Candidates and Derivations in Optimality Theory

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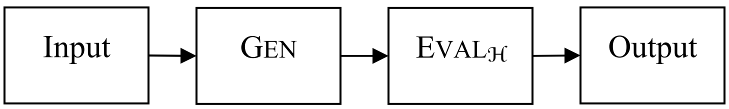
1 Introduction

Background

•In "classic" Optimality Theory (Prince and Smolensky 2004), the system of candidate generation GEN is entirely separate from the system of candidate evaluation EVAL:

(1) Structure of Classic OT



Explanation:

-Input, Output are levels of representation.

-GEN generates candidate outputs.

-EVAL compares the candidates, selecting the one that is most harmonic (optimal) according to the language-particular constraint hierarchy $\mathcal{H}$.

•Classic OT is nonderivational, mapping Inputs directly to Outputs without intermediate steps. Classic OT's EVAL compares fully formed Output candidates, each of which may differ in many ways from the Input.

This talk

•Explores an alternative OT architecture, differing in two main respects from the classic theory:

-The system of candidate generation has (limited) access to EVAL. The set of candidates for a given input will therefore differ from language to language, unlike classic OT.

-Candidates include output forms and information about the sequence of operations that produced them. These candidate "chains" have some similarities to derivations in rule-based phonology (RBP).

•Three kinds of arguments for this approach will be sketched, based on formal properties of the candidate set, impossible mappings, and phonological opacity.

•This talk won't be able to delve into all of the details of this approach, nor will it offer much in the way of comparison with alternatives, such as Stratal OT. These and other matters are treated in McCarthy (2006).

Invitation

•Feel free to interrupt if anything is unclear.

2 Candidate Chains

The definition

•A candidate chain associated with an input /in/ in a language with the constraint hierarchy $\mathcal{H}$ is an ordered *n*-tuple of forms $C = <f_0, f_1, ..., f_n>$ that meets the following conditions:

-Faithful initial form: f_0 is a faithful parse of /in/. (Specifically, it's the faithful parse of /in/ that's most harmonic according to $\mathcal{H}$. We won't be discussing this further today.)

-Gradual divergence: In every pair of immediately successive forms in C, $<..., f_i, f_{i+1}, ...>$ $(0 \leq i < n)$, f_{i+1} has all of f_i's unfaithful mappings, plus one.

-Harmonic improvement: In every pair of immediately successive forms in C, $<..., f_i, f_{i+1}, ...>$ $(0 \leq i < n)$, f_{i+1} is more harmonic than f_i according to $\text{EVAL}_{\mathcal{H}}$.

•There are various alternative ways of formulating the gradual divergence requirement — e.g., in terms of faithfulness, or phonological operations, or even perceptual similarity. I won't be saying too much about this today, but I'll mention it occasionally.

•The harmonic improvement requirement says, in effect, that $<..., f_i, f_{i+1}, ...>$ is valid only if $\text{EVAL}_{\mathcal{H}}$ prefers f_{i+1} over f_i when given these two forms and no others to choose between.

•Since f_{i+1} is less faithful than f_i by the gradual divergence requirement, f_{i+1} must be less marked than f_i, since there is no other way to improve harmonically in OT.

•The chain's output is $[f_n]$. This has the same status as the Output in classic OT.

A hypothetical illustration

(2) Constraint hierarchy $\mathcal{H}$
NO-CODA >> MAX >> DEP >> $*VC_{VCLS}V$ >> IDENT(voice)

Glossary: NO-CODA = $*C]_\sigma$; MAX = no deletion; DEP = no epenthesis; $*VC_{VCLS}V$ = *V*p*V; IDENT(voice) = no change in voicing.

(3) Some valid chains for input /pap/ under the grammar in (2)

<pap>	Faithful parse.
<pap, pa.pə>	Harmonically improving because NO-CODA ≫ DEP.
<pap, pa>	Harmonically improving because NO-CODA ≫ MAX.
<pap, pa.pə, pa.bə>	Harmonically improving because <pap, papə> is harmonically improving and $*VC_{VCLS}V$ ≫ ID(voice).

(4) Some invalid chains for input /pap/ under the grammar in (2)

**<pap, pab>	Final voicing is not harmonically improving under $\mathcal{H}$.
**<pap, pa.bə>	Not gradually divergent.

How candidate chains are like and unlike derivations in RBP

•Like: gradual divergence approximates effects of a sequence of rules. (The equivalence is inexact. *SPE* rules can be formulated as transformations (Chomsky and Halle 1968: 360ff.), which means that they can perform several operations at once. But there are also proposals in the literature to limit rules to certain elementary operations (e.g., Archangeli and Pulleyblank 1994, Prince 1983).)

