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GEN, EVAL, and Phonological Opacity

| | |
|--|----|
| 1. Goals of this course..... | 1 |
| 2. Classic OT (Prince and Smolensky 2004) | 2 |
| 3. Phonological opacity..... | 3 |
| 4. A taxonomy of approaches to opacity in OT | 5 |
| 5. Denial: Is opacity real? | 5 |
| 6. Substantive approaches to opacity | 7 |
| 7. Derivational and quasi-derivational approaches..... | 9 |
| 8. Contrast preservation and opacity..... | 12 |
| 9. Overview of OT-CC | 14 |
| 10. Candidate Chains | 16 |
| 11. Finiteness of chains and the candidate set | 18 |
| 12. OT-CC and impossible mappings..... | 20 |
| 13. Phonological Opacity in OT-CC (first pass)..... | 24 |
| 14. The Intellectual Roots of OT-CC..... | 28 |
| 15. A restriction on ranking PREC constraints | 30 |
| 16. Localized unfaithful mappings (LUMs) | 31 |
| 17. Chain convergence..... | 32 |
| 18. Definitions, etc..... | 33 |
| 19. Specimen analysis: Opacity in Levantine Arabic | 34 |
| 20. References..... | 42 |

1. Goals of this course

- Review the basic properties of GEN and EVAL in “classic” OT.
- Describe various proposals for modifying GEN and/or EVAL.
- We’ll look in particular detail at OT with candidate chains (OT-CC), and this course will serve as something of an advertisement for McCarthy (2006).
- As our empirical focus, we’ll also look in some detail at the problem of phonological opacity.

Bring this long handout with you every day, since we’ll be using it all week.

Questions for you to think about and perhaps answer appear in boxes like this one.

2. Classic OT (Prince and Smolensky 2004)

(1) The flowchart



Other components of Classic OT

CON = constraint set

\mathcal{F} = language particular constraint hierarchy.

The Input

- Classic OT shares central assumption of theory of generative phonology: every morpheme has a single underlying representation, except for suppletion and perhaps listed allomorphy (see McCarthy 2002b: 152-156, 183-184 for references).
- Richness of the base. No language-particular restrictions on inputs.
- Later, we'll see special role for fully-faithful candidate.

GEN

- “Freedom of analysis”: phrase introduced by McCarthy and Prince (1993) to describe GEN’s ability to transform any input form into any output candidate, even /kæt/ into [dɔg].
- That this mapping is no doubt impossible is not GEN’s problem. Instead, restrictions on possible mappings follow from the assumptions that there is a universal constraint component CON and that grammars are permutations of CON. Since the /kæt/ → [dɔg] mapping is impossible in any human language, [dɔg] must not be the most harmonic member of /kæt/’s candidate set under any ranking of CON.

CON

- There are finitely many constraints.
- Constraints are universal. (They could be innate or learned. Learning would have to occur via some universally shared experience, as in Hayes (1999).)
- Every constraint imposes a stratified partial ordering on the entire candidate set.
- There are only two kinds of constraints, markedness and faithfulness.
- Markedness constraints evaluate outputs only.
- Faithfulness constraints require identity in input-output mapping.
- Vague, implicit restriction on faithfulness constraints: something about the kinds of contexts they can mention.

Compare “don’t delete underlying low vowels” and “don’t delete consonants after underlying low vowels”. Do you find faithfulness constraints like the latter in the literature? Are they needed?

- Beginnings of a theory of the internal structure of CON: harmonic alignment of scales, local conjunction, alignment constraint schema.

EVAL

- Defines relative harmony.
- Selects most harmonic candidate (or candidates, if two or more distinct forms manage to have identical violation profiles).
- Applies constraints with reference only to candidate under evaluation (markedness constraints) plus its input (faithfulness constraints).
- Lumps together two sources of multiple violations: multiple instances of offending structure (e.g., [i.aj.i.aj.ow] gets 5 *s from ONSET) and gradient evaluation (e.g. [grumadwet] gets 2 *s from ALIGN-L(*um*, Stem)).

\mathcal{H}

- A total ordering of CON. Even theories that allow variable ranking within a language (Anttila 1997, Boersma and Hayes 2001) have fixed ordering in every evaluation.

The Output

- Most harmonic member of candidate set.
- Not different from surface structure of standard generative phonology.

The arrows in (1)

- Parallelism: fully-formed output candidates are evaluated. There’s no going back.

