Less than zero: Correspondence and the null output[1]

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1. Introduction

A central property of Optimality Theory is *competition* (Prince and Smolensky 2004). GEN associates an array of candidate output forms with each input, and these candidates compete against one another. EVAL chooses the winner of this competition, the candidate that satisfies the constraint hierarchy of the language in question better than any other candidate.

But what if some input has no output? What candidate is the winner of the competition? In phonology, this problem arises primarily and perhaps exclusively in paradigmatic gaps. In a paradigmatic gap, some combination of morphemes in the input is ruled absolutely ungrammatical for apparently phonological reasons, leaving a hole in the paradigm that is filled by periphrasis, suppletion, or allomorphy. Absolute ungrammaticality requires, or so it seems, that *all* candidates be ruled out. But this is at odds with the fundamental assumption in OT that all constraints are in principle violable: for any input, one of the candidates supplied by GEN will violate the constraints less seriously than the others, and hence will win. No candidate does so badly that it can't win except insofar as some other candidate does less badly. Therefore, it is impossible for all candidates to be eliminated from contention, which is what seems to happen when there is a gap.

Prince & Smolensky (2004: 57ff.) propose a solution to this problem: the gap is itself a candidate for every input. Under the appropriate conditions, the gap will be able to win like any other (non-harmonically bounded) candidate. The gap candidate — which they refer to as the *null parse* — is taken to violate only a single constraint, named MPARSE. Because the null parse *ex hypothesi* violates no other constraints, any constraint ranked above MPARSE is effectively inviolable, since any candidate that violates it will lose to the null parse, as shown in (1). (Throughout, we will represent the null parse with the symbol ⊙. For the comparative tableau format, see Prince (2002). The integers are tallies of violation-marks.)

(1) MPARSE harmony threshold

/in/	C	MPARSE
→ ⊙		1
a. ~ [out1]	1 W	L

Legendre, Smolensky, & Wilson (1998: 257, fn. 9) term this effect of MPARSE a *harmony threshold*: MPARSE is able to set a standard which any surface-viable candidate has to

[1] We are grateful for comments and questions from the UMass Phonology/Phonetics Reading Group.

satisfy, so constraints ranked higher than MPARSE are de facto inviolable (within MPARSE's morphological scope — see section 5.1).

Our primary goal in this paper is to rationalize the properties of the null parse (or *null output*, as we will refer to it). In particular, how is it possible for this candidate to violate only MPARSE and satisfy all faithfulness and markedness constraints?[2] We will argue for a revision of the theory of correspondence (McCarthy and Prince 1995, 1999) from which the null output's faithfulness status follows automatically, and we will also show why it violates no markedness constraints.

This paper is laid out as follows. In section 2, we illustrate the phenomenon of paradigmatic gaps and describe some necessary properties of the MPARSE model. Section 3 contains our proposal about correspondence theory and the place of the null parse in the candidate set. Section 4 then shows how the properties of the null parse under this proposal conform to the requirements deduced in section 2. Section 5 looks at the morphological specificity of MPARSE, section 6 describes some further applications of our proposal, and section 7 compares the proposal with a theory of gaps based on designating a class of inviolable constraints, as in the CONTROL model of Orgun & Sprouse (1999).

2. Paradigmatic gaps and their analysis

The MPARSE model was in some ways anticipated in work on gaps by Hetzron (1975), Iverson (1981), and Iverson & Sanders (1982). Their observations can be summarized as this: some languages have phonological processes that are exceptionless in attested surface forms, and crucially any forms that appropriately condition these processes but fail to undergo them lack any surface realization (rather than simply being an exception to the process and surfacing without having undergone it). Put somewhat differently, these are cases where some phonologically ill-formed configuration Γ is always eliminated on the surface, and where the phonological process that normally eliminates Γ is disallowed for some defined class of lexical items, forcing the grammar to resort to outright gaps in order to maintain the surface absence of Γ. In OT terms, this quite clearly corresponds to instances in which some markedness constraint, as well as the conflicting faithfulness constraints, all dominate MPARSE. Retaining the marked structure or making the changes that could eliminate it would both result in more serious violation profiles than having a gap in the paradigm, and so the gap wins.

A straightforward example, cited by Iverson (1981) from Eliasson (1975), involves gaps in Swedish adjective forms. In Swedish, the indefinite singular neuter form of adjectives is formed by adding the suffix /-t/:

(2) (= Iverson's (1981) (1))

a. en rysk pojke	(masculine)	'a Russian boy'
b. et rysk-t barn	(neuter)	'a Russian child'

[2] As Nevins and Vaux (2003) would have it, the null parse 'is mysteriously stipulated to satisfy all well-formedness and faithfulness constraints'. As we will show, there is no mystery and no stipulation.

There is, however, no indefinite singular neuter form of adjectives whose stem ends in /dː/:

(3) (= Iverson's (1981) (2))

a. en rädd pojke	(masculine)	'a scared boy'
b. *et rädd-t barn	(neuter)	'a scared child'

The hypothetical form given in (b) is what we would expect if processes attested elsewhere in Swedish were able to apply. These processes do in fact apply when verbs that end in /d/ simultaneously take the past participle suffix /d/ and the neuter singular suffix /t/. The result is final *tt* (i.e., [tː]):

(4) /reːd+d+t/ → [retː] 'prepared'

To illustrate the role of MPARSE, we will briefly sketch an OT analysis, beginning with the non-gapped phonology of (4). Cluster simplification can be attributed to an OCP constraint militating against sequences of coronal obstruents (cf. Iverson's (1981) (6)) ranked above the antagonistic faithfulness constraint UNIFORMITY (≈ 'no coalescence'). (See Keer (1999) for a different view of OCP-driven coalescence effects.)

(5) OCP(cor) >> UNIFORMITY

/reːd_3+d_4+t_5/	OCP(cor)	UNIFORMITY
→ retː$_{3,4,5}$		2
a. ~ red$_3$d$_4$t$_5$	2 W	L
b. ~ red$_3$t$_{4,5}$	1 W	1 L

As shown in (5), the result is double coalescence, reducing the sequence of coronals to a single segment that preserves the quantity of the original cluster as much as possible. The winner is voiceless rather than voiced in conformity with a general property of Swedish obstruent clusters, the dominance of voicelessness in assimilation processes (Lombardi 1999), which might be attributed to faithfulness to the [+spread glottis] specification of voiceless segments (cf. Beckman and Ringen 2004).

As usual in OT, the 'process' of cluster simplification takes place because the faithfulness constraint that militates against this change is dominated by a markedness constraint that disallows the faithful configurations. In neuter adjectives, however, *neither* option, being unfaithful or remaining marked, is available. This we attribute to the fact that OCP(cor), UNIFORMITY, and other relevant constraints all dominate a constraint MPARSE$_{/\text{-t}/}$, which is relativized to the grammatical category that displays the paradigmatic gap, here referred to by the adjectival neuter suffix /-t/. (See section 5.1 for the details of how MPARSE is morphologically conditioned.)

(6) UNIFORMITY >> MPARSE$_{/-t/}$

/rädː$_3$+t$_4$/	OCP(cor)	UNIFORMITY	MPARSE$_{/-t/}$
→ ⊙			1
a. ~ rädː$_3$t$_4$	1 W		L
b. ~ rätː$_{3,4}$		1 W	L

Because retaining or eliminating marked structure would each violate constraints ranked above MPARSE, the MPARSE-violating candidate — that is, the gap — is optimal. (Other constraints, also ranked above MPARSE, rule out other imaginable outcomes, such as epenthesis, dissimilation, or non-coalescent deletion.)

This example illustrates some of the principal properties of the gap phenomenon, properties that any theory of gaps must accommodate. Gaps are typically observed in inflectional paradigms (Rice 2005). As Iverson (1981) points out, derivational processes of the sort discussed by Halle (1973) can independently exhibit significant degrees of idiosyncrasy that often cannot be explained in phonological terms. For example, the adjective *callous* does not take the suffix *-ity* in English, and our understanding of this fact is not significantly advanced by analysis in terms similar to the account of Swedish. Formal gaps are also unnecessary in describing restrictions on phonotactics, segmental inventories, and the like (though see Prince and Smolensky 2004: 57 for an example of this mode of analysis). Phonotactic ill-formedness is more typically attributed to neutralizing mappings in which the prohibited structures merge with some other structure that is surface-licit. For example, it is not necessary that /bnɪk/ map to the null ouput in English; the non-existence of [bnɪk] can as well be accounted for by mapping /bnɪk/ to, say, [nɪk].

This is not to say, however, that the optimality of the null output is not a legitimate analytical tool for explaining derivational or phonotactic gaps — indeed, it has been used for both by various researchers, and since we will pursue a model in which the null output is among the candidates produced by GEN for every input — even monomorphemic inputs — mapping to the null output is always one option for the analyst or learner who needs to account for the failure of some known input to appear as such on the surface. Still, the point remains that it is inflectional gaps that most clearly show the need for the null output as candidate. For other examples of phonologically-conditioned gaps in inflectional paradigms, see Hetzron (1975) and Iverson (1981) on Hungarian verbs without jussive forms and Russian verbs without 1st.sg. non-past forms (for the latter, also see Halle 1973), and Rice (2003, 2005) on Norwegian verbs without imperatives.

In our MPARSE analysis of the Swedish adjective paradigmatic gap, it was necessary that the MPARSE constraint at work be indexed to a particular morphological situation. That is because, as illustrated in (5), UNIFORMITY is violable in other contexts, such as verbs, even though it is unviolated in neuter adjectives. For verbs, then, we assume that whatever MPARSE constraints that are indexed to them must be ranked at least above UNIFORMITY. This reflects a general property of systems with paradigmatic gaps: the same marked configuration that leads to a gap in one part of the paradigm may be resolved by an unfaithful mapping in another part of the paradigm. In an analysis of gaps that is based on null outputs, then, MPARSE will usually be relativized to specific morphological contexts; the question of how exactly to do this is dealt with in section 5.1.

The Swedish example also illustrates an important characteristic of the null output that we have noted previously: it satisfies all markedness and faithfulness constraints. We will examine the markedness properties of the null output below in section 4.2; for now, we will focus on its faithfulness properties. Clearly, the null output must obey UNIFORMITY, since otherwise it would lose in (6) to candidate (b), which is non-null and violates UNIFORMITY. An important but less obvious point is the difference between the null output and deletion. Among the candidates supplied by GEN is one in which every segment has mapped to zero. This candidate, which can be symbolized by Φ, violates the anti-deletion constraint MAX once for each segment in the input. Φ is usually non-viable and may even by harmonically bounded, depending on details of markedness theory (Gouskova 2003). Φ is non-viable because a candidate with less deletion is more harmonic. For example, in a language that is like Swedish except that UNIFORMITY dominates MAX, OCP(cor) could in principle be satisfied by mapping the input in (6) to [räd$_3$] or Φ. But since [räd$_3$] incurs one MAX violation to Φ's four, Φ is clearly a non-starter.

This argument about Φ's loser status and possible harmonic boundedness means that Φ and ⊙ cannot be the same thing, because then ⊙ would never win. The challenge, then, is to define the null output in such a way that it is distinct from the candidate that has deleted all of the underlying segments. This challenge is taken up in the next section.

3. Defining the null output

Prince & Smolensky (2004) suggest two possible means by which the null parse might be defined. One possibility is that it is the candidate in which no input phonological structure is parsed — i.e., under the PARSE/FILL model of faithfulness, the null parse would be the candidate that maximally violates PARSE. As we just showed, that definition is problematic: it is unlikely ever to produce paradigmatic gaps, since there will usually be candidates with fewer PARSE violations that equally well satisfy the markedness constraints that motivate the gap.

