Remarks on phonological opacity in Optimality Theory

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John J. McCarthy

Opacity is a measure of how well the context or consequences of a phonological process can be determined from examination of surface structure. Kiparsky (1971, 1973: 79) introduced this notion, defining it approximately as follows:

(1) **Opacity**

A phonological rule \( P \) of the form \( A \rightarrow B / C \_D \) is *opaque* if there are surface structures with any 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 \( C \_D \).

c. instances of \( B \) not derived by \( P \) that occur in the environment \( C \_D \).

A rule without these characteristics is *transparent*.

Kiparsky’s concern is with understanding how minimization of opacity drives diachronic change. My goal is different: to observe some implications of opacity for phonological theory.

Opacity often arises through the interaction of phonological processes. When Kiparsky first proposed this definition, phonological interaction meant just one thing:
rule ordering in a serial derivation. Consider, for example, Tiberian Hebrew post-vocalic consonant spirantization. Among other alternations, underlying /k/ surfaces as x after a vowel. The triggering vowel can be one that is present underlyingly and preserved at the surface (2a), present only at the surface because it is epenthetic (2b), or present only underlyingly because it is deleted (2c).

(2) Spirantization in Tiberian Hebrew (Prince 1975; Malone 1993 and refs. cited there)

a. After a vowel:
   /malakín/
   malāxīn 'kings'
b. After an epenthetic vowel:¹
   /málix/
   mélex 'king'
c. After a deleted vowel:
   /malakó/
   málix 'kings of'

The final case, (2c), is a typical situation of opacity. The phonological process /P is post-vocalic spirantization, which yields (among other things) x in the environment \( /x/._{\_}/.\) The form málix (2c) contains an x in an environment other than \( /x/._{\_}/.\) satisfying clause (1b) of the definition of opacity. Hence, Hebrew spirantization is an opaque rule. In the serial-derivational terms current in 1973, the reason for the opacity lies in rule ordering, as the following derivation shows:

(3) Opacity of Hebrew Spirantization in a Serial Derivation

Underlying:

\[ /malák/\]

Spirantization:

\[ /k \rightarrow /x/._{\_}/.\, maláxé\]

Syncope:

\[ /V \rightarrow /\emptyset/ \, /VC_{\_}CV/\, maláxé\]

Spirantization is opaque because it is followed by syncope, which may obliterate the context that triggered spirantization in the first place.

Rule ordering, the serial derivation, and rewrite rules like /P are no longer common currency; they have been largely or entirely replaced by theories based on satisfaction of surface constraints (Cognitive Phonology: Lakoff 1993; Constraint-Based Phonology: Bird 1990, Scobbie 1992; Government Phonology: Kaye, Lowenstamm, & Vergnaud 1985; Harmonic Phonology: Goldsmith 1990; Montague Phonology: Bach & Wheeler 1981, Wheeler 1981, 1988; Optimality Theory: Prince & Smolensky 1993; Two-Level Phonology: Koskenniemi 1983, Karttunen 1995; and others). This change in the phonological terrain means that phonological opacity must be re-examined. Here, I hope to take some steps toward understanding opacity in terms of output constraints within Optimality Theory (Prince & Smolensky 1993)². The richness of the problem is by no means exhausted by the remarks I offer here, and I make no claim to comprehensiveness.

The rest of this paper is organized as follows. Section 2 gives a brief overview of some aspects of Optimality Theory; anyone already familiar with OT should skip it. Section 3 introduces a model of opacity in OT and a theoretical context for that model, based on the idea of correspondence of linguistic representations (McCarty & Prince 1995). The Tiberian Hebrew example, and plausible (though hypothetical) variations on it are analyzed. Section 4 then turns to some alternatives: the structural approach to opacity in OT taken by Prince & Smolensky (1993), and the Two-Level Phonology of Koskenniemi (1983) and others. The Hebrew illustration is continued in this section, and another case is introduced, from the well-known Icelandic umlaut phenomenon. Section 5 summarizes the results.

2 Theoretical Background

Optimality Theory (Prince & Smolensky 1993) asserts that the correct surface form is selected by a set of well-formedness constraints that are ranked in a hierarchy of relevance, so that a lower-ranked constraint may be violated in order to satisfy a higher-ranked one. The constraints themselves are universal, except for the fixing of particular arguments within general constraint schema; only the ranking is language-particular. The constraint hierarchy of each language is called on to evaluate a (potentially infinite) set of candidate outputs relative to some input; the candidate that best satisfies the particular hierarchy is the actual output form.

On the basis of their function, Optimality-Theoretic constraints can be divided into two classes, structural constraints and faithfulness constraints. The structural constraints express, as categorical statements, such preferences as any theory of Universal Grammar must demand: syllables have onsets; vowels are not both front and rounded; metrical feet are binary; nasals agree in place of articulation with following consonants. Through ranking, the faithfulness constraints can determine the extent of activity of these broad categorical statements. Faithfulness constraints assert that the surface form and lexical form are identical. Thus, if the relevant faithfulness constraints are top-ranked, a structural constraint will typically show no phonological activity; it will be violated in any language with this ranking. With the opposite ranking, the structural constraint is triumphant, and faithfulness of the surface form to the lexical representation must suffer.

Applying these ideas to the Hebrew example (2) will make them more concrete. Let us assume that UG includes the structural constraint No-V-STROP, which asserts that the sequence vowel-stop consonant is prohibited. UG also provides various antagonistic faithfulness constraints, among them IDENT-cont), which says that an underlying stop cannot be replaced by a surface fricative. In a language like Tiberian Hebrew, with postvocalic spirantization, the structural constraint dominates the faithfulness constraint.²

¹ Hebrew nouns like 'king' have different stems in the singular and plural. The singular stem is /CVCC/; the plural stem is /CVCC/.² See Jones 1995 for a forceful characterization of the opacity question in relation to a particular view of phonology within Optimality Theory.
(4) No-V-STOP -> IDENT(cont) in Tiberian Hebrew

<table>
<thead>
<tr>
<th>/katb/</th>
<th>No-V-STOP</th>
<th>IDENT(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. קתב</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b. קתב</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>c. קתב</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>d. קתב</td>
<td>1</td>
<td>*</td>
</tr>
</tbody>
</table>

This constraint tableau observes certain notational conventions: constraints are written in their domination order, violations are marked by "1", crucial violations are also marked by "*", and shading emphasizes the irrelevance of the constraint to the fate of the candidate. A loser's cells are shaded after a crucial violation; the winner's, when there are no more competitors. As a reminder of their special status, constraints regarded as part of an Optimality-Theoretic hierarchy are in small capitals.

The tableau shows that surface post-vocalic spirants are favored over stops, even at the expense of faithfulness to the lexical form. The tableau also shows, incidentally, that multiple loci of violation do not affect the outcome: the Optimality-Theoretic imperative to violate minimally sorts out the plethora of candidates, favoring the one in which there are no post-vocalic stops whatsoever.

With the opposite ranking of these two constraints, we obtain the case of languages without post-vocalic spirantization, such as Arabic.