Which aspects of classic OT are most central? Which are least central? Why is this question important?

3. Phonological opacity

Opacity (Kiparsky 1973)

- Phonological processes are opaque if their effects or their contexts are not visible in surface forms.
- In rule-based phonology, opacity is the usual result of counterfeeding or counterbleeding orders in rule application.

(2) Counterfeeding order in Bedouin Arabic

| | | |
|--------------------------------|---------|-----------|
| Underlying | /gabr/ | ‘a grave’ |
| Raising (a→i/ __ CV) | — | |
| Vowel epenthesis (∅→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].

(3) Counterbleeding order in Bedouin Arabic

| | | |
|----------------|--------------------------|-----------------------------|
| Underlying | /ħa:kim-i:n/ | ‘ruling (masculine plural)’ |
| Palatalization | ħa:k ^ʲ imi:n | |
| Syncope | ħa:k ^ʲ mi:n | |
| Surface | [ħa:k ^ʲ mi:n] | |

Opacity — Syncope changes context that had made palatalization applicable.

Counterbleeding order — If applied in opposite order, syncope would bleed palatalization (transparently): /ħa:kim-i:n/ → [ħa:kmi:n].

Counterfeeding 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 [gaa,bur].

-Crucially dominated faithfulness constraints

DEP — no epenthesis.

IDENT(low) — no raising.

(4) Wrong result in classic OT

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

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.

(5) Wrong result in classic OT

| | /hɑ:kim-i:n/ | *iCV | *ki | MAX | ID(back) |
|------|-------------------------|------|-----|-----|----------|
| a. → | *hɑ:kmi:n | | | * | |
| b. | hɑ:k ⁱ mi:n | | | * | *! |
| c. | hɑ:kimi:n | *! | *! | | |
| d. | hɑ:k ⁱ imi:n | *! | | | * |

These examples illustrate the challenge that opacity presents to classic OT. Can you explain in a more intuitive way *why* opacity is a challenge?

To handle opacity, we need to change our assumptions. Which assumption(s) should we examine first? In other words, what's the most conservative approach we could take, even though it might eventually be proven wrong?

4. A taxonomy of approaches to opacity in OT

- Denial
- Approaches based on altered substantive properties of the theory
 - Opacity via enriched representations.
 - Counterfeeding opacity with local constraint conjunction.
 - Counterbleeding opacity as segmental coalescence.
- Derivational and quasi-derivational approaches
 - Multi-grammar serial OT.
 - Sympathy.
 - Targeted constraints.
 - Comparative markedness.
- Contrast preservation

5. Denial: Is opacity real?

- Natural Generative Phonology (NGP): authentic phonological rules must state surface-true generalizations and they must be unordered (Hooper [Bybee] 1976, 1979, Vennemann 1972, 1974).

How do these principles exclude all opaque analyses? Are both needed?

- So opaque processes are merely the lexicalized residue of sound changes that are no longer productive — opaque rules said to be “not psychologically real”.
- Recent work advocating similar views in an OT context includes Green (2004), Mielke, Hume, and Armstrong (2003), and Sanders (2002, 2003).

- This is, as the saying goes, an empirical question, and Al-Mozainy's (1981) study of Bedouin Arabic presents considerable evidence bearing on it.
- Opaque processes include raising of low vowels and deletion of high vowels, both in open syllables.
- These processes apply in loan words:

(6) Raising in borrowed words (84ff.)

| Source word | Source language | Borrowed word | Gloss |
|-------------|------------------|---------------|------------|
| kabak | Turkish | kibak | 'cufflink' |
| ʔalʔaqabah | Jordanian Arabic | ʔalʔgibah | 'Aqaba' |
| madrasah | Standard Arabic | madrisah | 'school' |

- High vowel deletion applies in external sandhi:

(7) Phrase-level deletion in Bedouin Arabic (Al-Mozainy 1981: 50-51)

| | | |
|----------------------------|----------------------------|--|
| /ka:tib al-zuwa:b/ | ka:t.bal.zu.wa:b | 'writing the letter' |
| | *ka:ti.bal.zu.wa:b | |
| /tiʔtʔu:nih al-muse:ʔi:di/ | tiʔ.tʔu:n.hal.m.se:ʔi:di | 'you give it to the one from the clan of Musai`id' |
| | *tiʔ.tʔu:ni.hal.m.se:ʔi:di | |