•Unlike: there's nothing like the harmonic improvement requirement in RBP. Harmonic improvement is unique to OT, which defines relative harmony in terms of EVAL and $\mathcal{H}$.

How OT with candidate chains (OT-CC) is like and unlike classic OT

- •Like: violable constraints, constraint hierarchy, candidate comparison (the most important stuff).
- •Unlike: classic OT evaluates fully formed output candidates; OT-CC also evaluates the steps along the way.

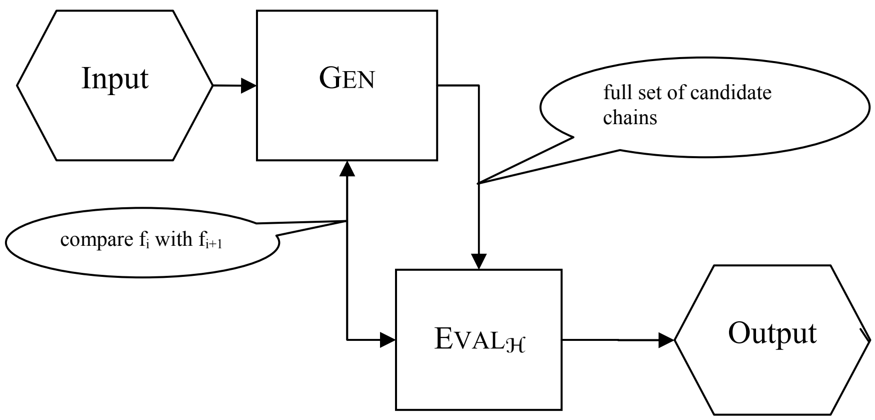
The most important precursor to OT-CC

•Prince and Smolensky (2004: 94-95) mention an alternative to classic OT's GEN (also see McCarthy 2000, 2002: 159-163):

> "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… There are constraints inherent in the limitation to a single operation and in the requirement that each operation in the sequence improve Harmony."

The structure of OT-CC

(5)



What's next?

- •Formal result: finiteness.
- •Typological/empirical result: reduction of global power.
- •Empirical result: opacity.

3 Finiteness of chains and the candidate set

The infinite candidate set in Classic OT

- •Classic GEN imposes no natural upper bound on epenthesis ([paʔəʔəʔəʔə...]).
- •These candidates are ruled out in EVAL by faithfulness constraints.

Claim

- •For any input in any language, the set of valid candidate chains is finite.

Chains are bounded in length

- •This follows from the harmonic improvement requirement on chains and Moreton's (2003) results about harmonic improvement in classic OT.
- •Necessary (and mostly uncontroversial) assumptions:

-ℋ includes only markedness and faithfulness constraints.

Markedness constraints evaluate well-formedness of output structures.

Faithfulness constraints penalize disparity between input and output.

-The number of constraints in ℋ is finite.

-GEN(x) always includes [x] as a candidate (so "do nothing" is always an option).

•Moreton's (2003) proof

-Under these assumptions, any OT grammar (that is, GEN and EVAL$_{\mathcal{H}}$) is *eventually idempotent* [ˈajdəmˌpotənt].

A function f is idempotent iff $f(a) = f \circ f(a)$ for any a — i.e., the result of applying f to a is the same as the result of applying f to the result of applying f to a.

A function f is *eventually* idempotent iff $\forall a\ \exists n$ s.t. $f^{n}(a) = f^{n+1}(a)$. In other words, for a given input, there's always some power of f that is idempotent.

-To say that any OT grammar G is eventually idempotent, then, is to say that $\forall$/in/ $\exists n$ s.t. G^{n}(/in/) = G^{n+1}(/in/).

-Why is this true? Moreton has a formal proof, but its intuitive basis is clear enough. Markedness constraints are the only opposition to faithfulness constraints, so the only reason to be unfaithful is to become less marked (relative to the language-particular hierarchy ℋ). So unfaithfulness (=change) can only occur to improve markedness. Since markedness constraints evaluate outputs only (so they can't say "Change!"), since they assign marks for violation rather than satisfaction, and since they are finitely many (so they can't collectively set unreachable targets), markedness improvement is necessarily limited.

•Relevance of Moreton's proof

-No matter where you start, no matter how you proceed, and no matter how ℋ is ranked, there will always come a point when a candidate chain cannot get any longer and still be harmonically improving.

-For instance, suppose (implausibly) that <pa, paʔ, paʔə, paʔəʔ, paʔəʔə, paʔəʔəʔə, paʔəʔəʔəʔ> was known to be a valid chain. Is the longer chain obtained by adding [paʔəʔəʔəʔə] also valid? Only if DEP is dominated by some markedness constraint that (even more implausibly) forbids words with fewer than five syllables. There must come a point when further harmonic improvement and therefore further valid extension of any chain is impossible because the markedness constraints are finite in number.

