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Less than zero: Correspondence and the null output

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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.Δ

But what if some input has no output? What candidate is the winner of the competition? In phonology, this problem arises primarily 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 cannot 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 and 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 other candidates. The gap candidate — which they refer to as the *null parse* — is taken to violate only a single constraint, named MPARSE. If the null parse violates no other constraints, any constraint C ranked above MPARSE is effectively inviolable, since any candidate that violates it will lose to the null parse, as shown in (1). Legendre, Smolensky, and Wilson (1998: 257, fn. 259) term this effect of MPARSE a *harmony threshold*: MPARSE is able to set a standard that any viable candidate has to satisfy, so constraints ranked higher than MPARSE are de facto inviolable. (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, and W or L indicates whether a constraint favors the winner or a loser.)

(1) MPARSE harmony threshold

/in/	C	MPARSE
→ ⊙		1
out	W_1	L

Our primary goal in this chapter 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? In section 3, 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 the null output violates no markedness constraints. But first we will look at some general properties of the gap phenomenon and some preconditions for an adequate theory of MPARSE.

2. On gaps

The MPARSE model was in some ways anticipated in work on gaps by Hetzron (1975), Iverson (1981), and Iverson and 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 exceptions 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 words, forcing the grammar to resort to outright gaps in order to maintain the surface absence of Γ. In OT terms, this situation involves rankings 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 particularly fine example comes from Rice (2003, 2005a, 2005b). In Norwegian, the imperative is normally identical to the infinitive, except that the imperative lacks the suffix [-ə]. But verb roots ending in a rising-sonority cluster have no imperative (compare (2) with (3)). The bare root *[åpn] is unpronounceable because of its final cluster, and obvious alternatives like epenthetic *[åpən] are ruled out for most speakers. Hence, those speakers have no imperative of ‘open’, and so they must resort to circumlocution when they wish to convey this meaning.

(2) Norwegian imperatives

å spise	‘to eat’	spis!	‘eat!’
å snakke	‘to talk’	snakk!	‘talk!’
å løfte	‘to lift’	loft	‘lift’

(3) Norwegian imperative gaps

å åpne	‘to open’	*gap*	‘open!’
å paddle	‘to paddle’	*gap*	‘paddle!’
å sykle	‘to bicycle’	*gap*	‘bicycle!’

In Rice’s analysis, the constraint SONSEQ rules out faithful *[åpn] as the surface realization of the imperative, and faithfulness constraints like DEP prohibit alternatives like *[åpən]. These constraints must dominate MPARSE, as shown in (4). 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 nongapped outcomes, such as obstruentization or deletion of /n/.

(4) SONSEQ, DEP >> MPARSE in Norwegian

/åpn/	SONSEQ	DEP	MPARSE
→ ⊙			1
a. åpn	W_1		L
b. åpən		W_1	L

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 2005a, 2005b). 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 Norwegian imperatives. Formal gaps are also unnecessary in describing restrictions on phonotactics, segmental inventories, and the like. 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 instance, it is not necessary that /bnɪk/ map to the null ouput in English; absent alternations, the non-existence of [bnɪk] can as well be accounted for by mapping /bnɪk/ to, say, [nɪk].

Nonetheless, various researchers have used the null output in analyses of derivational gaps (Raffelsiefen 2004) and phonotactic gaps (Prince and Smolensky 2004: 57). Since we will pursue a model in which the null output is among the candidates produced by GEN for *every* input, even monomorphemic ones, 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 surface faithfully. 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), Iverson (1981), and Rebrus and Törkenczy (this volume) on Hungarian verbs without jussive forms; Eliasson (1975) and Iverson (1981) on Swedish adjectives without singular neuter forms,; Steriade (1988: 112--113) and McCarthy and Prince (1993b: 143--144) on Sanskrit verbs without reduplicated intensives; and Halle (1973), Hetzron (1975), and Iverson (1981) on Russian verbs without first person singular nonpast forms.

The Norwegian 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 DEP, since otherwise in (4) it would lose to candidate (b), which is non-null and violates DEP. 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. Φ is non-viable because a candidate with less deletion is more harmonic. For example, in a language that is like Norwegian except that DEP dominates MAX, SONSEQ could in principle be satisfied by mapping /åpn/ to [åp] or to Φ. But since [åp] incurs one MAX violation to Φ's three, Φ is clearly a non-starter.

This point about Φ's usual loser status means that Φ and ⊙ cannot be the same thing, because then ⊙ would never win. The challenge 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 Φ. The foundation is laid in the next section, and then the null output is defined — and the challenge addressed — in section 3.

3. String correspondence and faithfulness

3.1. The nature of candidates

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), 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 therefore equivalent to saying that $\mathfrak{R}$ is one-to-one from *i* to *o* or that its inverse $\mathfrak{R}^{-1}$ is a function from *o* to *i*. In deletion, $\mathfrak{R}$ is a partial relation from *i* to *o*. Thus, the anti-deletion constraint MAX is equivalent to saying that $\mathfrak{R}$ is a total relation from *i* to *o*. In epenthesis, $\mathfrak{R}$ is not onto *o*, or, equivalently, $\mathfrak{R}^{-1}$ is a partial relation from *o* to *i*. Hence, 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 (see section 4). Except for the null output, then, $\mathfrak{R}$ is a total bijective function in all candidates, even candidates with deletion, epenthesis, coalescence, and diphthongization.[1] 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). 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:

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 $d_j \frown ... \frown d_k = S$.

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. (McCarthy and Prince 1993a: 89--90)

For example, among the concatenative decompositions of the string *ABC* are the sequences of strings listed in (5).

(5) Some concatenative decompositions of *ABC*

<ABC>
<e, ABC, e, e>
<A, B, C>
<AB, C>
<A, BC>
<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 correspondence*, to contrast it with the McCarthy and Prince (1995, 1999) version, with its *segmental correspondence*. The difference becomes clear once we look at some of the unfaithful mappings that languages may permit under string correspondence. The hypothetical examples in (6) are representative. In deletion (b) or epenthesis (c), $\mathfrak{R}$ includes a mapping between a monosegmental string and the null string, which we write as # to avoid confounding the more usual notation *e* with phonetic transcriptions. In coalescence (d) or diphthongization (e), $\mathfrak{R}$ includes a mapping between a bisegmental string and a monosegmental string.

(6) Some unfaithful mappings under string correspondence[2]

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)}

In (6), the correspondence relation $\mathfrak{R}$ 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 string in <i> has a unique correspondent in <o>, and every string in <o> has a unique correspondent in <i>. Except for metathesis, in MParse-obeying candidates the *k*th string in <i> is in correspondence with the *k*th string in <o> for all $1 \leq k \leq n$, where *n* is the cardinality of both <i> and <o>. In metathetic candidates, the cardinalities of <i> and <o> are also identical, but corresponding strings do not occupy identical positions in the concatenative decompositions.

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 strings in the sequence <x>. Among the subsets of {<i>}X{<o>} is of course the null set Ø.

3.2. The faithfulness constraints

Since $\mathfrak{R}$ is different in string correspondence than in segmental correspondence, the faithfulness constraints need to be redefined.

The faithfulness constraint Max militates against configurations in which any string in <i> maps to a null string 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, #. The new definition of MAX appears in (7), and an example of a MAX-violating candidate is given in (8).

(7) 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.

(8) MAX violation in Lardil /ŋawuŋawu/ → [ŋawuŋa] 'termite'
<i> = <ŋ, a, w, u, ŋ, a, w, u>
<o> = <ŋ, a, w, u, ŋ, a, #, #>
$\mathfrak{R} = \{(\text{ŋ}_1, \text{ŋ}_1), (a_2, a_2), (w_3, w_3), (u_4, u_4), (\text{ŋ}_5, \text{ŋ}_5), (a_6, a_6), (w_7, \#_7), (u_8, \#_8)\}$

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. The new definition of DEP appears in (9), and an example of a DEP-violating candidate is given in (10).

(9) 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.

(10) DEP violation in /kaŋ/ → [kaŋka] 'speech'
<i> = <k, a, ŋ, #, #>
<o> = <k, a, ŋ, k, a>
$\mathfrak{R} = \{(k_1, k_1), (a_2, a_2), (\text{ŋ}_3, \text{ŋ}_3), (\#_4, k_4), (\#_5, a_5)\}$

The constraint UNIFORMITY (UNIF) exists primarily to regulate segmental coalescence. In segmental correspondence, coalescence is the mapping of two input segments to a single output segment, usually preserving some of the features of each parent segment: /$p_1a_2n_3$/ → [$p_1\tilde{a}_{2,3}$]. Under string 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 in (12). The definition of UNIFORMITY, which is given in (11), 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, without even mentioning <o>:

(11) 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.

(12) UNIFORMITY violation in /pan/ → [pã]
<i> = <p, an>
<o> = <p, ã>
$\mathfrak{R} = \{(p_1, p_1), (an_2, \tilde{a}_2)\}$

The constraint INTEGRITY (INT) is violated by diphthongization or breaking — that is, it is violated by mappings in which a single input segment maps to two output segments, as in (14). INTEGRITY, defined in (13), is the dual of UNIFORMITY in the same way that DEP is the dual of MAX.

(13) 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.

(14) INTEGRITY violation in /pã/ → [pan]
<i> = <p, ã>
<o> = <p, an>
$\mathfrak{R} = \{(p_1, p_1), (\tilde{a}_2, an_2)\}$

The string-based approach to coalescence and breaking is very different from the approach taken in segmental correspondence theory, and hence it makes different empirical predictions. In string correspondence, coalescence is necessarily local in the sense that it cannot affect two nonadjacent input segments without also affecting any segment(s) intervening between them. Likewise, breaking cannot produce two nonadjacent output segments without also producing any segment(s) intervening between them. In the segmental correspondence model, on the other hand, coalescence and breaking need not be local in this sense. For instance, the mapping $/p_1a_2t_3n_4/ \rightarrow [p_1\tilde{a}_{2,4}t_3]$ represents nonlocal coalescence and $/a_1p_2\tilde{a}_3t_4/ \rightarrow [n_3a_1p_2a_3t_4]$ represents nonlocal breaking.

To our knowledge, there are no clear examples of nonlocal coalescence or breaking, so the additional descriptive power of segmental correspondence appears to be unnecessary. This power has been used in two more controversial cases, however. De Lacy (1999) proposes that morphological haplology involves merger of segments that need not be (and typically are not) adjacent, such as French $/d_1e_2i_3k_4s_5i_6s_7\text{-}i_8s_9t_{10}/ \rightarrow [d_1e_2i_3k_4s_5i_{6,8}s_{7,9}t_{10}]$ 'deixis+ist'. De Lacy and Kitto (1999) propose that in copy-vowel epenthesis a single input segment has two output correspondents that need not be adjacent, such as Selayarese $/p_1o_2t_3o_4l_5/ \rightarrow [p_1o_2t_3o_4l_5o_4]$ 'pencil'. There are alternative theories of both phenomena, and pretty good reasons to think that those alternatives are right (Kawahara 2004, 2006, Kurisu 2001, Plag 1998, Russell 1995). Absent solid examples of nonlocal phonological coalescence or true nonlocal diphthongization, it would seem that string correspondence has the upper hand empirically.