(5) IDENT(cont) -> No-V-STOP in Arabic

<table>
<thead>
<tr>
<th>/katb/</th>
<th>IDENT(cont)</th>
<th>No-V-STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. קתב</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>b. קתב</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>c. קתב</td>
<td>1</td>
<td>*</td>
</tr>
<tr>
<td>d. קתב</td>
<td>1</td>
<td>*</td>
</tr>
</tbody>
</table>

With this ranking, preservation of the lexical form takes precedence over obedience to the structural constraint. In this way, it makes sense to say that structural constraints like No-V-STOP are truly universal: they are present in the grammars of all languages, but when they are low-ranking, they are violated freely. Significantly, this is not an empty claim: even when crucially dominated by faithfulness constraints, structural constraints like No-V-STOP can be active in circumstances where faithfulness is not at issue, such as in determining the form of epenthetic segments or of reduplicative copies, both of which are known to favor structurally unmarked configurations. This phenomenon, called "emergence of the unmarked", is studied in McCarthy & Prince (1994). The possibility of emergence of the unmarked separates OT from parametric theories, in which markedness constraints like No-V-STOP are either "on" or "off" — and if "off", then completely inactive.

The surface forms evaluated by an Optimality-Theoretic grammar show the effects of various phonological processes in parallel; there is no serial derivation. The Tiberian Hebrew examples (2b) and (2c) involve epenthesis or syncope in addition to spirantization. In accordance with parallelism, the consequences of all these processes are realized simultaneously rather than serially in the candidate surface forms under evaluation. For example, consider the derivation of melāx from /ma/ (disregarding the vowel-quality alternation in the first syllable). The constraint responsible for epenthesis is a structural one. *COMPLEX, which prohibits tautosyllabic clusters. It crucially dominates the faithfulness constraint DEP (stated below), which prohibits phonological epenthesis. The requirements of top-ranked *COMPLEX and No-V-STOP are satisfied together, in parallel, in the observed surface form melāx. (The dotted lines indicate constraints that are not ranked, usually because they do not conflict.)

(6) *COMPLEX, No-V-STOP -> DEP, IDENT(cont)

<table>
<thead>
<tr>
<th>/ma/</th>
<th>COMPLEX</th>
<th>No-V-STOP</th>
<th>DEP</th>
<th>IDENT(cont)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. מלך</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>b. מלק</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c. 말ק</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>d. מלק</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

The optimal form (6a) uniquely satisfies both of the high-ranking constraints. In rule-based theories, a serial derivation like (3) is called on to deal with this interaction of epenthesis and spirantization. In OT (and in the other constraint-based approaches cited in section 1) there is no serial derivation; rather, the surface form is determined by evaluating the effects of all phonological alternations simultaneously.

3 Phonological Opacity Within Optimality Theory

This brings us to the topic of these remarks. Rule-based theories account for opacity in terms of ordering in a serial derivation, such as (3). Under parallelism, though, there is no rule ordering and no serial derivation: the effects of all processes are felt simultaneously, through best-satisfaction of a language-particular constraint hierarchy. Therefore, opaque interactions must be understood in different terms: indeed, Chomsky (1994) has cited Hebrew spirantization facts like maled (2c) as evidence of prima facie failure of OT*. In actual fact, there is no mystery about how OT addresses phonological opacity, as the discussion of Prince & Smolensky's "Containment" model in section 4 makes clear. Nonetheless, there are interesting questions of detail: precisely low are the specifics of phonological opacity to be understood in terms of constraint satisfaction? This section contains one answer to that question; section 4 evaluates alternatives.

The account of opacity I will offer rests on two developments. The first is a theory of faithfulness constraints, which has been motivated on grounds that are quite distinct from the problem of opacity. The other is a theory of markedness constraints which incorporates a novel element motivated by the need to analyze opaque phonological interactions. Taken together, these two developments allow us to ana-
lyze opaque interactions in a fully parallel way, thereby remaining consistent with this premise of Optimality Theory.

I begin with the theory of faithfulness. Faithfulness is regulated by constraints that are sensitive to a relation of correspondence between two structures, the lexical form and the surface form:

(7) Correspondence
Given two strings S_1 and S_2, correspondence is a relation R from the elements of S_1 to those of S_2.
Segments α ∈ S_1 and β ∈ S_2 are referred to as correspondents of one another when αRβ.

This definition, and indeed the Correspondence Theory of faithfulness in which it is embedded, are from McCarthy & Prince (1995), which may be consulted for additional formal details. The text below briefly summarizes some of the relevant points from this work.

In this model, candidate surface forms are subject to evaluation together with the corresponding lexical form and some particular R that relates them. Faithfulness constraints assess each candidate pair with its R, considering such aspects of faithfulness as the completeness of correspondence in S_1 or S_2, the featural identity of correspondent elements in S_1 and S_2, and so on. In general, it will often be enough to leave the details of each particular R implicit, or to make them explicit by co-indexation of segments in the input and output, as in the following hypothetical illustrations:

(8) Hypothetical Illustrations. From Input = /p_1 a_2 u_3 k_4 t_5 a_6/
\[ p_1 a_2 u_3 k_4 t_5 a_6 \]
A fully faithful analysis = perfect correspondence.
\[ p_1 a_2 u_3 k_4 t_5 a_6 \]

Thus prohibited (by high-ranking ONSET), so epenthesis of \( \gamma \), which has no correspondent in the input.
\[ p_1 u_3 k_4 t_5 a_6 \]

Thus prohibited, leading to V-deletion. The segment \( \alpha \) in the input has no correspondent in the output.
\[ p_1 a_2 u_3 t_4 a_6 \]

The \( \kappa \) in the input has a non-identical correspondent in the output, for phonological reasons.
\[ b l u r k \]
No element of the output stands in correspondence with any element of the input. Typically fatal.

The variety of forms shown emphasizes some of the richness of the candidate set. It falls to the language-particular constraint hierarchy to determine what is optimal and what is not.

The comments on the hypothetical illustrations hint at some of the faithfulness constraints that can be formulated under Correspondence Theory. They are formalized as follows:

(9) Max
Every segment of S_1 has a correspondent in S_2.
(I.e., there is no phonological deletion.)

(10) Dep
Every segment of S_2 has a correspondent in S_1.
(I.e., there is no phonological epenthesis.)

(11) IDENT(CF)
Let \( \alpha \) be a segment in S_1 and \( \beta \) be a correspondent of \( \alpha \) in S_2. If \( \alpha \) is \( \gamma \), then \( \beta \) is \( \gamma \).
(I.e., underlying \( \gamma \) cannot change to \( \gamma \), assuming full specification.)

Dep and IDENT are, of course, the same constraints seen in (6), which illustrates their use.

Correspondence is the theory of faithfulness that will be called on in the analysis of opacity. The other main idea, with links to Correspondence Theory, is a particular conception of how markedness constraints are formulated—that is, a partial theory of the non-faithfulness portion of Con, the UC component of constraints whose rankings make up particular grammars.

One fundamental idea of OT, shared with some other approaches, is that markedness constraints specify only targets, and not the repairs that lead to satisfaction of those targets (Prince & Smolensky 1993). This is an important and compelling insight because, both across languages and within a language, we find homogeneity of the target and heterogeneity of the repair (i.e., conspiracies, in the sense of Kisseberth 1970). For example, a target like ONSET ("vowel-initial syllables are prohibited") is satisfied in different languages by consonant epenthesis (\( /p a+V \rightarrow pa\gamma \)), vowel deletion (\( /p a+V \rightarrow pa \) or \( /p a \)), or deracemization (\( /p a+V \rightarrow pa \)). Even within a single language, this heterogeneity of repair can be found: in Atinica Campa (McCarthy & Prince 1993), the prohibition on vowel-initial syllables is satisfied by epenthesis under suffixation (/igkoma+V \( \rightarrow \) igkomati) and by incomplete copying in reduplicative morphology (/osampi+REDV \( \rightarrow \) osampi-sampi).

