined complex constraint

	$[X \cap Y]_D$	X	Y
i.	✓	✓	✓
ii.	*	*	✓
iii.	*	✓	*
iv.	*	*	*

      b. Cup-joined complex constraint

	$[X \cup Y]_D$	X	Y
i.	✓	✓	✓
ii.	✓	*	✓
iii.	✓	✓	*
iv.	*	*	*

c. If-joined complex constraint[2]

	$[X \rightarrow Y]_D$	X	Y
i	✓	✓	✓
ii	✓	*	✓
iii	*	✓	*
iv	✓	*	*

As the violation tables in (10) show, the cap-joined constraint, $[X \cap Y]_D$, is satisfied if and only if both X and Y are satisfied in a given domain. This complex constraint passes only the best form in the sense that it filters out any candidate which violates either A or B or both. Crowhurst (2011) uses the cap-joined constraint to explain the stress patterns of Diyari. Y. Lee (2010) employed this conjunctive combination of markedness constraints to explain the distribution of ergative allomorphs in Dyirbal.

The disjunctive combination in (9b), or its notational variations, is frequently employed in the literature. The local constraint conjunction as proposed by Smolensky (1995) is actually the disjunctive combination of faithfulness constraints. This cup-joined constraint is violated if and only if both X and Y are violated in the given domain as (10b) shows. This complex constraint is employed to explain positional markedness such as coda conditions (Itô and Mester 1998) and various examples of underapplication opacity (Moreton and Smolensky 2002 and others) including chain-shift (Kirchner 1996).

The third type of constraint combination in (9c) and (10c), the implicational combination, or if-junction, is not overtly discussed in the literature. But Y. Lee (2013) notes that the onset condition, *ŋ/Onset, that onset does not contain /ŋ/ in Korean (or in English) presents a typical case of the implicational combination of markedness constraints that can be rewritten as $[Onset \rightarrow *ŋ]_{SEG}$, meaning if a segment satisfies Onset, then it should also satisfy *ŋ as well. The positional faithfulness constraint like IDONS(voice) as introduced by Lombardi (1999) to explain the directionality of voicing assimilation is another case of if-junction as IDONS(voice) is a notational equivalent of $[Onset \rightarrow ID(voice)]_{SEG}$. As a matter of fact, positional faithfulness constraints are the complex constraints formed by the implicational combinations of structural markedness and segmental faithfulness. This paper argues that this if-joined constraint is responsible for choosing the opaque form over the transparent form in overapplication

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[2] In formal logic, the implicational combination $[X \rightarrow Y]$ may be re-written as $[-X \cup Y]$, dispensing with the implicational combination by replacing it with the introduction of negative operator in the cup-junction. But that is not a viable way as long as we do not introduce anti-faithfulness. Note that here both X and Y are faithfulness and –X filters out everything that satisfy the faithfulness constraint X, which would invite chaos in interpreting faithfulness constraints. It would be like arguing that satisfaction of ONSET is actually the violation of NOONSET.(see Hammond (1999: 44) for NOONSET.)

opacity.[3]

3.2 Disjunctive combination and underapplication opacity

In this subsection, we review the local constraint conjunction and see that the local constraint conjunction is formally represented as disjunctive combination and it can explain the underapplication opacity. Consider some of the representative cases of underapplication opacity in the literature other than the Bedouin Arabic case given in (3):

(11) Western Basque Chainshift (Moreton and Smolensky 2002)
    a. /e/ → [i]/ ___V (⟦Hiatus Raising (=HR) ≫ IDENT(high)⟧)
    b. /a/ → [e]/ ___V (⟦HR ≫ IDENT(low)⟧)
    c. alabaa → alabea (*alabia)

alaba-a	Hiatus Raising	IDENT (high)	IDENT (low)
? surface alabea	*!		*
✓ chosen alabia		*	*