In segmental correspondence, the anti-metathesis constraint LINEARITY bans changing the linear order of pairs of correspondent segments. Under string correspondence, the natural move is to define it as in (15), so that it forbids changing the sequencing of strings in the <i> → <o> mapping. The correspondence relation of a LINEARITY violator may be fully faithful, as in (16), but the ordering discrepancy between <i> and <o> is what triggers the violation. (On reordering of segments *within* corresponding strings, see the next section.)

(15) 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 $\mathfrak{R}(\kappa_1)$.

(16) Linearity violation in /pra/ → [par]

<i> = <p, r, a>

<o> = <p, a, r>

$\mathfrak{R} = \{(p_1, p_1), (r_2, r_2)\ (a_3, a_3)\}$

Finally, the constraint Ident must be revised to reflect the differences between string-based and segmental correspondence. 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, segmental 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 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 segmental 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 (17) is intended to cover all of these situations. 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 mapping <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.

(17) 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) ($1 \leq p \leq n$, $1 \leq q \leq m$)

where κ_p is [αF] and λ_q is [-αF].

IDENT constraints are typically associated with theories of representation in which features are attributes of segments but not representational entities in their own right. A natural question to ask is whether string correspondence can accommodate faithfulness to autosegmental representations, in which features are distinct representational primes and can bear correspondence relations of their own. Superficially, it might appear that string correspondence, dependent as it is on breaking the input and output into a sequence of linearly consecutive substrings, cannot handle faithfulness to nonlinear structure.

On closer inspection, however, such worries prove to be unfounded. In autosegmental theories, the representational primes (features, tones, class nodes, etc.) are regarded as occupying one of a number of tiers, with relations of adjacency and linear precedence defined between pairs of elements on each tier, but not between pairs of elements on different tiers. This means that a nonlinear 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 and Beckman (1988).) For example, the standard feature-geometric representation in (18) is equivalent to (19). The first subscript on each element in (19) 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 are shown with empty sets of associations because no further structure is depicted and not for some deeper reason.)

(18) Autosegmental representations as coindexed strings.

Coronal tier $[\text{cor}]_i$

Place tier o_j

Root tier o_k o_l

(19) Example (18) as a set of tiers

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

Once the equivalence between (18) and (19) is recognized, it becomes clear how nonlinear representations can be handled in string correspondence. The input *i* and output *o* may be regarded, in a theory with such representations, as consisting of not a single string but as a set of strings, each of which contains all of the structural elements occupying one of the prosodic or autosegmental tiers. Accordingly, <i> and <o> can be regarded not as concatenative decompositions of a single string, but rather as *sets* of contatenative decompositions, one for each tier, since each tier is a string. Tier-specific faithfulness constraints like MAX(μ), DEP(high tone), or MAX(coronal) can then be straightforwardly defined on the appropriate tier-specific concatenative decompositions.

Faithfulness to autosegmental associations can also be defined on these representations, but it is not strictly necessary. We have already defined IDENT(F) in (17). 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 correspondence. For ease of illustration, we will continue for the remainder of this chapter to refer only to strings of segments in our examples, but we emphasize that this is strictly an expository and not a theoretical choice; as we have just argued, string correspondence is entirely compatible with the use of nonlinear representations.

3.3. Harmonic bounding relationships, part I

Harmonically bounded candidates can never win under any permutation of the universal constraint set CON; they are perpetual losers. In the simplest case, one candidate harmonically bounds another by virtue of having a proper subset of the bounded candidate's violation marks. Here and in section 4.3, we show that our proposal entails harmonic bounding of various candidates that would otherwise present problematic ambiguities or typological impossibilities.

In principle, two candidates can have the same input *i* and output *o*, but different concatenative decompositions <i> and <o> and different correspondence relations $\Re$. For instance, instead of the <i>, <o>, and $\Re$ in (8), the Lardil mapping /ŋawuŋawu/ → [ŋawuŋa] could be obtained, or so it seems, with the <i>, <o>, and $\Re$ in (20). In (8), the monosegmental strings /w/ and /u/ each map individually to #, while in (20) the bisegmental string wu/ maps to #. The concern, naturally, is that the revised theory has introduced a formal ambiguity: how do learners (or analysts) know whether the correct analysis is the one in (8) or the one in (20)?

(20) Lardil /ŋawuŋawu/ → [ŋawuŋa] revisited
<i> = <ŋ, a, w, u, ŋ, a, wu>
<o> = <ŋ, a, w, u, ŋ, a, #>
$\Re = \{(ŋ_1, ŋ_1), (a_2, a_2), (w_3, w_3), (u_4, u_4), (ŋ_5, ŋ_5), (a_6, a_6), (wu_7, \#)\}$

In reality, there is no ambiguity because (8) harmonically bounds (20), so (20) cannot win over (8) under any permutation of the constraints in CON. These two candidates are juxtaposed in (21) for ease of comparison. Both candidates have the same output *o*, so they have identical markedness violations. Both candidates violate MAX exactly twice, since MAX counts the number of segments in any string in <i> that maps to # in <o>. But candidate (b) also violates UNIFORMITY, which prohibits multisegmental strings in <i>. Since (a) has no violations that are not shared with (b), and since (b) has a violation that is not shared with (a), (b) is harmonically bounded by (a). There is no ambiguity for learners to unravel, since (b) is not even among the contenders for optimality.

(21) Harmonic bounding of (20) (=b) by (8) (=a)

a. $<i> = <\text{ŋ}, a, w, u, \text{ŋ}, a, w, u>$

$<o> = <\text{ŋ}, a, w, u, \text{ŋ}, a, \#, \#>$

$\mathfrak{R} = \{(\text{ŋ}_1, \text{ŋ}_1), (a_2, a_2), (w_3, w_3), (u_4, u_4), (\text{ŋ}_5, \text{ŋ}_5), (a_6, a_6), (w_7, \#_7), (u_8, \#_8)\}$

b. $<i> = <\text{ŋ}, a, w, u, \text{ŋ}, a, wu>$

$<o> = <\text{ŋ}, a, w, u, \text{ŋ}, a, \#>$

$\mathfrak{R} = \{(\text{ŋ}_1, \text{ŋ}_1), (a_2, a_2), (w_3, w_3), (u_4, u_4), (\text{ŋ}_5, \text{ŋ}_5), (a_6, a_6), (wu_7, \#_7)\}$

Harmonic bounding of (b) by (a) is surely a desirable result; when bisegmental or longer strings delete, learners should not be forced to choose between 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 sequence of monosegmental strings to a sequence of instances of #; mapping from a bisegmental or longer string to a single instance of # is never possible.

For a similar reason, candidate (a) in (22) harmonically bounds candidate (b). Both of these candidates violate DEP twice. Furthermore, 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.

(22) Lardil /kaŋ/ → [kaŋka] revisited

a. $<i> = <k, a, \text{ŋ}, \#, \#>$

$<o> = <k, a, \text{ŋ}, k, a>$

$\mathfrak{R} = \{(k_1, k_1), (a_2, a_2), (\text{ŋ}_3, \text{ŋ}_3), (\#_4, k_4), (\#_5, a_5)\}$

b. $<i> = <k, a, \text{ŋ}, \#>$

$<o> = <k, a, \text{ŋ}, ka>$

$\mathfrak{R} = \{(k_1, k_1), (a_2, a_2), (\text{ŋ}_3, \text{ŋ}_3), (\#_4, ka_4)\}$

Another seeming ambiguity involves metathesis. When two segments metathesize, are monosegmental strings reordered — i.e., $<a_1, b_2, c_3> \rightarrow <a_1, c_3, b_2>$ — or is there reordering within a multisegmental string — i.e., $<a_1, bc_2> \rightarrow <a_1, cb_2>$? This question is particularly pressing because LINEARITY as defined in (15) bans reordering of strings but says nothing about string-internal reordering. If $<a_1, bc_2> \rightarrow <a_1, cb_2>$ were a possible mapping, then it would offer a way of doing metathesis without violating LINEARITY. This would be a problematic result, since it undermines LINEARITY and faithfulness generally.

In reality, there is no ambiguity and no threat to LINEARITY. The mapping $<a_1, bc_2> \rightarrow <a_1, cb_2>$ is harmonically bounded. This mapping violates UNIFORMITY and INTEGRITY, since these constraints prohibit multisegmental strings in <i> and <o>, respectively. Furthermore, this mapping violates all of the IDENT constraints relevant to featural differences in the pairs (b, c) and (c, b). It is harmonically bounded by the mapping $<a_1, b_2, c_3> \rightarrow <a_1, c_2, b_3>$, in which /b/ stands in correspondence with [c] and /c/ with [b]. This candidate has exactly the same IDENT violations incurred by $<a_1, bc_2> \rightarrow <a_1, cb_2>$, but it satisfies UNIFORMITY and INTEGRITY as well as LINEARITY. Since these two candidates have identical markedness violations, as they both represent the output form [acb], the mapping $<a_1, bc_2> \rightarrow <a_1, cb_2>$ has a proper superset of the marks incurred by $<a_1, b_2, c_3> \rightarrow <a_1, c_2, b_3>$, so $<a_1, bc_2> \rightarrow <a_1, cb_2>$ is harmonically bounded. String correspondence thus runs no risk of letting segmental metathesis occur for free.

3.4. Summary

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 multisegmental strings in <i> or <o>. When strings are in correspondence, IDENT requires that all of their constituent segments match pairwise in their featural composition.

The immediate goal of reformulating the faithfulness constraints 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 segmental correspondence, by contrast, 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.

One candidate in which $\mathfrak{R}$ fails to be a total bijective function is the null output $\odot$, and in so failing this candidate violates the constraint MPARSE, while satisfying all markedness and faithfulness constraints. Further, the candidate $\odot$ harmonically bounds all other candidates in which $\mathfrak{R}$ is not a total bijective function. In the next section we demonstrate how our theory obtains these results.

4. MPARSE and the null output

4.1. Previous formulations of MPARSE

Prince and Smolensky (2004) suggest two possible means by which the null parse might be defined. One of these is equivalent to what we have been calling Φ: a candidate in which every input segment has been deleted. In terms of their PARSE/FILL model of faithfulness, the null parse would be the candidate that maximally violates PARSE. As we just showed, Φ 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 the morphological content of the input into a morphological structure. This candidate violates just a single constraint, the original MPARSE: ‘Morphological structure is parsed into constituents.’ On this view, the null parse could well still contain phonological structure that is parsed into prosodic constituents (and hence avoid the difficulties faced by Φ) but would be ineffable because it lacks a morphosyntactic category, and hence is unable to participate in syntax or be semantically interpreted. This definition is attractive, since it correctly distinguishes ⊙ from Φ.

