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OPACITY IN CLASSIC AND DERIVATIONAL OPTIMALITY THEORY: TIBERIAN HEBREW SPIRANTIZATION AND POLISH O-RAISING

ABSTRACT

Classic Optimality Theory treats phonological computation as a one-step parallel evaluation of output candidates. Such an approach does not handle well phonological opacity, in which the context of phonological processes is obscured on the surface. This article shows two examples of phonological opacity: Tiberian Hebrew Spirantization and Polish o-Raising. While these mappings are impossible to account for in classic OT, they are readily analyzed using the framework of Derivational OT.

KEYWORDS: phonological opacity, Derivational Optimality Theory, Tiberian Hebrew, Polish phonology

INTRODUCTION

Phonological processes or generalizations are transparent when the context in which they operate is visible in the surface representation. The reverse situation, that is, when the operation of a phonological process is obscured on the surface, is dubbed phonological opacity. For instance, if a language exhibits a phonological rule R that states $A \rightarrow B / \_\_C$, the presence of forms AC on the surface indicates that such a rule is opaque. Even though the structural description of the rule suggests that any A before C must change into B, the application of the rule is obscured due to other phonological processes. Similarly, opacity is found in surface forms BD, assuming that B has been derived by rule R. In the latter case, the rule applied even though its context is no longer present on the surface. The opaque interactions are summarized in (1).
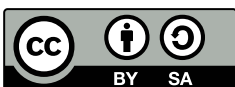
(1)   Opacity (Kiparsky 1976: 79)
      A phonological rule P of the form A → B / C__D is opaque if there are
      surface structures with either of the following characteristics:
      a. instances of A in the environment C__D.
      b. instances of B derived by P that occur in environments other than C__D.

Opacity is possible in rule-based frameworks, such as SPE (Chomsky, Halle
1968), where rule ordering may result in opaque interaction. Optimality Theory (OT,
Prince, Smolensky 2004; McCarthy, Prince 1995), on the other hand, a representative
of an output-oriented framework, predicts that phonological opacity is nonexistent.
One of the main tenets of OT, strict parallelism, excludes any intermediate
representations. As a result, no opaque interaction of processes is possible and all
phonological mappings must be transparent. Such an approach to phonological
computation has been criticized by the proponents of intermediate representations as
being insufficient to account for many processes, including Polish palatalization
(Rydzewski 2017; Rubach 2017), Ukrainian mid vowel fronting (Rubach 2005),
Polish labial fission (Rubach 2003) or Tiberian Hebrew Spirantization (Idsardi 1998).
Importantly, phonological opacity is acknowledged by the proponents of parallel
evaluations as well as by the proponents of level distinction in OT, which makes it an
uncontroversial phenomenon. The main difficulty lies in modelling phonological
opacity in formal analyses (cf. McCarthy 1999, 2007; Baković 2007, 2011).

This article presents two examples of phonological opacity: Tiberian Hebrew
Spirantization and Polish o-Raising. It is shown that classic parallel evaluation in
Optimality Theory is unable to account for these processes. A solution to this
problem may be found in Derivational OT (Rubach 1997), which admits
intermediate representations into phonological computation. An alternative approach
couched in the framework of OT Candidate Chains (McCarthy 2007) proves inferior
to the proposed Derivational OT analysis since it does not generate the attested
outputs for the Tiberian Hebrew data.

OPACITY IN TIBERIAN HEBREW

Tiberian Hebrew Spirantization is a textbook example of opaque rule interaction.
It has been analyzed in rule based frameworks as well as in Optimality Theory
(Prince 1975; Benua 1995; Idsardi 1998; McCarthy 1999). Consider the data in (2).

(2) Tiberian Hebrew spirantization (Prince 1975)

Underlying representation	Surface form	Gloss
a. //ktob//	[kəθoβ]	'to write'
b. //la+ktob//	[lixtoβ]	'to write' inf.