(12) Jeonnam Korean vowel raising (Seo and Jo 2007)
    a. /e/ → [i] (⟦MidVowelRaising (=VR1) ≫ IDENT(high)⟧)
    b. /ɛ/ → [e] (⟦LowVowelRaising (=VR2) ≫ IDENT(low)⟧)
    c. /kɛ/ → [ke] (*ki)

kɛ	VR1	VR2	IDENT (high)	IDENT (low)
? surface ke	*!			*
✓ chosen ki			*	*

(13) English flapping and vowel lengthening (Y. Lee 2006)
    a. V → long / ___ [+voice] (⟦LENGTH ≫ IDENT(length)⟧)
    b. t→D/V__V (⟦FLAP ≫ IDENT(voice)⟧)
    c. /rayt-ər/ → [rayDər] (*ra:yDər)

rayt + ər	LENGTH	FLAP	IDENT (length)	IDENT (voice)
? surface rayDər	*!			*
✓ chosen ra:yDər			*	*

(14) Isthmus Nahuat apocope and devoicing (modified from Kager 1999)
    a. C → [-voice] in coda (⟦*VOICED-CODA ≫ IDENT(voice)⟧)
    b. V → Ø / __## (⟦FINAL-C ≫ MAX⟧)

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[3] We limit the discussion to Faithfulness-Faithfulness combination as it is relevant to opacity issues. Please refer to Y. Lee (2013) Markedness-Markedness combination and the issues regarding Faithfulness-Markedness combination.

c. /ʃikakili/ → [ʃikakil̥] (*[ʃikaki])

	ʃikakili	*Voiced-Coda	Final-C	Ident (voice)	Max
? surface	ʃikakil̥	*!			*
✓ chosen	ʃikaki			*	*

First note that in all the examples given in (11) through to (14), the first rule of each example, ((11a), (12a), (13a) and (14a)) is applied before the second rule ((11b), (12b), (13b) and (14b)). If the second rule is applied first, then it feeds the first rule, resulting in the wrong surface form. The extrinsic ordering, the counterfeeding ordering, is enforced in rule based approach. However, we do not have such a device in OT. We see the repetition of same patterns in underapplication opacity. Phonological change in OT is viewed as the violation of faithfulness constraints in a given focus to satisfy markedness required for that focus. In other words, we need the rankings, $[\![M_A \gg F_A]\!]$ and $[\![M_B \gg F_B]\!]$ to explain the phonological alternation. However, as long as we have the ranking, $[\![M_A \gg F_A]\!]$, no possible permutation can select the actual surface form. We may represent the problem schematically as in (15)[4]:

(15) Schematic representation of underapplication opacity problem

	M_A	M_B	F_A	F_B
? *Cand A*	*!			*
✓ *Cand B*			*	*

(15) shows that the form *Cand A*, the actual surface form, cannot win over *Cand B*, the wrongly chosen form. Given the violation status, one way to make the surface form optimal is to put F_A over M_A. But for other transparent interactions we know M_A should be higher than F_A, which leads to the conceptual dilemma of evaluation. Observing that the wrongly chosen form shows multiple violations of faithfulness constraints, and thereby showing radical departure from the input, the local constraint conjunction advocates put forth $[F_A \& F_B]_D$ to eliminate the one that shows the violation of both faithfulness constraints. Here the locally conjoined constraint, $[F_A \& F_B]_D$, represents disjunctively combined constraints as shown in (9b) and can be rewritten using a formal connective as $[F_A \cup F_B]_D$. Now all we have to do is to put this complex constraint anywhere above M_A. See the following schematic evaluation:

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[4] The example in (11) is different from the rest in that it has just one markedness constraint. The Hiatus Raising, however, actually represents two separate markedness, Hiatus Raising 1, and Hiatus Raising 2 as is the case in (12).

(16) Schematic representation of underapplication opacity evaluation

	$[F_A \cup F_B]_D$	M_A	M_B	F_A	F_B
✓ *Cand A*		*			*
Cand B	*!			*	*

We see the work of the disjunctively combined complex constraint, $[F_A \cup F_B]_D$, in the evaluation tableau in (16). Putting it over M_A, we can choose the actual surface form as the optimal output. Theoretically, we can see that the underapplication opacity is the result of filtering out the radical change of input faithfulness. The argument presented in this subsection is substantially supported in the literature on underapplication opacity.

