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Restraint of Analysis

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Restraint of Analysis

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1. Introduction

In Optimality Theory (Prince and Smolensky 2004), GEN is the grammatical component that performs linguistic operations. *Freedom of analysis* is the phrase introduced by McCarthy and Prince (1993a) to describe GEN's ability to transform any input form into a wide range of output candidates. Under correspondence theory (McCarthy and Prince 1995, 1999), GEN even supplies [dɔg] as one of the candidates for input /kæt/. The mapping /kæt/ → [dɔg] is unattested, of course, but that is not GEN's concern. Instead, the limits on possible mappings follow from the assumptions that there is a universal constraint component CON and that grammars are permutations of CON. The /kæt/ → [dɔg] mapping never occurs in any language because [dɔg] is not the most harmonic member of /kæt/'s candidate set under any ranking of CON.

This much is OT orthodoxy. But there are inklings of a heterodox view of freedom of analysis in Prince and Smolensky's analysis of Berber syllabification and a few other works (Black 1993, McCarthy 2000, 2002:159-163, 2006, Norton 2003). The *locus classicus* is this quotation:

> Universal grammar must provide a function Gen that admits the candidates to be evaluated. In the discussion in chapter 2 we have entertained two different conceptions of Gen. The first, closer to standard generative theory, is based on serial or derivational processing: some general procedure (Do-α) is allowed to make a certain single modification to the input, producing the candidate set of all possible outcomes of such modification. This is then evaluated; and the process continues with the output so determined. In this serial version of grammar, the theory of rules is narrowly circumscribed, but it is inaccurate to think of it as trivial. There are constraints inherent in the limitation to a single operation and in the requirement that each individual operation in the sequence improve Harmony. (An example that springs to mind is the Move-x theory of rhythmic adjustments in Prince (1983); it is argued for precisely on the basis of entailments that follow from these two conditions, pp. 31-43.) (Prince and Smolensky 2004:94-95)

In this statement, Prince and Smolensky are sketching an alternative architecture for OT based on *restraint* rather than freedom of analysis. In classic OT, maximal harmony is reached in one fell swoop because GEN supplies candidates that may show the simultaneous effects of many phonological operations. The quotation describes a different version of OT, one in which maximal harmony is achieved in small steps of gradual harmonic improvement, because a more restrained GEN is limited to making modest changes in the input one at a time. What restrained GEN lacks in freedom, however, it makes up for in persistence: the most harmonic candidate selected by EVAL is fed back into restrained GEN as an input, whence it yields a new candidate set that is subject to a new round of evaluation. The GEN → EVAL → GEN → … loop continues until there is nothing left to do. I will, accordingly, refer to this alternative architecture as *persistent OT*. (The earlier literature calls it *harmonic serialism*.)

In this chapter, I explore some of the differences between classic OT with free GEN on the one hand and persistent OT with restrained GEN on the other. We will see, as Prince and Smolensky suggest, that the single-operation and harmonic-improvement requirements do indeed have consequences that are different from those of the familiar OT model. This chapter's goal is not to decide squarely for one version of OT over the other, though elsewhere (McCarthy 2006) I argue in favor of a derivative of persistent OT called OT-CC (for OT with candidate chains).

This chapter is organized as follows. In §2, I summarize the relevant aspects of Prince (1983), which Prince and Smolensky mention parenthetically at the end of the quotation. I then apply similar ideas to OT. In §3 and §4, some basic properties of this modified theory are discussed, while §5 identifies some situations where this theory makes novel predictions.

2. A single harmony-improving operation

In the quotation, Prince and Smolensky cite the work of Prince (1983:31-43), and so we will begin there. Prince analyzes the rhythmic stress shift observed in English and other languages; the standard example is *thir*ˌ*teen* ˈ*men* → ˌ*thirteen* ˈ*men*. In Prince's system, stress prominence is represented by a metrical grid with the following properties:

- Every syllable projects a grid position, marked by an *x*.
- Syllables that are more prominent project taller stacks of *x*s.
- Grid positions are subject to a Continuous Column Constraint: except for the bottom level of the grid, every *x* is supported by another *x* on the level immediately below it.

In a typical rhythmic shift situation, such as (1), an *x* moves leftward from a position of stress clash, thereby improving the rhythmic alternation.

(1) Rhythmic stress shift

		x				x
	x	**x**		x		x
x	x	x		x	x	x
thir	**teen**	**men**	→	thir	teen	men

Prince analyzes stress shift with an elementary operation on metrical grids and conditions on the application of that operation. The operation is called Move-*x*, and it does exactly what its name implies: it moves any *x* to a different syllable while remaining in the same row and not skipping over any *x*s in that row. Speaking a bit anachronistically, Move-*x* only applies when it improves harmony by eliminating stress clashes, such as the clash between *teen* and *men* highlighted in (1). But Move-*x* cannot apply when it would introduce violations of the Continuous Column Constraint. That is why the stress clash in *an*ˈ*tique* ˌ*store* remains unresolved (see (2)).

(2) Unresolved clash in *an*ˈ*tique* ˌ*store*

	x				x		x		
	x	**x**		x		x		x	x
x	x	x		x	x	x	x	x	x
an	**tique**	**store**	→	*an	**tique**	store,	* **an**	tique	store

By assumption, only one *x* can be moved at a time, and each movement must effect a harmonic improvement by resolving clash without violating the Continuous Column Constraint. Example (2) shows that these assumptions do real work in the analysis. The problem in (2) is that all leftward movements of a single *x* violate the Continuous Column Constraint. (Rightward movement never occurs in English, so ˌ*antique* ˈ*store* is not a possible resolution.) If two *x*s could be moved leftward at the same time, then it would be possible to resolve the clash and satisfy the Continuous Column Constraint at the same time, yielding *ˈ*antique* ˌ*store*. But two *x*s cannot be moved at once, *ex hypothesi*. The clash therefore remains unresolved, and a general prediction is obtained: clash is never resolved by shifting the location of the stronger of two clashing stresses. The Continuous Column Constraint is the basis for this prediction, but only if Move-*x* is limited to one-at-a-time application.

This example shows, as Prince and Smolensky promised, that significant results can be derived from the assumption that derivations are limited to one harmony-improving operation at a time. We will now study how a similar limitation can affect OT.