Attributing the violation that the null output ⊙ incurs to a failure of *morphological* parsing presents other problems, however. First, it is difficult to maintain that all cases of phonologically-conditioned gaps involve a failure in the lexical, word-level phonology, as a morphological interpretation of the null parse would seem to require. The main evidence that gaps are not purely a matter of morphology comes from the observation that the Norwegian imperative gap depends on the phrasal phonological context (section 4.2). Second, even if the null parse is morphologically defective in a way that prevents it from participating as a word in the syntax, it is unclear why speakers should not be able to produce it as a citation form—unless the null parse is devoid of surface *phonological* structure as well, which brings us back to the problem of Φ's nonviable status.

It seems that we will still need a non-stipulative way for the null output ⊙ to eliminate all input phonological structure without violating the anti-deletion constraint MAX. 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. The next section expands on that idea, while section 6 considers alternative formalizations of Prince and Smolensky's basic insight.

4.2. *Defining and using MPARSE*

A null output is any candidate that violates MPARSE as defined in (23).

(23) 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.

The candidate ⊙ has two related properties: in the (*o*, <i>, <o>, ℜ) ordered 4-tuple that represents ⊙, *o* and its concatenative decomposition <o> are 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. An example of ⊙, the winning candidate in (4), is given in (24). MPARSE is violated by (24) because ℜ is a partial relation from <i> to <o>; indeed, no string in <å, p, n> has a correspondent in <o>

(24) An instance of ⊙
<i> = <å, p, n>
<o> = < >
ℜ = Ø

The discussion of Norwegian 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 immediately below. Section 4.3 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.

The candidate ⊙ violates no faithfulness constraints. 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. Thus, the null output represented in (24) satisfies every faithfulness constraint in CON.

A desirable result of string correspondence is that ⊙ is not the same as the candidate that has deleted all input material. Compare the two candidates in (25). As we noted in section 2, ⊙ is optimal in paradigmatic gaps, but Φ is rarely if ever optimal — and definitely non-optimal in Norwegian — 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 they are indeed distinct under string 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.

(25) ⊙ vs. Φ

a. $\odot=([\ ], \langle p_1, a_2, t_3\rangle, \langle\ \rangle, \emptyset)$

b. $\Phi =([\ ], \langle p_1, a_2, t_3\rangle, \langle \#_1, \#_2, \#_3\rangle, \{(p_1, \#_1), (a_2, \#_2), (t_3, \#_3)\})$

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’). Even constraints that seem to require the presence of structure are dependent on the presence of some other structure in order to issue violation marks.[3] For instance, 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 any minimality constraints.

We now have most of the formal tools necessary to analyze the Norwegian imperative gap in terms of string correspondence. In (26), several of the most important candidates are compared with the winner. Candidate (a) is faithful, and it incurs a fatal violation of the markedness constraint SONSEQ. Candidate (b) has total deletion, and (c) has partial deletion. Either way, high-ranking MAX is violated. The winner is the null output. This candidate satisfies SONSEQ because it has no forbidden tautosyllabic clusters (indeed, no syllables or segments at all), and it satisfies MAX because it places no strings in <i> in correspondence with #.

(26) Norwegian imperative gap with string correspondence

	/åpn/	SonSeq	Max	MParse
→	⊙ <i> = <å, p, n> <o> = < > ℜ = Ø			1
a.	åpn <i> = <å, p, n> <o> = <å, p, n> ℜ = {(å, å), (p, p), (n, n)}	W$_1$		L
b.	Φ <i> = <å, p, n> <o> = <#, #, #> ℜ = {(å, #), (p, #), (n, #)}		W$_3$	L
c.	åp <i> = <å, p, n> <o> = <å, p, #> ℜ = {(å, å), (p, p), (n, #)}		W$_1$	L

Tableau (26) shows why deletion is disallowed as a remedy for SonSeq-violating clusters. Another logical possibility is epenthesis, producing *[åpən] or *[åpnə]. Interestingly, epenthesis is possible when similar conditions arise in nouns, such as /adl/ → [adəl] 'nobility' (Rice 2005a). This contrast between nouns and imperatives shows that some constraint(s) must have morphologically restricted scope. There are two options to consider: restricting MParse or restricting Dep. We will work through both accounts with the aim of showing that the morphological restriction is imposed on Dep and not MParse.

A morphologically restricted MParse is in the spirit of Rice's (2005b) proposal that the anti-gap constraints require all slots in a paradigm to be filled. (See section 6.1 for further discussion of this theory of gaps.) Suppose that there is a universal set of morphological features, so the set of possible paradigmatic slots is simply the set of morphological feature combinations made possible by UG. For any feature combination, Con would contain an MParse constraint that applies when a word bearing those features is submitted as an input to the phonology. In Norwegian, because nouns allow epenthesis, MParse$_{\text{Noun}}$ would be ranked above Dep. But imperatives prefer a gap to epenthesis, so MParse$_{\text{Imp}}$ would have to be ranked below Dep.

Difficulties arise when evaluating candidate utterances that contain both a noun and an imperative verb, as will occur in the phrasal phonology. Nouns cannot be gapped because MParse$_{\text{Noun}}$ is undominated. Therefore, the presence of a noun anywhere in the phrase will effectively knock out the null output, and an imperative occurring in the same phrase will not be gapped. Tableau (27) shows the problem; absurdly, the imperative form of /åpn/ is being rescued by the presence of any noun elsewhere in the utterance.

(27) Unwanted effect of MParse$_{Noun}$

/…*noun*…åpn…/	MParse$_{Noun}$	SonSeq	Dep	MParse$_{Imp}$
→ …*noun*…åpən…			1	
a. ⊙	W$_1$		L	W$_1$
b. …*noun*…åpn…		W$_1$	L	

This problem with MParse$_{Imp}$ might be avoided by recognizing a separation of word-level and phrase-level phonology. It would not be necessary to go as far as stratal OT, which posits different grammars for words and phrases (see, among many others, Kiparsky 2000); rather, it would suffice to 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 would be fed to Gen as an input. If the output of the phonology is ⊙, then no form corresponding to the given set of morphological features would be entered into the lexicon. The syntax therefore would have no access to such items, and so evaluations like (27) could never take place.

Further evidence from Norwegian shows, however, that this approach is incorrect. Norwegian must not have a *lexical* gap for the imperative of verbs like /åpn/, because these imperatives actually occur when the final sonorant can be syllabified as an onset before a following vowel-initial word (Rice 2005a): *Sykl opp bakken* 'Bicycle up the hill!' vs. **Sykl ned bakken* 'Bicycle down the hill!'. This contrast shows that the gap — that is, the victory of the candidate ⊙ — cannot be determined until the phrase-level phonology. We conclude that an analysis with morphologically restricted MParse is untenable.

An analysis with morphologically restricted Dep fares much better. Nouns permit epenthesis, but imperatives do not. Therefore, Dep$_{Imp}$ must rank above MParse, while Dep$_{Noun}$ is ranked below MParse.[4, 5] The ranking arguments are presented in (28) and (29).

(28) Dep$_{Imp}$ >> MParse

/åpn/$_{Imp}$	Dep$_{Imp}$	MParse	Dep$_{Noun}$
→ ⊙ <i> = <å, p, n> <o> = < > ℜ = Ø		1	
a. åpən <i> = <å, p, #, n> <o> = <å, p, ə, n> ℜ = {(å, å), (p, p), (#, ə), (n, n)}	W$_1$	L	

(29) MParse >> Dep$_{\text{Noun}}$

	/adl/$_{\text{Noun}}$	Dep$_{\text{Imp}}$	MParse	Dep$_{\text{Noun}}$
→	adəl <i> = <a, d, #, l> <o> = <a, d, ə, l> ℜ = {(a, a), (d, d), (#, ə), (l, l)}			1
a.	⊙ <i> = <a, d, l> <o> = < > ℜ = Ø		W$_1$	L

This model has no need to posit a word level phonology that determines the contents of the lexicon. When an utterance would contain both a noun like /adl/ and an imperative verb like /åpn/, the winning candidate is (correctly) the null output (see (30)). But when a following vowel-initial word allows the imperative to be syllabified without epenthesis, there is no gap (see 31).

(30) Null output when phrase contains imperative of /åpn/

	/…adl…åpn…/	Dep$_{\text{Imp}}$	SonSeq	MParse	Dep$_{\text{Noun}}$
→	⊙			1	
a.	…adəl…åpən…	W$_1$		L	W$_1$
b.	…adəl…åpn…		W$_1$	L	W$_1$

(31) Nonnull imperative when a vowel follows

	Sykl opp bakken	Dep$_{\text{Imp}}$	SonSeq	MParse	Dep$_{\text{Noun}}$
→	*Sykl opp bakken*			1	
a.	⊙			L	

The null output is certainly a possible outcome in the phrasal phonology; **Sykl ned bakken* was just cited as an example. More generally, Zec and Inkelas (1990), Golston (1995), and others have argued that phonological restrictions can make sentences ungrammatical. (For the contrary view, that the phonology cannot exert influence on the syntax, see Zwicky and Pullum (1986), Myers (1987), and Vogel and Kenesei (1990).) For example, according to Zec and Inkelas, Heavy NP Shift in English is only permitted when the postposed NP is realizable as a branching phonological phrase.

It would be beyond the scope of this chapter to give MParse analyses of all claimed cases of phonological filtering of syntactic forms. Still, 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. For an example of this mode of analysis, see the discussion of the *–ŋgu/–gu* allomorphy of the Dyirbal ergative suffix in McCarthy and Prince (1993b: Chapter 7).

4.3. Harmonic bounding relationships, part II

Simply by allowing GEN to create candidates where 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. If we wish to avoid stipulative restrictions on GEN, ⊙ is not the only MPARSE-violating candidate. The candidate ⊙ has a phonologically null output and an undefined correspondence relation. In principle, there can be candidates that violate MPARSE but have phonologically nonnull outputs.

One example of this type is the candidate ([ʔə], <p, a, t>, <ʔ, ə>, Ø), in which input /pat/ and output [ʔə] are juxtaposed with a completely undefined ℜ. This candidate has deletion, of a sort, and epenthesis, of a sort, but it violates neither MAX nor DEP, since it posits no mappings to or from the null string #. It doesn't violate IDENT either, since it asserts no correspondence relations between input and output segments. It is, in short, perfectly faithful because it does an end run around the theory of faithfulness. The theory of faithfulness would be completely subverted if such candidates could ever emerge as optimal. This candidate violates MPARSE, of course, but then so does ⊙.

In reality, candidates like ([ʔə], <p, a, t>, <ʔ, ə>, Ø) 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 these strategems violate 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 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. The threat from ([ʔə], <p, a, t>, <ʔ, ə>, Ø) and its kin is illusory, since all such candidates are harmonically bounded by ⊙.