Looking at the data in (2), we can posit a generalization that stops become fricatives after vowels. Additionally, in (2a), an ill-formed complex onset is repaired by a schwa insertion. This insertion feeds Spirantization, which converts the voiceless stop /t/ into a fricative. Importantly, in (2b), the underlying //t// remains unchanged in the output since the context for Spirantization is not met. Based on the data in (2), we can propose a set of constraints operating in Tiberian Hebrew.

(3) Tiberian Hebrew constraints
   a. SPIRANTIZATION (SPIR)
       Do not be a [-continuant] segment after a vowel.
   b. NOCOMPLEXONSET (*COMONS)
       Do not be a complex onset.
   c. IDENT[±continuant] (ID[±cont])
       Input value of [±continuant] must be preserved in the output correspondent.
   d. DEPSEG (DEP)
       Do not insert segments.

The evaluations in (4) demonstrate that the transparent outputs listed in (2) are readily selected using classic OT.

(4) Tiberian Hebrew in classic OT

(i) //ktob// → [kəθoβ] 'to write'

	ktob	SPIR	*COMONS	ID[±cont]	DEP
	a. ktob	*!	*		
	b. ktoβ		*!		
☞	c. kə.θoβ			**	*
	d. kə.tob	*!*			*

(ii) //la+ktob// → [lixtoβ] 'to write' inf.[1]

	laktob	SPIR	*COMONS	ID[±cont]	DEP
	a. lik.tob	*!*			
☞	b. lix.toβ			**	
	c. li.xə.θoβ			***!	*

Candidates violating the high-ranked constraints SPIRANTIZATION and NOCOMPLEXONSET are eliminated. Gratuitous schwa insertion in candidate (4ii-c) is penalized by a violation of either IDENT[±continuant] or DEPSEG (the exact ranking of these two constraints is unknown based on the data at hand). At any rate, classic

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[1] I ignore vowel alternations as they fall beyond the scope of the current paper.

one-step OT evaluation is sufficient to account for the analyzed examples. Let us consider an additional mapping presented in (5).

(5) Tiberian Hebrew – opaque output (Prince 1975)

Underlying representation	Surface form	Gloss
//ba#ktob//	[bixθoβ]	'when writing'

In the surface form [bixθoβ] 'when writing', the underlying voiceless stop becomes a fricative even though the context for this change is not met. In rule-based theories, such an unwarranted mapping entails a counterbleeding ordering. The alternation is gratuitous from the perspective of Optimality Theory, as demonstrated in (6).

(6) Opacity in Tiberian Hebrew – failed evaluation of //ba#ktob// → [bixθoβ] 'when writing'[2]

	baktob	SPIR	*COMONS	ID[±cont]	DEP
	a. bik.tob	*!*			
☹	b. bix.θoβ			***!	
☞	c. bix.toβ			**	
	d. bi.xə.θoβ			***!	*

The attested output, (6b), incurs an additional violation of IDENT[±continuant] without any reduction of markedness, effectively losing to candidate (6c). The result of evaluation (6) is similar to the result in (4ii), which is an expected yet undesired outcome. Importantly, the ranking paradox cannot be amended by constraint reranking since the attested output contains a superset of the violations of another candidate.

A solution to the problem of opacity in Tiberian Hebrew might be provided by Derivational Optimality Theory (Rubach 1997). Derivational OT, similar to Lexical Phonology (Kiparsky 1982b; Booij, Rubach 1987), recognizes the role of derivational steps in phonological computation. Accordingly, OT evaluation is divided into four levels (stem/cyclic, word, clitic and phrase level; Rubach 2011). The output of a previous level becomes the input to the following level. Moreover, the constraints can be reranked between levels. Effectively, parallel evaluations are maintained within individual levels; however, intermediate representations may play a role in the entire process of arriving at the surface form.

Consider the Derivational OT evaluation of the opaque Tiberian Hebrew form in (7), which uses the familiar constraints as well as MAXSEG (MAX) militating against segment deletion and NOSCHWA (*ə)[3], formulated as *do not be a schwa*.