3. Restraint of analysis and finiteness

The classic OT candidate set is infinite because, under freedom of analysis, GEN includes unrestricted structure-building operations, of which epenthesis is the most obvious example. With an epenthesis operation in GEN and with no limit on the number of epenthesis operations that a candidate can undergo, there is no upper bound on the length of a candidate. Classic OT's GEN has unrestricted epenthesis for reasons of theoretical parsimony: all observed limits on epenthesis are adequately explained by factorial typology. Excessive epenthesis brings additional faithfulness violations with no concomitant improvement in markedness performance, so there is no need for a GEN-internal restriction on iterated epenthesis.

In persistent OT, the candidate set after each pass through GEN is finite. This conclusion follows from the assumptions that restrained GEN allows only one phonological operation at a time and that the number of distinct phonological operations in GEN is finite. The restriction to one operation at a time is, of course, the hypothesis we are exploring here. That the number of distinct operations in GEN is finite is a universal but usually tacit assumption in classic OT as well. There is a short list of licit phonological operations, each of which is associated with some faithfulness constraint: epenthesis, deletion, alterations of feature values, and various transformations on autosegmental and metrical structures. The number of different ways in which a finite input string can be altered by one application of one of these operations is therefore finite. In short, there is an upper bound on the number of ways that GEN can apply a single operation to an input.

The derivations in persistent OT are also finite. That is, there is an upper bound on the number of passes that must be made through the GEN → EVAL → GEN → … loop. The existence of this bound follows from the results in Moreton (2003). Moreton shows that, under certain assumptions, OT grammars have a property he dubs *eventual idempotency*. A function f is idempotent if and only if $f(a) = f \circ f(a)$ for any a — that is, if the result of applying f to a is the same as the result of applying f to the result of applying f to a, so reapplications of the function to its own output have no effect. Any generative grammar, including an OT grammar, is a function

G(/in/) → [out]. This function G is *eventually* idempotent if and only if, for any input, there comes a point when repeated application of G to its own output yields no further changes. That is, $\forall$/in/ $\exists n$ s.t. G^{n}(/in/) = G^{n+1}(/in/). Eventual idempotency is provably true of OT grammars if Con is finite and is limited to markedness and faithfulness constraints, and if Gen supplies the faithful candidate [in] as a member of the candidate set for any input /in/.

To say that every classic OT grammar is eventually idempotent is therefore to say that there is always an upper bound on any input's potential for harmonic improvement; if the grammar is repeatedly given its own output as input, there will always come a point when the output is identical to the input because no further harmonic improvement is possible. These results apply with equal force to persistent OT, which is not different in any relevant respect. This means that there is always a limit on how many passes will be possible through the Gen → Eval → Gen → … loop before there is convergence, where the most recent output of the grammar is the same as the most recent input. This limit exists for any input and any permutation of Con.

Consider again the problem of iterated epenthesis. The classic OT candidate set for input /pa/ is infinite because there is no limit on how many epenthesis operations Gen can perform: [paʔ], [paʔə], [paʔəʔ], [paʔəʔə], … In persistent OT, it is possible to derive iterated epenthesis by repeated passes through the Gen → Eval → Gen → … loop: /pa/ → [paʔ] → [paʔə] → … But because OT grammars are eventually idempotent, there is always an upper bound on how many iterations are possible before they cease to be harmonically improving.[1]

Intuitively, the result about eventual idempotency follows from the basic character of OT constraints. Faithfulness constraints alone cannot compel unfaithful mappings, so no faithfulness constraint by itself could cause epenthesis. We must therefore focus on markedness constraints. In principle, a markedness constraint could favor [paʔə] over [paʔ] or even [paʔəʔə] over [paʔəʔ], relative to the input /pa/. But there are only finitely many markedness constraints, so growth by iterated epenthesis must eventually cease to be harmonically improving. Alternative assumptions about Con, such as constraints favoring antifaithfulness (Alderete 2001a, 2001b) or morpheme realization (Kurisu 2001), could undermine these results, but that is perhaps sufficient reason to approach these alternatives with skepticism.

To complete the picture, we ought to consider other potential sources of unbounded candidate growth besides iterated epenthesis. Two come to mind: nonbranching recursion ($[\ldots[[\mathit{dog}]_{\mathrm{PWd}}]_{\mathrm{PWd}} \ldots]_{\mathrm{PWd}}$) and iterated construction of empty constituents ($[\mathit{pa}]_{\sigma}\ [\ ]_{\sigma}\ [\ ]_{\sigma} \ldots$). In classic OT, candidates like these lose because of markedness constraints that have structural economy effects (Gouskova 2003, 2004, Grimshaw 2002). If we assume that insertion of a prosodic constituent node is among the operations that restrained Gen is limited to doing one at a time, then those same structural economy constraints will account in persistent OT for why no derivation ever heads off in the direction of $[\ldots[[\mathit{dog}]_{\mathrm{PWd}}]_{\mathrm{PWd}} \ldots]_{\mathrm{PWd}}$ or $[\mathit{pa}]_{\sigma}\ [\ ]_{\sigma}\ [\ ]_{\sigma}$ …

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[1] This result harks back to Tesar's (1995b) syllabic parsing model, which proceeds directionally rather than derivationally but with the same basic idea.

The finiteness of the candidate sets and derivations in persistent OT is not an uninteresting result, but neither is it very significant from a computational point of view. It is the responsibility of linguistic theory to define the function G that maps inputs to outputs. The responsibility to offer a well-defined G is entirely separate from the question of whether G is efficiently computable, a point that has often been emphasized by Chomsky (e.g., 1965:9, 1968:117). The study of computation must be conducted using the theories and methods of that field. The "challenge" of the infinite candidate set comes from assuming that the computational model looks just like the competence model, struggling with the Sisyphean task of sorting an infinite set into harmonic order. Serious work in computation does not proceed in this way (see, e.g., Tesar 1995a, 1995b).

4. Ranking arguments in persistent OT

Persistent OT can require certain constraints to be ranked even when they are nonconflicting and therefore unrankable in classic OT. This situation can occur when at least two operations are required to map the underlying form to the surface form. This difference in constraint rankability is by itself neither an advantage nor a disadvantage of persistent OT; it is merely a difference from classic OT. But in §5 we will see that this difference leads to novel predictions about what kinds of linguistic systems can be analyzed in persistent OT.

The reason for the rankability difference is that persistent OT approaches the ultimate output gradually, through a succession of intermediate forms. Each intermediate form must (at least) improve harmonically over its predecessor if it is to win on its pass through EVAL. Constraints can and do conflict over the choice of an intermediate form, sometimes even if they do not conflict over the choice an ultimate output form in classic OT.