The target-defining constraints in OT have been formalized in various ways. To make headway on the problem of opacity, it will be necessary to make some decisions about exactly how constraints are to be formalized, and some oversimplification is necessary. I will assume that every constraint is a prohibition or negative target defined over no more than two segments, \( \alpha \) and \( \beta \). That is, the canonical constraint is something like \( \gamma (\alpha, \beta) \), with appropriate conditions imposed on \( \alpha \) and \( \beta \). These conditions are as follows:

(i) a specification of the featural properties of \( \alpha \) and \( \beta \) as individual segments.

(ii) a specification of the linear order relation between \( \alpha \) and \( \beta \) (\( \alpha < \beta \) or \( \beta < \alpha \), or both in the case of mirror-image rules (on which see Bach 1968; Anderson 1974)).

For the distinction between IDENT(CF) and IDENT(\( \gamma \)), see Pater (1995).
(iii) a specification of the adjacency relation between $\alpha$ and $\beta$ (e.g., strict adjacency, vowel-to-vowel adjacency, etc. (see Myers 1987; Selkirk 1988; Archangeli & Pulleyblank 1987, 1994.))

This decomposition of the conditions on $\alpha$ and $\beta$ is inspired by the ideas about formalization in Archangeli & Pulleyblank 1994. Chapt. 4, though it should be noted that the conditions they discuss are somewhat different, having been designed for phonological operations rather than targets. The proposal made here will ultimately need to be elaborated in light of their results and the empirical material they discuss.

This decomposition of the conditions imposed by a phonological constraint will be crucial in accounting for the range of opacity phenomena. Even more importantly, though, is this: each condition -- the featural composition of $\alpha$, the featural composition of $\beta$, linear order, and adjacency -- must also name the level (underlying, surface, or either) at which it obtains. Correspondence Theory allows us to make sense of conditions obtaining at one level or the other. As a bookkeeping device, I will state constraints in the form of a table (also inspired by Archangeli & Pulleyblank 1994):

(12) Canonical Constraint Schema

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td></td>
</tr>
<tr>
<td>Linear Order</td>
<td></td>
</tr>
<tr>
<td>Adjacency</td>
<td></td>
</tr>
</tbody>
</table>

The large "*" is a reminder that, in this schema, constraints specify negative targets or prohibited configurations. Thus, any structure matching the conditions and levels specified is in violation of this constraint. The conditions on $\alpha$ and $\beta$ are featural; the conditions of linear order are $\alpha$ first, $\beta$ first, or indifferent (for mirror-image configurations); the conditions of adjacency include strict linear adjacency and the various types of non-strict adjacency afforded by phonological theory. The permissible level specifications include surface, underlying", and indifferent.

This final aspect of the proposal echoes some of the ideas of Two-Level Phonology (Koskenniemi 1983), which I discuss below in section 4. It also recalls some of the work on global rules, especially Kisselberth (1973). In global-rule terms, opacity ensues when, by virtue of a stipulation in the form of the rule itself, it "applies to structures of a specified sort provided they do not arise through the operation of particular rules" or it "applies in a given environment if that environment occurs either in the input or is present in an 'ancestral' structure but has been distorted by particular rules" (Kisselberth 1973: 436). The latter type of global interaction subsumes the non-surface-level specifications of the proposal above; differences come from

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6 As Sharon Inkelas has pointed out to me, this proposal presupposes that there is an underlying representation. It is therefore incompatible with the handful of works arguing that underlying representations should be replaced by constraints (Colston 1995; Hammond 1995; Rysell 1999). Presumably, therefore, as Diana Archangeli has pointed out to me, it presupposes that underlying representations have linear order, even between morphemes.

7 The use of constraints rather than rules, the limitation to two levels (underlying and surface), and the details of how constraints are formalized in the schema (7).

8 Through Correspondence Theory, this constraint schema imposes a set of conditions on the surface segments $\alpha_s$ and $\beta_s$ and/or the underlying segments $\alpha_u$ and $\beta_u$. Surface $\alpha_s$, if any, stands in correspondence with underlying $\alpha_u$, if any, and likewise for $\beta_s$ and $\beta_u$. In this way, conditions may be met specifically at the underlying level or at a combination of the underlying and surface levels. Suppose, for instance, that the condition $\alpha \sim V$ is specified for the underlying level, $\beta \sim C$ is specified for the surface level, and $\alpha > \beta$ ("$\alpha$ precedes $\beta$") is specified for the underlying level. Then, for the constraint to be applicable, a surface $C$ identified as $\beta_s$ must have an underlying correspondent $\beta_u$ which is preceded by a vowel (identified as $\alpha_u$). Conditions which are not mentioned are irrelevant, as usual; thus, it does not matter whether $\beta_u$ is a consonant, nor does it matter whether $\alpha_u$ has a surface correspondent $\alpha_s$, or even whether $\alpha_s > \beta_s$. In this way, the (negative) targets defined by phonological constraints are more complex than simple output-string configurations: they include aspects of the input as well, through the input/output correspondence relation.

Accepting Kiparsky's (1971, 1973) dictum that phonological opacity is marked, I stipulate that the default form of a phonological constraint -- the form in which it is represented in UG has all of its level specifications set to "surface". A constraint of this type is a true output target of the type usually contemplated in naive theorizing about constraints. It is not opaque, since the conditions of obedience or violation can be read off of surface structure in a completely transparent way. For example, the constraint responsible for Tiberian Hebrew spirantization, without opacity (that is, with malke rather than malkē for (2c)), is represented in UG as (13). (Spirantization of voiced stops in Spanish is a real example of this type, since all and only surface vowels trigger the process.)

(13) No-V-Stop, Default Version (no opacity)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>V</td>
</tr>
<tr>
<td>$\beta$</td>
<td></td>
</tr>
<tr>
<td>Linear Order</td>
<td></td>
</tr>
<tr>
<td>Adjacency</td>
<td></td>
</tr>
</tbody>
</table>

The column labeled "Condition" characterizes the prohibited configuration: the segment $\alpha$, which is a vowel, is immediately followed by the segment $\beta$, which is a stop. Since these conditions must be met at the surface, the form malkē obeys this constraint, whereas the underlying vowel of malke has no bearing on the result. In this hypothetical language, then, malkē is optimal, since it and the competing candidate
makê equally obey (13), the decision falls to the faithfulness constraint IDENT(-cont), which selects the more faithful makê.