This assurance of harmonic bounding by ⊙ crucially depends on MPARSE issuing a categorical assessment: any candidate in which $\Re$ 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 $\Re$ (like MAX in segment-based correspondence), then ⊙, where $\Re$ is undefined for *every* string in <i>, would incur more MPARSE violations than candidates where $\Re$ is undefined for some, but not all, strings in <i>. See (32) for an illustration.

(32) 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	W_6	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 (32) 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 (23) has exactly this property.

Our argument about ⊙'s ability to harmonically bound all of the non-null MPARSE violators also depends on the assumption that all constraints (besides MPARSE itself) are either markedness or faithfulness constraints. While this assumption is entirely standard, several constraints that may stand outside the markedness/faithfulness typology have been proposed. We will now examine two such constraint types, morpheme realization and antifaithfulness, concluding that morpheme realization constraints are compatible with our proposals but antifaithfulness constraints are not. It should be noted that we do not wish to seem to endorse any of these extracanonical constraints; our goal is simply to check compatibility.

Some of the various MORPHREAL constraints do stand outside of the basic markedness/faithfulness typology. (References include, among others, Samek-Lodovici (1993), Akinlabi (1996), Gnanadesikan (1997), Rose (1997), and Kurisu (2001).) Many formulations of these constraints demand that all morphemes have overt exponence or realization on the surface, with 'exponence' and 'realization' defined in various ways and with various degrees of explicitness. Such formulations, at an intuitive level, would seem to imply that ⊙ would violate MORPHREAL, since ⊙'s total absence of output structure means that no input morpheme has an exponent.

Somewhat paradoxically, however, ⊙ actually satisfies MORPHREAL in most, if not all, proposed versions of this constraint. Many formulations of MORPHREAL are, in fact, faithfulness constraints: they demand that some piece of every input morpheme be preserved in the output. Under string correspondence, this could be stated as a demand to 'assign a violation mark if every string in <i> containing some unit of structure in the lexical representation of some morpheme stands in correspondence with #'. Since in ⊙ no string in <i> stands in correspondence with # (or with anything else), ⊙ would satisfy MORPHREAL, in just the same way that it vacuously satisfies every other faithfulness constraint.

The version of MORPHREAL proposed in Kurisu (2001) is not a faithfulness constraint. Instead, it demands that the phonological output of *stem+affix* be distinct from the phonological output of *stem*. It thus tests for dissimilarity between two output forms. One of the main arguments adduced by Kurisu in support of this alternative formulation is that certain languages exhibit morphophonological processes that cannot be obviously construed as the result of faithfulness to input structure, such as morphological truncation, deletion of root accents triggered by dominant affixes, or morphological metathesis. These processes remove or alter structure in *stem*, but they do not seem to involve faithfulness to the input structure of *affix*. They do, however, render the output of *stem+affix* different from the output of *stem* — for instance, because *stem* contains segments that are truncated in *stem+affix*.

Under Kurisu's definition, if *stem* is nonnull and *stem+affix* is ⊙, MORPHREAL is technically satisfied. It is certainly counterintutive that the null output would count as having 'realized' any of its input morphemes, but so long as deletion (as in truncative processes) of some *part* of the input counts as morpheme realization, then so would the deletion of *all* parts of the input, as in the candidate Φ where all strings in <i> map to #. Since Φ and ⊙ are identically structureless at the output level, both will then satisfy Kurisu's version of MORPHREAL, again provided that the output of *stem* does not also yield an output with no structure.

Given the preceding discussion, the claim that ⊙ violates no constraint except MPARSE may be non-stipulatively maintained irrespective of one's position on the presence in or absence from CON of any of the heretofore proposed versions of MORPHREAL. We do not, however, have this luxury of agnosticism regarding a competing theory of morpheme realization, transderivational anti-faithfulness (TAF) constraints (Alderete 2001a, 2001b). As we will now show, TAF conflicts with our proposal in a quite fundamental way. Specifically, TAF constraints would spoil the harmonic bounding of the non-null MPARSE violators.

Under this theory, input morphemes may be associated with one or more TAF constraints, which are literally negations of output-output faithfulness constraints (Benua 1997, Crosswhite 1998, Kager 1999, Pater 2000, and others). Since ⊙ vacuously satisfies all faithfulness constraints, including output-output faithfulness constraints (see section 4.4), it necessarily violates any anti-faithfulness constraints that might be associated with input morphemes. This fact is not merely an analytic inelegance that causes ⊙ to violate constraints other than MPARSE — it subverts our result about harmonic bounding because some non-null MPARSE violators will satisfy the anti-faithfulness constraints that ⊙ violates.

Consider the following hypothetical scenario. Imagine a language identical to Norwegian except that the imperative morphology is associated with the antifaithfulness constraint ¬IDENT(+low), which requires mutation of a low stem vowel. If ¬IDENT(+low) dominates MPARSE and IDENT(+low), as in (33), then a nonnull MPARSE violator can be chosen over ⊙. Worse yet, once a nonnull MPARSE violator is admitted, then faithfulness constraints can be fully subverted. Hence, the winner in (33) is maximally unmarked — except for the (a, e) correspondence relation that is necessary to satisfy ¬Ident(+low), this form has discarded the input and replaced it with maximally unmarked structure at no cost in faithfulness. This result is obviously disastrous, and it shows the steep price that must be paid for breaking the harmonic bounding of nonnull MParse violators.

(33) Incorrect victory of non-null MParse violator in pseudo-Norwegian

	/apn/	SonSeq	Dep$_{Imp}$	¬Ident (+low)	MParse	Ident (+low)
→	ʔe <i> = <a, p, n> <o> = <ʔ, e> ℜ = {(a, e)}				1	1
a.	⊙ <i> = <a, p, n> <o> = < > ℜ = Ø			W_1	1	L
b.	apn <i> = <a, p, n> <o> = <a, p, n> ℜ = {(a, a), (p, p), (n, n)}	W_1		W_1	L	L
c.	epn <i> = <a, p, n> <o> = <e, p, n> ℜ = {(a, e), (p, p), (n, n)}	W_1			L	1
d.	epən <i> = <a, p, #, n> <o> = <e, p, ə, n> ℜ = {(a, e), (p, p), (#, ə), (n, n)}		W_1		L	1

This argument shows that string-based correspondence is incompatible with antifaithfulness, at least insofar as these theories are developed here and in Alderete (2001a, 2001b), respectively. The presence of antifaithfulness constraints in Con breaks the harmonic bounding of nonnull MParse violators, and it thereby vitiates the broader theory of faithfulness. Hence, string correspondence and antifaithfulness cannot both be correct. This is not an entirely unexpected conclusion, since TAF is already far from uncontroversial; see, among others, Apoussidou (2003), Inkelas and Zoll (2003), Kurisu (2001), Trommer (2005), van Oostendorp (2005), and Wolf (2006) for critiques.

To sum up, we have argued that ⊙ is the most harmonic MParse-violating candidate because it violates only MParse, whereas all other MParse violators will incur violations of other constraints. Thus, there is no profusion of MParse-violating candidates among the contenders for optimality, and there is no danger of undermining the theory of faithfulness.

The harmonic bounding results that we have shown here and in section 3.3 go a long way toward ensuring that string correspondence does not introduce any novel ambiguities in input-output relations. We have not quite arrived at establishing ⊙'s uniquness, however, since for any input there will still be infinitely many null outputs. The reason: ⊙ has an empty output, and an empty output has infinitely many concatenative decompositions: < >, <#>, <#, #>, <#, #, #>, and so forth. Outputs like <#> and <#, #> satisfy MAX as long as the correspondence relation is undefined. Under the constraint system presented above, the candidates ⊙, <#>, <#, #>, etc. are equally harmonic, since they violate MPARSE and no other constraint.

Strictly speaking, nothing intrinsic to OT rules out the possibility of obtaining an infinity of winners in some evaluations. Samek-Lodovici and Prince (1999) demonstrate that the number of non-harmonically bounded *violation profiles* is finite for every input, but multiple candidate forms can in principle have identical violation profiles. That is the situation with ⊙, <#>, <#, #>, … Nonetheless, the theoretical possibility of distinct candidates with identical violation profiles has rarely been exploited in actual OT analyses (though see Grimshaw (1997: 410--411) and Hammond (1994)), presumably because the richness of CON makes it almost impossible for two candidates to be equally harmonic on all constraints. Allowing an infinite number of contenders would thus not be a change to the formal properties of OT, but would be empirically unlikely (if not impossible) under previous proposals about the substantive contents of GEN and CON. It would therefore be preferable to distinguish ⊙ from <#>, <#, #>, … in terms of some constraint.

A similar technical problem arises with nonnull outputs as well: the inclusion of #→# mappings in candidates that obey MPARSE, so that there are infinitely many equally faithful candidates for any input (see (34)). A #→# mapping does not violate any of the faithfulness constraints above. Moreover, since markedness constraints only see the literal output *o*, which does not contain any #s, they cannot militate against the presence of these gratuitious #s. As a result, alongside any given candidate with no #→# mappings, there are infinitely many candidates with such mappings, all of which tie on all constraints (van Oostendorp 2005).

(34) #→# mappings

<p, a, t>	→	<p, a, t>
<p, a, t, #>	→	<p, a, t, #>
<p, a, t, #, #>	→	<p, a, t, #, #>
<#, p, #, a, #, t, #>	→	<#, p, #, a, #, t, #>
…		

The most straightforward way of resolving both problems is to introduce a constraint that requires #s in <o> to have nonnull correspondents in <i> (see (35)). The null-output candidates in which <o> equals <#>, <#, #>, <#, #, #>, … all violate NO-#, while the null output with empty <o> obeys it. Therefore, the candidate that we have been calling ⊙, with empty <o>, harmonically bounds all of the null-output candidates with <o> equal to <#>, <#, #>, <#, #, #>, … Similarly, the candidate in (34) with <o> equal to <p, a, t> harmonically bounds all of the candidates with #→# mappings, since all of these other candidates also violate NO-#.

(35) NO-#
Given a candidate (*o*, <i>, <o>, $\Re$),
for every string κ=# in <o>
if $\Re^{-1}(\kappa)$ = # or $\Re^{-1}(\kappa)$ is undefined
assign a violation mark.

The constraint NO-# has the unusual property of not conflicting with any other constraint, and hence it is irrelevant where it is ranked. If the reader finds such a constraint to be aesthetically displeasing, other solutions to the same problem can be imagined. For example, on a view in which candidates are produced serially via a succession of harmonically-improving steps (McCarthy 2006a, 2006b), it may be that candidates with gratuitous #→# mappings cannot arise, since no constraint favors the presence of such a mapping, and consequently adding one is never harmonically improving.

4.4. 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 thus far, candidates with a reduplicative morpheme in the input also contain a base-reduplicant (BR) correspondence relation. The main thesis of correspondence theory is that all 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 will be distinct MPARSE constraints for each dimension of correspondence, just as there are distinct faithfulness constraints for each such dimension. We will therefore investigate MPARSE-BR in some detail. The parallels are not perfect, however, and we will conclude this section with an explanation for why there is no MPARSE constraint on output-output (OO) correspondence.