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[2] The symbol ☹ indicates the attested output that has been rejected; ☞ indicates the unattested winner.

[3] As reported by Prince (1975), schwa is systematically deleted in VCəC sequences.

(7) Derivational OT evaluation of //ba#ktob// → [bixθoβ] 'when writing'

(i) Level 1: //ktob// → /kəθoβ/

	ktob	Spir	*ComOns	Max	Id[±cont]	Dep	*ə
	a. ktob	*!	*				
	b. ktoβ		*!		*		
☞	c. kə.θoβ				**	*	*
	d. kə.tob	*!*				*	*
	e. toβ			*!	*		

(ii) Level 4: /ba#kəθoβ/ → [bixθoβ]

	bakəθoβ	Spir	*ComOns	*ə	Max	Id[±cont]	Dep
	a. bi.kə.θoβ	*!		*			
	b. bi.xə.θoβ			*!		*	
☞	c. bix.θoβ				*	*	
	d. bix.toβ				*	**!	

On Level 1, the evaluation is similar to the evaluation of //ktob// → [kəθoβ] 'to write' in (4i). The winner, candidate (7i-c), conforms to the requirements of SPIRANTIZATION and NoCOMPLEXONSET. The ranking paradox from the previous evaluations is resolved on the phrase level (Level 4), where NoSCHWA is promoted to an undominated position. The unattested classic OT winner, candidate (7ii-d), which is the transparent candidate, loses due to an additional violation of IDENT [±continuant]. As the input to Level 4 already contains the spirantized segment /θ/ instead of the underlying stop /t/, the seemingly unwarranted spirantization is actually preferred. The mapping //la+ktob// → [lixtoβ] 'to write' inf. is also achieved in Derivational OT since the entire word is evaluated on the cyclic level in exactly the same way as in (4ii). Consequently, on the phrase level, no crucial changes are made and [lixtoβ] is selected as the optimal contender.

A reviewer suggests that the opacity found in Tiberian Hebrew may be attributed to paradigm uniformity effects (cf. Green 2004). Paradigm uniformity belongs to the general theory of output-output correspondence developed in a plethora of works (Kuryłowicz 1945–1949; Benua 1995; Kenstowicz 1996; Buckley 1999; Steriade 2000, to name a few). The general idea behind output-output faithfulness is that attested outputs influence the computation of other related output forms. In Optimality Theory, output-output (O-O) correspondence is expressed via O-O faithfulness constraints (Benua 1995). For instance, DEP-OO penalizes segment insertion between an output candidate and its O-O base, i.e., a morphologically simpler surface form (Benua 1997). Another possibility is a more general constraint,

UNIFORM EXPONENCE, which militates against differences in the realization of a lexical item (Kenstowicz 1996).