-Antifaithfulness constraints (Alderete 2001), if they exist, would subvert this result.

Chains diverge in finitely many ways

•Suppose we have a valid chain <f_0, …, f_n>, and we want to know whether there is any f_{n+1} that will give a valid chain <f_0, …, f_n, f_{n+1}>.

•Because of the gradualness requirement, the number of "candidates" for f_{n+1} is finite. f_{n+1} differs from f_n by the addition of one faithfulness violation, the number of faithfulness constraints is finite, and for each constraint the number of possible loci of violation is also finite.

Unlimited prosodic structure?

•In phonology, the only other identifiable threats of the infinite besides epenthesis come from nonbranching prosodic recursion ([…[[*dog*]$_{\mathrm{PWd}}$]$_{\mathrm{PWd}}$ …]$_{\mathrm{PWd}}$) and empty prosodic structure ([*dog*]$_\sigma$ [ ]$_\sigma$ [ ]$_\sigma$ [ ]$_\sigma$ …).

•In classic OT, these candidates are ruled out by markedness constraints that have structural economy effects (Gouskova 2003, 2004, Grimshaw 2002).

•OT-CC can use the same constraints and maintain a finite candidate set if the gradualness requirement is (re)defined so that prosodic-structural nodes can only be added one at a time. (We should also probably reconsider whether recursive and empty prosodic structure should be allowed by GEN.)

Summary

•Chain construction and evaluation in OT-CC are bounded tasks. This allows OT-CC to have a very direct computational implementation of in Becker (2006). On the other hand, finiteness is no panacea, and infinity is not necessarily an impediment to computational efficiency.

•OT-CC's strongly finitistic cast, in comparison with classic OT, follows from the harmonic improvement and gradualness requirements that are imposed on chains.

•As we will see, these two requirements are needed for other reasons as well.

4 OT-CC and impossible mappings

In Classic OT…

•The existence of the mapping /ktub/ → [ʔuktub] (in Arabic) requires that [ʔuktub] be more harmonic, according to $\mathcal{H}_{Arabic}$, than [ktub], [uktub], [ʔktub], [kutub], … (Harmony is relative to input /ktub/, of course.)

(6) Harmonic ordering in classic OT: [ʔuktub] > [ktub], [uktub], etc.

In OT-CC …

•The /ktub/ → [ʔuktub] mapping tells us that [ʔuktub] must be more harmonic, according to $\mathcal{H}_{Arabic}$, than [ktub], [uktub], [ʔktub], [kutub], … — same as Classic OT.

•But this mapping also requires that [uktub] be more harmonic than [ktub], since [uktub] is necessarily intermediate in the chain <ktub, uktub, ʔuktub>. (Gradualness rules out the fell-swoop chain **<ktub, ʔuktub>.)

(7) Harmonic ordering in OT-CC: [ʔuktub] > [uktub] > [ktub], etc.

In general…

•Whenever an observed phonological mapping /A/ → [C] involves more than one instance of unfaithfulness — and therefore a chain of length greater than two — OT-CC may impose stricter markedness requirements than Classic OT.

•Suppose /A/ → [C] must go by way of [B]: <A, B, C>. Then [C] is less marked than [B] is less marked than [A], according to markedness constraints as ranked in $\mathcal{H}$.

•Classic OT is weaker: [C] is less marked than [A] and [B]. (Relative markedness of [A] and [B] doesn't affect outcome.)

From which it follows that…

•In OT-CC, that /A/ → [C] mapping can't occur unless both of the following conditions are met:

(i) the universal constraint set CON includes a markedness constraint favoring [B] over [A]

(ii) in $\mathcal{H}$ this constraint is ranked higher than any markedness constraint with the opposite favoring relation.

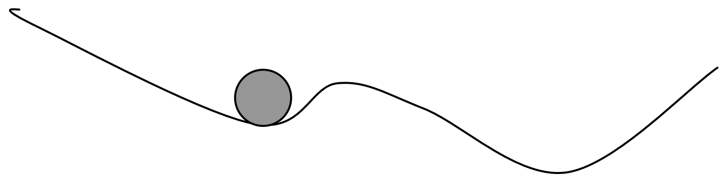
•This means that some mappings that are possible in classic OT are impossible in OT-CC, *ceteris paribus*. In general, these mappings are ruled out because all paths from input to intended output go through local minima (see (8)).

•In classic OT, the route from input to output is irrelevant; all that matters is relative harmony. Local minima are equally irrelevant; the global minimum is what the grammar always finds.

•We can therefore use typological observations to compare the two theories.

(8) Local minima (arguably, a **good** thing about OT-CC)

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



Example: Massive truncation to get a favored word-ending segment

•Some languages require every phonological word to end in a consonant (FINAL-C).