- Raising is inapplicable after a guttural consonant ([ʔ], [h], [ʕ], [ħ], [χ], [ʁ]), or before a guttural consonant or coronal sonorant ([l], [r], [n]) that is itself followed by [a]. Bedouin Arabic has a secret language that permutes the consonants of the root, and this will sometimes affect the position of gutturals or coronal sonorants relative to the potentially raised vowel. When that happens, the vowel raises or fails to raise in exact conformity with these generalizations:

(8) Raising alternations in a secret language

| | |
|---------|----------------------------------|
| /dafaʔ/ | Underlying representation |
| difaʔ | Unpermuted form |
| fidaʔ | Raising as expected |
| daʔaf | No raising before guttural + [a] |
| faʔad | " |
| ʔadaf | No raising after guttural |
| ʔafad | " |

- Other evidence of productive but opaque processes can be found in Donegan and Stampe (1979).

Secret languages and the like constitute natural experiments testing the productivity of opaque processes. How might you go about designing artificial experiments to do the same thing?

6. Substantive approaches to opacity

- These approaches are inherently attractive because they leave OT's fundamentals alone — they don't touch EVAL or OT's flowchart in (1). They include:
 - Opacity via enriched representations.
 - Counterfeeding opacity with local constraint conjunction.
 - Counterbleeding opacity as segmental coalescence.

We'll focus on the first two, which are the most promising.

Enriched representations

- PARSE/FILL theory of faithfulness (“Containment”) in Prince and Smolensky (2004).
- Turbidity (Goldrick 2000, Goldrick and Smolensky 1998).
- Colored Containment (van Oostendorp 2005)

(Turbidity and Colored Containment are proposals to improve on PARSE/FILL theory — see the cited works for discussion.)

I assume that I don't need to explain the PARSE/FILL theory of faithfulness to anyone in this class. Since you're already familiar with it, can you tell me how it's applicable to opacity? Can you think of any examples in Prince and Smolensky (2004) where an opaque process is analyzed in these terms? What are its limitations as a theory of opacity and as a theory of faithfulness?

Local constraint conjunction

- Counterfeeding opacity can be accommodated in classic OT if the theory of faithfulness constraints is sufficiently rich. (There is no comparable way of dealing with counterbleeding opacity.)
- It has been proposed that *local conjunction* of faithfulness constraints is the proper mechanism for incorporating this richer theory of faithfulness into CON (Ito and Mester 2003c, Kirchner 1996, Moreton and Smolensky 2002).
- Local constraint conjunction is proposed by Smolensky (1995) as a theory of the internal structure of CON. Complex constraints are built by conjoining simpler constraints. The simpler constraints may be irreducible, or they may themselves be the product of local conjunction.
- The local conjunction of constraints A and B, $[A\&B]_{\delta}$, is defined as a constraint that is violated once for each instance of the domain δ in which both A and B are violated.
- Conjunction of markedness constraints supplies the most persuasive examples. Codas are marked by the constraint NO-CODA and voiced obstruents are marked by the constraint NO-VCD-OBST. The local conjunction of these constraints within the domain of a segment, $[NO-CODA \& NO-VCD-OBST]_{\text{seg}}$, militates against the combination of these two marked properties, a voiced obstruent in coda position. In general, local conjunction of markedness constraints forbids the cooccurrence of marked structures in near proximity to one another.

- The counterfeeding interaction in Bedouin Arabic /gabr/ → [gabur] requires the local conjunction of IDENT(low) and DEP in the domain of adjacent syllables: [IDENT(low)&DEP]_{Adj-σ}:

(9) Counterfeeding opacity with local conjunction

| /gabr/ | [ID(low)&DEP] _{Adj-σ} | *COMP-CODA | *aCV | DEP | ID(low) |
|----------|--------------------------------|----------------|------|-----|----------------|
| → gabur | | | 1 | 1 | |
| a. gibur | W ₁ | | L | 1 | W ₁ |
| b. gabr | | W ₁ | L | L | |

- This is an elegant theory of counterfeeding opacity, but it predicts a kind of pseudo-opacity that does not seem to exist (McCarthy 1999: 365-366, 2002a, 2003a, Padgett 2002). The reason goes right to the core of local-conjunction theory: real counterfeeding opacity is a matter of forbidden process *interaction*, but local conjunction regulates process *proximity*. Proximity can often serve as a proxy for interaction in phonology, but ultimately interaction and proximity are two very different things, and it is a mistake to confound them.
- Raising in Bedouin Arabic is blocked when the epenthetic vowel *follows* the syllable with the potentially raised vowel, but not when the epenthetic vowel *precedes* (see (10)). The conjoined constraint [IDENT(low)&DEP]_{Adj-σ} can't make this distinction.