A more radical and more successful idea is their suggestion that the null output is the result of failure to parse even the morphological content of the input. This candidate violates just a single constraint, MPARSE: 'Morphological structure is parsed into constituents.' This interpretation of the null parse is attractive insofar as it makes the null parse a maximally simple candidate to use in analyses, since it always incurs only a single violation of a single constraint, which moreover is violated by no other candidate. Therefore, unlike the first option, it correctly distinguishes the null output from the candidate with maximal deletion.

Attributing the violation that the null output incurs to a failure of *morphological* parsing is somewhat problematic, however, especially once one shifts to Correspondence-based faithfulness (McCarthy and Prince 1995, 1999). If we assume that no phonological structure is produced in the null output, then it is hard to see why the anti-deletion constraint MAX is not violated, since all units of structure in the underlying representations of the input morphemes lack output correspondents. It would seem to be much more satisfactory if we could define ⊙ within the *phonology* in such a manner that its failure to violate faithfulness constraints would not require any additional stipulation.

McCarthy (2003) moves in this direction by suggesting in passing that the null output's correspondence relation with the input is *undefined*, and that as such it cannot violate any faithfulness constraints. This section expands on that idea, and section 4 studies the consequences of this move, addressing among other issues the distinction between the null output and a candidate with across-the-board deletion of all input material.

In the McCarthy and Prince (1995, 1999) version of correspondence theory, correspondence is defined as a relation $\mathfrak{R}$ between the segments of an input string *i* and the segments of an output string *o*. Requiring that $\mathfrak{R}$ be a relation says very little about $\mathfrak{R}$, since 'relation' is a very general concept. Tighter restrictions on $\mathfrak{R}$ are left up to ranked, violable constraints. For example, the constraint INTEGRITY is violated by one-to-many mappings from input to output (e.g., diphthongization or copying epenthesis), so INTEGRITY is equivalent to saying that $\mathfrak{R}$ must be a function from *i* to *o*. The constraint UNIFORMITY is violated by coalescence processes, in which a single input segment maps to two output segments. UNIFORMITY is equivalent to saying that $\mathfrak{R}$ is one-to-one from *i* to *o* or that its inverse R^{-1} is a function from *o* to *i*. In deletion, $\mathfrak{R}$ is a partial relation from *i* to *o*. The anti-deletion constraint MAX is equivalent to saying that $\mathfrak{R}$ is a total relation from *i* to *o*. In epenthesis cases, $\mathfrak{R}$ is not **onto** *o*, or, equivalently, $\mathfrak{R}^{-1}$ is a partial relation from *o* to *i*. The anti-epenthesis constraint DEP is equivalent to saying that $\mathfrak{R}$ is a relation from *i* **onto** *o*. If all of the aforementioned faithfulness constraints are obeyed, then $\mathfrak{R}$ is a total bijective (i.e., one-to-one and onto) function from *i* to *o*.

Our proposal alters these original assumptions about $\mathfrak{R}$. Faithfulness constraints no longer have responsibility for ensuring that $\mathfrak{R}$ is a total bijective function; instead, we leave that up to MPARSE. Except for the null output, then, $\mathfrak{R}$ is a total bijective function in all candidates, even candidates with deletion, epenthesis, coalescence, and diphthongization. The faithfulness constraints are redefined accordingly.

Deletion and epenthesis, which in the old model require $\mathfrak{R}$ or $\mathfrak{R}^{-1}$ to be a partial relation, will now involve mappings between segments and *e*, the identity element under concatenation. We implement this idea by using the notion of a *concatenative decomposition* of a string, which is defined in McCarthy and Prince (1993a: 89-90) for a very different purpose. Instead of a relation between the literal input string *i* and some literal output string *o*, as in the earlier theory of correspondence, $\mathfrak{R}$ is now to be understood as a relation between concatenative decompositions of *i* and of *o*, which will be notated as <i> and <o>, respectively.

Concatenative decomposition is defined and explained as follows in McCarthy & Prince (1993a: 89-90):

> Dfn. Concatenative Decomposition.
> A concatenative decomposition of a string S is a *sequence* of strings $\langle d_i \rangle_{j \leq i \leq k}$ such that $d_j \frown \ldots \frown d_k = S$.
> The concatenative decompositions of a given string are numerous indeed, because any of the d_i may correspond to the empty string *e*, which has the property that $s \frown e = e \frown s = s$, for any string s. Compare the role of 0 in addition: 3+0 = 0+3 = 0+3+0 = 3. All these refer to the same number, but all are distinct as expressions. The notion 'concatenative decomposition' allows us to distinguish among the different ways of expressing a string as a sequence of binary concatenations.

For example, among the concatenative decompositions of the string *ABC* are the sequences listed in (7).

(7) Some concatenative decompositions of *ABC*

<ABC>
<A, B, C>
<AB, C>
<A, CB>
<A, e, BC>
<A, e, B, e, C>
<e, ABC>
…

A concatenative decomposition of a string is a sequence of strings. Because $\mathfrak{R}$ is a relation between concatenative decompositions of strings, $\mathfrak{R}$ maps strings to strings rather than segments to segments. Thus, the new proposal can be referred to as *string-based correspondence*, to contrast it with the McCarthy & Prince (1995, 1999) version, with is *segment-* (or more generally *element-*) *based correspondence*. The difference becomes clear once we look at some of the unfaithful mappings that languages may permit under string-based correspondence. The hypothetical examples in (8) are representative. (To avoid confusion with the phonetic alphabet, the empty string has been indicated by # rather than the more usual *e*.)

(8) Some unfaithful mappings under string-based correspondence

a. Faithful

<i> = <a, p, i>	/api/
<o> = <a, p, i>	[api]
$\mathfrak{R}$ = {(a, a), (p, p), (i, i)}	

b. Deletion

<i> = <a, p, i> /api/
<o> = <#, p, i> [pi]
$\mathfrak{R}$ = {(a, #), (p, p), (i, i)}

c. Epenthesis

<i> = <#, a, p, i> /api/
<o> = <ʔ, a, p, i> [ʔapi]
$\mathfrak{R}$ = {(#, ʔ), (a, a), (p, p), (i, i)}

d. Coalescence

<i> = <p, an> /pan/
<o> = <p, ã> [pã]
$\mathfrak{R}$ = {(p, p), (an, a)}

e. Diphthongization

<i> = <p, ã> /pã/
<o> = <p, an> [pan]
$\mathfrak{R}$ = {(p, p), (ã, an)}

(Notational shortcut: Since we're dealing with strings and other sequences, everything should have indices, but we don't bother with them unless they're necessary to avoid ambiguity.) In deletion (b) or epenthesis (c), $\mathfrak{R}$ includes a mapping between a monosegmental string and the null string. In coalescence (d) or diphthongization (e), $\mathfrak{R}$ includes a mapping between a bisegmental (or perhaps longer) string and a monosegmental string.

In (8), $\mathfrak{R}$ is stated explicitly, but this is not usually necessary, because $\mathfrak{R}$ is often obvious from inspection of the <i> and <o> pair. In candidates that obey MPARSE, $\mathfrak{R}$ is a total bijective function: every segment in <i> has a unique correspondent in <o>, and every segment in <o> has a unique correspondent in <i>. Except for metathesis, which we discuss in the appendix, in MPARSE-obeying candidates the *k*th element of <i> is in correspondence with the *k*th element of <o> for all $1 \leq k \leq n$, where *n* is the cardinality of <i> and <o>.

To sum up the proposal, a candidate for the input *i* consists of an ordered 4-tuple ([o], <i>, <o>, $\mathfrak{R}$(<i>) →<o>). The output *o* is evaluated by markedness constraints, as usual. The concatenative decompositions <i> and <o>, together with the correspondence relation $\mathfrak{R}$(<i>) →<o>, are consulted by faithfulness constraints. All of the elements of the candidate are freely assigned by GEN, subject of course to the proviso that <i> and <o> must be possible concatenative decompositions of *i* and *o*. $\mathfrak{R}$(<i>) →<o> (usually referred to as just $\mathfrak{R}$) is any relation from <i> to <o> — that is, it is any subset of the Cartesian product {<i>}X{<o>}, letting {<x>} stand for the set of elements in the sequence <x> with their indices. Among the subsets of {<i>}X{<o>} is the null set Ø, whose importance will emerge when we look at MPARSE violators in section 4.

Given this revision in the definition of a candidate, the faithfulness constraints also need to be redefined. We consider each of the major faithfulness constraints in this section, and deal with a few other faithfulness constraints in the appendix.

The faithfulness constraint MAX militates against configurations in which some string(s) in <i> map to null string(s) in <o>. If it is to duplicate the effects of MAX in segmental correspondence, the string-correspondence version of MAX must assign a mark for every segment in an input string if that input string's output correspondent is the null string, #.

(9) MAX (new version)
    Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),
        for every string κ in <i> where $\mathfrak{R}(\kappa) = \#$
            for every segment in κ
                assign a violation-mark.

Under this definition, both of the candidates in (10) violate MAX twice. Furthermore, as we will see, candidate (b) also violates UNIFORMITY. Since they are otherwise identical, (a) harmonically bounds (b). This is a desirable result; when bisegmental or longer sequences delete, learners should not be forced to choose among two paths to the same end. Harmonic bounding of candidates like (b) ensures that there is no ambiguity: even when several adjacent segments are deleted, the winning candidate maps from a succession of monosegmental strings to instances of # and never from a bisegmental or longer string to a single instance of #.

(10) /ŋawuŋawu/ → [ŋawuŋa] 'termite' (Lardil)
    a. <i> = <ŋ, a, w, u, ŋ, a, w, u>
       <o> = <ŋ, a, w, u, ŋ, a, #, #>
    b. <i> = <ŋ, a, w, u, ŋ, a, wu>
       <o> = <ŋ, a, w, u, ŋ, a, #>

The definition of DEP is similar, but it uses $\mathfrak{R}$'s inverse, $\mathfrak{R}^{-1}$. Since $\mathfrak{R}$ is a bijective total function in all MPARSE-obeying candidates, $\mathfrak{R}^{-1}$ is also a bijective total function in those candidates.

(11) DEP (new version)
    Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),
        for every string κ in <o> where $\mathfrak{R}^{-1}(\kappa) = \#$
            for every segment in κ
                assign a violation-mark.

Under this definition, both of the candidates in (12) violate DEP twice. Furthermore, as we will see, candidate (b) also violates INTEGRITY. Since they are otherwise identical, (a) harmonically bounds (b). This too is a desirable result; when bisegmental or longer sequences are epenthesized, learners should not be forced to choose among two paths to the same end. Harmonic bounding of candidates like (b) ensures that there is no ambiguity: even when several adjacent segments are epenthesized, the winning candidate maps from instances of # to a succession of monosegmental strings and never from a single # to a bisegmental or longer string.[3]

(12) /kaŋ/ → [kaŋka] 'speech' (Lardil)
 a. <i> = <k, a, ŋ, #, #>
  <o> = <k, a, ŋ, k, a>
 b. <i> = <k, a, ŋ, #>
  <o> = <k, a, ŋ, ka>

The constraint UNIFORMITY (UNIF), whose segment-based version was invoked in the analysis of Swedish, exists primarily to regulate segmental coalescence. In segment-based correspondence, coalescence is the mapping of two input segments to a single output segment, usually preserving some of the features of each parent segment: $/p_1a_2n_3/ \rightarrow [p_1\tilde{a}_{2,3}]$. Under string-based correspondence, $\mathfrak{R}$ is always one-to-one in MPARSE-obeying candidates. Coalescence must therefore be analyzed as correspondence between a bisegmental string in <i> and a monosegmental string in <o>, as shown in (8)d. The definition of UNIFORMITY need not be so specific; in fact, it is useful if UNIFORMITY militates against all strings in <i> that are longer than a single segment:

(13) UNIFORMITY (new version)
 Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),
  for every string κ in <i>
   for every pair of segments in κ
    assign a violation-mark.