•If FINAL-C is ranked above the anti-deletion faithfulness constraint MAX, then in Classic OT we get a (hypothetical) language that deletes everything after the rightmost consonant in the word:

/kapan/ → [kapan]
/palata/ → [palat]
/tapasai/ → [tapas]

•Now imagine that this hypothetical language disallows obstruents (*t*, *s*, etc.) at the end of a syllable (CODA-COND).

•The result is truncation of everything to the right of the rightmost sonorant consonant.

•Multisegment truncation is never observed to occur for this or similar reasons (though it can happen because of constraints on higher-level prosodic structure (McCarthy and Prince 1994)).

(9) Unwelcome effect of FINAL-C, CODA-COND >> MAX in classic OT

/palasanataka/	FINAL-C	CODA-COND	MAX
→ palasan			*****
a. palasanataka	*!		
b. palasanatak		*!	*
c. palasanata	*!		**
d. palasanat		*!	***
e. palasana	*!		****

•These constraints cannot produce this mapping in OT-CC, however. To get from /palasanataka/ to [palasan] requires a chain of single-segment deletions, each of which produces markedness improvement relative to some consistent ranking of the constraints. But there's no ranking of FINAL-C and CODA-COND meeting that requirement:

(10) <palasanataka, palasanatak> Valid only if FINAL-C >> CODA-COND.
<palasanataka, palasanatak, palasanata> Also requires CODA-COND >> FINAL-C.

What is the reason for this difference between classic OT and OT-CC?

•In the /palasanataka/ → [palasan] mapping, no individual deletion achieves satisfaction of both FINAL-C and CODA-COND, but all of the deletions taken together do get satisfaction. Classic OT is global in its evaluations, requiring harmonic improvement in the net result of all operations taken together.

•But OT-CC is more local in its evaluations. It could obtain the /palasanataka/ → [palasan] mapping only if there were a chain of forms with single-segment deletions linking input and output with monotonic harmonic improvement. That's not the case with these constraints.

A reminder. Such typological predictions depend on …

•Exactly how the gradualness requirement is stated. Here, I make the reasonable assumption that GEN cannot remove more than one segment at a time. But if (implausibly) it could delete multisegmental strings in one pass, then /palasanataka/ → [palasan] would be possible.

•Exactly what the constraints in CON are. If there were (also implausibly) a constraint that is violated once for every segment intervening between the rightmost sonorant consonant and the right edge of the word, then /palasanataka/ → [palasan] would be possible. (On why such constraints do not exist, see McCarthy (2003, 2004).)

Example: Domino-effect metathesis

-If NO-CODA (which forbids syllable-final consonants) is ranked above the antimetathesis faithfulness constraint LINEARITY, then Classic OT can force /apekto/ to map to [paketo] by double metathesis (/ap/ → [pa] and /ek/ → [ke]).

(11) Double metathesis from NO-CODA >> LINEARITY in classic OT

/apekto/	NO-CODA	LINEARITY
→ pa.ke.to		**
a. a.pek.to	*!	
b. pa.ek.to	*!	*
c. ap.ke.to	*!	*

-NO-CODA cannot produce this unattested and presumably impossible pattern in OT-CC. The reason: neither of the logically possible routes via one-at-a-time metatheses — <apekto, pa.ekto, paketo> and <apekto, apketo, paketo> — is harmonically improving at its intermediate step.

Example: Obstruent nasalization in Vimeu Picard

•In Vimeu Picard, voiced stop codas become nasals after nasalized vowels: /repɔ̃d/ → [repɔ̃n] 'to answer' (cf. [repɔ̃dy] 'answered'). José and Auger (2004) propose that nasalization of coda /d/ is a response to the same markedness requirement that accounts for coda devoicing in German.

•Simplified, their analysis goes like this:

(12) Voiced obstruent coda nasalization in Vimeu Picard

/repɔ̃d/	*VOICEDOBSTCODA	IDENT(nasal)
→ repɔ̃n		*
repɔ̃d	*!	

•Nasality can only come from assimilation (DEP(nasal) is undominated). The segment that contributes nasality must be immediately adjacent: /nead/→ *[nẽãn] does not happen.

•OT-CC can explain the adjacency requirement: the putative chain **<nead, nẽad, nẽãd, nẽãn> is not harmonically improving under this grammar until its last step, so it is invalid. (Skipping, as in <nead, nean>, must be ruled out independently.)

•Classic OT can do no better than stipulate the adjacency requirement.

•In sum, you can't get long-distance assimilation to achieve a highly local result in OT-CC.