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. The literal output *o* exhaustively consists of these two substrings, which by hypothesis bear separate correspondence relations to the string *input*. What we have been calling IO correspondence in the discussion so far is thus, strictly speaking, *input-base* correspondence. Since BR and IO are distinct correspondence relations, the string *base* can have different concatenative decompositions as B and as O — e.g., if there is coalescence in the reduplicant but not the base. The concatenative decomposition of *base* which is relevant to IO-correspondence, whose substrings stand in correspondence with substrings of <i>, can continue to be called <o>. (The string *reduplicant* is thus entirely outside the scope of the IO-correspondence relation, and so the presence of reduplicated structure violates neither DEP-IO nor MPARSE-IO (McCarthy and Prince 1995, 1999).) The other concatenative decomposition of *base* is used for BR correspondence and can be called <b>. The substrings in <b> stand in correspondence with substrings in the concatenative decomposition of *reduplicant*, which we can call <r>.[6]

Example (36) illustrates these various concatenative decompositions and the relations between them:

(36) Illustration of concatenative decompositions in /RED-pamək/ → [pãpam]

Description	Form	Concatenative Decomposition
Input	/pamək/	<i> = <p, a, m, ə, k>
Output	[pãpam]	
Base	[pam]	<o> = <p, a, m, #, #> <b> = <p, am>
Reduplicant	[pã]	<r> = <p, ã>
IO correspondence relation	$\mathfrak{R}_{IO}$ = {(p, p), (a, a), (m, m), (ə, #), (k, #)}	
BR correspondence relation	$\mathfrak{R}_{BR}$ = {(p, p), (am, ã)}	

In this hypothetical example, there is coalescence in the B→R mapping but not in the I→O mapping. Therefore, <i> and <o> contain only monosegmental (or null) strings, in keeping with our harmonic bounding results in section 3.3. By contrast, the presence of coalescence in the B→R mapping results in [am] forming a bisegmental substring in <b>, despite these segments belonging to distinct, monosegmental strings in <o>.

For each of the two relevant correspondence dimensions, $\mathfrak{R}_{IO}$ and $\mathfrak{R}_{BR}$, there exists an MPARSE constraint that tests whether it is a total bijective function. The conditions that produce violations of MPARSE-BR and MPARSE-IO are quite different, however, as we will now show.

Among the output candidates for any RED-containing input is ⊙. This candidate violates MPARSE-IO, of course, but it vacuously satisfies MPARSE-BR. The reason: in the null output, the concatenative decompositions of the base <b> and the reduplicant <r> are both empty. $\mathfrak{R}_{BR}$, being a relation between empty sequences (or, strictly speaking, from the empty sequence to itself), is vacuously a total bijective function.

The situation is a little more complicated when MPARSE-BR is violated. For concreteness, suppose that MAX-BR and NOCODA dominate MPARSE-BR, as in (37). (We use a violation tableau instead of a comparative tableau because the purpose of (37) is to investigate potential winners rather than locate a specific winner.)

(37) Potential effects of MPARSE-BR violation

	/RED-pam/	MAX-BR	NOCODA	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 (37) 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-BR 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 reduplicated *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. Candidate (e) is favored over (d) by any constraints favoring the presence of phonological material in the reduplicant. MORPHREAL is such a constraint, if indeed it exists (see section 4.2); 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 that there can be a system of reduplication where copying is either exact or doesn't happen at all. In a language with a ranking like (37), the input /RED-ta/ can be copied exactly, yielding [ta-ta], but the input /RED-pam/ cannot be copied at all, so it yields either [pam] or [ʔə-pam], depending on how other constraints are ranked. 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 can be found in Cebuano, Tagalog, and Makassarese (Aronoff *et al.* 1987, Carrier-Duncan 1984, McCarthy and Prince 1990, 1994), all of which discriminate between exact and inexact copies.

One final remark about MPARSE-BR: the fact that candidates like (37) are not harmonically bounded demonstrates that ineffability does not result from the presence of an empty correspondence relation *pre se*. Rather, gaps—instances of the candidate ⊙—are ineffable for the more simple and concrete reason that they contain no output structure to be phonetically interpreted. Candidates in which $\Re_{BR}$ is not a total bijective function, as (37) shows, can well have overt output structure, and hence, when they emerge as optimal, are entirely utterable.

We might expect there to be an MPARSE-OO constraint as well, but OO correspondence differs in a basic way from IO and BR correspondence. Although IO and BR correspondence relations are freely posited by GEN, OO correspondence is dependent on IO correspondence and is not free. For example, because the [t] of German [bʊnt] 'federation' and the [d] of [bʊndə] have the same input correspondent in the root /bʊnd/, they must be in OO correspondence with one another. In other words, OO correspondence is a kind of transitivization of IO correspondence from one output via the shared input to another output. Theories of OO correspondence typically do not acknowledge this dependence on IO correspondence (though see McCarthy 2005), but no analysis in the literature known to us relies on positing a fully independent OO correspondence relation.

The dependence of OO correspondence on IO correspondence has two consequences that are relevant to our current concerns. First, it means that MPARSE-OO can be dispensed with: there can be no OO correspondence relation if there is no IO correspondence relation because of OO correspondence's dependent status. Second, it supports the claim made earlier (section 4.3) that ⊙ obeys *all* faithfulness constraints, including OO faithfulness constraints. Because ⊙ has an empty IO correspondence relation with the input, it cannot have any OO correspondence relations with the surface forms of morphologically related inputs either, given the dependence of OO correspondence on IO correspondence. And because ⊙ has no OO correspondence relations, OO faithfulness constraints like MAX-OO or DEP-OO are not violated by it.

5. MPARSE and learning

Gaps present an obvious challenge to the language learner. If grammars are learned only from positive evidence, then learners cannot discover the existence of gaps or the constraint rankings that produce them. This means that learners must assume gaps until proven otherwise — they must go from a grammar that allows only gaps to a grammar that disallows some gaps. This is in accordance with the Subset Principle, which requires learning to proceed from the maximally restrictive grammar to successively less restrictive ones (Baker 1979, Berwick 1985, Gold 1967).

In the OT literature, learning in accordance with the Subset Principle is taken to mean that there is a durable bias toward ranking markedness constraints over faithfulness constraints (Hayes 2004, Prince and Tesar 2004 and references cited there). Learners assume that markedness constraints are unviolated unless they observe noncompliant forms in the primary data.

Our theory requires another ranking bias: faithfulness is ranked over MPARSE. This means that learners only permit unfaithful mappings that are supported by alternations in the primary data, and otherwise they assume a gap. This ranking bias follows from the same reasoning as the markedness over faithfulness bias: learning from positive evidence must be driven by that which occurs rather than that which does not occur. Henceforth, we will refer to these combined ranking biases as M-F-MP.

As we delve into this matter, we adopt certain assumptions that are by now standard in the OT literature on learning phonological grammars. (For references to this extensive work, see McCarthy (2002: 202--216, 230--232) and Kager, Pater, and Zonneveld (eds.) (2004).) Early learning is focused on phonotactics: which structures are allowed or disallowed in the target language? The phonotactic learner's goal is a grammar that performs an identity map from perceived adult forms to the learner's own productions. Later, in morphophonemic learning, the learner's goal is to obtain a unique underlying representation for each morpheme and a grammar that maps these underlying representations to the observed surface forms.

For the phonotactic learner, the M-F-MP bias is overridden by experience with marked structures in the ambient language. For example, the Egyptian Arabic learner who hears [ʔibn] 'son' has evidence that SONSEQ must be ranked below MPARSE and the relevant faithfulness constraints MAX and DEP. This ensures that /ʔibn/ maps to [ʔibn] and not to *⊙, *[ʔib], or *[ʔibin]. But the Norwegian learner's experience does not include coda clusters that violate SONSEQ, so he/she never has reason to demote SONSEQ below MPARSE and the faithfulness constraints. Since the M-F-MP bias puts MPARSE at the bottom until proven otherwise, the Norwegian phonotactic learner's grammar would most harmonically map hypothetical /ʔibn/ to ⊙.

At the conclusion of phonotactic learning, the Norwegian learner's grammar includes the ranking SONSEQ >> DEP >> MPARSE. The target grammar was shown in section 4.2: SONSEQ >> DEP_{Imp} >> MPARSE >> DEP_{Noun}. For the morphophonemic learner to get to this target, he/she must proceed in maximal compliance with the M-F-MP ranking bias. This means that unfaithfulness is allowed in a particular paradigmatic slot only when required by alternations observable in the primary data. When a particular morphosyntactic feature combination MS exhibits epenthesis, the DEP_{MS} constraint proper to MS will be demoted below MPARSE. Absent such alternations, forms in the MS category would map to ⊙ if the alternative is violation of SONSEQ. Since the morphosyntactic features are presumably universal, every DEP_{MS} constraint may be immanent in CON or it (and its complement) may be constructed on the fly by learners — how this is done is unimportant. What is important is that learners need not discover gaps because they presume gaps everywhere until they encounter evidence to the contrary.

To sum up, this analysis shows that gaps do not present special difficulties to learners equipped with a theory that includes a null output candidate and MPARSE. The resources required to learn systems with paradigmatic gaps are no different from the resources required to learn OT grammars generally, so we were able to call on familiar ideas from the OT learning literature.

This situation stands in stark contrast to the problem of learning gaps in a theory based on inviolable constraints, Orgun and Sprouse's (1999, this volume) CONTROL model. This model posits a grammatical component called CONTROL that inspects the output of EVAL and may reject it as ill-formed. The constraints in CONTROL come from CON; on a language-particular basis, constraints in CON can be lifted out of the regular constraint hierarchy and placed in CONTROL. 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). We will not dwell on this empirical material here, but rather we will look at learning in the CONTROL model in comparison with MPARSE.

Learners have two tasks in the CONTROL model: they have to determine the language's regular constraint hierarchy, and they also have to figure out which unviolated constraints belong in CONTROL. Reasoning from the Subset Principle, we might suppose that all constraints start out in CONTROL and then some are moved into the regular hierarchy as the learner observes violations of them. But this simple approach will not work: it has the effect of keeping all unviolated constraints in CONTROL, when in reality only some unviolated constraints produce gaps. In a CONTROL-style analysis of Norwegian, for instance, $\text{SONSEQ}_{\text{Imp}}$ has to be in CONTROL because it causes a gap, but $\text{SONSEQ}_{\text{Noun}}$ needs to end up in the regular constraint hierarchy so that it can favor epenthetic [adəl] instead of causing a gap. Since both $\text{SONSEQ}_{\text{Imp}}$ and $\text{SONSEQ}_{\text{Noun}}$ are unviolated in the primary data, a learner proceeding from only positive evidence has no way of knowing which constraint belongs where.