(10) Adjacent epenthesis and raising in Bedouin Arabic

/tʰarad ʁanam-ih/ [tʰa.ra.dʱɛ.ni.mih] 'he pursued his sheep'

Why does the position of the epenthetic vowel matter? Could a more sophisticated theory of domains of conjunction help?

What happens if you conjoin the same constraints in a bigger domain, such as [IDENT(low)&DEP]_{wd}?

What happens if you conjoin a different pair of faithfulness constraints, such as [IDENT(low)&IDENT(voice)]_{Adj-σ}?

There are various proposals in the literature for formal restrictions on local conjunction (Bakovic 1999, Fukazawa and Miglio 1998, Hewitt and Crowhurst 1996, Ito and Mester 2003a: 102ff., 2003c, Łubowicz 2002, 2006). Are they likely to help with the issues raised here?

7. Derivational and quasi-derivational approaches

- These include:
 - Multi-grammar serial OT.
 - Sympathy.
 - Targeted constraints.
 - Comparative markedness.

We'll focus on the first two.

Multi-grammar serial OT

- It's known by many names, including some names with overt connections to the rule-based theory of Lexical Phonology.
- The idea appears in the OT literature from the very beginning (Cohn and McCarthy 1994/1998, many of the contributions to Hermans and van Oostendorp 1999, McCarthy and Prince 1993, Orgun 1996, Potter 1994, many of the contributions to Roca 1997a), and there has been a flurry of interest in it lately, with particular emphasis on the Lexical Phonology connection (Bermúdez-Otero 1999, 2004, Hale and Kisser 1998, Ito and Mester 2001, 2003b, 2003c)
- The main assumptions are these:
 - The phonology of a language consists of several OT grammars linked serially.
 - The output of one grammar becomes the input to another pass through GEN and the next grammar.
 - These grammars are distinct in the sense that they require different rankings of CON. (Only meaning of “distinct grammars” that makes sense in OT.)
 - Like the strata of the theory of Lexical Phonology, the various grammars are correlated with the difference between words and phrases or differences in the morphology.
- Example: palatalization/syncope interaction in Bedouin Arabic

(11) Lexical stratum

| /ħa:kim-i:n/ | MAX | *ki | *iCV | ID(back) |
|---------------------------|----------------|----------------|------|----------|
| → ħa:k ^l imi:n | | | 1 | 1 |
| a. ħa:kmi:n | W ₁ | | L | L |
| b. ħa:k ^l mi:n | W ₁ | | L | 1 |
| c. ħa:kimi:n | | W ₁ | 1 | L |

(12) Postlexical stratum

| /ħa:k ^j imi:n/ | *iCV | *ki | MAX | ID(back) |
|----------------------------|----------------|----------------|-----|----------------|
| → ħa:k ^j mi:n | | | 1 | |
| a. ħa:kmi:n | | | 1 | W ₁ |
| b. ħa:k ^j imi:n | W ₁ | | L | |
| c. ħa:kimi:n | W ₁ | W ₁ | L | W ₁ |

- Note the ranking difference between the two strata — this really *is* a multi-grammar theory of opacity.
- Three main problems confront this approach to opacity:
 - Insufficient restrictiveness.
 - Within-stratum opaque interactions.
 - Strata sometimes give wrong ordering.

I'll discuss the first two points, and I'll ask you about the third.

- Insufficient restrictiveness:
 - There are no known limits on reranking between strata within a language. E.g., Kiparsky (1997: 17) proposes that the ranking of markedness constraints is constant across all of the strata of a language, but Ito and Mester (2001: 274-276) argue that the postlexical stratum in German promotes one markedness constraint over another, relative to the lexical stratum.
 - Rule-based Lexical Phonology, in contrast, tried to address the equivalent problem with its Strong Domain Hypothesis (Borowsky 1986, Kiparsky 1984, Myers 1991, Selkirk 1982): all strata, lexical and postlexical, share a single *SPE*-type grammar.
 - But rule-based LP principles like Structure Preservation can't be imported into OT.

Why can't the effect of Structure Preservation be reproduced in OT?