•Long-distance assimilation is still possible; it just requires a markedness constraint that imposes the harmonic ordering [nẽãn] ≻ [nẽãd] ≻ [nẽad] ≻ [nead]. (The typological claim is that no language will limit long-distance nasal assimilation to just in those cases where a voiced obstruent coda follows, at any distance.) Classic OT analyses need this constraint too as a way of accounting for assimilation that continues up to but not past a blocking segment (McCarthy 2003, Wilson 2003, 2004). Because gradient alignment constraints impose this harmonic ordering, they have been favored as the impetus for autosegmental spreading since the early days of OT. There are alternatives to gradient alignment, some of which have this property and some of which do not. For discussion, see McCarthy (2004).

Application: The too-many-repairs problem

•The too many repairs problem is the observation that the attested ways of satisfying a markedness constraint are often rather limited (Lombardi 2001, Pater 2003, Steriade 2001, Wilson 2000, 2001). OT focuses attention on this problem because OT is inherently typological, and permuting the ranking of faithfulness constraints may predict a typology in which the same markedness constraint should be satisfied in diverse ways in different languages. The predicted typology doesn't always match observations.

•For example, Wilson notes that medial heterosyllabic clusters may be simplified by deleting the first consonant (/patka/ → [pa.ka]) but not by deleting the second consonant, even when it is less marked (/patka/ → *[pata]).

•OT-CC offers a novel approach to this problem. Perhaps the unattested repairs are blocked by local minima.

•For example, suppose that the gradualness requirement is fine-tuned so that deletion of oral consonants must go through an intermediate lenition step: **<patka, paka> is invalid under gradualness, but <patka, pahka, paka> is suitably gradual.

•This means that deletion of the second consonant would require a putative chain <patka, patha, pata>, and this chain isn't valid because [pat.ha] is not more harmonic than [pat.ka] (since presumably no constraint favors lenition of postconsonantal onsets).

•How should gradualness be defined so as to obtain results like this? Steriade's (2001) proposal suggest that perceptual similarity is a possibility: in the chain <A, B, C, …>, B is (in some sense) minimally perceptually different from A, C is minimally perceptually different from B, and so on. (This of course requires that there be quanta of perceptual distance, such as JNDs.)

Summary:

•The combination of the gradualness and harmonic improvement requirements on chains limits OT-CC's ability to do certain kinds of global optimization. This appears to be an advantage of OT-CC over classic OT.

•These results may also be relevant to the difficult problem of too many repairs.

5 Phonological Opacity in OT-CC

Opacity (Kiparsky 1973)

•Phonological processes are opaque if their effects or their contexts are not visible in surface forms.

•In RBP, opacity is the usual result of counterfeeding or counterbleeding orders in rule application.

(13) Counterfeeding order in Bedouin Arabic

Underlying	/gabr/	'a grave'
Raising (a→i/__CV)	—	
Vowel epenthesis (Ø→V/C__C#)	gabur	
Surface	[gabur]	

Opacity — Epenthesis alters context that had made raising inapplicable.

Counterfeeding order — If applied in opposite order, epenthesis would feed raising (transparently): /gabr/ → [gabur] → *[gibur].

(14) Counterbleeding order in Bedouin Arabic

Underlying	/ħaːkim-iːn/	'ruling (masculine plural)'
Palatalization	ħaːk^{j}imiːn	
Syncope	ħaːk^{j}miːn	
Surface	[ħaːk^{j}miːn]	

Opacity — Syncope changes context that had made palatalization applicable.

Counterbleeding order — If applied in opposite order, syncope would bleed palatalization (transparently): /ħaːkim-iːn/ → [ħaːkmiːn].

Opacity in OT-CC

•Classic OT has a natural bias toward transparent (feeding and bleeding) interaction.

•Why? Because markedness constraints can only state generalizations about surface structure and not about other levels of representation. (Faithfulness constraints refer to underlying structure, but they are limited to requiring underlying-surface identity.)

•OT-CC offers a way of integrating the analysis of opacity into OT by using constraints that override that natural bias. These constraints evaluate derivations, in the form of candidate chains.

Candidate chains and opacity (somewhat simplified)

•Interaction of raising and epenthesis in Bedouin Arabic

-Visibly active markedness constraints:

*Complex-Coda — violated by final cluster in *[gabr].

Raise — violated by any [a] in a nonfinal open syllable, such as [ga.bur].

-Crucially dominated faithfulness constraints

Dep — no epenthesis.

Ident(low) — no raising.

(15) Wrong result in classic OT

/gabr/	RAISE	*COMPLEX-CODA	IDENT(low)	DEP
a. → *gibur			*	*
b. gabur	*!			*
c. gabr		*!		

(16) Valid chains from /gabr/ in Bedouin Arabic, given ranking in (15)

a. <gabr>
b. <gabr, ga.bur>✓
c. <gabr, ga.bur, gi.bur>

(17) PREC(edence) constraints (somewhat informally)

PREC(A, B)

Let A′ and B′ stand for forms that add violations of the faithfulness constraints A and B, respectively.