In real Tiberian Hebrew, though, the constraint NO-V-STOP is different from the default (13). Rather, as in (14), it characterizes a situation of opacity, in which some of the operative conditions can be met at the underlying level as well as at the surface:

(14) NO-V-STOP, Tiberian Hebrew Version (with opacity as in (2c))

<table>
<thead>
<tr>
<th></th>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>V</td>
<td>Indifferent</td>
</tr>
<tr>
<td>β</td>
<td></td>
<td>son, -cont</td>
</tr>
<tr>
<td>Linear Order</td>
<td>α ≻ β</td>
<td>Indifferent</td>
</tr>
<tr>
<td>Adjacency</td>
<td>Strict</td>
<td>Indifferent</td>
</tr>
</tbody>
</table>

In correspondence terms, the meaning of this constraint is as follows: the constraint is violated if a surface stop β or its underlying correspondent is immediately preceded by a vowel. That is to say, the prohibited configuration is one in which a stop is immediately preceded by a vowel in the candidate surface form (i.e., just as in (13)) or in which the segment that underlies the stop is immediately preceded by a vowel. Thus, even if surface βs is not preceded by a vowel, but its underlying correspondent βs is preceded by a vowel, then the constraint is violated. This is a type of opacity.

The following diagram shows in a schematic way how this constraint can be interpreted. Several faithful pairings of underlying forms and their surface candidates are given; each involves a post-vocalic stop which ought to be a fricative, so (14) is violated. In the pairings, segments standing in correspondence with one another are linked by vertical lines.9

(15) Constraint (14) Applied

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underlying</td>
<td>malakîm</td>
<td>ma,k</td>
</tr>
<tr>
<td>Surface Candidate</td>
<td>malakîm</td>
<td>melek</td>
</tr>
<tr>
<td>Conditions Observed</td>
<td>in these Candidate S/U</td>
<td></td>
</tr>
<tr>
<td>Constraints Applicable</td>
<td>Pairings</td>
<td></td>
</tr>
<tr>
<td>α ≻ V at S or U</td>
<td>α ≻ V at S</td>
<td>α ≻ V at U</td>
</tr>
<tr>
<td>β ≻ stop at S</td>
<td>β ≻ stop at S and U</td>
<td>β ≻ stop at S and U</td>
</tr>
<tr>
<td>α ≻ β at S or U</td>
<td>α ≻ β at S and U</td>
<td>α ≻ β at S and U</td>
</tr>
<tr>
<td>α ≻ β at S or U</td>
<td>α ≻ β at S</td>
<td>α ≻ β at U</td>
</tr>
<tr>
<td>Conclusion</td>
<td>(14) is applicable</td>
<td>(14) is applicable</td>
</tr>
<tr>
<td>and violated</td>
<td>and violated</td>
<td>and violated</td>
</tr>
</tbody>
</table>

It is crucial that the constraint be applicable to these faithful candidates and that they violate it, to compel spirantization. The individual examples can be understood as follows:

- In case (15a), the surface k and its underlying correspondent are both immediately preceded by a vowel; hence the conditions are met and the constraint is violated by *malakîm, as desired. Since that candidate is ruled out by top-ranked NO-V-STOP (14), the less faithful malakîm, which violates only low-ranking IDENT(-cont), is chosen instead.

- In case (15b), the triggering vowel is epenthetic. Hence, the condition can only be met at the surface: the surface k is immediately preceded by a vowel, tout court. This and (15a) together constitute what I have designated as the default case, in which a surface vowel and only a surface vowel is sufficient to induce spirantization.

- The case of greatest interest is (15c), since it is a situation of opacity. Here, the surface stop k is not immediately preceded by a vowel, but its underlying correspondent is. The conditions are met, so *makê violates the constraint. Opacity arises here because a condition is satisfied in part by the underlying correspondent of a surface segment rather than by the surface segment itself.

Another type of opacity is logically possible. In Bedouin Arabic dialects such as the one described in Al-Mozaimi 1981, velar palatalization is triggered by exactly the underlying front vowels, underlying i regardless of whether it is deleted, triggers the process, but epenthetic i does not. As a hypothetical variation on the Hebrew spirantization pattern, this would yield a language with malakîm and makê, but melek. The melek type of opacity conforms to rule (1a) of Kiparsky's definition, combined with the (1b) type of opacity seen in malakê. Facts like these will follow, ceteris paribus, if the level specifications for NO-V-STOP are set as follows:

(16) NO-V-STOP for a Language with malakîm, melek, and makê

<table>
<thead>
<tr>
<th></th>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>V</td>
<td>Underlying</td>
</tr>
<tr>
<td>β</td>
<td></td>
<td>son, -cont</td>
</tr>
<tr>
<td>Linear Order</td>
<td>α ≻ β</td>
<td>Underlying</td>
</tr>
<tr>
<td>Adjacency</td>
<td>Strict</td>
<td>Underlying</td>
</tr>
</tbody>
</table>

In correspondence terms, for this constraint to be violated, a surface stop must have an underlying correspondent that is preceded by a vowel. Even if the vowel itself is deleted, the constraint is violated. Yet if the vowel is epenthetic, the constraint is obeyed, since the stop's underlying correspondent is not postvocalic. These circumstances can be schematized as follows:
A final hypothetical variation on Tiberian Hebrew illustrates this possibility. Suppose spirantization is observed only after a vowel that is present at both the underlying and surface levels, yielding spirantized *malakim* versus unspirantized *melek* and *malkë*. (In rule-based theories, this result can be obtained from the ordering Sympcope > Spirantization > Epenthesis.) The constraint driving the alternation is one that prohibits a surface stop whose underlying correspondent is preceded by a vowel and whose surface correspondent is adjacent to a vowel — a conjunction of conditions that only a non-epenthetic, undeleted vowel can match.\(^{11}\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)</td>
<td>V</td>
</tr>
<tr>
<td>(\beta)</td>
<td>[son, cont]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Linear Order</th>
<th>(\alpha &gt; \beta)</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjacency</td>
<td>Strict</td>
<td>Surface</td>
</tr>
</tbody>
</table>

The role of the separate conditions on adjacency and featural composition can be seen in the following schematization:  

\[\begin{align*}
\text{Underlying} & \quad \begin{array}{ccc}
\text{a} & \text{b} & \text{c} \\
\text{malakim} & \text{mal k} & \text{malakë} \\
\end{array} \\
\text{Faithful Cand.} & \quad \begin{array}{ccc}
\text{Conditions Observed in These Candidate S/U} \\
\text{malakim} & \text{mlek} & \text{mal kë} \\
\end{array} \\
\text{Required Conditions for Constraint Applicability} & \quad \text{Pairings} \\
\alpha = V \text{ at } U & \alpha = V \text{ at } S \text{ and } U & \alpha = V \text{ at } S ! \text{ and } U & \alpha = V \text{ at } U \\
\beta = \text{stop at } S & \beta = \text{stop at } S \text{ and } U & \beta = \text{stop at } S \text{ and } U & \beta = \text{stop at } S \text{ and } U \\
\alpha > \beta \text{ at } U & \alpha > \beta \text{ at } S \text{ and } U & \alpha > \beta \text{ at } S ! \text{ and } U & \alpha > \beta \text{ at } U ! \\
\alpha \sim \beta \text{ at } U & \alpha \sim \beta \text{ at } S \text{ and } U & \alpha \sim \beta \text{ at } S ! \text{ and } U & \alpha \sim \beta \text{ at } U ! \\
\text{Conclusion} & \text{Pairings} &\text{Pairings} &\text{Pairings} \\
(\beta) \text{ is applicable} & (\beta) \text{ is inapplicable} & (\beta) \text{ is inapplicable} & (\beta) \text{ is inapplicable} \\
\text{and violated} & \text{and violated} & \text{and violated} & \text{and violated} \\
\text{so obeyed} & \text{so obeyed} & \text{so obeyed} & \text{so obeyed} \\
\end{align*}\]

Since the constraint (18) is obeyed by both (19b) and (19c), the faithful, unspirantized output is optimal. Only a vowel present at both underlying and surface representation, as in (19a), will suffice to trigger the alternation, because only such a vowel can precede the stop at the underlying level and be adjacent to it at the surface.