Prince and Smolensky's (2004:141) analysis of augmentation in Lardil illustrates this point nicely. As shown in (3), unaffixed monomoraic roots are augmented by epenthesizing [Ca], where C is a stop that is homorganic with the preceding consonant. Augmentation is a response to the requirement that feet be bimoraic, FT-BIN, which dominates DEP. But FT-BIN would be satisfied just as well even if only [a] were epenthesized, yielding *[ɽil**a**], so another constraint is required to force epenthesis of the [C] part of the [Ca] augment. In Prince and Smolensky's analysis, that constraint is ALIGN-R(MWord, σ), which is satisfied only if the rightmost segment in the (underlying) morphological word (MWord) is also syllable final. Since it compels consonant epenthesis, ALIGN-R(MWord, σ) must also dominate DEP. These classic OT ranking arguments are summarized in tableau (4).[2] (Where relevant, word-internal syllable boundaries are indicated by a period/full stop.)

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[2] Throughout, I follow Prince (2002) in using comparative tableaux. The winning candidate appears to the right of the arrow, and losers are in the rows below it. Subscripted integers stand for the number of violation marks incurred by a candidate, replacing the familiar strings of asterisks. In loser rows, the effects of the constraints are indicated by W and L, W if the constraint favors the winner and L if it favors the loser.

(3) Lardil augmentation (Hale 1973, Klokeid 1976, Wilkinson 1988)

Root	Nominative	Locative	
/ɽil/	ɽil.**ta**	ɽil.e	‘neck’
/t̲al/	t̲al.**ta**	t̲a.le	‘vulva’
/maɽ/	maɽ.**ʈa**	ma.ɽe	‘hand’
/kaŋ/	kaŋ.**ka**	ka.ŋe	‘speech’

(4) Ft-Bin, Align-R(MWord, σ) >> Dep in Lardil

/ɽil/	Ft-Bin	Align-R(MWord, σ)	Dep
→ ɽil.**ta**			2
a. ɽi.l**a**		W$_1$	L$_1$
b. ɽil	W$_1$		L

In classic OT, the /ɽil/ → [ɽil.ta] mapping does not supply evidence about how Ft-Bin and Align-R(MWord, σ) are ranked with respect to one another; since [ɽil.ta] obeys both of these constraints, they are not in conflict. In persistent OT, though, there is another basis for ranking these constraints: conflict over the selection of an intermediate form in the derivation. Under the assumption that restrained Gen can epenthesize only one segment at a time, the direct mapping /ɽil/ → [ɽil.**ta**] is not possible. Persistent OT instead requires a derivation with an intermediate stage where only one epenthesis operation has occurred, either /ɽil/ → [ɽi.l**a**] → [ɽil.**t**a] or /ɽil/ → [ɽil**t**] → [ɽil.t**a**].[3] The latter derivation begins with a mapping, /ɽil/ → [ɽil**t**], that is not harmonically improving: [ɽil**t**] violates Dep without purchasing better performance on Ft-Bin. (Codas are never moraic in Lardil.) So the intermediate form must instead be [ɽi.l**a**].

The derivation /ɽil/ → [ɽi.l**a**] → [ɽil.**t**a] is possible only if the mapping /ɽil/ → [ɽi.l**a**] is possible. And the mapping /ɽil/ → [ɽi.l**a**] is possible only if Ft-Bin dominates Align-R(MWord, σ), as tableau (5) shows. This tableau presents a kind of ranking argument that is possible in persistent OT but not classic OT. Intermediate [ɽi.l**a**] must improve harmonically over faithful [ɽil] if it is to be favored by Eval on the first pass through the Gen → Eval → Gen → … loop. The constraints Ft-Bin and Align-R(MWord, σ) conflict over [ɽi.l**a**] and [ɽil], and that is why they must be ranked.

(5) Intermediate-form ranking argument: Ft-Bin >> Align-R(MWord, σ)

/ɽil/	Ft-Bin	Align-R(MWord, σ)	Dep
→ ɽi.l**a**		1	1
ɽil	W$_1$	L	L

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[3] Persistent OT derivations like /ɽil/ → [ɽi.l**a**] → [ɽil.**t**a] show that the resyllabification that accompanies epenthesis cannot count for the one-operation-at-a-time restriction on Gen. An “operation”, in the relevant sense, is an unfaithful mapping, and resyllabification is not in itself unfaithful. See McCarthy (2006) for discussion.

The /ʈil/ → [ʈi.l**a**] derivation in (5) is not complete. The form [ʈi.l**a**] is submitted to another pass through Gen, and among the candidates emitted are [ʈi.l**a**] and [ʈil.**ta**]. Align-R(MWord, σ) favors the latter, as shown in (6). After this, no further harmonic improvement is possible.[4]

(6) Final stage of /ʈil/ → [ʈil**a**] → [ʈil**t**a]

/ʈila/	Ft-Bin	Align-R(MWord, σ)	Dep
→ ʈil.**t**a			1
ʈi.la		W_1	L

The ranking result obtained from an intermediate form in (5) is independently supported by a conventional ranking argument — that is, a ranking argument where the winner is the final output form and not one of the intermediate forms. The [C] part of the [Ca] augment is omitted when the result would be an illicit cluster: /jak/ → [ja.k**a**], *[jak.**ka**] 'fish' because geminates are prohibited; /teɾ/ → [te.ɾ**a**], *[teɾ.**ta**] 'thigh' because [ɾt] clusters are prohibited. These examples show that vocalic augmentation occurs even when it results in bad alignment in the ultimate output form, so Ft-Bin must dominate Align-R(MWord, σ). The ranking argument appears in (7).

(7) Ultimate output ranking argument: Ft-Bin >> Align-R(MWord, σ)

/teɾ/	*ɾt	Ft-Bin	Align-R(MWord, σ)	Dep
→ te.ɾ**a**			1	1
teɾ		W_1	L	L

Tableau (7) shows the persistent (and classic) OT derivation /teɾ/ → [te.ɾ**a**]. This derivation is complete because no further phonological operations will produce a harmonically improving result. The operation of interest is consonant epenthesis, and in (8) it fails to win because of an undominated markedness constraint against [ɾt] clusters. This is *convergence*: the output of a pass through Gen and Eval is identical to the input, so further attempts at harmonic improvement are pointless.