To any chain of the form <X, B′, Y>, if X does not contain A′, assign a violation mark, and

to any chain of the form <X, B′, Y >, if Y contains A′, assign a violation mark.

(18) Effect of PREC(IDENT(low), DEP) in OT-CC

/gabr/	*COMPLEX-CODA	PREC(IDENT(low), DEP)	RAISE	IDENT(low)	DEP
a. → <gabr, gabur> <DEP>		*	*		*
b. <gabr, gabur, gibur> <DEP, IDENT(low)>		**!		*	*
c. <gabr> < >	*!				

•Markedness constraints evaluate outputs (final form in chain); faithfulness constraints evaluate input-output relation (initial-final forms in chain). This is the same as classic OT.

•<gabr, gabur> (candidate (a) in (18)) is the optimal *derivation*, even though its *output* [gabur] would be nonoptimal in classic OT, as (15) shows. By evaluating derivations as well as the output forms that they produce, we can regulate the sequence of operations (unfaithful mappings) required to produce an output.

•The restrictions on derivations are implemented as ranked, violable constraints — as usual in OT. PREC constraints can override OT's natural bias toward transparency. In examples of sufficient complexity, crucial domination of PREC constraints can be demonstrated.

•This example shows why the *gradualness* restriction on chains is needed. If nongradual **<gabr, gibur> were valid, then it would beat (and in fact harmonically bound) the intended winner.

•This example also shows why the *harmonic improvement* restriction on chains is needed. If **<gabr, gibr, gibur> were valid, then it too would beat (and harmonically bound) the intended winner.

•Interaction of palatalization and syncope in Bedouin Arabic

-Visibly active markedness constraints:

*ki — violated by any sequence of a nonpalatalized velar and a front vowel.
*iCV — violated by any short high vowel in a nonfinal open syllable.

-Crucially dominated faithfulness constraints:

Max — no deletion — dominated by *Complex-Coda.
Ident(back) — no palatalization.

(19) Wrong result in classic OT

/ħa:kim-i:n/	*iCV	*ki	Max	Id(back)
a. → *ħa:kmi:n			*	
b. ħa:k^{j}mi:n			*	*!
c. ħa:kimi:n	*!	*!		
d. ħa:k^{j}imi:n	*!			*

(20) Valid chains from /ħa:kim-i:n/ in Bedouin Arabic, given ranking in (19)

a. <ħa:kimi:n>
b. <ħa:kimi:n, ħa:k^{j}imi:n>
c. <ħa:kimi:n, ħa:kmi:n>
d. <ħa:kimi:n, ħa:k^{j}imi:n, ħa:k^{j}mi:n>✓

(21) Effect of Prec(Id(back), Max) in OT-CC

/ħa:kim-i:n/	*iCV	*ki	Max	Prec(Id(back), Max)	Id(back)
a. → <ħa:kimi:n, ħa:k^{j}imi:n, ħa:k^{j}mi:n>			*		*
b. <ħa:kimi:n>	*!	*!			
c. <ħa:kimi:n, ħa:k^{j}imi:n>	*!				*
d. <ħa:kimi:n, ħa:kmi:n>			*	*!	

•This example confirms the need for the harmonic improvement requirement on chains. If chains didn't need to be harmonically improving, then among the chains from input /t-ħakum-in/ 'they (f.) rule' would be **<tħakumin, tħak^{j}umin, tħak^{j}min>, with palatalization in a nonpalatalizing environment. This chain would wrongly beat the intended winner <tħakumin, tħakmin> because it satisfies Prec(Id(back), Max).

A restriction on the ranking of Prec constraints

•Suppose Prec(Id(back), Max) were ranked above *iCV. This permutation would not affect the analysis of (21), but it would have the strange effect of blocking syncope in words that contain no velar to palatalize:

(22) Unwanted effect of ranking PREC(ID(back), MAX) above **i*CV

/ʃarib-at/	PREC(ID(bk), MAX)	**ki*	**i*CV	MAX	ID(back)
→ *<ʃaribat>			*		
<ʃaribat, ʃarbat>	*!			*	

•In general, PREC(A, B) cannot be permitted to affect satisfaction of B (though it typically does affect satisfaction of A). That's guaranteed if PREC(A, B) can never dominate B, since domination is the only way that one constraint has the potential to affect satisfaction of another.

(23) Metaconstraint on the ranking of PREC constraints
B >> PREC(A, B)

Convergent chains

•Two chains are *convergent* if they have the same input and output and involve the same unfaithful mappings, in different orders. Differences between convergent chains are ignored by PREC constraints.