Returning to the opacity effects discussed in this section, Green (2004) suggests that surface postconsonantal spirantization found in Tiberian Hebrew may be attributed to paradigm leveling rather than to opaque interaction of phonological processes. In other words, if the majority of forms in a paradigm contains a spirant instead of a stop in a given position, the exceptional forms containing a consonant cluster yield to the paradigmatic pressure, which results in an unwarranted postconsonantal spirant. For instance, in the *k-t-b* 'write' paradigm, the majority of surface forms contain a transparent postvocalic spirant for the last consonant of the root, e.g., [kɔ:θáβti:] 1sg. perf., [nixtó:β] 1pl. imperf. 'write' (Green 2004: 65)[4]. Accordingly, the outputs where the final consonant of the root is found in a postconsonantal position, such as [kiθβú:] 'write' 2m.pl. imper., undergo paradigm leveling, rendering the labial stop as a fricative without the necessary phonological context. In OT, such relations may be expressed either by an O-O constraint referencing a specific attested output form (e.g., the citation form, the most frequent form, the morphologically simplest form, etc.) or a general Paradigm Uniformity constraint. One of the crucial differences between these alternatives is that in O-O faithfulness the base form to which candidates must remain faithful is an attested surface representation. In contrast, Paradigm Uniformity constitutes a more powerful theory allowing entire paradigms, including bound morphemes, to serve as reference points (Kiparsky to appear). The problem with both of the aforementioned approaches is that they require additional theoretical machinery in order to differentiate between the spirantizing and non-spirantizing forms, such as [bixθoβ] 'when writing' *vs.* [lixtoβ] 'to write' inf. In other words, there is no apparent reason why one of these forms conforms to the O-O faithfulness constraint and the other form is allowed to violate it without losing the evaluation. An analysis that admits the distinction between cyclic phonology and phrase phonology, on the other hand, provides sufficient tools to account for the data without generating additional theoretical machinery. Since the discussion regarding the rationale behind the entire concept of O-O correspondence falls beyond the scope of the current paper, I conclude that Derivational OT successfully accounts for the Tiberian Hebrew opacity presented in this section, without making any strong claims against the solution based on paradigm uniformity.

The presented Tiberian Hebrew data show that classic OT evaluation is unable to account for phonological opacity. Derivational OT combines the insights of parallelism and constraint ranking with derivational levels familiar from previous rule-based frameworks. The division between cyclic level, word level and phrase level phonology constitutes a classic approach to phonological computation

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[4] Green (2004) uses [v] instead of [β] for the spirant corresponding to the labial voiced stop. Since this detail does not influence the point of the current discussion, I use the bilabial version after McCarthy (1999).

confirmed by phenomena such as derived environment effects (Chomsky 1965; Kean 1974; Mascaró 1976; Kiparsky 1982a; Rubach 1984) or the life cycle of phonological processes (Bermúdez-Otero 2007, 2015; Bermúdez-Otero, Trousdale 2012; Ramsammy 2015). The next section shows that phonological opacity found in Polish o-Raising is also successfully accounted for by Derivational OT.

OPACITY IN POLISH

In Polish, the mid back vowel /ɔ/ alternates with the high back vowel /u/ in the context of word-final voiced consonants. This alternation, dubbed o-Raising, affects words regardless of their grammatical category.

(8) Polish o-Raising (Gussmann 2007: 262–263, 265)

masculine nouns	[sɔkɔw+ɨ] 'falcon' nom.pl.	[sɔkuw] nom.sg.
	[lɔd+ɨ] 'ice' nom.pl.	[lut] nom.sg.
adjectives	[zdrɔv+a] 'healthy' fem.	[zdruf] masc.
feminine nouns	[sɔv+a] 'owl' nom.sg.	[suf] gen.pl.
	[zmɔr+a] 'nightmare' nom sg.	[zmur] gen.pl.
verbs	[rɔb+ɨ] 'he/she makes'	[rup] 'make' imper.sg.

The generalization observed in the data in (8) may be formulated as a phonological rule of the shape ɔ → u / _C[+voice -nasal]# (cf. Herbert, Nykiel-Herbert 1991; Bethin 1992; Baranowski, Buckley 2003; Gussmann 2007)[5]. The specification [-nasal] is necessary since no raising is found in the context of nasals (Gussmann 2007). An *ad-hoc* OT constraint driving Polish o-Raising is given in (9).

(9)   O-RAISING: do not be ɔC[+voice -nasal])PW (PW stands for phonological word).