(8) Convergence after (7)

/teɾa/	*ɾt	Ft-Bin	Align-R(MWord, σ)	Dep
→ te.ɾa			1	
~ teɾ.**t**a	W_1		L	W_1

In Lardil, the ranking argument based on an intermediate form in (5) is confirmed by a ranking argument based on a final form in (7). But it can also happen that persistent OT will require a ranking that, while not contradicted by final-form ranking arguments, is not necessarily supported by them either. Augmentation in

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[4] Tableau (6) reckons faithfulness violations relative to the local input rather than the underlying representation. This is a point on which implementations of persistent OT might differ. See McCarthy (2006) for a different approach.

Axininca Campa (Arawakan, Peru) is an example (McCarthy and Prince 1993a, 1993b, Payne 1981, Spring 1990).[5] Under certain conditions, stems must be minimally bimoraic to satisfy FT-BIN. Monomoraic roots like /t^{h}o/ augment to bimoraicity by epenthesizing the syllable [ta]: [t^{h}o**ta**]. Since the [t] and the [a] cannot be epenthesized in a single operation, the derivation requires an intermediate step, presumably /t^{h}o/ → [t^{h}o.**a**] → [t^{h}o**t**a].[6] For [t^{h}o.a] to be the intermediate form, it must be more harmonic and therefore less marked than faithful [t^{h}o]. As shown in (9), this is only true if FT-BIN dominates ONSET, trading [t^{h}o]'s monomoraicity for [t^{h}o.a]'s onsetless syllable.

(9) Intermediate-form ranking argument: FT-BIN >> ONSET

/t^{h}o/	FT-BIN	ONSET	DEP
→ t^{h}o.**a**		1	1
t^{h}o	W$_1$	L	L

In the McCarthy and Prince (1993a) analysis of Axininca Campa, FT-BIN and ONSET are unrankable because they do not conflict over any output forms. The ranking required in the persistent OT analysis is therefore compatible with but not independently supported by the ranking obtained from conventional argumentation.[7]

The general point is this. In classic OT, if a language with the constraint hierarchy $\mathcal{H}$ maps /A/ unfaithfully to [B], then [B] must be less marked than [A] according to the markedness constraints in CON as they are ranked in $\mathcal{H}$. If /A/ and [B] differ by the effect of two or more phonological operations, however, persistent OT imposes a stricter requirement: there must be a harmonically improving path of forms linking /A/ to [B] by single operations. That is, there must be a sequence of forms [I$_1$], [I$_2$], …, [I$_n$] meeting the following two conditions:

- The mappings /A/ → [I$_1$], /I$_n$/ → [B], and /I$_j$/ → [I$_{j+1}$], $1 \leq j < n$, each require exactly one phonological operation (however "operation" is defined).
- $\mathcal{H}$ imposes the harmonic order [B] ≻ [I$_n$] ≻ … ≻ [I$_1$] ≻ [A].

These properties of persistent OT may require constraint rankings that are unjustifiable in (though not inconsistent with) classic OT, as we have already seen. They may also make some phonological mappings impossible, as I will show in the next section.

5. Persistent OT and language typology

If /A/ and [B] differ by the effect of two or more phonological operations, then persistent OT requires a derivation with one or more intermediate forms [I$_j$]. Each

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[5] I am indebted to Nicole Nelson for pointing this out.

[6] The derivation cannot be /t^{h}o/ → [t^{h}o**t**] → [t^{h}ot**a**]. Since codas are not moraic in this language, [t^{h}o**t**] does not improve performance on FT-BIN.

[7] In the analysis of Axininca Campa sketched by Downing (1998:18-22), ranking (the equivalent of) FT-BIN over ONSET can be independently justified using conventional argumentation. This ranking accounts for the difference in reduplicative behavior between short and long vowel-initial roots: initial onsetless syllables are forced into the reduplicative base when the root is short ([asi-asi] 'cover more and more') but not when the rest of the root is long enough ([osampi-sampi] 'ask more and more').

intermediate form must be chosen by EVAL from the limited candidate set provided by restrained GEN. In consequence, the intermediate form must be more harmonic than its predecessor and less harmonic than its successor. The various dimensions of phonological difference between /A/ and [B] must be decomposable into a derivation that has these properties. Sometimes, this is not possible, either universally or given other ranking requirements of the system in which the /A/ → [B] mapping is embedded. When that happens, classic OT and persistent OT can make different predictions, even when they incorporate identical assumptions about CON. I will illustrate this phenomenon first with an example based on Lardil. This example has the virtue of familiarity, but it yields a rather uninteresting prediction. I will then present some more substantial examples.

Recall the constraint ranking in Lardil: ALIGN-R(MWord, σ) dominates DEP to account for the consonantal part of the augment in [ʈilta]; and FT-BIN dominates ALIGN-R(MWord, σ) to account for the intermediate stage [ʈila] and for augmentation without the consonant in [teɾa]. Now suppose we change this ranking from ⟦FT-BIN ≫ ALIGN-R(MWord, σ) ≫ DEP⟧ to ⟦ALIGN-R(MWord, σ) ≫ FT-BIN ≫ DEP⟧. In classic OT, this permuted ranking predicts that vocalic augmentation will be blocked just in those cases where consonantal augmentation is blocked, as shown in (10) (cf. (7)). Augmentation of /teɾ/ fails entirely because there is no way of augmenting while maintaining good alignment and satisfying the prohibition on [ɾt] clusters. Augmentation still goes through in those forms like [ʈilta] where there is no problem with augmenting while still satisfying ALIGN-R(MWord, σ).

(10) Effect of ⟦ALIGN-R(MWord, σ) ≫ FT-BIN ≫ DEP⟧ in classic OT

	*ɾt	ALIGN-R(MWord, σ)	FT-BIN	DEP
/ʈil/				
→ ʈil.**ta**				2
a ʈi.l**a**		W_1		L_1
b. ʈil			W_1	L
/teɾ/				
→ teɾ				
c. teɾ.**ta**	W_1		L	W_2
d. te.ɾ**a**		W_1	L	W_1

In persistent OT, however, the same ranking blocks augmentation across the board, for all inputs: /ʈil/ → [ʈil] and /teɾ/ → [teɾ], as shown in (11). With ALIGN-R(MWord, σ) ranked above FT-BIN, there is no way to get from /ʈil/ to [ʈil.ta], since intermediate [ʈi.la], which violates ALIGN-R(MWord, σ), does not improve harmonically over faithful [ʈil], which violates FT-BIN.[8]

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[8] What about [ʈil.a] as the intermediate step from /ʈil/ to [ʈil.ta]? In Lardil, ONSET must dominate ALIGN-R(MWord, σ) to account for the syllabification [te.ɾa] rather than *[teɾ.a]. Therefore, the mapping /ʈil/ → [ʈil.a] is not harmonically improving.