- Within-stratum opaque interactions are common in the literature on rule-based Lexical Phonology. Some examples include Kiparsky's (1984) analysis of Icelandic and Kiparsky's (1985) analyses of Catalan and Russian. Perhaps they can be reanalyzed, but that remains to be seen. (See also Noyer 1997: 515, Paradis 1997: 542, Roca 1997b: 14ff., Rubach 1997: 578 for similar remarks). If it were possible to eliminate opaque rule orderings using strata, why wasn't this move already made in rule-based LP?

Suppose rule A precedes rule B in counterbleeding order. What can we infer about the strata where A and B can and cannot be applicable?

Suppose rule A precedes rule B in counterfeeding order r . What can we infer about the strata where A and B can and cannot be applicable?

If a process occurs in the postlexical stratum, can it be opaque? What about syncope in Bedouin Arabic (cf. (7))?

Sympathy

- Sympathy (McCarthy 1999, 2003c) uses a third form, neither input nor output, to influence the choice of the output.
- This third form, the sympathetic candidate, is the most harmonic candidate among those that obey a designated faithfulness constraint, called the selector.
- The sympathetic candidate influences the choice of the actual output form by way of sympathy constraints. Sympathy constraints look like faithfulness constraints, but they evaluate resemblance to the sympathetic candidate rather than resemblance to the input.
- Example:

(13) Counterbleeding opacity with sympathy

| $/\text{ħa:kim-i:n}/$ | ID(back) _{Sym} (sympathy) | *iCV | *ki | MAX (selector) | ID(back) |
|---|---------------------------------------|----------------|----------------|-------------------|----------|
| → ħa:k ^l mi:n | | | | 1 | 1 |
| a. ħa:kmi:n | W ₁ | | | 1 | L |
| b. ħa:k ^l imi:n (sympathetic cand.) | | W ₁ | | L | 1 |
| c. ħa:kimi:n | W ₁ | W ₁ | W ₁ | L | L |

- An important argument against sympathy theory comes from Kiparsky (2001). This argument relies on the fact that sympathy theory must allow for more than one selector constraint per language and more than one sympathetic candidate per tableau, because there are languages with several opaque processes.
- Problematic example:

(14) An unwelcome result of sympathy

| /pam/ | DEP-C _{DEP-V} (sympathy) | MAX-V _{MAX-C} (sympathy) | NO-CODA | DEP-V (selector) | MAX-C (selector) |
|------------------------------------|--------------------------------------|--------------------------------------|----------------|---------------------|---------------------|
| → paə | | | | 1 | 1 |
| a. pam | W ₁ | W ₁ | W ₁ | L | L |
| b. pamə (sympathetic via MAX-C) | W ₁ | | | 1 | L |
| c. pa (sympathetic via DEP-V) | | W ₁ | | L | 1 |

| |
|-------------------------------|
| What's the problem with (14)? |
|-------------------------------|

8. Contrast preservation and opacity

- Donegan and Stampe (1979), Kaye (1974, 1975), Kisseberth (1976), and Gussmann (1976) propose that opaque rule ordering has a functional explanation. The general idea is that opacity preserves phonemic contrasts, avoiding neutralizations that would occur if the rules applied in transparent order.
- Examples:

(15) Counterbleeding order in Ojibwa (Kaye 1974: 140)

| | |
|------------------------|-----------------------------------|
| Underlying | /takossin-k/ |
| Place assimilation | takossin̥k |
| Cluster simplification | takossin̥ |
| Surface | [takof̥ʃin̥] '(if) he arrives' |

- Because all surface [ɲ]s are derived by assimilation in Ojibwa, the presence of a surface [ɲ] without a following surface velar is an indication of the underlying presence of a velar.

(16) Counterfeeding order in English *plant it* (Donegan and Stampe 1979)

| | |
|----------------|---|
| Underlying | /plænt it/ |
| [t] flapping | <i>Inapplicable because [t] is not intervocalic</i> |
| Nasal deletion | plæ̃t it |
| Surface | [plæ̃t it] |

- Because V#V is a flapping environment in American English, the presence of a surface [t] rather than [ɾ] is an indication that a consonant originally preceded the [t].

Recent developments

- Łubowicz (2003) develops an Optimality-Theoretic system, called PC theory (for “preserve contrast”), in which these ideas about opacity’s functional motivation are given a formal basis.
- Like Flemming (1995), Padgett (2003), and others, she assumes that the objects of phonological evaluation are systems of contrasts, which she calls “scenarios”.