This variety of examples, real and hypothetical, shows that the constraint schema (12) is equipped to handle a range of opacity phenomena. The core notions are these:

- A markedness constraint describes a target. For simplicity, I have assumed that all targets are expressed as prohibitions.

\(^{11}\) In addition to this opacity-yielding condition and the one in (17c), it's worth noting a further prediction. If the stop is epenthetic, then the constraint is also obeyed, since an epenthetic stop has no underlying correspondent and therefore its underlying correspondent is adjacent to a vowel — a conjunction of conditions that only a non-epenthetic, undeleted vowel can match.

\(^{12}\) Equivalently, the linear-order condition can be set to the surface level and the adjacency condition to the underlying level. These alternatives can be teased apart empirically only in languages where the linear order and adjacency relations vary independently — e.g., in metathesis.
Markedness constraints impose separate conditions on the featural composition of segments, their linear order relation, and their adjacency relation.

In its default form, every markedness constraint imposes conditions on surface structure only. But through correspondence, specified conditions can be imposed on underlying structure or on either underlying or surface structure.

Opacity will arise whenever non-surface conditions obtain in constraint satisfaction and violation.

### Comparison with Other Theories of Opacity

Having presented one approach to the analysis of opacity within Optimality Theory, I will now proceed to look at two alternatives. The first, due to Prince & Smolensky (1993), is by-and-large standard in OT work today. The second is Two-Level Phonology (Koskenniemi 1983) and extensions. I will show that both approaches encounter problems in dealing with the full range of observed opacity phenomena.

Prince & Smolensky (1993) proceed as I have done, by relating opacity to faithfulness. The details of their approach, though, are different: they conceive of faithfulness, and hence of opacity, in structural or representational terms, rather than via correspondence. The main idea is this: the phonetically obvious surface structure is enriched by the inclusion of information about the character of the underlying form. This model, which is dubbed "Containment" in McCarthy & Prince 1993, will be referred to here as the structural approach, contrasting it with the correspondence approach introduced in section 3.

In the structural approach, segments that are (to-be) deleted are present in the output, but not parsed syllabically, making use of the notion of Stray Erasure in Steriade 1982. The constraint PARSE (rather than MAX) militates against these unparsed segments. In a parallel way, epenthesis is understood as the result of providing prosodic structure with no segment to fill it, the phonetic identity of the epenthetic segment being determined by extra-systemic rules of phonetic interpretation, exactly as in Selkirk 1981, Lowenstamm & Kaye 1985, and Ko 1986. The constraint FILL (rather than DEF) militates against these unfilled prosodic nodes. An alternative is that epenthetic segments are identified by their lack of morphological affiliation with the constraint: MSEG (McCarthy 1993, McCarthy & Prince 1994). In both deletion and epenthesis, the characterization of faithfulness is given an interpretation in terms of prosodic or morphological structure.

The predicates "parsed" and "morphologically affiliated", when applied to constraints other than the faithfulness variety, yield a range of transparent and opaque interactions comparable to what we saw in section 3. Consider the Tiberian Hebrew spirantization phenomenon and its hypothetical variants. In the structural approach, the constraint prohibits a vowel-stop sequence outright, with differences in opacity determined by conditions imposed on the triggering vowel. The following table shows the range of possibilities: in keeping with the tenets of the structural approach, unparsed (= deleted) and morphologically unaffiliated (= epenthetic) segments are designated formally by angled brackets and outlining, respectively. The equivalents in the correspondence approach are noted in the column headed "Comments".

<table>
<thead>
<tr>
<th>Condition on V</th>
<th>Observed Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Parsed</td>
<td>mala\textsuperscript{x}</td>
<td>Alternation triggered by epenthetic but not deleted vowel (equivalent to (13)). Fully transparent.</td>
</tr>
<tr>
<td>b. None</td>
<td>mala\textsuperscript{x}</td>
<td>Alternation triggered by epenthetic or deleted vowel (equivalent to (14)). This is real Hebrew, with opacity in mala\textsuperscript{x}e.</td>
</tr>
<tr>
<td>c. Morphologically Affiliated</td>
<td>mala\textsuperscript{x}</td>
<td>Alternation not triggered by epenthetic vowel (equivalent to (16)). Opaque in mala\textsuperscript{x}e and mala\textsuperscript{k}.</td>
</tr>
<tr>
<td>d. Parsed and Morphologically Affiliated</td>
<td>mala\textsuperscript{k}</td>
<td>Alternation triggered by neither epenthetic nor deleted vowel (equivalent to (18)). Hence opacity in mala\textsuperscript{k}.</td>
</tr>
</tbody>
</table>

The equivalent of the default, non-opaque, surface-only constraint (13) is the one where V must be parsed (20a). The condition (20b), where no limitations are placed on V, yields the situation in actual Tiberian Hebrew, with opacity.

It's clear from this analysis that the structural approach to faithfulness and opacity approaches yield much the same array of opaque and transparent phonological relations. Both can contend with opacity and transparency by imposing special restrictions on general constraint schemata. Presumably, both theories must regard those conditions as learned rather than innate aspects of the grammar. There are differences, however. One has to do with the conception of faithfulness and its relation to other kinds of linguistic identity relations; it is explored in McCarthy & Prince 1995. Another difference has to do with opacity and the analysis of opaque alternations.

The structural approach permits a type of opacity that is impossible in the correspondence approach. Specifically, as Paul Smolensky has noted, it makes sense in the structural approach to both epenthize a segment and delete it. An epenthetic segment is nothing more than a morphologically unaffiliated one added to the underlying string, a deleted segment is nothing more than a syllabically unparsed one; the conjunction of these two properties, represented as (M), makes perfect sense within the structural approach. Yet it is an impossibility under the correspondence approach. Under correspondence, deleted segments are those which have underlying but not surface correspondents, and epenthetic segments are just the opposite. A deleted epenthetic segment is an inherent contradiction.

---

I am indebted to Alan Prince for discussion of this material. As Ortal Orgun has emphasized to me, diacritical as well as structural approaches to faithfulness predict the existence of deleted epenthetic elements, since nothing prevents a segment from bearing both faithfulness diacritics simultaneously.
In the structural approach, deletion of an epenthetic segment will involve violation of both PARSE and FILL/MSEG, which mitigate against deletion and epenthesis, respectively. Since the result is phonetically no different from the input, such a form might seem pointless and therefore unproblematic, since this greater descriptive freedom of the structural approach would never be judged as optimal under any ranking of the constraints supplied by UF. But in fact there are constraints that directly require deletion and other constraints that indirectly prohibit it. Through interaction of these constraints, situations can be created which would be expected to favor deletion of an epenthetic segment, yet no such phenomenon is observed.

A real-life example comes from Prince & Smolensky’s (1993: Chpt. 7) analysis of the Australian language Lardil. They argue that apocope in Lardil is a consequence of satisfying the constraint FREE-V, which directly requires deletion:

(21) **FREE-V** in Lardil (Prince & Smolensky 1993: 101)

Word-final vowels must not be parsed (in the nominative).