(11) Effect of ⟦ALIGN-R(MWord, σ) ≫ FT-BIN ≫ DEP⟧ in persistent OT

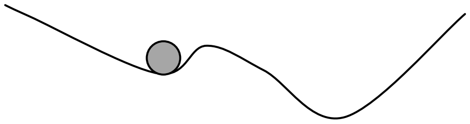
	*ɾt	ALIGN-R(MWord, σ)	FT-BIN	DEP
/ʈil/				
→ ʈil			1	
a. ʈi.l**a**		W_1	L	W_1
/teɾ/				
→ teɾ			1	
b. te.ɾ**a**		W_1	L	W_1

The upshot is that classic OT and persistent OT describe different languages under the ranking ⟦ALIGN-R(MWord, σ) ≫ FT-BIN ≫ DEP⟧. In classic OT, the [a] part of [Ca] augmentation is blocked whenever the [C] part is blocked, but otherwise [Ca] augmentation occurs. In persistent OT, there is no augmentation anywhere, the same as if the ranking were ⟦DEP >> FT-BIN⟧. In short, classic OT predicts the existence of a language Lardil′ with /ʈil/ → [ʈilta] and /teɾ/ → [teɾ], while persistent OT denies that there could be such a language — keeping all the *cetera* exactly *paria*, of course.

In classic OT, where fully realized output forms compete with one another, [ʈilta]'s advantage in satisfying both ALIGN-R(MWord, σ) and FT-BIN wins the day. In persistent OT, though, [ʈilta]'s advantage is not apparent at the earlier stage of the derivation, when only [a] has been epenthesized. The ranking ⟦ALIGN-R(MWord, σ) ≫ FT-BIN ≫ DEP⟧ never allows [ʈilta] to see the light of day because it blocks the derivation at the [ʈila] intermediate step. Abstractly, this example is the same as *anˈtique ˌstore* in (2): if both *x*s could be moved at once, then *ˈ*antique ˌstore* would be the result, but there is no way to get to that result by moving one *x* at a time while satisfying the Continuous Column Constraint along the way.

In these situations, [ʈil] and *anˈtique ˌstore* are *local minima* in potential for harmonic improvement. The picture in (12) is intended to illustrate this concept. The ball has rolled part of the way down the hill, but it is stuck in a local minimum of the terrain. The global minimum — the next valley — is more attractive but unreachable. Winning candidates in classic OT are guaranteed to be at the global minimum for further harmonic improvement: there is no more harmonic candidate from the same input. Winning candidates in persistent OT are at some local minimum that may or may not be the same as the global minimum. Like the ball in (12), they can get stuck when the global minimum is reachable only by way of one or more operations that fail to improve harmony. (These are the equivalent of the ball rolling uphill to crest the next rise.)

(12) Stuck in a local minimum of potential for further harmonic improvement



The difference between local and global minima is the basis for all of the predictions that distinguish between persistent OT and classic OT. A hypothetical apocope phenomenon supplies another example. The constraint Final-C requires that every phonological word end in a consonant (Gafos 1998, McCarthy 1993, McCarthy and Prince 1994, Wiese 2001). When combined with a constraint Coda-Cond that prohibits syllable-final obstruents (Ito 1989, Zec 1995), Final-C will favor words that end in sonorant consonants. If both Final-C and Coda-Cond are ranked above Max, then all words will be truncated after the rightmost sonorant consonant, as shown in the classic OT tableau (13).

(13) Effect of Final-C, Coda-Cond >> Max in classic OT

/palasanataka/	Final-C	Coda-Cond	Max
→ palasan			5
a. palasanataka	W_1		L
b. palasanatak		W_1	L_1
c. palasanata	W_1		L_2
d. palasanat		W_1	L_3
e. palasana	W_1		L_4

In tableau (13), the winning candidate [palasan] is the global minimum in potential for further harmonic improvement. In persistent OT, however, this global minimum is unattainable using these constraints. The persistent OT derivation gets stuck in a local minimum: the local minimum is faithful [palasanataka] if Coda-Cond dominates Final-C (see (14)) and it is [palasanatak] if Final-C dominates Coda-Cond (see (15)). With Coda-Cond top-ranked, there can be no truncation, since truncating the final vowel of /palasanataka/ produces a forbidden coda. With Final-C at the top, we get [palasanatak] with vowel truncation, but further truncation is impossible because [palasanata] violates Final-C.

(14) Effect of Coda-Cond >> Final-C >> Max in persistent OT

/palasanataka/	Coda-Cond	Final-C	Max
→ palasanataka		1	
palasanatak	W_1	L	W_1

(15) Effect of Coda-Cond >> Final-C >> Max in persistent OT

a. First pass through Gen and Eval

/palasanataka/	Final-C	Coda-Cond	Max
→ palasanatak		1	1
palasanataka	W_1	L	L

b. Second pass through GEN and EVAL

palasanatak	FINAL-C	CODA-COND	MAX
→ palasanatak		1	
palasanata	W_1	L	W_1

Classic OT and persistent OT make different predictions in this situation, and these predictions are at least in principle testable. In classic OT, the grammar (13) describes a language where words are truncated after the rightmost sonorant consonant, or not at all if there is no sonorant consonant in the word. In persistent OT, the same grammar describes a language that truncates the final vowel in /…CV/ words (if FINAL-C is top-ranked), or a language that limits this truncation to words where C is a sonorant (if CODA-COND is top-ranked). Readers may judge for themselves which predictions are more plausible; certainly, no known language works like (13).

It may go without saying, but it should nonetheless be said, that all such results depend on substantive assumptions about the contents of CON. For example, suppose CON were to include the dubious gradient alignment constraint ALIGN-R(Word, [+son, +cons]). which measures the distance in segments between the rightmost sonorant consonant and the right edge of phonological word. Since every deletion of a segment in the trailing string /ataka/ purchases better performance on this constraint, the mapping /palasanataka/ → [palasan] would be possible in persistent OT. This is one of many dubious results that follow from adopting gradient alignment constraints (McCarthy 2003).

It is important to note that truncation, even truncation of long sequences of segments, is not impossible in principle in persistent OT. For example, like classic OT, persistent OT can describe a pattern of truncation that reduces all words to a single foot. Among the constraints responsible for this pattern is PARSE-SYLL "every syllable belongs to some foot" (McCarthy and Prince 1994). If PARSE-SYLL dominates MAX, then there can be a harmonically improving derivation like (16). (The foot is delimited by parentheses.) This derivation eliminates syllables outside the word's sole foot by deleting their nuclei and cleaning up the excess consonants, one segment at a time. It is harmonically improving if PARSE-SYLL dominates *COMPLEX-CODA, which itself also dominates MAX.