As defined, UNIFORMITY is violated not only by obviously coalescent mappings like (8)d, but also by mappings like (10)b, in which a bisegmental string in <i> maps to # in <o>. As was previously mentioned, candidates like (10)b are harmonically bounded by candidates like (10)a in which each segment separately maps to #. Tableau (14) shows why this harmonic bounding relationship obtains.

(14) Harmonic bounding of (10)b by (10)a

/ŋawuŋawu/	MAX	UNIFORMITY
→ [ŋawuŋa] <i> = <ŋ, a, w, u, ŋ, a, w, u> <o> = <ŋ, a, w, u, ŋ, a, #, #>	2	
a. ~ [ŋawuŋa] <i> = <ŋ, a, w, u, ŋ, a, wu> <o> = <ŋ, a, w, u, ŋ, a, #>	2	1 L

[3] Given what we have said about GEN, there can be candidates where # is in correspondence with #: <p, a, t, #> → <p, a, t, #>. Such candidates should be harmonically bounded, because otherwise they are equally harmonic with the intended winner, which lacks the gratuitous #→# mapping. One way to ensure this is to tweak the definitions of MAX and/or DEP so that they also penalize #→#.

The constraint INTEGRITY (INT) is violated by mappings in which a single input segment maps to two output segments, such as (8)e. INTEGRITY is the dual of UNIFORMITY in the same way that DEP is the dual of MAX.

(15) INTEGRITY (new version)
Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),
for every string κ in <o>
for every pair of segments in κ
assign a violation-mark.

Candidates like (12)b violate INTEGRITY as well as DEP (the latter assigns two marks) so they are harmonically bounded by candidates like (12)c, which violates only DEP. The argument is identical to (14), *mutatis mutandis*, and need not detain us further.

The constraint IDENT must also be revised to reflect the differences between string-based correspondence and the previous segment-based model. Four situations can be identified that the reformulation will need to address:

(i) Correspondence between a monosegmental string in <i> and a monosegmental string in <o>. In this case, IDENT is unremarkable; it requires featural identity between the unique segment in each string.

(ii) Correspondence between a monosegmental (or longer) string and the null string #. In earlier, segment-based correspondence, IDENT is defined in such a way that it is not violated in segmental deletion and epenthesis (though MAX- and DEP-feature constraints have been proposed as an alternative; see, for example, Causley (1997) and Lombardi (1998)). If this assumption is to be maintained under string-based correspondence, then segmental strings corresponding with # should not violate the reformulated IDENT constraint.

(iii) Coalescence and diphthongization, in which a bisegmental (or longer) string stands in correspondence with a monosegmental string. In segment-based correspondence, IDENT requires that each segment be featurally identical to all of its correspondents, with the ranking of various IDENT constraints determining which feature values are treated faithfully in coalescence and diphthongization.

(iv) Correspondence between bisegmental or longer strings in both <i> and <o>, such as <i>= <pat> and <o> = <pat>. Since the same results can be achieved with correspondence between monosegmental strings, it would be preferable if candidates like this were harmonically bounded, so as to avoid pointless and confounding analytic ambiguities.

The definition in (16) is intended to cover all of these situations.

(16) IDENT(αF) (new version)

Given a candidate ([o], <i>, <o>, $\Re$),

for every string κ in <i>, where $\kappa = \kappa_1 \ldots \kappa_n$ and $\Re(\kappa) = \lambda = \lambda_1 \ldots \lambda_m$,

assign one violation-mark for every pair (κ_p, λ_q) where κ_p is [αF] and λ_q is [-αF].

If, say, a bisegmental string in <i> maps to a monosegmental string in <o>, as in the coalescent mapping <p, an> → <p, ã>, then each of the segment pairs (a, ã) and (n, ã) is required to be featurally identical in every respect, exactly as the earlier version of IDENT worked. Mappings to or from the null string # do not violate IDENT because # contains no segments and therefore no feature values. Candidates that put two multisegmental strings into correspondence, such as <pat> → <pat> or <pan> → <pã>, incur pointless violations of IDENT constraints. The map <pat> → <pat>, for example, violates an IDENT constraint for every disagreeing feature value in the pairs (p, a), (p, t), (a, p), (a, t), (t, p), and (t, a). Since the map <p, a, t> → <p, a, t> produces the same result without these IDENT violations or any UNIFORMITY and INTEGRITY violations either, <pat> → <pat> is harmonically bounded by <p, a, t> → <p, a, t>. Hence, there is no ambiguity in the faithful mapping.

In conclusion, we have proposed a theory of correspondence based on strings rather than segments. The input *i* and the output *o* are represented by their concatenative decompositions <i> and <o>, which consist of sequences of segmental strings rather than sequences of segments. Deletion and epenthesis involve correspondence between monosegmental strings and the null string #, and the constraints MAX and DEP militate against correspondence with #. Coalescence and diphthongization involve correspondence between multisegmental strings and monosegmental strings, and the constraints UNIFORMITY and INTEGRITY militate against bisegmental or longer strings in <i> or <o>. When strings are in correspondence, IDENT requires that all of their constituent segments match pairwise in their featural composition. (Other faithfulness constraints are discussed in the appendix.)

The immediate goal of this reformulation is to support the proposition that correspondence is a total bijective function from <i> to <o> even in candidates that are unfaithful by reason of deletion, epenthesis, coalescence, or diphthongization. In segment-based correspondence, any of these types of unfaithfulness are sufficient to prevent correspondence from being a total bijective function. The larger goal of this reformulation is to identify any departure from a total bijective correspondence function as categorically different from simple unfaithfulness. If correspondence is not a total bijective function in some candidate, then that candidate is an instance of the null output. The next section explores this proposal in detail.

4. Properties of the null output under string-based correspondence

A null output is any candidate that violates MPARSE as defined in (17).

(17) MParse (new version)
Given a candidate ([o], <i>, <o>, ℜ),
if ℜ is not a total bijective function from <i> to <o>,
assign a violation-mark.

Under string-based correspondence, candidates that are unfaithful in the familiar ways have a correspondence relation that is a total bijective function. The null output, the candidate ⊙, has a correspondence relation that is partial, not bijective, or not a function. Any or all of these deficiencies in ℜ is sufficient to earn a candidate a violation-mark from MParse.

Our discussion of Swedish in section 2 identified an important characteristic that the null output *qua* candidate must have if it is to suffice as a theory of paradigmatic gaps: it must satisfy all constraints other than MParse, including the faithfulness constraint Max. This desideratum for a theory of the null output is discussed in section 4.1. Section 4.2 discusses another property of our theory of the null output: there are many MParse-violating candidates in every candidate set, but one of them, ⊙, harmonically bounds the others. Related topics discussed in that section include the strict categoricality of MParse and the effects of having a non-null candidate that nonetheless violates MParse.

4.1 ⊙ violates only MParse

The candidate ⊙ — that is, the null output — has two related properties: in the ([o], <i>, <o>, ℜ) ordered 4-tuple that represents ⊙, <o> is empty, and ℜ is undefined for all strings in <i> (that is, ℜ = Ø). Since it is undefined for all strings in <i>, ℜ is the most degenerate type of partial relation, and so ⊙ violates MParse.

Importantly, ⊙ violates no faithfulness constraints. In segment-based correspondence, ℜ is undefined for any input segment that is deleted in the output; but under the string-based regime, ℜ *is* defined for deleted segments, since they are in correspondence with the null string #. Because ⊙ has no correspondence relations, Max and all the other faithfulness constraints that mention correspondence relations are vacuously satisfied. Furthermore, Integrity is vacuously satisfied because <o> is empty, and Uniformity is satisfied as long as <i> contains no multisegmental strings. For example, the null output from input /pat/ is $⊙=([\ ], <p_1, a_2, t_3>, <\ >, Ø)$, and it satisfies every faithfulness constraint in Con.

A desirable result of string-based correspondence is that ⊙ is not the same as the candidate that has deleted all input material. Compare the null output $⊙=([\ ], <p_1, a_2, t_3>, <\ >, Ø)$ with the candidate $\Phi =([\ ], <p_1, a_2, t_3>, <\#_1, \#_2, \#_3>, \{(p_1, \#_1), (a_2, \#_2), (t_3, \#_3)\})$, which also has no overt phonological realization. As we noted in section 2, ⊙ is optimal in paradigmatic gaps, but Φ, even if it is not harmonically bounded (cf. Gouskova 2003), is rarely optimal — and definitely non-optimal in Swedish — because some of its Max violations can usually be avoided while still satisfying all markedness constraints ranked higher than MAX. For this reason, it is important that ⊙ and Φ be distinct candidates with distinct constraint violations, and indeed they are under string-based correspondence. Φ violates MAX once for every segment in the input, but it obeys MPARSE, while ⊙ violates MPARSE but obeys MAX and every other faithfulness constraint in CON.

Furthermore, ⊙ does not violate any markedness constraints, since it lacks output structure. All markedness constraints either militate against certain structures (e.g., NOCODA 'there are no codas') or demand that certain structures, if present, have specified properties (e.g. ONSET, 'any syllables have onsets').[4] Even constraints that seem to require the presence of structure, such as word minimality, are dependent on some other structure. Word minimality requirements derive from constraints specifying that every foot must be binary and every phonological word must contain at least one foot. Since ⊙ lacks even a phonological-word node, it vacuously satisfies the minimality constraints.

We are now close to an ideal of analytical simplicity in which ⊙ violates just the single constraint MPARSE. It remains to consider those (not uncontroversial) constraints that do not fit into the classic OT markedness/faithfulness typology.

Some versions of the variously-named MORPHREAL constraints stand outside the basic constraint typology. (References include, among others, Samek-Lodovici (1993), Akinlabi (1996), Gnanadesikan (1997), and Kurisu (2001).) In typical formulations, MORPHREAL demands that all morphemes have overt surface exponence. If 'exponence' is defined in terms of correspondence, then MORPHREAL is just another faithfulness constraint and hence unproblematic. If, however, exponence were defined in some other way, so that MORPHREAL acts like a faithfulness constraint but does not use correspondence, then ⊙ would presumably violate it. Generally, the modest literature on MORPHREAL does not offer much guidance on this question, but Kurisu (2001) is an exception.

Kurisu observes that if by 'morphemes have overt exponence' we mean 'morphemes have structure affiliated with them', certain morphological processes such as truncation or metathesis cannot be attributed to MORPHREAL. These processes remove or alter structure in the base of affixation, but they do not introduce new units of structure that could be regarded as 'affiliates' of an affix. Kurisu's alternative definition of MORPHREAL demands instead that an affixed form be 'phonologically different' from the output that obtains when the unaffixed base is fed to EVAL as an input. Thus, if an input consisting of a root and affix(es) maps to ⊙, this version of MORPHREAL is not violated unless the unaffixed root would also map to a phonologically empty output. For example, in the case of the Swedish adjectives considered in Section 2, because input /rädd/, when submitted to the phonology on its own, surfaces faithfully as [rädd], Kurisu's

[4] Strictly speaking, constraints of the second type may also be seen as banning particular types of structure- in the case of ONSET, onsetless syllables. Regardless of how one looks at it, the point remains that no markedness constraint demands the presence of structure as such.

formulation of MorphReal is not violated the mapping /rädd+t/ → ⊙, since ⊙'s empty output structure is, clearly, phonologically non-identical to [rädd].