Through domination of PARSE, **FREE-V** is visibly active in Lardil, compelling apocope.

Another high-ranking constraint of Lardil is antagonistic to **FREE-V**. This constraint is called **ALIGN**.

(22) **ALIGN**

The final edge of the stem corresponds to the final edge of a syllable.

**ALIGN** is obeyed by any form whose stem-final segment is also syllable-final. Since PARSE demands parsing of stem-final segments (so they are syllable-final), and since **FREE-V** demands no parsing of stem-final segments, the two constraints are in conflict. The ranking favors **FREE-V**.

(23) **FREE-V** > **ALIGN**, from /ŋiŋi/-i to /ŋiŋi/-i 'oyster species' (cf. /ŋiŋi/-i 'id. (fut., acc.)')

<table>
<thead>
<tr>
<th>Candidates</th>
<th>FREE-V</th>
<th>ALIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>σ σ σ / / /\</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. yi li yil i</td>
<td></td>
<td></td>
</tr>
<tr>
<td>σ σ σ / / /</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. yi li yil i</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In (a), the stem-final segment is unparsed, so it is not also syllable-final, violating **ALIGN** but satisfying **FREE-V**. Form (b) shows the opposite outcome, fatally violating the higher-ranked constraint.

It is possible in principle, however, to satisfy both **FREE-V** and **ALIGN**, by simultaneous deletion and epenthesis (cf. Prince & Smolensky 1993: 111-112). Compare the actual output (a) with the form in (b):

High-ranking **ALIGN** is required to account for cases of augmentation in Lardil, such as /mwy/ → mwy, a *mara.

The normal epenthetic vowel in Lardil is a, so there is nothing unusual about form (b). It satisfies **FREE-V** because the word-final vowel is unparsed. It also satisfies **ALIGN**, because the stem-final vowel is also syllable-final. (The epenthetic vowel has no morphological affiliation; hence, it is not in the morphological constituent stem.) Therefore, (b) ought to be optimal, but is not.

The only mechanism available to exclude form (b) is constraint ranking: if the antiepenthetic constraint FILL/MSEG dominates **ALIGN**, then (b) will not be optimal. But this seems a less-than-ideal solution — the situation in (24) ought to be ruled out universally rather than parochially, as Prince & Smolensky (1993: 112f.) observe in a comparable case. It should not be necessary to stipulate, through language-particular ranking, that apocope cannot be rendered vacuous by combining it with epenthesis. In this respect, the greater descriptive freedom of the structural approach seems to be a liability and the correspondence approach seems preferable.

There are other circumstances, however, where the correspondence approach to opacity, as laid out in section 3, opens up wider descriptive possibilities than the structural approach, to the advantage of correspondence. This happens when there is radical de-coupling of the level specifications on the featural, linear order, and adjacency conditions in the standard constraint schema (12). I will illustrate this point by examining one case in some detail, the well-known Icelandic uumlaut phenomenon (Anderson 1974; Kiparsky 1985). My analysis depends entirely on Anderson’s characterization of the facts and descriptive generalizations.

In Icelandic, the vowel a is realized as o when followed by orthographic u (phonetic [ø]) in the next syllable (25a). The triggering u may be present underlyingly, though deleted at the surface (25b). The triggering u and affected a can even be separated by another vowel underlyingly, so long as the intervening vowel is deleted at the surface (25c). Yet epenthetic u does not trigger uumlaut (25d). Finally, there is a complex interaction between uumlaut and a process reducing o to u in unstressed syllables. (In Icelandic, stress falls on the initial syllable.) The product of uumlaut in an unstressed syllable is u rather than o (25e). Strikingly, the u derived in this way can itself serve as a trigger for uumlaut (25f), leading to "iteration" of uumlaut.

(25) **Icelandic Data (Represented Orthographically)**

<table>
<thead>
<tr>
<th>Candidates</th>
<th>FREE-V</th>
<th>ALIGN</th>
</tr>
</thead>
</table>
| a. Simple Cases (Anderson 1974: 14)
| /barnum/ | børnum | 'child' (dat.)' cf. barn 'child' |
Remarks on Phonological Opacity in Optimality Theory

(bracketed) form:

(26) Icelandic Short Vowels (Anderson 1972: 19)

a. In Stressed Syllables

\[ \begin{array}{c|c|c|c}
\text{i} & \text{y} & \text{u} & \text{u} \\
\text{e} & \text{e} & \text{o} & \text{o} \\
\end{array} \]

b. In Unstressed Syllables (Anderson 1972: 20)

\[ \begin{array}{c|c|c|c}
\text{i} & \text{y} & \text{u} & \text{u} \\
\end{array} \]

The system is sharply skewed toward the front. In unstressed syllables, there is significant reduction of contrasts, with no mid vowels and only an unrounded low vowel. The uumlaut phenomenon, then, involves raising, fronting, and rounding of a before a high, front, rounded vowel. In stressed syllables, where mid vowels are permitted, the result of uumlaut is mid ɔ, in unstressed syllables, which bar mid vowels, the result is high ʊ, just like the triggering vowel.

In Optimality Theory, the geometry of a particular vowel system is determined in the usual O'T way: by the interaction of markedness constraints and faithfulness constraints (Prince & Smolensky 1993: Chapt. 9). Some of the main features of the Icelandic vowel system are determined by the following rankings:

(27) Constraint Rankings for Icelandic Vowel System

a. \[ *\text{back}. \text{low} \rightarrow \text{IDENT} \text{(-back)} \]

Non-low back vowels are prohibited (cf. Anderson 1972: 24).

b. \[ *(\text{stress}, \text{-high}, \text{low}) \rightarrow \text{IDENT} \text{(-high)} \]

Unstressed mid vowels are prohibited (cf. Anderson 1972: 11).

Assume for the moment the existence of a constraint UMLAUT which bars the sequence [aC, U]. (This constraint is studied in detail below.) To trigger alternations, it must dominate a set of faithfulness constraints, since UMLAUT-triggered alternations affect all of the features in which [a] differs from [o] and [u] and [A].

(28) Constraint Ranking for Uumlaut Phenomenon

\[ \text{UMLAUT} \rightarrow \text{IDENT} \text{(-low)}, \text{IDENT} \text{-round}, \text{IDENT} \text{(-back)}, \text{IDENT} \text{(-high)} \]

What we have, then, are three top-ranked markedness constraints (UMLAUT included) which dominate a set of faithfulness constraints on vowel features, as in (27, 28). These rankings are sufficient to fully determine the surface form. The most complex case, "iterative" uumlaut, shows the result clearly:

This is obviously a complex pattern of opacity (25b, d) and transparency (25a, e, f). In rule-based theories, it requires significant departure from linear ordering, in the direction of Local Ordering (Anderson 1974) or the phonological cycle (Kiparsky 1985). In Optimality Theory enhanced by the constraint schema (12), though, a fully parallel analysis of Icelandic is possible, as I will now show.