(16) Persistent OT derivation with PARSE-SYLL >> *COMPLEX-CODA >> MAX

Underlying	/kamasapata/	Improvement
	(ˈkama)sa.pa.ta	✓ PARSE-SYLL
	(ˈkama)sa.pat	✓ PARSE-SYLL
	(ˈkama)sapt	✓ PARSE-SYLL
	(ˈkamaspt)	✓ PARSE-SYLL
	(ˈkamasp)	✓ *COMPLEX-CODA
	(ˈkamas)	✓ *COMPLEX-CODA
Surface	[(ˈkamas)]	

We have seen two different patterns of truncation. In one of them, words are truncated from the right until a satisfactory word-final segment is found. In the other, words are truncated from the right until only a single disyllabic foot is left. Persistent

OT cannot accommodate the first pattern, but it can accommodate the second. What is the reason for this difference?

The mapping /palasanataka/ → [palasan] in (13) requires multiple phonological operations in pursuit of a distant goal: satisfaction of FINAL-C and CODA-COND. Taken individually, the operations offer no harmonic improvement; the harmonic improvement is realized only when all of the operations have applied. This behavior is well within the analytic scope of classic OT, since the candidates that are evaluated may show the simultaneous effects of many processes. But persistent OT cannot elide the intermediate steps between /palasanataka/ and [palasan]. Persistent OT requires local harmonic improvement at each step in the derivation. Under the grammar in (13), the /palasanataka/ → [palasan] mapping offers only global harmonic improvement: if all of the segments in /ataka/ are deleted, then and only then will FINAL-C and CODA-COND be satisfied.

In (16), on the other hand, there is local harmonic improvement because each vowel that is eliminated also eliminates a violation of PARSE-SYLL and each consonant that is omitted improves performance on *COMPLEX-CODA. It is significant that the system with only global harmonic improvement in (13) is not only unattested but almost surely impossible. It is equally significant that systems with local harmonic improvement like (16) are attested in prosodic morphology and language acquisition (McCarthy and Prince 1994, Pater 1997). This match between prediction and reality suggests that local harmonic improvement may be an authentic property of human language and that persistent OT is on the right track.

Metathesis processes present further opportunities for studying this difference between classic and persistent OT. If ONSET or NO-CODA is ranked above the antimetathesis constraint LINEARITY, classic OT can force /apekto/ to map to [paketo] by double metathesis (/ap/ → [pa] and /ek/ → [ke]). Tableau (17) shows how this happens.

(17) Double metathesis from ONSET *or* NO-CODA >> LINEARITY in classic OT

/apekto/	ONSET *or* NO-CODA	LINEARITY
→ paketo		2
a. apekto	W_1	L
b. pa.ekto	W_1	L_1
c. apketo	W_1	L_1

In persistent OT, however, this mapping is not possible. I will make the natural assumption that GEN includes a phonological operation that transposes a pair of adjacent segments: /ab/ → [ba]. The /apekto/ → [paketo] mapping involves two applications of this operation, so there must be an intermediate derivational step, either [pa.ekto] or [apketo]. Neither intermediate step is harmonically improving, however. The mapping /apekto/ → [pa.ekto] swaps one ONSET violation for another, and the mapping /apekto/ → [apketo] swaps one NO-CODA violation for another. Persistent OT, then, cannot obtain the /apekto/ → [paketo] mapping from the constraints in (17). Since double metathesis of this type has never been reported and seems improbable, persistent OT's more limited descriptive power is supported by this example.

Long-distance metathesis shows very clearly the difference between local and global harmonic improvement. Synchronic long-distance metathesis is attested in only a couple of morphologized processes (Carpenter 2002, Hume 2001:7, Poser 1982),[9] but it is relatively easy to construct rankings that allow it. For example, to obtain the long-distance metathesis of /art/ → [tar] in classic OT requires only that a Coda-Cond prohibiting obstruent codas dominate Linearity. This ranking result is shown in (18).

(18) Long-distance metathesis in classic OT

/art/	Coda-Cond	Linearity
→ tar		2
a. art	W_1	L
b. atr	W_1	L_1
c. rat	W_1	L_1

The situation in persistent OT is different, however. The path from /art/ to [tar] must go by way of [atr], so the /art/ → [atr] mapping must be harmonically improving. It is not. The pattern of long-distance metathesis illustrated in (18), though consistent with classic OT, is predicted to be impossible in persistent OT. This pattern is also unattested.

In general, although persistent OT does not prohibit long-distance metathesis categorically, it establishes relatively stringent conditions under which it can be possible. In classic OT, the unfaithful mapping /abc/ → [cab] requires that distantly metathetic [cab] be less marked than faithful [abc] and locally metathetic [acb] or [bac]. Succinctly, [cab] ≻ [abc], [acb], [bac]. Persistent OT imposes an additional requirement: locally metathetic [acb] must be less marked than faithful [abc] ([acb] ≻ [abc]). As metathesis gets more distant, the markedness requirements become even stricter, since every intermediate step must improve over its predecessors. Long distance metathesis must be analyzable as a succession of harmonically improving local metatheses under the persistent OT regime, and in most situations that will be impossible.[10]

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[9] Hume (2001): "all regular cases of synchronic metathesis involve adjacent segments".

[10] These observations about metathesis in persistent OT are relevant to Horwood's (2004) proposal that infixation is reducible to metathesis. In his view, infixation in Tagalog /um-sulat/ → [sumulat] 'to write (actor focus)' is the result of a Linearity-violating transposition. If each transposition of a pair of adjacent segments requires a separate operation, as I have assumed, then this mapping would have to be obtained with a derivation like /umsulat/ → [usmulat] → [sumulat]. To my knowledge, nothing in Tagalog phonology explains how the initial step /umsulat/ → [usmulat] could be harmonically improving. Horwood's proposal would be a better fit to persistent OT if the entire morpheme /-um-/ could be shifted in a single operation. Something like this may be necessary anyway to explain why infixal morphemes normally remain contiguous even when the roots that they are infixed into do not.

The difference between local and global harmonic improvement also becomes apparent when we examine processes that manipulate autosegmental association lines. We will look first at flop and then at long-distance spreading.