Another class of constraints outside the basic markedness/faithfulness typology is trans-derivational antifaithfulness (TAF), proposed by Alderete (2001a, 2001b) (see also Horwoord (1999). Under this theory of morpheme realization, which is proposed as an alternative to MorphReal, affixes may be associated with one or more TAF constraints, which are literally negations of faithfulness constraints. Since ⊙ vacuously satisfies all faithfulness constraints, it will necessarily violate any TAF constraints that happen to be associated with its input morphemes. Even with these violations, ⊙ can still be optimal if, for example, the relevant TAF constraints are ranked below MParse. Still, adopting TAF theory costs us the assurance that ⊙ violates *only* MParse. The TAF proposal is far from uncontroversial; see Inkelas and Zoll (2003), Kurisu (2001), and van Oostendorp (2005) for discussion.

This will be all we have to say on this matter. For the remainder of this paper, we will treat ⊙ as violating only MParse, retaining the (not strictly necessary) working assumption that TAF constraints do not exist. With respect to at least Kurisu's version of MorphReal, however, we retain the luxury of being agnostic as to its existence.

4.2 ⊙ among the MParse violators

Simply by allowing Gen to create candidates where $\mathfrak{R}$ is not a total bijective function — that is, by identifying our revised MParse as a violable constraint — we ensure that ⊙ is a member of every candidate set. The candidate ⊙ has a phonologically null output and an undefined correspondence function. If we wish to avoid unnecessarily stipulative restrictions on Gen, then ⊙ is not the only MParse-violating candidate. Other possibilities include a phonologically non-null output combined with an undefined correspondence function, or a candidate with a phonologically non-null output and a correspondence relation that is a partial function from <i>. An example of the former is ([ʔə], <p, a, t>, <ʔ, ə>, Ø); an example of the latter is([pa], <p_1, a_2, t_3>, <p_1, a_2>, {(p_1, p_1), (a_2, a_2)}). Both violate MParse, though neither violates any faithfulness constraints.

If candidates like ([ʔə], <p, a, t>, <ʔ, ə>, Ø) or ([pa], <p_1, a_2, t_3>, <p_1, a_2>, {(p_1, p_1), (a_2, a_2)}) were ever to emerge as optimal, then chaos would rule. Because they obey all faithfulness constraints, the triumph of either one of them would mean that arbitrary deletions and insertions can make an end run around the theory of faithfulness, leaving OT teetering on the precipice of changing every word in every language into [ba] (cf. Chomsky 1995: 380n., Uriagereka 1998: 558n.).

In reality, these candidates and others like them pose no analytic worries because they are harmonically bounded by ⊙, so they can never be optimal under any ranking of Con. This is because any candidate with output structure will incur at least one markedness violation, whereas ⊙ incurs none. Even if we adopt Gouskova's (2003) stance against 'nihilistic' markedness constraints like *Struc ('the output contains no structure'), this still follows because the markedness constraints in CON impose conflicting demands that cannot all be satisfied except in the total absence of structure.

We may illustrate this by attempting to construct a non-null candidate with no markedness violations. If all distinctive features are binary, and for every feature one value is marked and the other unmarked, our first step is to have every vowel and consonant be set to the unmarked value of every feature. Further, the unmarked syllable shape is CV, so presumably [ʔə.ʔə] (or the like) incurs no violations of featural markedness or syllable structure constraints.

But the search for a candidate with no markedness violations fails once we look at higher levels of prosodic structure. If [ʔə.ʔə] is parsed into a single disyllabic foot, then NONFINALITY is violated, because the final syllable in the prosodic word is parsed into a foot. Furthermore, depending on which syllable is stressed, the foot violates either IAMB or TROCHEE. We can satisfy all three of these constraints by creating a non-final monosyllabic foot or no foot at all, but this violates PARSE-SYLLABLE: 'All syllables are parsed into feet.' Obviously, if CON were to lack one of these constraints, then this particular avenue would be closed off, but all seem to be well-supported.

We could go on listing other cases of competing markedness demands but will refrain from belaboring the point. We can quite safely conclude that any candidate that contains phonological structure will have to incur one or more markedness violations, and hence if such a candidate also violates MPARSE, it will be harmonically bounded by ⊙, which has no markedness violations.[5]

A final remark. This assurance of harmonic bounding by ⊙ crucially depends on MPARSE issuing a categorical assessment: any candidate in which $\mathfrak{R}$ is wholly or partly undefined incurs exactly one violation-mark from MPARSE. If MPARSE instead assigned one violation-mark for every input segment that is not in the domain of $\mathfrak{R}$ (like MAX in segment-based correspondence), then ⊙, where $\mathfrak{R}$ is undefined for *every* input segment, would incur more MPARSE violations than candidates where $\mathfrak{R}$ is undefined for some, but not all, input segments

[5] Obviously, candidates with partially-undefined $\mathfrak{R}$ could also incur faithfulness violations, but whether they do or not is irrelevant, since even if such candidates are fully faithful to those parts of the input to which they do hold a defined correspondence relation, they still incur markedness violations and so are still harmonically bounded.

(18) Hypothetical tableau under incorrect definition of MParse

/patuki/	MParse	Markedness	Max
→ tuki <i> = <p, a, t, u, k, i> <o> = <t, u, k, i> $\Re$ = {(t, t), (u, u), (k, k), (i, i)}	2	1	
a. ~ ⊙ <i> = <p, a, t, u, k, i> <o> = < > $\Re$ = Ø	6 W	L	

Under this incorrect definition of MParse, the winning candidate is not harmonically bounded (obviously, since otherwise it could not be the winner). The problem with (18) is that it fundamentally subverts the theory of faithfulness: the mapping /patuki/ → [tuki] seems to involve deletion, but it does not violate Max. To avoid unwanted outcomes like this, MParse must be strictly categorical in its assessments, granting equal status to all candidates in which $\Re$ is not a total bijective function from <i> to <o>. The definition of MParse in (17) has exactly this property.

5. MParse and the lexicon

This section addresses several topics bearing on MParse's relationship to morphology and the lexicon: relativization of MParse constraints to specific morphological categories; the different effects of MParse violation on words and phrases; and the consequences of positing MParse constraints for base-reduplicant and output-output correspondence relations.

5.1 Morphological restrictions on MParse

As we noted in section 2, the activity of MParse constraints is relativized to particular morphological contexts. That is because unfaithful alternatives to the null output are unavailable only for certain morphological categories — in Swedish, for instance, OCP(cor) is satisfied by coalescence in verbs but not in adjectives. In this section we turn to the question of how to implement this relativization.

The Swedish case also makes it clear that we cannot simply relativize MParse to specific affixes, since the neuter singular suffix /-t/ generates gaps when affixed to an adjective that ends in a coronal geminate but not when affixed to a verb that does. The situations where a given MParse constraint applies must, therefore, be yet more specific. What we need is something in the spirit of Rice's (2005) proposal that what MParse does is to militate in favor of all slots in paradigms being filled.

We propose to implement this in a rather literal way. If we assume that there is a universal set of morphological features, then the set of possible paradigmatic slots is simply the set of morphological feature combinations made possible by UG. For any feature combination, CON (potentially) contains an MPARSE constraint that applies when a word bearing those features is submitted as an input to the phonology. In Swedish, for instance, the constraints relevant to the gaps in adjective paradigms, with their ranking, are something like OCP(cor) >> UNIFORMITY >> MPARSE(adj.-neuter-sing.).[6]

This approach is fully compatible with, but does not require, a theory where paradigms are evaluated in parallel as candidates (see the various contributions to Downing, Hall, and Raffelsiefen 2005, and, for specific discussion of the null output in this context, Rice 2005). Schematically, from the input paradigm </A+x/, /A+y/>, the competing candidates are ungapped <[A+x], [A+y]> and various combinations of gaps, <[A+x], ⊙>, <⊙, [A+y]>, and <⊙, ⊙>. On this view, there are separate instances of the input-output correspondence relation for each paradigm slot: /A+x/ is in correspondence with [A+x] and /A+y/ is in correspondence with [A+y]. Separate MPARSE constraints pertain to the +x and +y morphological feature combinations, with <⊙, [A+y]> and <[A+x], ⊙> violating these resepective constraints and <⊙, ⊙> violating both of them. Thus, gapped <[A+x], ⊙> will win if MPARSE(+x) dominates any constraints that [A+x] violates and MPARSE(+y) is dominated by some constraint that [A+y] violates.

5.2 MPARSE in word- vs. phrase-level phonology

Consider once again the Swedish adjectives. Suppose that the neuter singular adjective /radː-t/ is in the input of an utterance which also contains a neuter singular past participle of a verb, such as /reːd+d+t/, where we expect coalescence to apply. Since such verb forms can surface having undergone coalescence, it would have to be the case that MPARSE(verb-past.pple.-neuter) dominates UNIF. Since MPARSE constraints evaluate the total-bijective-functionhood of $\Re$ over the entire input, this ranking implies that ⊙ will lose to candidates where coalescence takes place, *even in the neuter singular adjective*. Such adjectives will surface just in case they occur in the same utterance as forms where coalescence can occur:

[6] There are cases where the gap is restricted not only morphologically but also lexically. For example, as discussed by Halle (1973), Hetzron (1975), and Iverson (1981), about 100 Russian second-conjugation verbs idiosyncratically lack a first person singular non-past form, thereby avoiding a [d]~[ʒ] alternation. The complication is that only some verbs meeting these phonological and morphological conditions behave in this way; others simply undergo the alternation.

Under our approach, we assume that there is a constraint MPARSE(1st.sg.nonpast). This constraint must dominate the faithfulness constraints against the /d/ → [ʒ] mapping — presumably something like IDENT(palatal) and IDENT(cont) — because ⊙ loses to candidates where the palatalization process is able to apply. As for the verbs that do not undergo this process in the first singular non-past, they are indexed to a lexically-specific version of one of the faithfulness constraints, which is ranked above MPARSE(1st.sg.nonpast). Such constraints, or something of equivalent effect, are required anyway to account for lexical stratification and other patterns of exceptions (as in Ito and Mester 1999).

(19) Unwanted potential effect of MPARSE in phrasal phonology

…/reːd+d+t/…/rädː-t/…	MPARSE (verb-pst.pple.-neut.)	UNIFORMITY	MPARSE (adj.-neut.-sg.)
→ … retː ... ratː …		3	
a. ~ ⊙	1 W	L	1 W

In order for individual words ruled out on phonological grounds to be barred from appearing in any utterance of a given language, we must recognize some separation of word-level and phrase-level phonology. We need not go as far as stratal OT, which posits different grammars for words and phrases (see, among many others, Kiparsky 2000); rather, all we need to do is retain the basic idea of Lexical Phonology that the phonological component of the grammar is involved in calculating the contents of the lexicon. At some stage of word-formation, each individual morphosyntactic word is fed to EVAL as an input. If the output of the phonology is ⊙, then no form corresponding to the given set of morphological features is entered into the lexicon. The syntax therefore has no access to such items, and can never submit to the phonology utterances like that illustrated in (19) that contain them.

This model, crucially, has no need of multiple strata. Whether the input to the phonology is a single word or a full utterance, the set of constraints and their ranking is always the same. Indeed, the only thing that allows us to distinguish whether 'word' or 'phrase' phonology is going on is the size of the object which the morphosyntactic component of the grammar submits to EVAL as an input.