(17) Arabic scenarios in PC theory

a. Transparent

/gabur/ → [gibur]

/gabr/ → [gibur]

b. Opaque (winning scenario)

/gabur/ → [gibur]

/gabr/ → [gabur]

(18) Counterfeeding opacity in PC theory

| /gabur/ /gabr/ | PC _{IN} (V/∅) | *COMP-CODA | *aCV | DEP | ID(low) |
|--|------------------------|----------------|------|-----|----------------|
| → /gabur/ → [gibur] /gabr/ → [gibur] | | | 1 | 1 | 1 |
| a. /gabur/ → [gibur] /gabr/ → [gibur] | W ₁ | | L | 1 | W ₂ |
| b. /gabur/ → [gibur] /gabr/ → [gabr] | | W ₁ | L | L | 1 |

(19) Ojibwa scenarios in PC theory

a. Transparent

/...in/ → [...in]

/...ink/ → [...in]

b. Opaque

/...in/ → [...in]

/...ink/ → [...iŋ]

(20) Counterbleeding opacity in PC theory

| /...in/ /...ink/ | PC _{IN} (C/∅) | *COMP-CODA | *ŋ | ID(coronal) |
|---|------------------------|----------------|----|-------------|
| → /...in/ → [...in] /...ink/ → [...iŋ] | | | 1 | 1 |
| a. /...in/ → [...in] /...ink/ → [...in] | W ₁ | | L | L |
| b. /...in/ → [...in] /...ink/ → [...ink] | | W ₁ | L | L |

What's wrong in (20)? It gets the right result, so the problem must be with the way it gets that result. (Hint: Remember that Ojibwa independently has a process of nasal place assimilation (e.g., [takofʃiŋkipan] '(if) he arrived then').)

Homework exercise

Analyze the English phenomenon in (16) in terms of one or more of the theories of opacity that we've talked about. (I haven't tried to do this, so I don't know whether it can be done.)

9. Overview of OT-CC

(taken, with light editing, from chapter 1 of McCarthy (2006))

This book's principal thesis is that the best theory of opacity — and of phonology generally — is a synthesis of Optimality Theory (hereafter OT) with derivations. I argue that a candidate in OT includes not just a surface form but also a series of intermediate forms, each of which is minimally different from the form that immediately precedes it. A candidate, then, supplies information about the sequence of operations needed to link the underlying and surface forms. In the *planted* example,¹ for instance, the winning candidate is the ordered *n*-tuple <plænt-d, plæntəd, plænəd>, and among its competitors is *<plænt-d, plænd>. In the *mankind* example, the winning candidate is <mænkajnd, mæŋkajnd>, and its most important competitor is *<mænkajnd, mæŋkajnd, mæɛŋkajnd>. These ordered *n*-tuples are called *candidate chains*. This theory is referred to as *OT with candidate chains*, or *OT-CC* for short.

Candidate chains are subject to three well-formedness conditions:

First, all chains are *faithfully initiated*. This means that the first form in a chain is identical with the underlying representation, except for syllabification and the like.

Second, chains are *gradually divergent*. This condition has already been hinted at: the successive forms in a chain are minimally different from their neighbors, so the path from input to output proceeds in small steps.

Third, chains are *harmonically improving*. Every form in a chain is more harmonic than its predecessor, relative to the constraint hierarchy of the language in question. Because of the gradualness requirement, a form's successor in a chain may not be the ultimate surface form, but it must be more harmonic.

The evaluation of a candidate chain by the grammar has some familiar properties: markedness constraints assess the last form in the chain, which is the chain's output; and faithfulness constraints measure discrepancies between the first and last forms in the chain. A novel type of constraint, *PREC* (for "precedence"), specifies the preferred order of faithfulness violations in a chain. For example, the winning chain from the input /mænkajnd/ is opaque <mænkajnd, mæŋkajnd>. Its transparent competitor *<mænkajnd, mæŋkajnd, mæɛŋkajnd> loses because of the constraint *PREC*(*DEP*, *IDENT*(Place)), which says that the *IDENT*(Place)-violating mapping of /n/ to [ŋ] cannot precede the *DEP*-violating insertion of the off-glide [ɛ].

This proposal raises two fundamental questions: Why analyze opacity by incorporating derivations into *OT*? Why analyze opacity by incorporating *derivations* into *OT*? These questions and the issues they raise merit serious consideration.