As a preliminary, we need to gain some control over the phonology of Icelandic vowels. The system of short vowels is given below in both orthographic and phonetic form:

This is obviously a complex pattern of opacity (25b, d) and transparency (25a, e, f). In rule-based theories, it requires significant departure from linear ordering, in the direction of Local Ordering (Anderson 1974) or the phonological cycle (Kiparsky 1985). In Optimality Theory enhanced by the constraint schema (12), though, a fully parallel analysis of Icelandic is possible, as I will now show.

As a preliminary, we need to gain some control over the phonology of Icelandic vowels. The system of short vowels is given below in both orthographic and phonetic form:
The actual output form [bokürüm] (orthographic bokturum) violates all of the low-ranked faithfulness constraints, sometimes more than once. Nonetheless, it is optimal, since the alternatives are worse. Forms (29b, c) are in fatal violation of UMLAUT, since they exhibit the prohibited configuration of [i] followed by [i]. Form (29d) violates the restriction against mid vowels in unstressed syllables, again with fatal results. Form (29e) contravenes another unviolated structural constraint of Icelandic, which prohibits non-low back vowels. Finally, form (29f) shows the result of /a/ → [i] in a stressed syllable: an unmotivated violation of the faithfulness constraint IDENT(high).

This sets the scene in which the uumlaut constraint is active. We turn now to the actual statement of the constraint, focusing on the opacity problem. Within the correspondence-based view developed in section 3, UMLAUT is formulated as follows.\[30\]

### UMLAUT

<table>
<thead>
<tr>
<th>Condition</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>α</td>
</tr>
<tr>
<td>β</td>
<td>α</td>
</tr>
<tr>
<td>Linear Order</td>
<td>α &gt; β</td>
</tr>
<tr>
<td>Adjacency</td>
<td>V-to-V</td>
</tr>
</tbody>
</table>

The configuration prohibited by this constraint is essentially [aG0] that is, an [a-] sequence under V-to-V adjacency, as is typical of harmony and uumlaut processes. The interest of the constraint and the complexity of the results it yields come from the level specifications:

- The constraint looks for surface αωa, hence, it is satisfied by surface sequences where the first vowel is not a, in particular [aC0] (in [börnüm]) or [aC1] (like [dömürüm]).

---

\[30\] The formulation of this constraint raises an issue which is important but orthogonal to the main topic of these remarks. Icelandic uumlaut is really the effect of an assimilatory constraint demanding a positive target, rather than the negative target I assume in (30). Indeed, the unstated assumption of the operative constraint is necessary to explain why a phonetic /u/ is not the result. Ultimately, then, it is necessary to extend the proposals made here to positive targets in general and to assimilation in particular.
The interaction of umlaut and epenthesis leads to a different kind of opacity, in which epenthetic á does not suffice to trigger the alternation. As formulated in (30), the UMLAUT constraint is violated only when trigger follows target in underlying representation. When the trigger is itself epenthetic, this condition is not met, but the constraint is inapplicable, and the faithful output emerges instead. The following schematization illustrates this result.

(32) Application of (30), Epenthesis Case

<table>
<thead>
<tr>
<th>Underlying</th>
<th>faithful cand.</th>
<th>Conditions observed in this candidate S/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>α at S</td>
<td>α at S and U</td>
<td>α &gt; β at S</td>
</tr>
<tr>
<td>β &gt; β at S</td>
<td>α at S</td>
<td>(30) is inapplicable</td>
</tr>
<tr>
<td>α &gt; β at U</td>
<td>β &gt; β at S</td>
<td>so obeyed</td>
</tr>
</tbody>
</table>

This candidate S/U pairing obeys UMLAUT because the conditions for applicability of this constraint are not met. Specifically, the α argument does not precede the β argument at underlying structure. Hence, the constraint is irrelevant (it is vacuously obeyed), and faithful [á] rather than unfaithful [ó] is optimal.

The final and most complex cases involve the interaction of the α-umlaut alternation with reduction of mid vowels to high in unstressed syllables:

(33) Application of (30), Unstressed Syllable and “Iterative” Cases

<table>
<thead>
<tr>
<th>Underlying</th>
<th>faithful cand.</th>
<th>Conditions observed in these candidate S/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>dōmarum</td>
<td>dōmarum</td>
<td>dōmarum</td>
</tr>
<tr>
<td>bakartum</td>
<td>bakartum</td>
<td>bakartum</td>
</tr>
</tbody>
</table>

In example (33a), UMLAUT is violated in the familiar way, and an unfaithful candidate is chosen instead: [dōm̩̊m̩̊r̩̊m̩̊]. In this case, the affected syllable is unstressed, the vowel [á] rather than [ó] is chosen, for the reasons given in (29). In (33b), stressed, the vowel [i] rather than [ó] is chosen, because the condition on the featural make-up of α can be met at the surface level, a [i] derived from /u/ is sufficient to trigger umlaut. The α > β condition must be met at underlying structure for the constraint to be applicable. In this case, it is, since neither trigger nor target is epenthetic. This stands in contrast to the case of [akár] in (32), which does not match the α > β condition in underlying representation.

In summary, the correspondence approach to Icelandic u-umlaut rests on decoupling conditions on the featural make-up, linear order, and adjacency of segments from each other with respect to the levels at which those conditions obtain. By virtue of this move, two crucial results are obtained:

- The V-to-V adjacency requirement can be met at underlying or surface structure, correctly yielding umlaut in cases where the triggering vowel is deleted ([bóggíl] → [bógíl]) and where deletion of an intervening vowel creates the requisite adjacency condition ([ragnúm] → [rignon]).

- When the vowel [ó] is derived by umlaut, it can itself serve as a trigger for umlaut ([barkum] → [bókúm]). But when [ó] is derived by epenthesis, it does not match the α > β condition at underlying structure, and so no umlaut is observed ([áakú] → [akár]).

In contrast, the structural approach encounters difficulties with exactly these cases. The problems center around consistency in the treatment of unparamed morphologically unsponsored segments:

- Forms like [bóggíl] allow that even unfaithful á triggers the alternation. Why then doesn’t unparamed á in [kótúlm] render the vowels of the first and last syllables non-adjacent? Unparamed elements are inconsistently visible to the constraint, depending on whether their role is crucial or contextual.

- Forms like [akár] show that morphologically unsponsored (i.e., epenthetic) [ó] does not trigger the alternation. But in [bókúm], a vowel which is morphologically unsponsored as [ó] does trigger the alternation. Evidently, two different notions of morphological sponsorship will be required.9

These are exactly the thorniest cases of existing opacity and transparency in Icelandic. Technical solutions within the structural approach are no doubt possible, though it remains to be seen whether they will differ in any interesting way from the correspondence approach.

9 This issue does not arise if epenthetic vowels are phonologically just empty nodes, with their quality determined extra-syntactically, by the phonetics. Then, phonetic [áakú] is phonological [akár], with no [ó] in sight, and no need to limit the constraint to morphologically-sponsored segments. In contrast, I assume here that the quality of epenthetic segments is under grammatical control—indeed, independently-required constraints on featural markedness select the least offensive material to satisfy the driving syllabic constraints. In this way, the featural make-up of epenthetic segments can figure in grammatical generalizations, as in Yavavini (Kurdz 1987, Archangell 1985). See Prince & Smolensky (1993), Chapt. 9, Smolensky (1999), McCarthy (1993), McCarthy & Prince (1994) for recent discussion.
We turn now to Two-Level Phonology (Koskenniemi 1983; Karttunen 1993), which in some respects anticipates the proposal made in section 3. Each constraint of Two-Level Phonology consists of a licensed input/output relation and a context in which that relation obtains. This aspect of Two-Level Phonology is exactly like the rewrite rules of standard generative phonology. Unlike the standard theory, though, it recognizes only the input and output levels, with no intermediate stages. Thus, there can be no rule-ordering— all constraints are applied in parallel. Many of the effects of rule ordering, including the treatment of phonological opacity, are obtained by specifying whether the contextual conditions obtain at the underlying level, the surface level, or either exactly as in section 3.