This is not to say, however, that the null output is an impossible outcome in the phrasal phonology. Even when an utterance is assembled out of words drawn from the lexicon, thereby excluding paradigmatic gaps, the utterance as a whole could yield the null output as a response to phonological conditions that obtain in external sandhi. Since the candidate ⊙ for a multi-word utterance violates the MPARSE constraints relevant to the feature combinations of every word in that utterance, the ranking conditions that can produce this result are rather special, though the theoretical possibility is certainly there.

This possibility may be more than merely theoretical. Among others, Zec & Inkelas (1990) and Golston (1995) have argued that phonological restrictions can make sentences ungrammatical. (For the contrary view, that the phonology cannot exert influence on the syntax, see Zwicky & Pullum (1986), Myers (1987), and Vogel & Kenesei (1990).) For example, according to Zec & Inkelas, Heavy NP Shift in English is only permitted when the postposed NP is not one that is realizable as a branching phonological phrase.

It would be beyond the scope of this paper to give MPARSE-analyses of all claimed cases of phonological filtering of syntactic forms. However, it does seem that the current proposal offers a coherent means of implementing this: when a PF form submitted by the syntax as an input to the phonology yields ⊙, the syntax is forced to 'go back' and try another form. This sort of model is also relevant to the matter of syntactic periphrasis and how it relates to listed allomorphy, a matter we discuss in section 6.1.

To sum up, we have proposed that *lexical* gaps are created due to optimality of ⊙ when single words (or paradigms) are run through the phonology; when whole phrases are run through and the null output wins, the result is not and cannot be the exclusion from the lexicon of one (or all) of the morphological forms present in the input, but rather the ruling out of the input's syntactic configuration on phonological grounds. This approach to lexical gaps has relevance to three other issues in the general theory of gaps.

First, we are not aware of any language in which some paradigm is incomplete due to sandhi or other phrase-level processes being idiosyncratically blocked from applying to that morphological category. That is, lexical gaps are the result of word phonology. This is obviously not unexpected, given what we have said. The contents of the lexicon are determined solely by word-internal phonology, so we do not expect to find nor do we actually observe cases where, say, an adjective lacks a neuter singular form because this might yield a marked structure in some junctural situations. Sandhi effects can, arguably, block an entire utterance, but they cannot produce a paradigmatic gap.

Second, this approach accounts for gaps in derivational morphology as well. Unlike inflection, which is usually robustly productive, derivational processes often exhibit entirely idiosyncratic gaps that cannot be attributed to phonological factors. Nonetheless, there are instances where derivational morphology does seem to be blocked phonologically (see Raffelsiefen (2004) for discussion of a number of cases of this type) and, in the interest of maximum generality, we would like the theory of gaps to subsume these cases also.

We make two additional assumptions to accommodate derivational gaps: MPARSE constraints can be indexed to derivational as well as inflectional morphology; and like inflected stems, uninflected (though possibly derived) stems are run through the phonology and entered into the lexicon only if the result is not ⊙. From this it follows that a phonologically motivated gap in derivation will produce no lexical entry whatsoever, so there is no derived form to undergo inflection or participate in the syntax.

Third, our assumption about the connection between lexical listing and non-optimality of ⊙ bears on a puzzling question: why exactly does optimal ⊙ result in a gap? Clearly, when a whole utterance maps to ⊙, the output of the phonology is phonetically uninterpretable. However, when the phonology is doing the job of calculating the lexicon, it is not so obvious that ⊙'s victory for some paradigmatic slot or derivational form should result in a gap. This is due to the fact that the lexicon is taken under many (though by no means all) syntactic theories to contain phonologically empty morphemes such as *pro*. Why should these morphemes, but not ⊙, be allowed to pass into the lexicon, when both have identically empty output structures?

There is a difference: morphemes like *pro* have empty underlying representations as well. (Obviously, there are no data that could ever induce a learner to posit a non-empty underlying representation for *pro*.) Therefore, we need only suppose that lexical insertion is sensitive to the difference between a candidate that maps from structure to an empty output (i.e., ⊙) and a candidate that maps from an empty input to an empty output. When the phonology is selecting an output utterance to be submitted for phonetic interpretation, however, we do not need to make the implausible assumption that the phonetic interpretation function has access to the input portion of phonological candidates. This is because, as mentioned, the optimality of ⊙ in the phrasal phonology does not result in lexical gaps, but rather rules out a syntactic configuration.

5.3 MPARSE and other correspondence relations

Correspondence theory recognizes more than one dimension of faithfulness (McCarthy and Prince 1995, 1999). In addition to input-output (IO) correspondence, which has been the focus of our attention thusfar, candidates with a reduplicative morpheme in the input also contain a base-reduplicant (BR) correspondence relation. Further, it is widely accepted that there exists some form of output-output (OO) correspondence between morphologically related forms (Benua 1997). It is a basic assumption of the original correspondence theory that the various dimensions of correspondence have the same formal properties. It seems desirable to retain this assumption in our revised theory of correspondence, and this means *inter alia* that there must be distinct MPARSE constraints for each authentic correspondence relation, just as there are distinct faithfulness constraints for each correspondence relation.

In reduplicative correspondence, there is a relation between the reduplicant, which is defined as the output exponent of the reduplicative morpheme RED, and the base, which is the output string to which the reduplicant is affixed (to the reduplicant's right in prefixing reduplication and to its left in suffixing reduplication). In our terms, reduplicative correspondence maps a concatenative decomposition of the base onto a contatenative decomposition of the reduplicant. Since there are separate BR and IO correspondence relations, and the base bears both, the base can in principle have different concatenative decompositions for BR and IO purposes — e.g., if there is coalescence in the reduplicant but not the base, or if the reduplicative base and the nonreduplicative portion of the output are not coextensive, as in infixing reduplication. The concatenative decompositions of base and reduplicant will be denoted by <b> and <r>, respectively.

It follows that for each of the two relevant correspondence relations, $\Re_{IO}$ and $\Re_{BR}$, there exists an MPARSE constraint that tests whether it is a total bijective function. A welcome result of this assumption is that, even when the input includes RED, ⊙ violates only MPARSE-IO. In this case, for ⊙, <o> and hence <b> are empty, and <r> is empty as well. $\Re_{IO}$ is not a total bijective function, in violation of MPARSE-IO, but MPARSE-BR is vacuously satisfied. This is because $\Re_{BR}$, being a relation between empty sequences (or, strictly speaking, from the empty sequence to itself), is vacuously a total bijective function. The situation here is parallel to *pro*, which is empty in both <i> and <o>, so MPARSE-IO is vacuously satisfied.

The situation is a little more complicated when MPARSE-IO is undominated but MPARSE-BR is low-ranked. For concreteness, suppose that MAX-BR and NO-CODA dominate MPARSE-BR, as in (20). (We use a violation tableau instead of a comparative tableau because the purpose of (20) is to investigate potential winners rather than locate a specific winner.)

(20) Effects of MPARSE-BR violation

/RED-pam/	MAX-BR	NO-CODA	MPARSE-BR
a. pam-pam <b> = <p, a, m> <r> = <p, a, m> $\mathfrak{R}_{BR}$ = {(p, p), (a, a), (m, m)}		**!	
b. pa-pam <b> = <p, a, m> <r> = <p, a, #> $\mathfrak{R}_{BR}$ = {(p, p), (a, a), (m, #)}	*!	*	
c. pa-pam <b> = <p, a, m> <r> = <p, a> $\mathfrak{R}_{BR}$ = {(p, p), (a, a)} (NB: $\mathfrak{R}_{BR}$(m) is undefined.)		*	*
d. pam <b> = <p, a, m> <r> = < > $\mathfrak{R}_{BR}$ = Ø		*	*
e. ʔə-pam <b> = <p, a, m> <r> = <ʔ, ə> $\mathfrak{R}_{BR}$ = Ø		*	*

Candidates (c-e) in (20) cannily avoid violating MAX-BR (and, in the case of (e), DEP-BR) by having incomplete and even nonexistent BR correspondence relations. Because all MPARSE failures are treated equally, these candidates are not distinguished by the constraints shown in the tableau. The harmonic bounding relationships among (c-e) are instructive, however. Candidate (c) is harmonically bounded by (d) and (e) because (c)'s added *pa* sequence incurs additional markedness violations that (d) and (e) avoid. Although the reasoning here parallels our argument in section 4.2, there is an important difference: candidate (d), with the null reduplicant, does not harmonically bound candidate (e), where the reduplicant is realized by minimally marked structure. Candidates (e) is favored over (d) by any constraints demanding presence of phonological material in the reduplicant. MORPHREAL is such a constraint, if indeed it exists (cf. section 4.1); a constraint like FTBIN (foot binarity) could also have this effect.

Conversely (d) is favored over (e) by any constraints that militate against even (e)'s minimally marked reduplicant.

In sum, the existence of MPARSE-BR predicts a system of reduplication where copying is either exact or doesn't happen at all. In a language with a ranking like (20), the input /RED-ta/ yields [ta-ta], but the input /RED-pam/ yields either [pam] or [ʔə-pam]. Significantly, this is not an expansion of the earlier reduplicative typology. The reason is that this system could also be analyzed as emergence of the unmarked (McCarthy and Prince 1994) with crucial domination of MAX-BR (and, in the case of (e), DEP-BR). Close parallels include the Cebuano example in (29), Tagalog, and Makassarese (Aronoff *et al.* 1987, Carrier-Duncan 1984, McCarthy and Prince 1994). [7]

MPARSE-OO proves to be more troublesome, leading to unlikely predictions and interfering with our results about harmonic bounding of non-null MPARSE violators. The problems are best explained with an example. Pater (2000) attributes 'cyclic' stress in English to a version of OO-IDENT(stress). The word *condensation* [ˌkɑnˌdɛnˈsejʃən] is in OO correspondence with *condense* [kənˈdɛns]. Satisfaction of OO-IDENT(stress) accounts for the stress (and consequent lack of vowel reduction) on the second syllable of *condensation*, which thereby more closely resembles *condense.*

Satisfaction of OO faithfulness constraints is often imperfect, and the initial vowels of *condense* and *condensation* regularly alternate between [ə] in the former and [ɑ] in the latter, indicating that OO-IDENT(low) is crucially dominated in English. Now, imagine a language that is like English except that OO-IDENT(low) itself dominates MPARSE-OO. In that case, the presence of the [ə] ~ [ɑ] alternation in *condense*/*condensation* will be sufficient to favor a candidate in which the OO correspondence relation between these two words is undefined. If $\mathfrak{R}_{OO}$ is undefined, then OO-IDENT(low) is vacuously satisfied despite the [ə] ~ [ɑ] alternation. Furthermore, OO-IDENT(stress) is vacuously satisfied as well, even if *condensation* has a 'non-cyclic' stress pattern. In sum, the ranking OO-IDENT(low) >> MPARSE-OO predicts that pairs of related words that alternate in vowel height will not show any OO faithfulness effects whatsoever. More generally, rankings like this predict that an OO faithfulness effect can be pervasive in a language yet absent in just those forms that undergo a specific, unrelated alternation.

This prediction is bizarre and surely incorrect. The source of this prediction is the implicit assumption that candidates can differ solely in whether they have an OO correspondence relation. If we eliminate this assumption, then we may succeed in eliminating MPARSE-OO and this unwanted prediction.

IO and BR correspondence relations are freely assigned by GEN. A consequence of this freedom of analysis is that two candidates can differ solely in their correspondence relations (e.g., Tübatulabal initial-*ʔ* reduplication is structurally ambiguous between

[7] If it should prove necessary to eliminate the alternative, MPARSE-violating mode of emergence of the unmarked, that could be accomplished by the expedient of requiring MPARSE-BR to dominate MPARSE-IO universally.