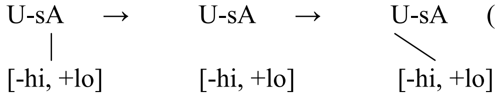
In autosegmental flop processes, a feature or tone is delinked from one host and relinked to another. Flop rules were introduced in the earliest work on autosegmental phonology (Goldsmith 1976) and flop mappings can be found in various classic OT analyses. Esimbi (Niger-Congo, Cameroon) supplies a nice example (Clements 1991, Hyman 1988, Stallcup 1980, Walker 1997, 2001). In this language, the height of a prefix vowel is determined by the underlying height of the root vowel, and the root vowel neutralizes to [+high]. For example, as shown in (19), the infinitival prefix is a back rounded vowel that alternates among [u], [o], and [ɔ], depending on the underlying vowel of the following root. Hyman and Walker analyze this as a flop process: the height features of the root vowel are transferred to the prefix syllable, and the root vowel becomes high by default.

(19) Esimbi vowel alternations

Underlying root	Infinitive	
/ri/	u-ri	‘to eat’
/zu/	u-zu	‘to kill’
/se/	o-si	‘to laugh’
/to/	o-tu	‘to insult’
/d͡zə/	o-d͡zɨ	‘to steal’
/rɛ/	ɔ-ri	‘to daub’
/hɔ/	ɔ-hu	‘to knead’
/ba/	ɔ-bɨ	‘to come’

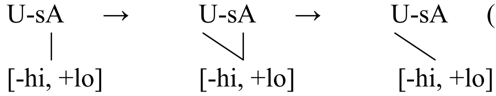
It is reasonable to assume that flop is not a primitive operation in GEN and that all instances of flop involve two operations, deletion and insertion of association lines. Flop phenomena, then, require persistent OT derivations that go through an intermediate stage. Two logical possibilities for this intermediate step are illustrated in (20) and (21). The derivation in (20) involves a temporary floating feature, and it is not obvious how this intermediate step constitutes a harmonic improvement. The derivation in (21), on the other, turns out to be fully compatible with Walker’s (2001) analysis. I therefore pursue the idea that (21) is the right persistent OT analysis of this phenomenon.

(20) Flop as delinking and reassociation



(i.e., /usa/ → [usɨ] → [ɔsɨ])

(21) Flop as spreading and delinking



(i.e., /usa/ → [ɔsa] → [ɔsɨ])

Walker argues that flop in Esimbi is a response to two markedness constraints. LIC([–high], $_{\text{Wd}}$[σ) requires any token of a [–high] feature value to be linked to a word-initial syllable (cf. Zoll 2004), and CRISP(σ, [high]) prohibits any token of the feature [high] from being linked to more than one syllable at a time (cf. Ito and Mester 1999). These constraints are ranked above IDENT(high), as shown in (22).

(22) Esimbi in Walker (2001)

/u-sa/ │ [-hi, +lo]	LIC([–high], $_{Wd}$[σ)	CRISP(σ, [high])	ID(high)
→ ɔ-sɨ ╲ [-hi, +lo]			2
a. u-sa │ [-hi, +lo]	W_1		L
b. ɔ-sa ╲│ [-hi, +lo]		W_1	L

In Walker's classic OT analysis (22), LIC([–high], $_{Wd}$[σ) and CRISP(σ, [high]) cannot be ranked relative to one another because both are obeyed by every winning candidate. In persistent OT, however, they are rankable based on the first step in the derivation /usa/ → [ɔsa] → [ɔsɨ] (see (23)). For [ɔsa] to improve harmonically over faithful [usa], a temporary violation of CRISP(σ, height) must be tolerated in exchange for immediate satisfaction of LIC([–high], $_{Wd}$[σ). This is another case where harmonic improvement in a derivation requires ranking two constraints that are unrankable in classic OT, since they do not conflict in surface forms of the language.

(23) Esimbi in persistent OT

a. First pass through GEN and EVAL

/u-sa/ │ [-hi, +lo]	LIC([–high], $_{Wd}$[σ)	CRISP(σ, [high])	ID(high)
→ ɔ-sa ╲│ [-hi, +lo]		1	1
u-sa │ [-hi, +lo]	W_1	L	L

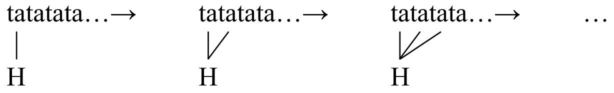
b. Second pass through GEN and EVAL

ɔ-sa [-hi, +lo]	LIC([–high], $_{\mathrm{Wd}}$[σ])	CRISP(σ, [high])	ID(high)
→ ɔ-sɨ [-hi, +lo]			1
ɔ-sa [-hi, +lo]		W_1	L

This reanalysis of Esimbi implies the claim that all instances of the flop phenomenon are reducible to combinations of spreading and delinking. If this surmise is correct, then flop should have properties that are similar to assimilatory spreading processes in other languages. This flop/assimilation connection seems right. For example, dialects of Emakhuwa (Bantu, Mozambique) differ in whether a particular process involves tone spreading or tone flop (Cassimjee and Kisseberth 1999). More generally, this approach to flop makes strong predictions: all proposed restrictions on assimilation, such as locality, should also be possible restrictions on flop, since flop *is* assimilation with an additional derivational step.

Long-distance autosegmental spreading has obvious relevance to persistent OT. A natural assumption is that GEN is limited to adding one association line at a time, so long-distance spreading involves a succession of local spreading operations (see (24)).

(24) Long-distance spreading in persistent OT



For derivations like (24) to show steady harmonic improvement, there must be some markedness constraint that imposes the harmonic ordering … ≻ [tátátá...] ≻ [tátáta...] ≻ [tátata...]. Such a constraint is equally necessary in classic OT analyses to account for those cases where an autosegment spreads as far as it can until it encounters a blocking segment (McCarthy 2003, Wilson 2003, 2004): /tátatatàta/ → [tátátátàta]. This is why gradient alignment constraints have been favored as the impetus for autosegmental spreading (Archangeli and Pulleyblank 1994, Cole and Kisseberth 1995, Kirchner 1993, Pulleyblank 1996, Smolensky 1993 etc.). There are alternatives to gradient alignment, some of which have the necessary properties and some of which do not. For discussion, see McCarthy (2004).

In persistent OT, long-distance autosegmental spreading or flop cannot be compelled by markedness constraints that do not impose harmonic orderings like … ≻ [tátátá...] ≻ [tátáta...] ≻ [tátata...]. This is a point of difference from classic OT, which allows a much wider range of markedness constraints to produce spreading or flop. The following example is based on José and Auger's (2004) analysis of Vimeu Picard (Romance, France).