For this reason, learning in the CONTROL model requires learners to discover any gaps, and that cannot be done from positive evidence alone. Orgun and Sprouse (1999: 219--221) sketch an approach based on so-called indirect negative evidence. The idea is that each time the learner encounters a paraphrase or other alternative to the gap, he or she receives a hint that there is a gap for which the paraphrase has been substituted. A sufficient accumulation of such hints is a prerequisite to moving a constraint into the CONTROL component.

This approach could perhaps be made to work when there is a consistent substitute for the gap, such as English *more violet* for **violeter.* But it is difficult to imagine a learning mechanism powerful enough to identify diverse expressions in Norwegian as paraphrases of or circumlocutions for 'open!' or 'bicycle!', and then to connect this with the absence of 'open!' and 'bicycle!' from the primary data. It would seem to be necessary for learners to scrutinize every phrase and ask whether it could be paraphrased with a single word using the language's morphological resources, and then to check whether that word has been previously heard.

This is clearly not a workable learning algorithm, and this failure suggests that the CONTROL model is on the wrong track. From an OT perspective, that is a welcome result, since the CONTROL model is at odds with several of OT's most basic premises.

6. Other theories of the null output

In section 4.1, we described Prince and Smolensky's (2004) two original ideas about the null output and MPARSE: failure to parse any input phonological structure, and failure to parse any input morphological structure. In 4.2, we showed why and how nonparsing or deletion of all input phonological structure (the candidate Φ) is distinct from and an inadequate substitute for the null output ⊙. Below, section 6.2 looks at Walker and Feng's (2004) interpretation of what nonparsing of morphological structure means. But first section 6.1 considers an idea closer to ours, Rice's (2005a, 2005b) proposal to replace MPARSE with constraints requiring paradigm slots to be filled.

6.1. MAX(Category) constraints

Rice (2005a, 2005b) proposes an alternative to the null output based on the idea that whole morphological paradigms are evaluated as candidates, as in McCarthy's (2005) Optimal Paradigms theory. Rice employs a family of MAX(*category*) constraints, which assign a violation mark if no form fills the paradigm slot labeled by *category*.

In Norwegian, for example, plurals are marked by a suffix *–er* and infinitives with a suffix *–e*, but normally the singular noun and imperative verb forms are identical to the bare root. When the root ends in a rising-sonority cluster, as we have seen, the result is epenthesis in the singular noun (*adel*) but a gap for the imperative verb. Rice's proposal captures this difference by having the MAX(category) constraints for the singular noun and imperative verb be ranked differently with respect to DEP. DEP dominates MAX(*imperative*) (38), but DEP is itself dominated by MAX(*singular-noun*) (39).

(38) SONSEQ, DEP >> MAX(*imperative*)

/åpn+{INF, IMP}/	SONSEQ	DEP	MAX(*imperative*)
→ {[åpne]$_{Inf.}$}			1
a. {[åpne]$_{Inf.}$, [åpn]$_{Imp.}$}	W$_1$		L
b. {[åpne]$_{Inf.}$, [åpən]$_{Imp.}$}		W$_1$	L

(39) SONSEQ, MAX(*singular-noun*) >> DEP

/adl+{SG, PL}/	SONSEQ	MAX(*singular-noun*)	DEP
→ {[adəl]$_{sg.}$, [adler]$_{pl.}$}			1
a. {[adler]$_{pl.}$}		W$_1$	L
b. {[adl]$_{sg.}$, [adler]$_{pl.}$}	W$_1$		L

Rice argues that this approach to gaps is conceptually superior to one that employs the null output because there is no need to augment the candidate set with a special object that is interpreted as meaning 'no output.' On closer examination, however, it is not so clear that this proposal is able to avoid the need for such a candidate. The problem has to do with affixation: what is the source of the affixes that appear on the plural and infinitive forms in these tableaux? The MAX(*category*) approach depicts the input as consisting of a bare root and a set of slots for which inflected forms of the root are to be computed, but affixes are not shown in the input.

Under an item-based theory of morphology, it is necessary to assume that affixes are present in the input. There are two main reasons for this. First, since the relationship between affix form and function is arbitrary, the phonological shape of affixes is unpredictable and therefore must be present in underlying representation. Second, the order of affixes relative to one another respects a number of universals and near-universals, and moreover affix-order has been observed to often (if not necessarily always) bear a non-trivial relationship to the constituent structure of the syntax, as required by the Mirror Principle (Baker 1985 and much subsequent work). The fact that such generalizations exists suggest that affixes must be (preliminarily) ordered before the phonology gets underway, as argued by Horwood (2002).

Under an item-based morphological theory, then, the input to an Optimal Paradigms-type phonology would have to consist not of a root plus a set of categories for which output forms can be constructed, but of a number of collections of the root plus affixes, each serving as the input to one paradigmatic slot: e.g., Latin {/am-oː/, /am-aːs/, /am-at/, …}. Under such a set-up, however, the MAX(*category*) approach runs directly into the same difficulty faced by the original version of MPARSE: producing no output form for a given paradigmatic cell would involve eliminating all of the structure present in the input for that cell, and, in order to avoid a gapped paradigm being harmonically bounded by one with partial deletion in the relevant cell, the MAX(*category*)-violating gap must be stipulated not to violate phonological MAX (i.e., MAX(*segment*)).

On the other hand, the MAX(*category*) approach does appear to be compatible with a process-based theory of morphology in which affixes are not regarded as actual objects in some lexical list, but rather are simply introduced into the output by rules or constraints that specify how certain morphosyntactic properties are to be expressed phonologically. OT approaches that adopt versions of this view of morphology include Hammond (1995), Russell (1999), and MacBride (2004); they are subjected to critical scrutiny in Bonet (2004). The main problem: without affixes in the input, affixes are not subject to faithfulness constraints, and so explanations for language typology based on (positional) faithfulness are not possible.

6.2. Gaps as morpheme deletion

The original version of MPARSE proposed in Prince and Smolensky (2004) demands that the morphemes in the input be parsed into morphological constituents. The null parse, in this formulation, consists of just the input morphemes with no tree structure linking them. The victory of this candidate results in a gap because unstructured morphological content cannot enter the syntax. The fate of morphemes in the null parse candidate, as originally conceived, is thus parallel to that suffered by deleted segments, which, under the PARSE/FILL theory, were not literally deleted but rather not parsed into *prosodic* constituents, and hence rendered unpronounceable.

With the supplanting of the PARSE/FILL model of faithfulness by correspondence, a number of researchers have proposed adapting the original conception of MPARSE to the new faithfulness regime, by replacing under-parsing of morphemes with literal deletion of morphemes. Kager (2000), for example, recasts MPARSE as M-MAX: 'every morpheme in the input has a correspondent in the output.' A more elaborate model along the same lines is presented in Walker and Feng (2004). They propose that there are three correspondence relations relevant to the phonology/morphology interface; they are defined in (40) along with the MAX constraints that operate on each dimension of correspondence. The idea is that both input and output have separate phonological and morphological structure. PP-correspondence constraints (a) require input-output faithfulness to phonological structure; MM-correspondence constraints (b) require input-output faithfulness to morphological structure; and MP-correspondence constraints (c) require an affiliation between morphological and phonological structure in the output. We will henceforth refer to this theory as Ternary Morphology-Phonology Correspondence, or TMPC.

(40) Correspondence relations in Walker and Feng (2004)

a. PP-Correspondence (= input-output correspondence on phonological structure)

MAX-PP: Every segment in the input has a correspondent in the output.

b. MM-Correspondence (= input-output correspondence on morphological structure)

MAX-MM: Every morpheme in the input has a correspondent in the output.

c. MP-Correspondence (=affiliation of phonological structure with morphemes)

MAX-MP: Every morpheme in the output is indexed with some phonological element in the output.

MAX-PM: Every phonological element in the output is indexed with some morpheme in the output.

In TMPC, paradigmatic gaps are analyzed as follows. Assume that faithful realization of the phonological content of some affix Af would result in violation of some markedness constraint MARK. If the ranking is MARK >> MAX-PP, then Af's phonological content will be deleted. (This is equivalent to MARK >> MAX in conventional correspondence theory.) If the grammar also contains the ranking MAX-MP >> MAX-MM, then (by MAX-MP) every morpheme is required to have some overt phonological exponence, and (at the expense of violating MAX-MM) Af is removed from the output *morphological* structure because it has no output *phonological* structure.

For illustration, consider how a paradigmatic gap in Swedish would be analyzed in TMPC. (For this phenomenon, see Eliasson (1975) and Iverson (1981).) In Swedish, the indefinite neuter singular suffix on adjectives is /-t/: *et rysk-t barn* 'a Russian child'. But adjectives whose stem ends in /dd/ have no neuter singular form: **et rädd-t barn* 'a scared child' (cf. masculine *en rädd pojke* 'a scared boy'). The ranking MARK >> MAX-PP, where MARK rules out **dd-t*, favors deletion of /-t/ from the output phonological structure. (This assumes that /-t/ rather than /dd/ deletes, perhaps because of greater faithfulness to root segments.) The ranking MAX-MP >> MAX-MM further favors deletion of INDEFINITE NEUTER SINGULAR from the output morphological structure (indicated here in small caps). The result, shown in (41), is a paradigmatic gap: an output without the morphological structure of an indefinite neuter singular adjective.

(41) Swedish gap in TMPC

	/rädd+t/ /SCARED+INDEF.NEUT.SG/	MARK	MAX-MP	MAX-PP	MAX-MM
→	rädd SCARED			1	1
a.	rädd-t SCARED+INDEF.NEUT.SG	W_1		L	L
b.	rädd SCARED+INDEF.NEUT.SG		W_1	1	L

This analysis of Swedish illustrates a key property of TMPC: because the only constraint in the theory that conflicts with MAX-MM is MAX-MP, deletion of morphological structure (that is, paradigmatic gapping) can only occur when some markedness constraint forces deletion of *all* of the phonological content of a morpheme, so the continued presence of that morpheme's morphological structure would violate MAX-MP.

This property proves to be the empirical Achilles' heel of the theory, because it means that TMPC cannot induce paradigm gaps involving morphemes that have no phonological exponent to begin with (i.e., zero affixes). The Norwegian imperative is an example. Because Norwegian has a zero affix in the imperative, the ranking MAX-MM >> MAX-MP must hold in the language, in order to prevent the imperative from being gapped across the board. But then there can be no imperative gaps whatsoever since, as (41) shows, the opposite ranking of these constraints is a prerequisite for paradigmatic gaps.

Another reason why TMPC cannot handle the Norwegian facts is that deleting the exponentless imperative morpheme does nothing to remedy the phonological markedness that motivates the gap in the first place. In other words, [åpn-∅//OPEN-IMP] and [åpn//OPEN] receive exactly the same marks from the constraint against rising-sonority coda clusters, and indeed from every phonological markedness constraint, since their phonological output shapes are identical. As one may see in (41), the TMPC account works only if deleting the affix's phonological structure improves performance on MARK. That is not the case in Norwegian, since the affix had no phonological structure to start with.