[ʔ$_1$u$_2$n$_3$-d$_1$u$_2$m$_3$uːga] and [ʔu$_2$n$_3$-d$_1$u$_2$m$_3$uːga] (Alderete *et al.* 1999)). There is no reason to allow such freedom in OO correspondence. Rather, OO correspondence relations can (almost) always be computed from IO correspondence relations, generalizing McCarthy's (2005a) proposal about intraparadigimatic faithfulness. The OO correspondence relation between *condense* and its derivative *condensation* is not a result of free invention by GEN, to be varied or dispensed with at will. Rather, that OO correspondence relation is computed from the IO correspondence relations that *condense* and *condensation* have with that which is common to their inputs, the stem /kɑndɛns/. Given any pair of morphologically related output forms and their IO correspondence relations, their OO correspondence relations are in general fixed, as in this example.[8]

Since the OO correspondence relations are computed by GEN rather than assigned by GEN, the character of OO correspondence is fundamentally different from IO or BR correspondence. In particular, there is no need for a constraint MPARSE-OO because there is no possibility of violating it: if MPARSE-IO is satisfied by both the base and the derived form, as it must be if they are non-null, then the OO correspondence relation between the base and derived form is a given and cannot be undefined.

This result is important for another reason: under the right conditions, MPARSE-OO could interfere with our result (section 4.2) that ⊙ harmonically bounds all other violators of MPARSE-IO. Consider what happens if we include MPARSE-OO in the analysis of Swedish (cf. (6)). (MPARSE-OO is not rankable with respect to the other two constraints. <o1> and <o2> are there for the OO correspondence relation; they are used to designate the concatenative decompositions of the output form from unaffixed /rädː/ (the 'base', in Benua's terminology) and the output from affixed /rädː-t/, respectively.)

[8] The story of OO is not quite finished, however. We need to deal with those aspects of the output that are not in the shared input: epenthetic segments and affixes that are present in the derived form but not the base. English level 2 suffixes show that OO faithfulness constraints can cause a vowel that is epenthesized in the simple form to be carried over to the derived form, even where it is not required for phonotactic reasons: *meter* ~ *metering* (cf. *metric*). This issue could perhaps be addressed with constraints on faithfulness to the syllabic roles of non-epenthetic segments. As for the second point, Gouskova (2004) argues that the affix added to the derived form violates OO-DEP relative to the base, from which it follows that affixes (in particular, reduplicative affixes) will be minimal in size. To use OO-DEP as Gouskova proposes, the concatenative decomposition of the output form of the base must include instances of # standing in OO correspondence with the segments of the affix.

(21) Unwanted effect of MPARSE-OO

/rädː-t/	UNIFORMITY	MPARSE-OO	MPARSE-IO
→ rädː <i> = <r, ä, dː, t> <o> = <r, ä, dː> $\mathfrak{R}_{IO}$ = {(r, r), (ä, ä), (dː, dː)} (NB: $\mathfrak{R}_{IO}$(t) is undefined.) <o1> = < r, ä, dː> <o2> = < r, ä, dː> $\mathfrak{R}_{OO}$ = {(r, r), (ä, ä), (dː, dː)}			1
a. ~ rätː <i> = <r, ä, dːt> <o> = <r, ä, tː> $\mathfrak{R}_{IO}$ = {(r, r), (ä, ä), (dːt, dː)} <o1> = < r, ä, dː> <o2> = < r, ä, tː> $\mathfrak{R}_{OO}$ = {(r, r), (ä, ä), (dː, tː)}	1 W		L
b. ~ ⊙ <i> = <r, ä, dː, t> <o> = <> $\mathfrak{R}_{IO}$ = Ø <o1> = < r, ä, dː> <o2> = < > $\mathfrak{R}_{OO}$ = Ø		1 W	1

As before, UNIF rules out coalescent [rätː]. The null output violates both MPARSE constraints, since its correspondence relations to both the input /rädː-t/ and the OO base [rädː] are undefined. The problematic winning candidate is [rädː] with the IO correspondence relation {(r, r), (ä, ä), (dː, dː)} — that is, where input /-t/ is not in correspondence with anything, including the null string. Because it overlooks /-t/, $\mathfrak{R}_{IO}$ is not a total function from <i>, so MPARSE-IO is violated. But MPARSE-OO is satisfied, since the OO base [rädː] and its 'affixed' derivative [rädː] are identical. MPARSE-OO clearly threatens this analysis and the theory in a rather fundamental way. (This is similar to the situation with antifaithfulness constraints.) Obviously, with the elimination of MPARSE-OO from the theory, the threat dissolves.

6. Extensions of the proposal

This section describes some applications of string-based correspondence that go beyond paradigmatic gaps. In 6.1, we describe how the null output can be useful in a theory of phonologically-conditioned allomorphy. Section 6.2 shows that string-based correspondence supplies a coherent definition of the notion 'unfaithful mapping', which may be useful in the analysis of language learning, optional processes, and phonological opacity.

6.1 The null output in phonologically-conditioned allomorphy

Many languages have morphemes with two or more surface alternants that are not phonologically related but are phonological conditioned in their distribution. Because these alternants (the 'allomorphs') are not phonologically related, they cannot be derived from a common underlying source and must be lexically listed. But because their distribution is phonologically conditioned, phonological constraints must be involved in allomorph selection. A by-now standard approach in OT is to suppose that the lexically listed allomorphs supply multiple underlying forms that, together with their outputs, compete in a single tableau.[9] Because there are multiple underlying forms, the output candidates derived from the different allomorphs are equally faithful, so the distribution of allomorphs is determined by markedness constraints.

For example, the third person masculine singular object/possessor enclitic in Moroccan Arabic appears as [h] following a V-final stem and as [u] following a C-final stem (Harrell 1962). Mascaró (1996) analyzes Moroccan with the rankings shown in (22) and (23).

(22) 'his error'

/xtˤa +{h, u}/	ONSET	NOCODA
→ xtˤah (wrt /xtˤa+h/)		1
a. ~ xtˤa.u (wrt / xtˤa+u/)	1 W	L

(23) 'his book'

/ktab +{h, u}/	ONSET	NOCODA
→ kta.bu (wrt /ktab+u/)		1
a. ~ ktabh (wrt /ktab+h/)		2 L

In (22), the winning candidate is a faithful parse of a stem with the underlying /h/ suffixal allomorphy. The /h/ is parsed as a coda, but the alternative has an onsetless syllable, and ONSET dominates NOCODA. In (23), by contrast, both choices do equally on ONSET, and NOCODA breaks the tie in favor of [u]. (*COMPLEX is also potentially relevant.) Crucially, analyses of this sort assume that each candidate stands in correspondence with, and is thus required to be faithful to, only one of the listed allomorphs of any given morpheme. This ensures that markedness is able to make the choice, as in (22)-(23), since choosing either allomorph over the other makes no difference in faithfulness cost.

[9] Output constraints were first applied to allomorphy by Siegel (1974). The idea of lexical entries as sets of allomorphic alternants originated with Hudson (1974) and is adopted by Hooper (1976) (though see Harris 1978, 1985 for rule-based and representational alternatives, respectively). S. R. Anderson's (1975) proposal that modularity is not based on ordering is also relevant here

There is a considerable literature applying OT to problems in allomorphy or lexical selection, beginning with Mester (1994) and including Alcantará (1998), Anttila (1997), Bresnan (2001a, 2001b), Burzio (1994, 1997), Drachman, Kager, and Drachman (1997), Grimshaw (1997), Hargus (1995), Hargus and Tuttle (1997), Kager (1996), Lapointe and Sells (1997), Mascaró (1996), McCarthy and Prince (1993b: Chapter 7), Perlmutter (1998), Russell (1995), Tranel (1996a, 1996b, 1998), and Urbanczyk (1999).

An important property of the Moroccan Arabic example and others discussed by Mascaró is that both allomorphs are marked, but in complementary contexts. This allows markedness constraints to take on the entire burden of allomorph selection. In some allomorphic systems, however, markedness cannot do the whole job. Rather, one allomorph has priority over the other; the role of markedness is limited to dislodging the privileged allomorph in certain contexts.

McCarthy & Prince (1993b: chapter 7) put MPARSE to use in their analysis of just such a case, the ergative suffix in Dyirbal (Dixon 1972). The ergative is marked by /-ŋgu/ on disyllabic V-final nouns, but by /-gu/ on longer V-final nouns:

(24) Dyirbal ergative

yaɽa-ŋgu	'man'
yamani-gu	'rainbow'
balagara-gu	'they'

McCarthy & Prince relate the distribution of the /-ŋgu/ allomorph to the prosodic structure of the language. Main stress falls on the initial syllable and feet are trochaic, so the disyllabic bases to which /-ŋgu/ is attached are coextensive with the head foot. The constraint in (25) enforces this requirement.

(25) AFX-TO-FT

The base to which /-ŋgu/ is affixed is the head foot.

The /-ŋgu/ allomorph has higher priority — it is 'tried first'. When the base is disyllabic, AFX-TO-FT is satisfied without further ado: [(yaɽa)$_{Ft}$-ŋgu]. But when the base is trisyllabic or longer, AFX-TO-FT cannot be satisfied and the null output wins instead, under a ranking where AFX-TO-FT dominates MPARSE, as shown in (26).

(26) AFX-TO-FT >> MPARSE

/yamani-ŋgu/	AFX-TO-FT	MPARSE
→ ⊙		1
a. ~ (ya.ma)$_{Ft}$ni-ŋgu	1 W	L

Another logical possibility, post-head-foot infixation as in *[(ya.ma)$_{Ft}$-ŋgu-ni], can be ruled out by a constraint on root contiguity or alignment of /-ŋgu/.

Normally the optimality of ⊙ will result in a gap. Because in this case there is a second-priority allomorph available, however, the grammar will now try the same input (/yamani/ + ergative) but with the /-gu/ allomorph instead of the /-ŋgu/ allomorph. Since /-gu/ is not indexed to AFX-TO-FT, it cannot violate it, and so we get a non-null output:

(27) Selection of lower-priority allomorph

/yamani-gu/	AFX-TO-FT	MPARSE
→ (ya.ma)$_{Ft}$ni-gu		
a. ~ ⊙		1 W

A key property of this analysis is the need for a stipulated priority relationship among allomorphs. If candidates corresponding to /-ŋgu/ and to /-gu/ were evaluated in parallel, as shown in the Moroccan Arabic example earlier, both would perfectly satisfy AFX-TO-FT when suffixed to a disyllabic base: [(yaɽa)$_{Ft}$-ŋgu], *[(yaɽa)$_{Ft}$-gu]. The competition between [(yaɽa)$_{Ft}$-ŋgu] and *[(yaɽa)$_{Ft}$-gu] would then fall to other markedness constraints, and the highest ranking markedness constraint that distinguishes between these candidates would have to favor [(yaɽa)$_{Ft}$-ŋgu] over *[(yaɽa)$_{Ft}$-gu]. But it is by no means clear — indeed it is quite unlikely — that CON supplies any such constraint. Worse yet, there is no shortage of markedness constraints that exercise the wrong preference, among them markedness constraints against nasals (and against velar nasals specifically) as well as any constraint that enforces a preference for shorter allomorphs. (On this last, see Hargus's (2000) BREVITY and Gouskova's (2004) use of OO-faithfulness to minimize reduplicants.)[10]

In assuming that the priority relationship among allomorphs is listed lexically, we follow Bonet, Lloret, and Mascaró (2003), though we depart from them in how this lexical information affects the output. Instead of an MPARSE-based system, they take a single-evaluation approach to allomorphy, as in (22) and (23), augmented with the constraint PRIORITY.