Going back to the Bedouin Arabic underapplication opacity discussed in connection with (3), we now have correct evaluation by introducing a complex constraint, $[\text{IDENT(low)} \cup \text{DEP(V)}]_{ADJ-\sigma}$, as in (17):

(17) Evaluation of /gabr/ → [ga.bur]

gabr	$[\text{IDENT(low)} \cup$ $\text{DEP(V)}]_{ADJ-\sigma}$	*aCV	NO COMPLEX	IDENT (low)	DEP(V)
✓ ga.bur		*			*
gi.bur	*!			*	*

The evaluation tableau in (17) is self-explanatory. The cup-joined constraint filters out the transparent form and selects the opaque one as the optimal form. McCarthy (2007: 35), however, finds fault with this analysis citing one apparently exceptional problem in the language.

(18) Violation of $[\text{IDENT(low)} \cup \text{DEP(V)}]_{ADJ-\sigma}$ in Bedouin Arabic
    /t$^{?}$arad ʁanam-ih/→[t$^{?}$a.ra.dɪʁ.nɪ.mih] ("he pursued his sheep")

We will have to note in passing that (18) is the only exceptional example cited in the literature to the best of the author's knowledge. This example shows vowel insertion, DEP(V) violation, in the first word and vowel raising, IDENT(low) violation, in the second word. As these changes take place in adjacent syllables, the actual output form, [t$^{?}$a.ra.dɪʁ.nɪ.mih], has to be eliminated by the cup-joined constraint whose domain is two adjacent syllables. Granted that McCarthy's observation is correct, we know that it is not the problem of the combined constraint per se. Actually, all we need is to refine the domain of the constraint. Taking into McCarthy's consideration that WORD cannot be the right domain as IDENT(low) and DEP(V) are frequently violated in non-adjacent syllables within a word, we may propose that the domain should be "adjacent syllables in a word," as in $[\text{IDENT(low)} \cup \text{DEP(V)}]_{ADJ-\sigma \cap WORD}$, which will surely guarantee the correct

application of the cup-joined constraint.[5]

　　As such, the cup-joined complex constraint penalizes the output which has multiple violations of faithfulness constraints in a given domain. We may interpret this to mean that the underapplication opacity is the natural result of the phonological force that works against certain types of radical faithfulness divergence from the input.

3.3 Implicational combination and overapplication opacity

We now turn to overapplication opacity. The basic problem of overapplication opacity is that a harmonically bounded candidate shows up on the surface as illustrated in (5) with Tiberian Hebrew examples. We show that an if-joined complex constraint breaks the shackle of harmonic bounding and correctly picks the opaque candidate as the actual output. Consider additional examples of overapplication opacity due to counter-bleeding order in the literature.

(19) Bedouin Arabic (McCarthy 2002: 25, McCarthy 2007: 39-40)
　　　a. k → kʲ / __ i (⟦*ki ≫ IDENT(back)⟧)
　　　b. i → Ø / __ CV (⟦*iCV ≫ MAX⟧)
　　　c. /ha:kim-i:n/ → [ha:kʲmi:n], (*[ha:kmi:n])

/ha:kim-i:n/		*ki	*iCV	IDENT(back)	MAX
? surface	ha:kʲmi:n			*!	*
✓ chosen	ha:kmi:n				*

(20) Catalan (Kiparsky 1985: 96-97, McCarthy 2007: 41)
　　　a. N → [αplace] / __ C[αplace] (⟦AGREE ≫ IDENT(place)⟧)
　　　b. C → Ø / C ___ (⟦NoCC ≫ MAX⟧)
　　　c. /bɛn-k/ → [bɛŋ] (*[bɛn])