Koskenniemi offers a notation for two-level rules that allows independent specification of the level at which any contextual conditions apply. Here are some examples for Tiberian Hebrew spirantization and variants:

(34) Two-Level Rule Notation Illustrated
Formulation      Interpretation
a. Stop: Fricative \( \Leftrightarrow V_- \)  Only a surface vowel triggers the alternation (like (13), (20a)).
b. Stop: Fricative \( \Leftrightarrow V \)  Any vowel, even deleted or epenthetic, triggers the alternation. (This is real Hebrew, as in (14), (20b)).
c. Stop: Fricative \( \Leftrightarrow V_- \)  Only underlying vowel triggers the alternation (like (16), (20c)).
d. Stop: Fricative \( \Leftrightarrow V \)  Only a vowel present at both levels triggers the alternation. (Neither epenthetic nor deleted vowels serve as triggers, like (18), (20d)).

The left-hand side of the rule (before the "\( \Leftrightarrow \)"), like a standard rewrite rule, expresses the licensed input/output relationship between underlying stop and surface fricative. The right-hand side of the rule expresses the context, where the expression "\( \alpha \)" denotes an underlying context and "\( \alpha' \)" a surface context. Boolean combinations are permitted, as in (34b, d).

This quick summary shows that there is considerable overlap, descriptively and even conceptually, between the Two-Level Theory and the correspondence or structural approaches to opacity in Optimality Theory. But there are differences too. One significant point of difference is that OT sees phonological alternations in terms of the interaction of markedness constraints and faithfulness constraints. That is, OT markedness constraints specify a target, but not a repair. The reason for this is that within and between languages, targets are homogeneous even when the repairs are not.

In contrast, Two-Level Phonology expresses target and repair together, in a single constraint, just like the rewrite rules of standard phonology. A loss of generalization is inevitable whenever one language or several languages support a single target in different ways. This loss of generalization can be seen plainly in Lakoff's (1993:124) two-level analysis of Lardil, with two distinct constraints whose effect is to delete unsyllabifiable consonants. This is a significant retrograde step in comparison to the rule-based accounts of Lardil in its 1986, 1989 and Wilkinson 1986, 1988, as well as the Optimality-Theoretic analysis in Prince & Smolensky (1993: Chapt. 7). (For further criticism of Two-Level Phonology from this perspective, see Orgun 1995.)

Another point of difference is that Two-Level Phonology, as formalized by Koskenniemi (1983), is unable to deal with complex systems of opacity and transparency like Icelandic. Therefore, Lakoff's (1993) extension of Two-Level Phonology, called Cognitive Phonology, analyzes Icelandic by calling on three levels (see also Goldsmith's 1993 Harmonic Phonology). The three levels are dubbed M(E)orphemic, M(ord), and P(honetic), connected as M → W → P. Constraints license transitions between a particular pair of adjacent levels or any pair of adjacent levels.

For Icelandic, Lakoff (1993: 73f.) proposes a M.W constraint of Syncope, a W.P constraint of Epenthesis, and the following constraints to govern unumlaut and related alternations:

(35) Cognitive Phonology Constraints for Icelandic

\[ \text{a. } \mu \text{-Umlaut (M.W)} \]
\[ \text{M: } \begin{cases} a & \text{W} \left[ \begin{array}{c} \text{low} \\ \text{back} \\ \text{rd} \end{array} \right] \quad \text{C} \quad \text{(i.e., before } C \text{ at either M or W level)} \\
\text{b. Vowel Reduction (W)} \\
\text{If } [\text{syll. stress, low}], \text{ then [high]}. \]

(In citing these constraints and the derivation below, I have used Icelandic orthography, as Lakoff does.) Applied to the crucial data, these constraints yield the following results:

(36) Cognitive Phonology Analysis Applied

\[ \text{a. } \mu \text{-Umlaut} \]
\[ \text{M: barnum} \quad \text{bagguli} \quad \text{c. ragnim} \]
\[ \text{W: börnum} \quad \text{böggli} \quad \text{rögnim} \]
\[ \text{P: börnum} \quad \text{böggi} \quad \text{rögnim} \]
\[ \text{d. } \text{akr} \quad \text{dömurm} \quad \text{rähkum} \]
\[ \text{W: } \text{akr} \quad \text{dömurm reduc} \quad \text{böküm} \]
\[ \text{P: akur} \quad \text{dömurm} \quad \text{böküm} \]

These examples nicely illustrate all of the main points of the analysis. The context for \( \mu \text{-Umlaut} \) — that is, before \( C \mu \) — can be met at \( M \) or \( W \), as in (36b) and (36c) respectively. Epenthesis cannot feed Umlaut because these two constraints are in a

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[a] I have modified this constraint from the original by removing unnecessary [back] from the antecedent and incorrect [round] from the consequent.
counter-feeding order, by virtue of the levels to which they are assigned. Umlaut and Vowel Reduction interact in examples [36a, f], with M-W Umlaut conditioned by a u that is itself derived by virtue of W-internal Vowel Reduction.

It is clear that the correspondence-based constraint (30), set within Optimality Theory, is too different from the Two-Level/Cognitive Phonology formulation of Umlaut in (35c). Both constraints see the role of u as trigger and the adjacency relation between a and u as conditions that can be met at either the underlying or the derived level. In (30), this characterization of the umlaut conditions is explicit, while in (35c) it is implicit in the expression ‘JC_{MP}’. But there are significant differences as well.

One point of difference, which it shares with Two-Level Phonology, is that Cognitive Phonology generally combines target and repair in a single constraint. As I have already noted, this leads to significant loss of generalization (in comparison to OT) when a single target is satisfied by different repairs, within a language or between languages. Problematically, though, Cognitive Phonology also recognizes one-level constraints like Reduction (35b), which make no mention of the repair. Cognitive Phonology has no theory of faithfulness beyond ‘default identity’ (Lakoff 1999: 141), so the mode of satisfying one-level constraints is not guaranteed to be determinate. For instance, why is Reduction satisfied by further vowel raising rather than, say, moving the stress? In OT, this is a straightforward matter of constraint interaction through ranking: the constraint demanding initial stress dominates IDENT-high.22

Another point of difference is that Cognitive Phonology (like Harmonic Phonology) assigns three levels to OT’s two. Forms like akur provide the crucial argument for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes clear, the lack of epenthesis/umlaut interaction is for three levels. As (36d) makes cl

References


For example, chain shifts are a type of opacity that presents its own problems. For relevant discussion, see McCarthy 1993, Orgun 1995, and Kirchner 1999b. Linearity, however, does not deal with instances of open syllables created by epenthesis of initial consonant.


Kirchner, Robert (1995b) Going the distance: Synchronic chain shifts in OT, Ms., UCL. Rutgers Optimality Archive #46.