The TMPC analysis of Swedish relies on the fact that MARK can only be satisfied by deleting *all* of the affix's phonological content, so that MAX-MP will be violated unless the affix's morphological structure is also deleted. The Swedish affix in question is monosegmental, but what about longer affixes, where partial deletion would suffice to satisfy MARK? Hungarian (Hetzron 1975, Rebrus and Törkenczy this volume) is a case in point. Certain verbs whose stem ends in a cluster, such as *csukl-* 'hiccup', have gaps for the following categories: the jussive (normally marked by *–j* plus a person marker), the potential (marked by *–hat/het*), and the verbal adverb (marked by *–va/ve*). What all of these affixes have in common is that, if they are concatenated to *csukl-*, a triconsonantal cluster would be created. In the case of the potential affix *–hat/het* and the verbal adverb affix *–va/ve*, though, the triconsonantal cluster could be eliminated by deleting just the initial consonant of the suffix: /csukl-hat/ → *[csuklat]. Since the affix is not completely deleted, MAX-MP is satisfied without further ado, and the gap is unanalyzeable under TMPC's assumptions. In an MPARSE-based theory, on the other hand, it would suffice to simply rank the constraint against triconsonantal clusters and all relevant faithfulness constraints above MPARSE. For this and all of the other reasons discussed in this section, it is clear that morpheme-deletion-based approaches like TMPC are simply not empirically adequate as theories of phonologically-motivated paradigm gaps.

7. Conclusion

In this chapter, we have argued for a revision of correspondence theory in which strings rather than segments are the formal objects that stand in correspondence. In this revision, well-behaved unfaithful mappings do not alter $\Re$'s status is a total bijective function. Candidates with a less orderly $\Re$ 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 gaps. Along the way, we have also discussed the general properties of MPARSE, the locality of coalescence and breaking, and alternative theories of gaps.

References

Akinlabi, Akinbiyi (1996) Featural alignment. *Journal of Linguistics* 32: 239--289. [Available on Rutgers Optimality Archive, ROA-185.]

Alderete, John (2001a) Dominance effects as transderivational anti-faithfulness. *Phonology* 18: 201--253.

Alderete, John (2001b) *Morphologically Governed Accent in Optimality Theory*. New York & London: Routledge. [1999 Doctoral dissertation, University of Massachusetts, Amherst. Available on Rutgers Optimality Archive, ROA-309.]

Apoussidou, Diana (2003) The deformity of anti-faithfulness. In Jennifer Spenader, Anders Eriksson, and Östen Dahl (eds.) *Proceedings of the Stockholm Workshop on Variation in Optimality Theory* 15--24. Stockholm: Department of Linguistics, Stockholm University. [Available at http://www.fon.hum.uva.nl/diana/The%20Deformity%20of%20AntiFaithfulness.pdf.]

Aronoff, Mark, Arsyad, Azhar, Basri, Hassan, and Broselow, Ellen (1987) Tier configuration in Makassarese reduplication. In A. Bosch, E. Schiller, and B. Need (eds.) *CLS 23: Parasession on Autosegmental and Metrical Phonology* 1--15. Chicago: Chicago Linguistic Society.

Baker, C. L. (1979) Syntactic theory and the projection problem. *Linguistic Inquiry* 10: 533--581.

Baker, Mark (1985) The Mirror Principle and morphosyntactic explanation. *Linguistic Inquiry* 16: 373--415.

Benua, Laura (1997) *Transderivational Identity: Phonological Relations between Words*. Doctoral dissertation. Amherst, MA: University of Massachusetts Amherst. [Available on Rutgers Optimality Archive, ROA-259. Published (2000) as *Phonological Relations Between Words*, New York: Garland. Excerpted in *Optimality Theory in Phonology: A Reader*, ed. by John J. McCarthy, Malden, MA and Oxford, Blackwell (2004).]

Berwick, Robert (1985) *The Acquisition of Syntactic Knowledge*. Cambridge, MA: MIT Press.

Bonet, Eulàlia (2004) Morph insertion and allomorphy in Optimality Theory. *International Journal of English Studies* 4: 73--104.
Carrier-Duncan, Jill (1984) Some problems with prosodic accounts of reduplication. In Mark Aronoff and Richard T. Oehrle (eds.) *Language Sound Structure* 260--286. Cambridge, MA: MIT Press.
Causley, Trisha (1997) Identity and featural correspondence: The Athapaskan case. In Kiyomi Kusumoto (ed.) *Proceedings of the North East Linguistic Society 27* 93--105. Amherst, MA: GLSA Publications.
Crosswhite, Katherine (1998) Segmental vs. prosodic correspondence in Chamorro. *Phonology* 15: 281--316.
de Lacy, Paul (1999) Morphological haplology and correspondence. In Paul de Lacy and Anita Nowak (eds.) *University of Massachusetts Occasional Papers in Linguistics 25: Papers from the 25th Anniversary* 51--88. Amherst, MA: GLSA. [Available on Rutgers Optimality Archive, ROA-298.]
de Lacy, Paul and Kitto, Catherine (1999) A correspondence theory of epenthetic quality. In Catherine Kitto and Carolyn Smallwood (eds.) *Proceedings of AFLA VI* 181--200. Toronto: Toronto Working Papers in Linguistics.
Eliasson, Stig (1975) On the issue of directionality. In Karl-Hampus Dahlstedt (ed.) *The Nordic Languages and Modern Linguistics 2* 421--445. Stockholm: Almqvist & Wiksell.
Gnanadesikan, Amalia (1997) *Phonology with Ternary Scales*. Doctoral dissertation. Amherst, MA: University of Massachusetts at Amherst. [Available on Rutgers Optimality Archive, ROA-195.]
Gold, E. Mark (1967) Language identification in the limit. *Information and Control* 10: 447--474.
Golston, Chris (1995) Syntax outranks phonology: evidence from Ancient Greek. *Phonology* 12: 343--368.
Gouskova, Maria (2003) *Deriving Economy: Syncope in Optimality Theory*. Doctoral dissertation. Amherst, MA: University of Massachusetts Amherst. [Available on Rutgers Optimality Archive, ROA-610.]
Grimshaw, Jane (1997) Projection, heads, and optimality. *Linguistic Inquiry* 28: 373--422.
Halle, Morris (1973) Prolegomena to a theory of word formation. *Linguistic Inquiry* 4: 3--16.
Hammond, Michael (1994) An OT account of variability in Walmatjari stress. Unpublished manuscript. Tucson, AZ: University of Arizona. [Available on Rutgers Optimality Archive, ROA-20.]
Hammond, Michael (1995) There is no lexicon! Unpublished manuscript. Tucson, AZ: University of Arizona. [Available on Rutgers Optimality Archive.]
Hayes, Bruce (1990) Diphthongization and coindexing. *Phonology* 7: 31--71.
Hayes, Bruce (2004) Phonological acquisition in Optimality Theory: The early stages. In René Kager, Joe Pater, and Wim Zonneveld (eds.) *Fixing Priorities: Constraints in Phonological Acquisition* 158--203. Cambridge: Cambridge University Press. [Available on Rutgers Optimality Archive.]
Hetzron, Robert (1975) Where the grammar fails. *Language* 51: 859--872.
Horwood, Graham (2002) Precedence faithfulness governs morpheme position. In Line Mikkelsen and Christopher Potts (eds.) *Proceedings of the 21st West Coast Conference on Formal Linguistics* 166--179. Cambridge, MA: Cascadilla Press. [Available on Rutgers Optimality Archive, ROA-527.]
Inkelas, Sharon and Zoll, Cheryl (2003) Is grammar dependence real? Unpublished manuscript. Berkeley, CA and Cambridge, MA: University of California and MIT. [Available on Rutgers Optimality Archive, ROA-587.]
Ito, Junko and Mester, Armin (1999) The phonological lexicon. In Natsuko Tsujimura (ed.) *The Handbook of Japanese Linguistics* 62--100. Oxford: Blackwell.

Iverson, Gregory K. (1981) Rules, constraints, and paradigm lacunae. *Glossa* 15: 136--144.
Iverson, Gregory K. and Sanders, Gerald (1982) On the government of phonological rules by laws. *Studies in Language* 6: 51--74.
Kager, René (1999) Surface opacity of metrical structure in Optimality Theory. In Ben Hermans and Marc van Oostendorp (eds.) *The Derivational Residue in Phonological Optimality Theory* 207--245. Amsterdam: John Benjamins.
Kager, René (2000) Stem stress and peak correspondence in Dutch. In Joost Dekkers, Frank van der Leeuw, and Jeroen van de Weijer (eds.) *Optimality Theory: Phonology, Syntax, and Acquisition*. Oxford: Oxford University Press.
Kager, René, Pater, Joe, and Zonneveld, Wim (eds.) (2004) *Constraints in Phonological Acquisition*. Cambridge: Cambridge University Press.
Kawahara, Shigeto (2004) Locality in echo epenthesis: Comparison with reduplication. In Keir Moulton and Matthew Wolf (eds.) *Proceedings of the North East Linguistics Society 34* 295--309. Amherst, MA: GLSA.
Kawahara, Shigeto (2006) Copy and spreading in phonological theory: Evidence from echo epenthesis. In Leah Bateman, Adam Werle, Michael O'Keefe, and Ehren Reilly (eds.) *University of Massachusetts Occasional Papers in Linguistics 32: Papers in Optimality Theory III*. Amherst, MA: GLSA.
Kenstowicz, Michael (1994) Syllabification in Chukchee: A constraints-based analysis. In Alice Davison, Nicole Maier, Glaucia Silva, and Wan Su Yan (eds.) *Proceedings of the Formal Linguistics Society of Mid-America 4* 160--181. Iowa City: Department of Linguistics, University of Iowa. [Available on Rutgers Optimality Archive, ROA-30.]
Kiparsky, Paul (2000) Opacity and cyclicity. *The Linguistic Review* 17: 351--367.
Kornai, Andras (1994) *Formal Phonology*. New York: Garland. [Preface available at http://www.kornai.com/Papers/sel97.pdf.]
Kurisu, Kazutaka (2001) *The Phonology of Morpheme Realization*. Doctoral dissertation. Santa Cruz, CA: University of California, Santa Cruz. [Available on Rutgers Optimality Archive, ROA-490.]
Legendre, Géraldine, Smolensky, Paul, and Wilson, Colin (1998) When is less more? Faithfulness and minimal links in *wh*-chains. In Pilar Barbosa, Danny Fox, Paul Hagstrom, Martha McGinnis, and David Pesetsky (eds.) *Is the Best Good Enough? Optimality and Competition in Syntax* 249--289. Cambridge, MA: MIT Press. [Available on Rutgers Optimality Archive, ROA-117.]
Lombardi, Linda (1998) Evidence for MaxFeature constraints from Japanese. In Haruka Fukazawa, Frida Morelli, Caro Struijke, and Yi-Ching Su (eds.) *University of Maryland Working Papers in Linguistics*. College Park, MD: Department of Linguistics, University of Maryland. [Available on Rutgers Optimality Archive, ROA-247.]
Łubowicz, Anna (2005) Infixaton as morpheme absorption. Unpublished manuscript. Los Angeles: University of Southern California. [Available on Rutgers Optimality Archive, ROA-773.]
MacBride, Alexander (2004) *A Constraint-based Approach to Morphology*. Doctoral dissertation. Los Angeles: UCLA. [Available at http://www.linguistics.ucla.edu/general/dissertations/MacbrideAlexPhD2004.pdf.]
McCarthy, John J. (2002) *A Thematic Guide to Optimality Theory*. Cambridge: Cambridge University Press.
McCarthy, John J. (2003) OT constraints are categorical. *Phonology* 20: 75--138. [Available at http://people.umass.edu/jjmccart/categorical.pdf.]
McCarthy, John J. (2005) Optimal paradigms. In Laura J. Downing, T. A. Hall, and Renate Raffelsiefen (eds.) *Paradigms in Phonological Theory* 170--210. Oxford: Oxford University Press. [Available on Rutgers Optimality Archive, ROA-485.]