/bɛn-k/		AGREE	NoCC	IDENT (place)	MAX
? surface	bɛŋ			*!	*
✓ chosen	bɛn				*

(21) Ojibwa (Kaye 1974: 140, McCarthy 2007: 54)
　　　a. N → [αplace] / __ C[αplace] (⟦Agree ≫ IDENT(place)⟧)
　　　b. C → Ø / C ___ (⟦NoCC ≫ MAX⟧)

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[5] Another possible way to deal with the problem is to set the domain to a foot. Al-Mozainy et al. (1985: 139) argues that the Bedouin Arabic has left-dominant foot, a trochaic foot. Adopting this analysis, we see that (ga.bur) forms a foot, while the example in (18) has the foot structures (tˤarad)(ʁanam). Now we see that [ga] and [bur] belong to the same foot while [rad] and [ʁa] belong to different feet. So we may define the domain to be a foot and formulate the combined constraint as [İDENT(low)∪DEP(V)]_FOOT, which surely helps to stay away from McCarthy's criticism on the local constraint conjunction.

c. /takossin-k/ → [takoʃʃiŋ] (*[takoʃʃin])

	takossin-k	AGREE	NoCC	IDENT (place)	MAX
? surface	takoʃʃiŋ			*!	*
✓ chosen	takoʃʃin				*

(22) Yokut (McCarthy 1999, Bakovič 2007: 223)
 a. [+long] → [-high] (⟦NoLongHigh (=NLH) ≫ IDENT(high)⟧)
 b. V → [-long] (⟦NoLongClosed (=NLC) ≫ MAX(μ)⟧)
 c. /ʔili:-l/ → [ʔilel] (*[ʔilil])

	/ʔili:-l/	NLH	NLC	IDENT (high)	MAX(μ)
? surface	ʔilel			*!	*
✓ chosen	ʔilil				*

(23) Canadian English (Joos 1942, Y. Lee 2006)
 a. ay → ʌy/ __C[-voice] (⟦Raise ≫ Ident(low)⟧)
 b. t → D /V__V (⟦Flap ≫ IDENT(voice)⟧)
 c. /rayt+ər/ → [rʌyDər] (*[rayDər]

	/rayt+ər/	Raise	Flap	IDENT (low)	IDENT (voice)
? surface	rʌyDər			*!	*
✓ chosen	rayDər				*

(24) Kyungsang Korean (Tak 2008)[6]
 a. Obs → [+c.g.] / Obs ___ (⟦Obs-Obs Tensing (=OO TENSING) ≫ IDENT(c.g.)⟧)
 b. C → Ø/ C___ (⟦NoCC ≫ MAX⟧)
 c. /malk-ta/ → [malt'a] (*[malda])

	/malk-ta/	OO TENSING	NoCC	IDENT (c.g.)	MAX
? surface	malt'a			*!	*
✓ chosen	malda				*

(25) Indonesian (Cohn and McCarthy 1998)
 a. N → [αplace] / __ C[αplace] (⟦AGREE ≫ IDENT(place)⟧)
 b. C̥ → Ø / N ___ (⟦NoNC̥ ≫ MAX⟧)
 c. /məŋ-tulis/ → [mənulis], *[məŋulis]

	/məŋ-tulis/	AGREE	NoNC̥	IDENT(place)	MAX
? surface	mənulis			*!	*
✓ chosen	məŋulis				*

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[6] For the sake of simplicity, we ignore the intervocalic voicing in the tableau.

Consider the example given in (19). To explain Bedouin Arabic overapplication in rule based grammar, we need two rules: palatalization rule, $k \rightarrow k^j / \_\_i$, and vowel deletion rule, $i \rightarrow \emptyset / \_\_CV$. Palatalization should apply before vowel deletion to get the right result. If vowel deletion rule applies first, then it destroys the environment for palatalization. Therefore, the counterbleeding ordering, Palatalization $\rightarrow$ Vowel insertion, should be enforced to get the right result. But the OT evaluation in (19) wrongly choose [ha:kmi:n] as optimal. The actual surface form, [ha:k^{j}mi:n], cannot win because it is harmonically bounded by the wrongly chosen one. Virtually the same explanation can be given to the rest of the examples in (20) through to (25). See the following schematized representation of overapplication opacity.