The problem with constraint (9) is immediately visible after examining the raised forms in (8). Even though the previously formulated generalization concerning the context of o-Raising is correct, this generalization cannot be captured just by looking at output candidates since obstruents are neutralized to [-voice] word-finally in Polish. A strictly parallel evaluation is blind to the underlying representation when it comes to

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[5] Admittedly, Polish o-Raising exhibits numerous counterexamples (Gussmann 2007). The aim of this paper, however, is not to account for the exceptionality of patterns, but to model phonological opacity, which must be accounted for regardless of the exceptions.

markedness constraints. The opacity of the outputs containing the underlying voiced obstruents is of a counterbleeding type. Final Devoicing obscures the context for o-Raising, rendering a strictly parallel evaluation impossible. The problem with a classic OT analysis of Polish o-Raising is demonstrated by the failed evaluation in (10). The active constraints involve the constraint given in (9) as well as (i) FINALDEVOICING (FD) that militates against word-final voiced obstruents, (ii) IDENT[±voice] (ID[±v]) stating that the input value of the feature [±voice] must be preserved on the output correspondent and (iii) IDENT[±high] (ID[±h]), which states that the input value of the feature [±high] must be preserved on the output correspondent.

(10) Opacity in Polish – failed evaluation of //sɔv// → [suf] 'owl' gen.pl.

	sɔv	FD	o-RAISING	ID[±h]	ID[±v]
	a. sɔv	*!	*		
	b. suv	*!		*	
☞	c. sɔf				*
☹	d. suf			*	*!

The established ranking fails to select the attested output, (10d). Candidates containing word-final voiced obstruents are correctly rejected. However, the raised form, (10d), incurs a gratuitous violation of IDENT[±high]. The winner, (10c), has a subset of the violations of the desired output and hence the evaluation cannot be salvaged by constraint reranking.

Similarly to the case of Tiberian Hebrew opacity, Derivational OT offers a satisfactory solution to the problem of Polish o-Raising. The process of Final Devoicing belongs to phrase level phonology, based on independent evidence (Rubach 1996). What follows is that the information about the voicing of word-final obstruents is available on the lower levels. As demonstrated in (11), o-RAISING operates on Level 1[6]; the raised outputs of Level 1 are subject to Final Devoicing on Level 4.

(11) Derivational OT evaluation of //sɔv// → [suf] 'owl' gen.pl.

(i) Level 1: //sɔv// → /suv/

	sɔv	ID[±v]	o-RAISING	ID[±h]	FD
	a. sɔv		*!		*
☞	b. suv			*	*
	c. sɔf	*!			
	d. suf	*!		*	

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[6] I abstract away from whether o-Raising should crucially operate on Level 1 or Level 2 since it does not influence the general proposal.

(ii) Level 4: /suv/ → [suf]

	suv	FD	o-Raising	Id[±h]	Id[±v]
	a. sɔv	*!	*	*	
	b. suv	*!			
	c. sɔf			*	*!
☞	d. suf				*

The ranking paradox present in the classic OT evaluation is resolved on Level 4. FINALDEVOICING, a low ranked constraint on the stem level, is promoted to an undominated position on the phrase level. Consequently, o-RAISING has access to the information about obstruent voicing on the lexical level. The already raised output of Level 1 constitutes an input to Level 4. As a result, the transparent candidate, (11c), incurs a gratuitous violation of IDENT[±high] and loses to the attested output, (11d).

A reviewer suggests that the opacity effects analyzed in this paper may be accounted for using OT Candidate Chains (OT-CC; McCarthy 2007). In OT-CC, the evaluation of output candidates is replaced by the evaluation of candidate chains, which mimics serial derivation in generative phonology. Three principles govern the well-formedness of a candidate chain. First, the initial form of a legal chain must be faithful to the input. Second, consecutive candidates change gradually, one unfaithful mapping at a time. Third, each change must introduce harmonic improvement in relation to the previous candidate in a chain (McCarthy 2007).

Using OT-CC, we can construct chains of candidates instead of individual outputs for the Polish data presented in this section. Consider the chains in (12) for the input //sɔv// that yields the surface form [suf] 'owl' gen.pl.