(28) PRIORITY (in Bonet *et al.* (2003) system)
Respect ordering relations on lexical material.

This is a type of faithfulness constraint, favoring those allomorphs that appear higher in the lexical listing. Differences between the MPARSE-based approach and the PRIORITY-based approach are not very great, but it is worth noting that PRIORITY must evaluate candidates gradiently to accommodate systems with more than two allomorphs of a single morpheme. For instance, in Bonet *et al.*'s analysis of Catalan, a three-allomorph priority hierarchy is required for the masculine gender suffix: [∅ > u > ə]. This means that PRIORITY must assign one violation-mark for the [-u] allomorph and two violation-marks for the [-ə] allomorph. If, as a matter of principle, gradient evaluation is banned for OT constraints (McCarthy 2003), then that is a reason to be skeptical of PRIORITY and a theory of allomorphy that requires it.

[10] Another example with the same basic character as Dyirbal comes from Axininca Campa (Payne 1981). Noun stems with two vocalic moras take the genitive suffix allomorph [-ni], whereas longer stems take the allomorph [-ti]: [no-mi:-ni] 'my otter', [no-mapi-ni] 'my rock', [no-maini-ti] 'my bear'. The problem for a fully parallel analysis lies in identifying a markedness constraint that would favor [no-mapi-ni] over *[no-mapi-ti].

Picanço (2002) adopts a different approach to arbitrary preference. He assigns a constraint of the PARSE-MORPH family (Akinlabi 1996) to each allomorph. A candidate violates PARSE-MORPH(X) if it fails to pick allomorph X, so the relative ranking of the PARSE-MORPH constraints that are specific to each allomorph determines their (i.e., the allomorphs') priority. Though this approach initially seems plausible, it makes a bizarre prediction: unless higher-ranking constraints prevent it, all allomorphs should be present simultaneously in the winning candidate, since this satisfies all of the PARSE-MORPH constraints. For instance, the Dyirbal ergative is predicted to be *[yaɽa-ŋgu-gu], which satisfies PARSE-MORPH(-ŋgu), PARSE-MORPH(-gu), and AFX-TO-FT. It might be possible to contrive a solution to this problem in Dyirbal, but that misses the point. To our knowledge, allomorphs are always mutually exclusive — in fact, that is why they are called allomorphs. A theory that predicts, as the normal case, that the allomorphs of a single morpheme will pile up seems fundamentally misconceived.

The MPARSE-based approach to allomorphy advocated here establishes a strong parallel between allomorphic alternation and paradigmatic gaps. This parallel is most evident when we look at a minimal pair of languages that respond to the same problem in different ways: selection of an alternative allomorph in one case and a gap in the other.

In Cebuano disyllabic prefixing reduplication (Luzares 1977: 101, Wolff 1966: 562-63), disyllabic roots are copied exactly (29)a, but longer roots almost entirely eschew reduplication, copying only the initial consonant followed by the fixed sequence [ulu] (29)b.

(29) Cebuano reduplication

a.	sulti	sulti-sulti	'talk'
	balik	balik-balik	'come back'
	higdaʔ	higdaʔ-higdaʔ	'lie'
b.	balibad	bulu-balibad	'refuse an offering'
	paŋutana	pulu-paŋutana	'ask a question'
	panaŋhid	pulu-panaŋhid	'ask to leave'
	pahulay	pulu-pahulay	'rest'

The alternation between disyllabic reduplication and C*ulu* reduplication is surely allomorphic, since the emergence of [ulu] has no plausible phonological explanation. The criterion that decides between allomorphs is whether or not the root can be entirely copied in a disyllabic reduplicant. (This same criterion has less dramatic effects on reduplication in Tagalog and Makassarese (Aronoff *et al.* 1987, Carrier-Duncan 1984, McCarthy and Prince 1994).)

In Kinande noun reduplication (Mutaka and Hyman 1990), disyllabic roots copy exactly (30)a, but longer roots simply lack reduplicated forms (30)b.

(30) Kinande reduplication

a.	o-ku-gulu	o-ku-gulu-gulu	'leg/a real leg'
	o-kú-boko	o- kú-boko-boko	'arm/a real arm'
b.	o-tu-gotseri	*gap*	'sleepiness'
	e-bí-nyurúgúnzù	*gap*	'butterflies'

The criterion is exactly the same as Cebuano: if a root can be entirely copied in the space of a disyllabic reduplicant, it is. The alternative is different, however: reduplication of longer roots leads to the null output instead of an allomorphic alternant.

In both languages, the crucial ranking is something like MIC, SR >> MPARSE. The abbreviation MIC stands for Mutaka and Hyman's Morpheme Integrity Constraint, which bans partial copying of morphemes. The abbreviation SR stands for the size restrictors that yield a disyllabic reduplicant by emergence of the unmarked (McCarthy and Prince 1994); they include ALIGN(Foot, Word) and PARSE-SYLLABLE. The main difference between Cebuano and Kinande is in the lexicon, not the grammar. The Cebuano lexicon offers a prioritized list of allomorphic alternants, while Kinande has just one choice. When the most harmonic reduplicative candidates violate the constraints abbreviated by MIC or SR, the MPARSE-violating null output is optimal. In Cebuano, harmonic evaluation then proceeds to an input with the second-ranked allomorph, while in Kinande the result is a gap.

A final point relevant to listed allomorphy is the question of whether syntactic periphrases need to be included in the candidate set with morphologically-constructed forms with the same meaning (e.g. **intelligenter* and *more intelligent* in English). To do this in the phonology seems highly implausible, but the MPARSE model provides a coherent way to describe the relation between gapped forms and their corresponding periphrases. As described in section 5.1, if inputs like /intelligent-er/ that map to ⊙ never get into the lexicon at all, then the syntax will never submit to the phonology an utterance that contains them, and will be constrained to producing periphrastic structures in order to express the meaning in question. This rather closely parallels what we take to be going on in cases where ⊙ wins in phrasal phonology: the input syntactic structure fails, and so a different one must be tried.

6.2 String-based correspondence and the notion 'unfaithful mapping'

At an intuitive level, it is clear what is meant when we refer to an unfaithful mapping: it is epenthesis, deletion, featural change, coalescence, etc. An example of an unfaithful mapping in this intuitive sense is /t/ → ∅ in the input-output pair /pat/, [pa].

For various reasons that will be discussed below, it is useful to have a coherent formal characterization of unfaithful mappings, and presumably the theory of faithfulness should supply it. But segment-based correspondence proves unsatisfactory in this respect. The problem is that deletion and epenthesis are technically not mappings at all in segmental correspondence: an input segment is deleted by virtue of being excluded from the domain of $\mathfrak{R}$, and an output segment is epenthesized by virtue of being excluded from the range of $\Re$. Since other species of unfaithfulness do involve actual mappings from $\Re$'s domain to its range, formal coherence in defining the notion 'unfaithful mapping' proves elusive.

The situation with string-based correspondence is very different. Because $\Re$ is a function from a concatenative decomposition of the input to a concatenative decomposition of the output, all types of unfaithfulness involve well-defined mappings. Any mapping of the form $x\Re\#$ is deletion, and any mapping of the form $\#\Re x$ is epenthesis. In general, an unfaithful mapping under string-based correspondence is any $x\Re y$ that violates some faithfulness constraint. Unlike segment-based correspondence, there are no unfaithful mappings that fly below $\Re$'s radar.

This definition of an unfaithful mapping is a welcome addition to several areas of research that make use of this notion. For example, language learners are required to generalize unfaithful mappings across identical outputs in the free-ride learning model (McCarthy 2005b). Unfaithful mappings are also key to identifying loci of faithfulness violation, which may have relevance to theories of local conjunction (Lubowicz 2005), optionality (Riggle and Wilson 2004), and phonological opacity (McCarthy in preparation).

7. Discussion of alternatives

Optimality Theory is inherently comparative, so nothing is ill-formed except in comparison with something else. The ill-formedness of *[bnIk] in English means that, for every input, there is some candidate more harmonic than *[bnIk]. For the input /bnIk/, this more harmonic candidate might be [nIk] or [bənIk]. In some linguistic systems, as Prince and Smolensky originally proposed, the most harmonic candidate is the null output, ⊙. Significantly, as we have argued throughout, ⊙ is just another candidate whose presence in the candidate set and violation-profile follow from the right definition of the correspondence relation.

OT's comparative and competitive approach to ill-formedness is a sharp departure from most other theories of language, which use inviolable constraints to mark words or sentences as ill-formed. Pesetsky (1997: 147-52, 1998: 377-81), Fanselow and Féry (2002), and Orgun and Sprouse (1999) have argued that OT also requires a component with inviolable constraints; Orgun and Sprouse dub this component 'CONTROL', and our discussion will focus on their proposal.

The inventory of constraints in CONTROL is not constant across languages; rather, on a language-particular basis, constraints in CON can be lifted out of the language-particular constraint hierarchy and placed in CONTROL. The null output is not in the candidate set, and there is no constraint MPARSE. Instead, a paradigmatic gap occurs when the most harmonic candidate chosen by EVAL is found to violate a constraint in CONTROL. The CONTROL constraints are inviolable, then, because they are outside of and posterior to the system of comparative evaluation.

The empirical arguments for CONTROL have been discussed and reanalyzed in MPARSE terms by McCarthy (2003) and, most extensively, Raffelsiefen (2004). Because it is so recent and accessible, we will not dwell on this material here, but rather we will look at the conceptual arguments that may be offered for and against the CONTROL component.

Orgun and Sprouse's (1999) conceptual argument for CONTROL is summarized in the following statements:

> This approach … makes clearer a crucial distinction between two kinds of inviolable constraints that has not enjoyed much explicit attention in the literature. Inviolable constraints in EVAL outrank all potentially conflicting constraints and cause repairs or block otherwise general alternations. Inviolable constraints in CONTROL cause ungrammaticality, never repair. (P. 192.)

> the MPARSE model partially obscures the observation that is the central theme of this paper: constraints that cause ungrammaticality are phonologically inert. They do not trigger phonological repair. The CONTROL model captures this observation directly by placing these constraints in a component that has no repair mechanism and no constraint interaction. (Pp. 218-9).

Stripped to its essentials, this argument takes CONTROL theory's main premise — that certain unviolated constraints are outside of EVAL — and describes it as an 'observation'. Competing theories are then faulted for not having such a close match between premise and observation. In reality, the so-called observation is nothing of the kind: the very notion of a 'repair' is undefined in OT (it comes from a different theory of constraints (Paradis 1988)), and there is no obvious dividing line between two types of unviolated constraints. Furthermore, it is not the case that the 'CONTROL model captures this observation directly'. The premises of a theory are supposed to account for the observations; whether they do so directly or indirectly is of no consequence in evaluating that theory. If a direct connection between premise and observation were a desideratum, then the best theory would have many premises, one for each observation. This seems rather the opposite of how theories are judged.