(26) Schematic representation of overapplication opacity

	M_A	M_B	F_A	F_B
? *Cand X*			*!	*
✓ *Cand Y*				*

Cand X is the actual surface form. But the evaluation in (26) wrongly chooses *Cand Y* as the optimal form. Conceptually, we can see that the problem with the wrongly chosen form is that one faithfulness violation leads to the satisfaction of two (or more) markedness constraints. Given the general assumption that a phonological change leads to the satisfaction of a markedness constraint at the sacrifice of a faithfulness constraint, we see that *Cand Y* represents a typical case of radical harmonic improvement in the sense that two markedness constraints, M_A and M_B are satisfied at the same time at the cost of a single F_B violation. One way to prevent this radical harmonic improvement is to set up an if-joined complex constraint as in (27):

(27) Implicational combination of faithfulness constraints : $[F_A \rightarrow F_B]_D$
    Assign an asterisk if and only if
    a. F_A is satisfied and
    b. F_B is violated
    c. in a specified domain D.

As already discussed in (10c), the if-joined constraint, $[F_A \rightarrow F_B]_D$, is not violated for any string with F_A violation, and for any string that satisfies both F_A and F_B. It penalizes the candidate that satisfies F_A but violates F_B. As such, the if-joined constraint favors the one with gradual harmonic change in the given domain. *Cand X* in (26) does not violate the if-joined constraint, as it fails to satisfy F_A, while the wrongly chosen form, *Cand Y*, violates it as F_A is satisfied but F_B is not. Now all we have to do is to rank the if-joined constraint anywhere over F_A (and F_B). See the schematic evaluation of (26) with the if-joined constraint.

(28) Schematic representation of overapplication opacity evaluation

	M_A	M_B	$[F_A{\to}F_B]_D$	F_A	F_B
✓ *Cand X*				*	*
Cand Y			*!		*
Cand Z		*!		*	

In (28), we see that the formerly chosen candidate, *Cand Y*, is now eliminated as it crucially violates the if-joined complex constraint, $[F_A{\to}F_B]_D$, which serves as an escape hatch from the harmonic bounding by filtering out *Cand Y* that shows the radical harmonic improvement. A third candidate, *Cand Z*, may also satisfy the if-joined constraint. But as shown in (28), the satisfaction of F_B simply means the violation of M_B and therefore, it cannot compete with *Cand X* with or without $[F_A{\to}F_B]_D$ present in the evaluation.

Now turning back to the Tiberian Hebrew overapplication opacity discussed in (5), we may introduce an if-joined constraint, $[\text{DEP(V)}{\to}\text{MAX(C)}]_{\text{ADJ-}\sigma}$, and put it over DEP(V) to get the right result.

(29) Evaluation of /deš?/ → [deše]

deš?	No Complex	Coda Cond	$[\text{DEP(V)}{\to}$ $\text{MAX(C)}]_{\text{ADJ-}\sigma}$	DEP (V)	MAX (C)
✓ a. deše				*	*
b. deš			*!		*

While the cup-joined constraints or locally conjoined constraints are employed by many previous researchers, no attempt has been made so far to apply constraint combination to the overapplication opacity. It is argued that introducing if-joined constraints is a simpler way to deal with the overapplication opacity, which has defied any easy explanation even with the major surgical operation on the Optimality Theory itself.