In Vimeu Picard, voiced stop codas become nasals after nasalized vowels: /repɔ̃d/ → [repɔ̃n] ‘to answer’ (cf. [repɔ̃dy] ‘answered’). José and Auger propose that nasalization of coda /d/ has essentially the same explanation as devoicing of coda obstruents in German. According to Lombardi (1999, 2001), coda devoicing satisfies the context-free markedness constraint *VCDOBST, which is violated by any voiced obstruent. The positional faithfulness constraint $\text{IDENT}_{\text{ONS}}$ protects onset consonants from alteration. As tableau (25) shows, the only real difference between German and Vimeu Picard is that the crucially dominated faithfulness constraint is IDENT(nasal) rather than IDENT(voice).

(25) Coda nasalization in Vimeu Picard

	IDENT(voice)	$\text{IDENT}_{\text{ONS}}$(nasal)	*VCDOBST	IDENT(nasal)
/repɔ̃d/				
→ re.pɔ̃n				1
a. re.pɔ̃d			W$_1$	L
b. re.pɔ̃t	W$_1$			L
/repɔ̃dy/				
→ re.pɔ̃.dy			1	
c. re.pɔ̃.ty	W$_1$		L	
d. re.pɔ̃.ny		W$_1$	L	W$_1$

Coda nasalization is subject to an important limitation: it can only happen by spreading from an adjacent segment (preceding or following). For example, the failure of coda nasalization in /berlœd/ → [berlœd], *[berlœn] ‘old ewe’ shows that the feature value [+nasal] cannot be epenthesized, only spread. (This form also shows that coda devoicing does not occur as an alternative.) The constraint DEP(nasal), ranked above *VCDOBST, accounts for this observation (see (26)). In forms like [repɔ̃n], [+nasal] is present in the underlying representation, so DEP(nasal) is satisfied (see (27)).

(26) DEP(nasal) >> *VCDOBST in Vimeu Picard

	IDENT(voice)	DEP(nasal)	*VCDOBST	IDENT(nasal)
/berlœd/				
→ berlœd			1	
a. berlœn / [+nas]		W$_1$	L	W$_1$
b. berlœt	W$_1$		L	

(27) Spreading does not violate DEP(nasal)

	IDENT(voice)	DEP(nasal)	*VCDOBST	IDENT(nasal)
/repɔ̃d/ | [+nas]				
repɔ̃n → |/ [+nas]				1
repɔ̃d a. | [+nas]			W_1	L
repɔ̃t b. | [+nas]	W_1			L
repɔ̃n c. | \\ [+nas][+nas]		W_1		1

In classic OT, *VCDOBST could in principle compel spreading of [+nasal] from a more distant host. For example, *VCDOBST would favor mapping hypothetical /mad/ to [mãn] or /nead/ to [nẽãn].[11] In these forms, [+nasal] is spreading from a nonadjacent segment to satisfy *VCDOBST, and only low-ranking IDENT(nasal) is violated. Distant spreading does not seem to happen in Vimeu Picard, and additional constraints ranked above *VCDOBST could be invoked to block it. But a language-particular solution to this problem misses the point: it is likely that *no* language could do what Vimeu Picard does not do. That is, the local advantage of avoiding a violation of *VCDOBST cannot be achieved by long-distance spreading in any language.

This typological claim is more problematic in classic OT. Classic OT's unrestrained GEN offers up output candidates like [nẽãn] for /nead/, and *VCDOBST favors [nẽãn] over faithful [nead] and other alternatives. In persistent OT, however, restrained GEN can only get from /nead/ to [nẽãn] by a succession of local spreading operations: /nead/ → [nẽad] → [nẽãd] → [nẽãn]. On the first pass through the GEN → EVAL → GEN → … loop, the candidate set includes [nẽad] and faithful [nead]. But *VCDOBST does not favor [nẽad], so the derivation terminates, Faithful [nead] is a local minimum, so [nẽãn] is unreachable from /nead/ with a grammar like the one in Vimeu Picard.

Nonlocal autosegmental spreading of [+nasal] is possible in persistent OT if the grammar has IDENT(nasal) ranked below a constraint that imposes the harmonic

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[11] These examples presuppose that spreading of [+nasal] never skips over segments. When feature or tone spreading is allowed to skip over segments or syllables, the differences between classic and persistent OT become less obvious, but they do not disappear entirely. For arguments that spreading never skips, see Gafos (1999), Ní Chiosáin and Padgett (2001), Rose and Walker (2004), and Walker (1998), among others.

ordering [nẽãn] ≻ [nẽãd] ≻ [nẽad] ≻ [nead]. But *VcdObst is not such a constraint — all it says is [nẽãn] ≻ [nẽãd], [nẽad], [nead]. In general, markedness constraints that offer a harmonic advantage only after several segments have been traversed can never compel nonlocal spreading in persistent OT, even though they are free to do so in classic OT. Persistent OT, then, offers a restrictive typology of harmony and tone-spreading processes.

6. Conclusion

This chapter began with a quotation from Prince and Smolensky. They describe an alternative implementation of OT in which progress toward maximal harmony is gradual. Gen is subject to restraint rather than freedom of analysis, but Gen and Eval apply repeatedly as long as greater harmony can be achieved. We looked at an important early precedent for this approach, the analysis of rhythmic stress shift in Prince (1983).

We have seen various ways in which persistent OT differs from classic OT. Persistent OT can impose stricter ranking requirements than classic OT because of the need to ensure harmonic improvement in the intermediate forms as well as the ultimate output. For the same reason, persistent OT predicts a more restrictive language typology. As we have seen, this more restrictive typology conforms rather well to observation.

What else can be gained from this alternative way of looking at OT? In McCarthy (2006) I argue that persistent OT's derivations are the candidates that the grammar evaluates. This means that Eval can optimize the properties of the derivations themselves as well as the forms that those derivations produce. This leads to a new perspective on the problem of phonological opacity in Optimality Theory.

Encomium

הוֹלֵךְ אֶת־חֲכָמִים יֶחְכָּם

Prov. 13, 20

I first met Alan Prince in early 1975. We argued about Tiberian Hebrew phonology. Later, we came to agree about it, and about other things as well. He has been my collaborator, my adviser, and my friend, and I am much the better for it. I am pleased to take this opportunity to honor him for his work and to thank him for his support and friendship.

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