A notable disadvantage of the CONTROL model is the way that it deals with the morphological specificity of paradigmatic gaps. As we discussed in sections 2 and 5, the same constraints that crucially favor the null output in one morphological situation may crucially favor alternations elsewhere in the same language. Hence, MPARSE constraints must be relativized to particular constellations of morphological features. Orgun and Sprouse similarly observe that, in known cases, all of the constraints in CONTROL are morphologically restricted. The problem is that the constraints that can be limited morphologically and promoted to the CONTROL component are notably diverse, including various types of markedness and faithfulness constraints. All else being equal, it is preferable if morphological sensitivity can be limited to only certain constraint-types, such as MPARSE. It is particularly important to avoid markedness constraints with arbitrary morphological restrictions, since the markedness constraints are already a notably large and diverse class.[11]

A related problem with the CONTROL model is learning. Learners must not only discover their language's constraint hierarchy, but they must also figure out which unviolated constraints should be removed from EVAL and placed in CONTROL. Since only some unviolated constraints produce gaps, learners need to discover those gaps and decide which unviolated constraint or constraints are responsible for them. Orgun and Sprouse (1999: 219-21) describe a learning algorithm that is intended to address this issue. Suppose the linguistic form F is ungrammatical, leading to a paradigmatic gap. Each time the learner hears an alternative to F — for instance, periphrasis or a different allomorph — this constitutes 'weak negative evidence'[12] of F's ungrammaticality. Nongapped paradigms — forms that have F's morphology but different phonology, so they are grammatical — also supply weak negative evidence. With sufficient accumulation of such evidence, learners might be able to identify paradigmatic gaps that require invocation of CONTROL. It is not explained how learners complete the process, using the newly-discovered gaps to decide which constraints should be moved into CONTROL.

In contrast, the MPARSE model can rely on well-established results about learning OT grammars from positive evidence only (e.g., Boersma and Hayes 2001, Tesar and Smolensky 2000). This is because the MPARSE model's basic structure is identical to that of classic OT — from the perspective of the learning algorithm, MPARSE is just another constraint and the null output is just another candidate. Equally well established results about the effect of the Subset Principle (Berwick 1985) on learning OT grammars[13] suggest a refinement: all constraints in the MPARSE family start out at the bottom of the constraint hierarchy, below the markedness and faithfulness constraints. When the learner identifies a word W as having the morphological feature-set α, all markedness and faithfulness constraints that W violates are demoted below MPARSE$_{\alpha}$. In accordance with the subset principle, learning proceeds from the maximally restrictive grammar (every morphological combination leads to a gap) to a much less restrictive grammar (few morphological combinations lead to a gap). Learners will still be able to generalize productive morphology once the primary data have led to demotion of the right

[11] Hansson (1999) cites this aspect of the CONTROL model in support of a surprising argument: 'Given that the CONTROL model — unlike the MPARSE one — makes no inherent claim that the constraints in CONTROL be phonologically "well-defined", I suggest that it can include parochial and even slightly bizarre constraints' like the one his analysis seems to require. He also asks 'whether we really want our *grammar* … to contain such constraints.'

[12] Orgun and Sprouse attribute the idea of weak negative evidence to Regier (1992), which we have not seen. Weak negative evidence, in this sense, appears to be a special case of indirect negative evidence (e.g., Chomsky 1981: 8-9).

[13] Relevant work includes Barlow (1997), Bernhardt & Stemberger (1998), Davidson, Juszcyk, & Smolensky (to appear), Demuth (1995), Gnanadesikan (1995/to appear), Goad (1997), Hayes (2004), Levelt (1996), van Oostendorp (1997), Pater (1997), Pater & Paradis (1996), Prince & Tesar (2004), Smolensky (1996), Sherer (1994), and Tesar & Smolensky (2000: Chapter 5).

constraints. For example, a learner of English can produce *drived* only after observing forms like *dragged* which show that MPARSE$_{Past}$ dominates *COMPLEX-ONSET.

A final argument adduced by Orgun and Sprouse in support of CONTROL is the observation that speakers can sometimes identify the form that is being blocked from filling the paradigmatic gap, such as *[rätː] in Swedish. In their view, this form's special status is that it is optimal according to EVAL but blocked in the post-EVAL stage by CONTROL. In the MPARSE model, we can look to a recent proposal by Coetzee (2004) that the output of EVAL is not a single optimal candidate but rather a ranking of all candidates for relative harmony. Coetzee argues that speakers sometimes access candidates other than the top-ranked one, and that this is a source of variation. When the top-ranked candidate is ⊙, it is not surprising that speakers may be able to access the second-ranked candidate. In Swedish, the second-ranked candidate is *[rätː], as shown in (6).

8. Conclusion

In this paper, we have argued for a revision of correspondence theory. In this revision, run-of-the-mill unfaithful mappings do not alter $\mathfrak{R}$'s status is a total bijective function. Candidates with a less orderly $\mathfrak{R}$ violate MPARSE; among these candidates there is one that harmonically bounds all of the others, the null output ⊙. The primary goal of this project is to explain why ⊙ uniquely violates no constraints except MPARSE, making it suitable for the analysis of phonologically-conditioned paradigmatic gaps. Along the way, we have also addressed some related issues, such as the analysis of phonologically-conditioned allomorphy and the definition of 'unfaithful mapping'.

Appendix: Other faithfulness constraints

Section 3 introduced string-based correspondence and supplied definitions of the core faithfulness constraints. This appendix deals with other faithfulness constraints in common use.

In segmental correspondence, the anti-metathesis constraint LINEARITY bans changing the relative linear order of pairs of correspondent segments between input and output. Under string-based correspondence, the natural move is to have it forbid changing the sequencing of strings in the <i> → <o> mapping:

(31) LINEARITY (new version)

Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),

For every pair of strings κ_1, κ_2 in <i>,

Assign one violation mark if κ_1 precedes κ_2 but $\mathfrak{R}(\kappa_2)$ precedes $\mathfrak{R}(\kappa_1)$.

While LINEARITY bans reordering of strings, it says nothing about *internal* reordering of multisegmental strings that stand in correspondence. For example, the mapping <a, bc, d> → <a, cb, d> incurs no Linearity violations. This is not a problem, however, because <a, bc, d> → <a, cb, d> is harmonically bounded. It violates quite a few constraints: Uniformity and Integrity, which bar multisegmental strings from <i> and <o> respectively, and all of the Ident constraints relevant to featural differences in the pairs (b, c) and (c, b). *b→c and *c→b. It is harmonically bounded by the mapping <a, b, c, d> → <a, c, b, d>, in which /b/ stands in correspondence with [c] and /b/ with [b]. This candidate therefore has all of the Ident violations incurred by <a, bc, d> → <a, cb, d>, but it satisfies Uniformity and Integrity. Since these two candidates have identical markedness violations, <a, bc, d> → <a, cb, d> has a proper subset of the marks incurred by <a, b, c, d> → <a, c, b, d>, so it is harmonically bounded. String-based correspondence thus runs no risk of letting segmental metathesis occur for free.

Anchor constraints require that a segment at the left/right edge of the input have a correspondent at the same edge of the output. They therefore forbid any deletion, epenthesis, or metathesis process that would subvert with that state of affairs. If we directly state this in terms of string-based correspondence, the schema for these constraints will follow (32).

(32) {R, L}-Anchor (new version)
Given a candidate ([o], <i>, <o>, $\mathfrak{R}$),
if κ is at the designated periphery of <i>, and
if $\mathfrak{R}(\kappa)$ is not at the same periphery of <o> or is #, then
assign a violation mark.

If string-based correspondence is to recapitulate the effects of Anchor in segmental correspondence, we must ascertain that violations of Anchor cannot be avoided by new means. As with the other faithfulness constraints, the cases requiring attention are those where the segment treated unfaithfully is part of a longer string that does not violate the constraint in Anchor. Consider, for example, a case of L-Anchor-violating peripheral deletion like <p, a, t> → <#, a, t>. The competing coalescent mapping <pa,t> → <a,t> does not violate L-Anchor, though it does violate Uniformity and the various Ident constraints for features that distinguish /p/ from [a]. The situation is no different in segmental correspondence: $/p_1a_2t_3/ \rightarrow [a_{1,2}t_3]$ also obeys L-Anchor, since the initial segment of the input has a correspondent that is initial in the output, and it also violates Uniformity and the same Ident constraints. L-Anchor violation by initial epenthesis presents the same parallels.

For the case of metathesis of a peripheral segment away from its edge, the comparison of interest is <p, a, t, a> → <a, p, t, a> versus <pa, t, a> → <ap, t, a>. The first violates L-Anchor and Linearity, while the second violates Uniformity, Integrity, and various Ident constraints. Under segmental correspondence, the equivalent competition is between a candidate with literal metathesis and one in which /p/ maps to [a] and /a/ to [p]. This second, more bizarre, candidate incurs the same violations of Ident as the second of our string-based candidates, but without the violations of Uniformity and Integrity. String-based correspondence thus makes this peculiar escape-hatch from Anchor violations even more costly, and as such our new model would seem not to impose undesirable consequences.

Next we turn to the Contiguity family. McCarthy & Prince (1995, 1999) set forth two of these constraints, I-Contig, ('no skipping') and O-Contig ('no insertion'). Metathesis aside, these are really contextual versions of Max and Dep which, respectively, forbid medial deletion and epenthesis. In the case of I-Contig, the potential worry is that a medial segment could be lost from within a larger string. That is, we want to compare <p, a, t, k, a> → <p, a, #, k, a>, which violates I-Contig and general Max, with <p, a, tk, a> → <p, a, k, a>, which violates Unif and Ident. But this is simply coalescence, which was already available in segmental correspondence. For O-Contig the situation is similar.

Finally, to cover the range of faithfulness constraints in current use, we have to address faithfulness to autosegmental and prosodic structure. It has generally been assumed that moras, tones, and perhaps distinctive features bear correspondence relations, with faithfulness constraints like Max(μ), Dep(H), or Max(coronal) referring to these relations. Furthermore, autosegmental and prosodic associations are subject to faithfulness constraints against delinking and spreading.

With some refinements, string-based correspondence is able to accommodate autosegmental and prosodic faithfulness. An autosegmental representation can be regarded as a set of strings — the tiers — with indices pointing from the elements of one string to the elements of another — the association lines. (For much more extensive formal development along the same general lines, see Hayes (1990), Kornai (1994) and Pierrehumbert & Beckman (1988).) For example, the standard feature-geometric representation in (33)a is equivalent to (33)b.

(33) Autosegmental representations as coindexed strings.

a.

Coronal tier	$[\text{cor}]_i$
Place tier	o_j
Root tier	$o_k \quad o_l$

b. $\{[\text{cor}]_{i,\{j\}},\ \text{Place}_{j,\{k,l\}}, \text{Root}_{k,\{\}}\ \text{Root}_{l,\{\}}\}$

In (33)b, the first subscript is that element's unique index and the second subscript is a (possibly empty) set of indices on the tier to which that element is associated. (The root nodes in (33)b are shown with empty sets of associations because no further structure is depicted and not for some deeper reason.)

In a theory with phonological representations like (33)b, what we have been calling <i> and <o> will be replaced by sets of concatenative decompositions, with one decomposition for each tier, since each tier is a string. The decompositions of input and output in this enriched sense might be symbolized as {<i>} and {<o>}. Tier-specific faithfulness constraints like Max(μ), Dep(H), or Max(coronal) can then be straightforwardly defined on the appropriate tier-specific concatenative decompositions in {<i>} and {<o>}. Faithfulness to autosegmental associations can also be defined on these representations, but it is not strictly necessary. We have already defined Ident(F) in (16). Spreading is just violation of Ident(F) without concomitant violation of Dep(F) — a segment gains a feature specification, but no feature token is added to the representation. Similarly, delinking is violation of Ident(F) without concomitant violation of Max(F) — a segment loses a feature specification, but no feature token is removed from the representation. If this approach to spreading and delinking should prove insufficient, we already have the tools in hand to develop a more sophisticated approach within the overall assumptions of string-based correspondence.

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