The solution illustrated in (29) is also applicable to all the examples given in (19) to (25). Further the same approach can present explanation for opacity that results from a feeding order as shown in (30) and (31):

(30) Turkish passive phonology (Baković 2007, Y. Lee 2011)
    a. Ø → i /C__C (⟦NOCC ≫ DEP⟧)
    b. k → Ø /V__V (⟦NOVkV ≫ MAX⟧)
    c. /bebek-n/ → [bebein] (*[beben])

/bebek-n/		NOCC	NOVkV	DEP	MAX
? surface	bebein			*!	*
✓ chosen	beben				*

(31) Javanese /hn/ deletion (Kenstowicz and Kisseberth 1979, M. Lee
1999)
a. $n \rightarrow \emptyset$ / C___ ($[\![$NoCN $\gg$ Max(N)$]\!]$)
b. $h \rightarrow \emptyset$ /V__V ($[\![$NoVhV $\gg$ Max(h)$]\!]$)
c. /omah-ne/ $\rightarrow$ [omae] (*omane)

/omah-ne/	NoCN	NoVhV	Max(N)	Max(h)
? surface omae			*!	*
✓ chosen omane				*

Though the opacity examples given in (30) and (31) are the result of
feeding order, not the usual counterbleeding order, the explanation is all the
same. Again, we see that an if-joined constraint, $[F_A \rightarrow F_B]_D$, ranked over F_A
(and F_B) rectifies the problem in evaluation, explaining how the opaque form
emerges as optimal. Consider the correct evaluation of (30) as shown in (32):

(32) Turkish passive opacity with constraint combination

/bebek-n/	NoCC	NoVkV	$[$Dep$\rightarrow$Max$]_W$	Dep	Max
✓ a. bebein				*	*
b. beben			*!		*
c. bebekn	*!				

The problem with (32b), [beben], is that one faithfulness violation leads to
the satisfaction of two markedness constraints. To prevent such radical
harmonic improvement, we need an if-joined constraint, $[$Dep$\rightarrow$Max$]_W$, and
place it anywhere above Dep and Max. Further (32c) shows that the
satisfaction of the if-joined constraint is not sufficient to become the optimal
form.

Now we understand that the if-joined constraint works against radical
harmonic improvement. i.e. satisfying two (or more) markedness constraints
with just one violation of faithfulness constraint. In this line of thought, the
overapplication opacity is the logical result from the ban on radical harmonic
improvement on the surface.

One final remark is in order. The constraint combination may result in
uncontrollable multiplication of constraint inventory as pointed out by Kager
(1999: 400).[7] There are at least two families of constraints, faithfulness and
markedness and there are three types of constraint combinations which may
lead to 6 different types of constraint combinations. The observation offers a
challenging   area   for   future   research.   It   is   already   noted   that
Markedness-Faithfulness combination should not be allowed. (Itô and
Mester 1998, Lee 2013) It is, however, admitted that the constraint
combination is subject to further research to see their typology, conditions on
combination   and   their   applicability   in   other   types   of   phonological

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[7] I thank one of the reviewers for pointing this out to me.

explanation.

4. Conclusion

This paper presents a comprehensive explanation for opacity in the OT framework. Based on much discussed constraint conjunction approach to underapplication opacity, we extend the types of constraint combinations to cover both types of opacity. To be more specific, we introduce conjunctive combination, disjunctive combination and implicational combination as legitimate ways of forming complex constraints from simple ones. In this approach, a disjunctive combination of faithfulness constraints explains underapplication opacity and an implicational combination of constraint is responsible for the surface overapplication opacity. The logic behind this explanation is that opaque form shows up on the surface either to avoid radical divergence of input faithfulness (in underapplication opacity) or to avoid the radical harmonic improvement of output markedness (in overapplication opacity) in a certain domain.

The constraint combination approach in this paper simplifies the opacity issues and obviates the unwanted complication of the theoretical assumption. First, it eliminates the need for any intermediate stage and keeps the principle of parallelism. Second, it does not need any special constraint(s), such as base-identity, sympathy constraint, paradigm contrast, OO correspondence, or precedence constraint. Finally, the proposal in this paper does not need any derivational history to be recorded in the form of chain as in OT-CC, which means that we do not have to make any fundamental change to the basic structure of OT or introduce serial or multiple evaluations. As such, this paper shows that the combined constraints can deal with opacity issues without any additional or arbitrary devices.

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