(12)   Candidate chains for //sɔv// 'owl' gen.pl.
<sɔv>
<sɔv, sɔf>
<sɔv, suv>
<sɔv, suv, suf>

In (12), the attested overapplication of o-Raising is successfully represented by a valid candidate chain <sɔv, suv, suf>. The second candidate in the chain offers harmonic improvement over the faithful form since it satisfies the requirement of o-RAISING. The final candidate in this chain, on the other hand, removes a violation of FINAL DEVOICING. Using a precedence constraint PREC(IDENT[±high], IDENT [±voice])[7], it is possible to arrive at the attested output, as shown in tableau (13).

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[7] A precedence constraint Prec(A, B) is violated by a chain in which the violation of B occurs and is either not preceded by a violation of A or is followed by a violation of A (McCarthy 2007; summarized in Wolf 2011).

(13) OT-CC evaluation of //sɔv// → [suf] 'owl' gen.pl.

	sɔv	Prec(Id[±h], Id[±v])	FD	o-Raising	Id[±h]	Id[±v]
	a. \<sɔv\>		*!	*		
	b. \<sɔv, sɔf\>	*!				*
	c. \<sɔv, suv\>		*!		*	
☞	d. \<sɔv, suv, suf\>				*	*

Candidate chain (13b) loses to (13d) due to its violation of the Prec constraint. This outcome is governed by the makeup of the chain itself. In chain (13b), Ident [±voice] is violated without a previous violation of Ident[±high]. In chain (13d), on the other hand, both Ident[±high] and Ident[±voice] are violated in the correct order, which meets the requirement of Prec(Ident[±high], Ident[±voice]).

Although Polish o-Raising seems to be readily accounted for using OT-CC, the opacity found in Tiberian Hebrew constitutes a more challenging example. Consider the candidate chains in (14) for the input //baktob// that yields the surface form [bixθoβ] 'when writing', discussed in the previous section.

(14)   Some candidate chains for //baktob// 'when writing'
\<biktob\>[8]
\<biktob, bixtob, bixtoβ\>
\<biktob, biktoβ, bixtoβ\>
*\<biktob, bikθob, …\>
*\<biktob, bikətob, bikəθob, …\>

Candidate chains listed in (14) demonstrate that under the assumptions of OT-CC, a mapping in which a stop spirantizes after a consonant is impossible. Such a chain violates the principle of harmonic improvement, which states that each consecutive candidate must be more harmonic than the preceding one. In other words, spirantization after a consonant violates a faithfulness constraint, Ident [±continuant], without compensating it in the reduction of markedness. Similarly, a chain in which a vowel is inserted, as in *\<biktob, bikətob, bikəθob, …\>, is ill-formed as no harmonic improvement is observed in the first step. The second member of this chain violates DepSeg, but does not satisfy any additional markedness constraint, such as NoComplexOnset. As a result, OT-CC is unable to account for the Tiberian Hebrew data since no legal chain generates the attested output.

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[8] For presentation, I omit the irrelevant vowel alternation in the listed chains, positing /i/ in the initial candidate instead of the faithful /a/.

CONCLUSION

The analysis presented in this paper shows that strictly parallel Optimality Theory evaluation is unable to successfully account for the data exhibiting phonological opacity. In rule-based theories, opaque rule interaction crucially refers to intermediate representations. Optimality Theory, a representative of an output-oriented framework, does not admit intermediate representations and predicts that phonological opacity is nonexistent. Such a prediction is counterfactual, as demonstrated by the examples from Tiberian Hebrew Spirantization and Polish o-Raising. A solution to this problem is found in Derivational Optimality Theory, which combines the long tradition of dividing phonological computation into lexical and postlexical phonology with the insights of parallelism and constraints on output candidates. As demonstrated in this paper, Derivational Optimality Theory provides sufficient tools to handle phonological opacity found in Tiberian Hebrew Spirantization as well as in Polish o-Raising. Interestingly, an alternative solution to derivational levels, OT Candidate Chains, also includes reference to intermediate representations when dealing with phonological opacity. However, although OT-CC accounts for Polish o-Raising, it is unable to handle the Tiberian Hebrew data.

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