•For instance, the mapping /kitib-aw/ → [k^{j}itbaw] can be derived by either of the convergent chains <kitibaw, kitbaw, k^{j}itbaw> or <kitibaw, k^{j}itibaw, k^{j}itbaw>, and these are associated with the respective orders of unfaithful mappings <MAX, ID(back)> and <ID(back), MAX>. ("Unfaithful mapping" in this sense, is a faithfulness violation localized to a particular segment, rather than, say, any MAX violation anywhere.)

•The empirical claim is that chain convergence isolates and eliminates all orders of noninteracting unfaithful mappings. (The analogous situation in RBP is that /kitib-aw/ → [k^{j}itbaw] would not be regarded as probative on the question of how palatalization and syncope are ordered.)

•PREC constraints do not evaluate chains *per se*; they evaluate the partial ordering of unfaithful mappings obtained by intersecting the total orderings of unfaithful mappings associated with each convergent chain.

•Convergent chains cannot be identified until the "full set of candidate chains" step in (5). Therefore, PREC constraints cannot be evaluated until this point either. In determining chain validity, PREC constraints are always vacuously satisfied. Therefore, they do not affect the results described earlier that follow from assuming that the harmonic improvement requirement on chains involves only markedness and faithfulness constraints.

Historical note

•*The Sound Pattern of English* (Chomsky and Halle 1968)

-Rules are totally ordered.

-This ordering is language-particular ("extrinsic"). In principle, two languages could have identical rules but different ordering.

-Intrinsic ordering is limited to longest-expansion-first disjunctivity among subrules abbreviated by ( ) or < >.

•Post-*SPE*, study of natural rule ordering. Two proposals:

-Maximize rule application. This makes feeding and counterbleeding orders natural (Anderson 1969, 1974, Kiparsky 1968, Koutsoudas, Sanders, and Noll 1974).

-Maximize rule transparency. This makes feeding and bleeding orders natural (Kenstowicz and Kisseberth 1971, Kiparsky 1973).

•Optimizing derivations in rule-based phonology (expanding on Anderson 1974: 217-218)

-System of priorities to determine ordering of set of rules R1, R2, …:

1. Absolute language-particular ordering restrictions.
2. Maximize rule application (favors feeding and counterbleeding).
3. Maximize transparency (favors feeding and bleeding).
4. Contingent language-particular ordering restrictions (if all else fails).

-Optimization by these principles isn't always reducible to decisions about how to order rule pairs, particularly since transparency is a property of final result of derivation. Whole derivations must be compared. (In fact, Anderson (1969: 12) describes a GEN-like mechanism for producing all possible rule sequences.)

-Work along these lines evoked criticisms that now sound very familiar:

> "Since, in principle, opacity is a property derived not from the interaction of just two rules but of all the rules that can participate in a derivation, in general it would be necessary to scan as many as ALL the possible sequences of the *n* rules in a grammar to determine the correct derivation. The magnitude of the number of derivations to be checked is *n*!, which of course is extremely large… It seems unlikely to me that a genuine principle of language organization in human beings could require anywhere near this amount of processing." (King 1976: 92n.)

As Ringen (1976) and Phelps and Brame (1973) noted, there are infinitely many "candidate" rule sequences, and not just *n*!, since rules can reapply in a derivation.

6 Conclusion

•We've looked at an implementation of OT that incorporates derivation-like objects in the form of candidate chains.

•Chains describe a path from input to output that must be gradual and harmonically improving.

•The evaluations that build chains and choose among them are finite.

•Chains can't accomplish some kinds of mappings that classic OT can get. These mappings may be unattested.

•Chains offer an approach to opacity that can be linked with the study of rule ordering in the 1970's.

7 References

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

Anderson, Stephen R. (1969) *West Scandinavian Vowel Systems and the Ordering of Phonological Rules*. Doctoral dissertation. Cambridge, MA: MIT.

Anderson, Stephen R. (1974) *The Organization of Phonology*. New York: Academic Press.

Archangeli, Diana and Pulleyblank, Douglas (1994) *Grounded Phonology*. Cambridge, MA: MIT Press.

Becker, Michael. (2006) CCamelOT -- An implementation of OT-CC's GEN and EVAL in Perl. Handout of talk presented at Linguistic Society of America, 80th Annual Meeting, Albuquerque, New Mexico.

Chomsky, Noam and Halle, Morris (1968) *The Sound Pattern of English*. New York: Harper & Row.

Gouskova, Maria (2003) *Deriving Economy: Syncope in Optimality Theory*. Doctoral dissertation. Amherst, MA: University of Massachusetts Amherst. [Available on Rutgers Optimality Archive, ROA-610.]