McCarthy, John J. (2006a) *Hidden Generalizations: Phonological Opacity in Optimality Theory*. London: Equinox Publishing.

McCarthy, John J. (2006b) Restraint of analysis. In Sylvia Blaho, Patrik Bye, and Martin Kraemer (eds.) *Freedom of Analysis*. The Hague: Mouton.

McCarthy, John J. and Prince, Alan (1990) Foot and word in prosodic morphology: The Arabic broken plural. *Natural Language and Linguistic Theory* 8: 209--283.

McCarthy, John J. and Prince, Alan (1993a) Generalized Alignment. In Geert Booij and Jaap van Marle (eds.) *Yearbook of Morphology* 79--153. Dordrecht: Kluwer. [Available on Rutgers Optimality Archive, ROA-7. Excerpts appear in John Goldsmith, ed., *Essential Readings in Phonology*. Oxford: Blackwell. Pp. 102–136, 1999 and in John J. McCarthy, ed., *Optimality Theory in Phonology: A Reader*. Oxford and Malden, MA: Blackwell (2004).]

McCarthy, John J. and Prince, Alan (1993b) Prosodic Morphology: Constraint Interaction and Satisfaction. Report. New Brunswick, NJ: Rutgers University Center for Cognitive Science. [Available on Rutgers Optimality Archive, ROA-482.]

McCarthy, John J. and Prince, Alan (1994) The emergence of the unmarked: Optimality in prosodic morphology. In Mercè Gonzàlez (ed.) *Proceedings of the North East Linguistic Society 24* 333--379. Amherst, MA: GLSA Publications. [Available on the Rutgers Optimality Archive, ROA-13. Excerpted in *Optimality Theory in Phonology: A Reader*, ed. by John J. McCarthy, Malden, MA and Oxford, Blackwell (2004).]

McCarthy, John J. and Prince, Alan (1995) Faithfulness and Reduplicative Identity. In Jill Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk (eds.) *University of Massachusetts Occasional Papers in Linguistics 18* 249--384. Amherst, MA: GLSA Publications. [Available on Rutgers Optimality Archive, ROA-103.]

McCarthy, John J. and Prince, Alan (1999) Faithfulness and identity in Prosodic Morphology. In René Kager, Harry van der Hulst, and Wim Zonneveld (eds.) *The Prosody-Morphology Interface* 218--309. Cambridge: Cambridge University Press. [Excerpted in *Optimality Theory in Phonology: A Reader*, ed. by John J. McCarthy, Malden, MA and Oxford, Blackwell (2004).]

Myers, Scott (1987) *Tone and the Structure of Words in Shona*. Doctoral dissertation: University of Massachusetts Amherst.

Orgun, C. Orhan and Sprouse, Ronald (1999) From MParse to control: Deriving ungrammaticality. *Phonology* 16: 191--220.

Pater, Joe (2000) Nonuniformity in English secondary stress: The role of ranked and lexically specific constraints. *Phonology* 17: 237--274. [Available on Rutgers Optimality Archive, ROA-107.]

Pierrehumbert, Janet and Beckman, Mary (1988) *Japanese Tone Structure*. Cambridge, MA: MIT Press.

Plag, Ingo (1998) Morphological haplology in a constraint-based morpho-phonology. In Wolfgang Kehrein and Richard Wiese (eds.) *Phonology and Morphology of the Germanic Languages* 199--215. Tübingen, Germany: Niemeyer. [Available on Rutgers Optimality Archive, ROA-344.]

Prince, Alan (2002) Arguing optimality. In Angela Carpenter, Andries Coetzee, and Paul de Lacy (eds.) *Papers in Optimality Theory II (= University of Massachusetts Occasional Papers 26)* 269--304. Amherst, MA: GLSA. [Available on Rutgers Optimality Archive, ROA-562.]

Prince, Alan and Smolensky, Paul (2004) *Optimality Theory: Constraint Interaction in Generative Grammar*. Malden, MA, and Oxford, UK: Blackwell. [Revision of 1993 technical report, Rutgers University Center for Cognitive Science. Available on Rutgers Optimality Archive, ROA-537.]

Prince, Alan and Tesar, Bruce (2004) Learning phonotactic distributions. In René Kager, Joe Pater, and Wim Zonneveld (eds.) *Constraints in Phonological Acquisition*

245--291. Cambridge: Cambridge University Press. [Available on Rutgers Optimality Archive, ROA-353.]

Raffelsiefen, Renate (2004) Absolute ill-formedness and other morphophonological effects. *Phonology* 21: 91--142.

Rice, Curt (2003) Dialectal variation in Norwegian imperatives. *Nordlyd* 31: 372--384. [Available on Rutgers Optimality Archive, ROA-642.]

Rice, Curt (2005a) Nothing is a phonological fact: Gaps and repairs at the phonology-morphology interface. Unpublished manuscript. Tromso, Norway: University of Tromso. [Available on Rutgers Optimality Archive, ROA-781.]

Rice, Curt (2005b) Optimal gaps in optimal paradigms. *Catalan Journal of Linguistics*: 155--170. [Special issue on phonology in morphology edited by Maria-Rosa Lloret and Jesús Jiménez. Available at LingBuzz, http://ling.auf.net/buzzdocs/.]

Rose, Sharon (1997) *Theoretical Issues in Comparative Ethio-Semitic Phonology and Morphology*. Doctoral dissertation. Montreal: McGill University.

Russell, Kevin (1995) Morphemes and candidates in Optimality Theory. Unpublished manuscript: University of Manitoba. [Available on Rutgers Optimality Archive, ROA-44.]

Russell, Kevin (1999) MOT: Sketch of an Optimality Theoretic approach to morphology. Unpublished manuscript. Winnipeg: University of Manitoba. [available at http://www.umanitoba.ca/linguistics/russell/mot.ps.]

Samek-Lodovici, Vieri (1993) A unified analysis of crosslinguistic morphological gemination. Unpublished manuscript. New Brunswick, NJ: Rutgers University. [Available on Rutgers Optimality Archive, ROA-149.]

Samek-Lodovici, Vieri and Prince, Alan (1999) Optima. Unpublished manuscript. London and New Brunswick, NJ: University of London and Rutgers University. [Available on Rutgers Optimality Archive, ROA-363.]

Steriade, Donca (1988) Reduplication and syllable transfer in Sanskrit and elsewhere. *Phonology* 5: 73--155.

Trommer, Jochen (2005) Against antifaithfulness in Luo. Unpublished manuscript. Leipzig: Institute of Linguistics, University of Leipzig. [Abstract available at http://www.uni-leipzig.de/~jtrommer/05.pdf.]

van Oostendorp, Marc (2005) The theory of faithfulness. Unpublished manuscript. Amsterdam: Meertens Institute. [Available at http://egg.auf.net/05/docs/handouts/oo-io.pdf.]

van Oostendorp, Marc (2006) Derived environment effects and Consistency of Exponence. In Sylvia Blaho, Patrik Bye, and Martin Kraemer (eds.) *Freedom of Analysis*. The Hague: Mouton.

Vogel, Irene and Kenesei, Istvan (1990) Syntax and semantics in phonology. In Sharon Inkelas and Draga Zec (eds.) *The Phonology-Syntax Connection* 339--364. Chicago: University of Chicago Press.

Walker, Rachel and Feng, Bella (2004) A ternary model of morphology-phonology correspondence. In B. Schmeiser, V. Chand, A. Kelleher, and A. Rodriguez (eds.) *WCCFL 23 Proceedings*. Somerville, MA: Cascadilla Press.

Wolf, Matthew (2006) For an autosegmental theory of mutation. In Leah Bateman, Adam Werle, Michael O'Keefe, and Ehren Reilly (eds.) *University of Massachusetts Occasional Papers in Linguistics 32: Papers in Optimality Theory III*. Amherst, MA: GLSA. [Available on Rutgers Optimality Archive, ROA-754.]

Zec, Draga and Inkelas, Sharon (1990) Prosodically constrained syntax. In Sharon Inkelas and Draga Zec (eds.) *The Phonology-Syntax Connection* 365--378. Chicago: University of Chicago Press.

Zwicky, Arnold M. and Pullum, Geoffrey (1986) The principle of Phonology-Free Syntax: Introductory remarks. *Ohio State University Working Papers in Linguistics* 32: 63--91.

Notes

[1] This is not quite true. As we will see in section 4.3, there are other candidates besides the null output in which $\Re$ is not a total bijective function and in which MPARSE is violated. We will demonstrate, however, that all such candidates are harmonically bounded by ⊙.

[2] In (6) and elsewhere, we omit indices on corresponding strings unless they are necessary for disambiguation.

[3] In general, the highest-scope statement in any markedness constraint is always universal quantification over structures of some type. It is never universal quantification over outputs — no markedness constraint can have the form "∀output∃structure", so no markedness constraint can be violated by the absence of structure. See Gouskova (2003) for related discussion.

[4] Morphological indexation of DEP constraints presents a minor technical challenge. Under Consistency of Exponence (McCarthy and Prince 1993b), epenthetic segments have no morphological affiliation. There is recent work arguing that Consistency of Exponence should be abandoned (Łubowicz 2005, Walker and Feng 2004), as well as a recent defense (van Oostendorp 2006). If Consistency of Exponence is retained, then the effect we desire can be obtained with morphological indexation of the faithfulness constraint O-CONTIG, which prohibits morpheme-internal epenthesis (Kenstowicz 1994, McCarthy and Prince 1995, 1999).

[5] 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. Since only some verbs meeting these phonological and morphological conditions behave in this way, the appropriate IDENT constraint must be indexed lexically as well as morphologically. Such constraints are required anyway to account for lexical stratification and other patterns of exceptions (as in Ito and Mester 1999).

[6] If we wish to permit input-reduplicant correspondence, then the strings *input* and *reduplicant* will also each require an additional concatenative decomposition, the substrings of which would stand in IR-correspondence.