Gouskova, Maria (2004) Minimal reduplication as a paradigm uniformity effect. In B. Schmeiser, V. Chand, A. Kelleher, and A. Rodriguez (eds.) *The Proceedings of the 22nd West Coast Conference on Formal Linguistics* 265-278. Somerville, MA: Cascadilla Press. [Available at http://homepages.nyu.edu/~mg152/downloads/gouskova_wccfl2004.pdf.]

Grimshaw, Jane (2002) Economy of structure in OT. In Angela Carpenter, Andries Coetzee, and Paul de Lacy (eds.) *University of Massachusetts Occasional Papers in Linguistics 26: Papers in Optimality Theory II* 81-120. Amherst, MA: GLSA. [Available on Rutgers Optimality Archive, ROA-434.]

José, Brian and Auger, Julie (2004) (Final) nasalization as an alternative to (final) devoicing: The case of Vimeu Picard. In Brian José and Ken De Jong (eds.) *Indiana University Linguistics Club Working Papers Online*. Bloomington, IN: Indiana University Linguistics Club. [Downloaded (1/19/2006) from https://www.indiana.edu/~iulcwp/pdfs/04-jose.pdf.]

Kenstowicz, Michael and Kisseberth, Charles (1971) Unmarked bleeding orders. *Studies in the Linguistic Sciences* 1: 8-28.

King, Robert D. (1976) In defense of extrinsic ordering. In Andreas Koutsoudas (ed.) *The Application and Ordering of Grammatical Rules* 76-103. The Hague: Mouton.

Kiparsky, Paul (1968) Linguistic universals and linguistic change. In Emmon Bach and Robert Harms (eds.) *Universals in Linguistic Theory* 170-202. New York: Holt, Rinehart and Winston.

Kiparsky, Paul (1973) Abstractness, opacity and global rules. In O. Fujimura (ed.) *Three Dimensions of Linguistic Theory* 57-86. Tokyo: TEC.

Koutsoudas, Andreas, Sanders, Gerald, and Noll, Craig (1974) On the application of phonological rules. *Language* 50: 1-28.

Lombardi, Linda (2001) Why Place and Voice are different: Constraint-specific alternations in Optimality Theory. In Linda Lombardi (ed.) *Segmental Phonology in Optimality Theory: Constraints and Representations* 13-45. Cambridge: Cambridge University Press. [Available (1995) on Rutgers Optimality Archive, ROA-105.]

McCarthy, John J. (2000) Harmonic serialism and parallelism. In Masako Hirotani (ed.) *Proceedings of the North East Linguistics Society 30* 501-524. Amherst, MA: GLSA Publications. [Available on Rutgers Optimality Archive, ROA-357.]

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. (2004) Headed spans and autosegmental spreading. Unpublished manuscript. Amherst, MA: University of Massachusetts Amherst. [Available on Rutgers Optimality Archive, ROA-685.]

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

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).]

Moreton, Elliott (2003) Non-computable functions in Optimality Theory. In John J. McCarthy (ed.) *Optimality Theory in Phonology: A Reader* 141-163. Malden, MA, and Oxford, UK: Blackwell. [Available on Rutgers Optimality Archive, ROA-364.]

Pater, Joe (2003) Balantak metathesis and theories of possible repair in Optimality Theory. Unpublished manuscript. Amherst, MA: University of Massachusetts Amherst. [Available at http://people.umass.edu/pater/pater-balantak.pdf.]

Phelps, Elaine and Brame, Michael (1973) On local ordering of rules in Sanskrit. *Linguistic Inquiry* 4: 387-400.

Prince, Alan (1983) Relating to the grid. *Linguistic Inquiry* 14: 19-100.

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.]

Ringen, Catherine O. (1976) Vacuous application, iterative application, reapplication, and the unordered rule hypothesis. In Andreas Koutsoudas (ed.) *The Application and Ordering of Grammatical Rules* 55-75. The Hague: Mouton.

Steriade, Donca (2001) The phonology of perceptibility effects: The P-map and its consequences for constraint organization. Unpublished manuscript. Los Angeles: UCLA. [Downloaded (9

September 2003) from http://www.linguistics.ucla.edu/people/steriade/papers/P-map_for_phonology.doc.]

Wilson, Colin (2000) *Targeted Constraints: An Approach to Contextual Neutralization in Optimality Theory*. Doctoral dissertation. Baltimore, MD: Johns Hopkins University.

Wilson, Colin (2001) Consonant cluster neutralization and targeted constraints. *Phonology* 18: 147-197.

Wilson, Colin (2003) Unbounded spreading in OT (or, Unbounded spreading is local spreading iterated unboundedly). Handout from SWOT 8, Tucson, AZ.

Wilson, Colin (2004) Analyzing unbounded spreading with constraints: Marks, targets, and derivations. Unpublished manuscript. Los Angeles: UCLA.