¹ The excerpt is alluding here to two analyses from Donegan and Stampe (1979). In English, the past tense suffix is pronounced as [əd] after [t] or [d]: *planted*, *braided*. This generalization is sometimes hidden, though, because [t] can be deleted after a nasal consonant: *planted* is pronounced carefully as [plæntəd] but more usually as [plænəd]. Even when the [t] is absent, the suffix is still pronounced as [əd], so *planted* never merges with *planned*. Another example: some English dialects add a rising off-glide between [æ] and tautosyllabic [ŋ]: [bæɛŋ] *bang*. But when [ŋ] is derived by place assimilation from /n/, the generalization is hidden and does not seem to hold: [mæŋkajnd], *[mæɛŋkajnd] *mankind*.

Why OT? Opacity figures prominently in critiques of OT by proponents of rule-based phonology. These critiques suffer from selective vision, however, seeing only OT's opacity problem and ignoring the very real problems that typically afflict rule-based phonology, such as dearth of explanation and absence of typological predictions. A central failing of rule-based phonology in the tradition of Chomsky and Halle (1968) is that it promotes descriptive completeness over all other goals of linguistic theory, a miscasting of priorities that means that the theory with the richest descriptive resources inevitably wins.

OT's very real advantages in explaining phonological systems and limiting their typological possibilities need not be reviewed here. (Readers who need convincing might want to consult McCarthy 2002b.) Since OT has many strengths, if opacity is OT's principal weakness, then it makes sense to explore ways of remedying this weakness instead of giving up on the enterprise.

Why derivations? There have been many proposals for accommodating opacity in OT, and most of them rely on a third level of representation, neither underlying nor surface, as a crucial part of the analysis of opaque alternations. The defining property of a derivation, in the sense I am employing here, is the presence of this third (or fourth or fifth) level of representation. It is therefore not inaccurate to say that derivations or something like them have already been shown to play a necessary role in any reasonably complete approach to opacity in OT. But these more limited proposals for incorporating derivations into OT turn out to be insufficient when the full range of opaque alternations is considered, and so I argue that a richer theory of derivations, candidate chains, is required in OT.

If candidate chains are to be a welcome addition to OT, then they should offer more than just a way out of the opacity jam — and they do. For one thing, the well-formedness requirements on candidate chains have the effect of severely limiting the size of the candidate set. Because there is no natural limit on the number of epenthesis operations that GEN can perform, classic OT imposes no upper bound on the length of a candidate and therefore no bound on the size of the candidate set for any input. But the harmonic improvement requirement ensures that candidate chains are of bounded length, for all inputs and for all constraint hierarchies.

For another, the harmonic improvement and gradualness requirements operate in concert to impose limitations on what kinds of mappings from underlying to surface representation are possible. In classic OT, a necessary and sufficient condition for the mapping /A/ → [B] in a language L is that [B] is more harmonic, according to L's constraint hierarchy, than any other candidate derived from /A/. With chains, this condition is still necessary but it is no longer sufficient: for [B] to be a possible output form /A/, there must be a well-formed chain connecting /A/ with [B]. Suppose that the chain must contain the intermediate form [C] because of the gradualness requirement: <A, C, B>. Then [C] must be more harmonic than [A] and less harmonic than [B] according to L's hierarchy. Sometimes this means that L's hierarchy must rank constraints that would be nonconflicting and therefore unrankable in classic OT. More importantly, sometimes it means that the /A/ → [B] mapping will be impossible in L. In this way, candidate chain theory restricts OT's power to perform certain global optimizations. This is also a major point of difference between chain theory and standard derivational models, which have no analogous notion of improvement or progress in their derivations.

10. 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 $C = \langle f_0, f_1, \dots, f_n \rangle$ that meets the following conditions:

-Faithful initial form: f_0 is the faithful parse of /in/ that's most harmonic according to \mathcal{H} .

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

-Harmonic improvement: In every pair of immediately successive forms in C , $\langle \dots, f_i, f_{i+1}, \dots \rangle$ ($0 \leq i < n$), 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 $\langle \dots, f_i, f_{i+1}, \dots \rangle$ 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

(21) Constraint hierarchy \mathcal{H}

NO-CODA \gg MAX \gg DEP \gg *VC_{VCLS}V \gg IDENT(voice)

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

(22) Some valid chains for input /pap/ under the grammar in (21)

| | |
|--|---|
| $\langle \text{pap} \rangle$ | Faithful parse. |
| $\langle \text{pap}, \text{pa.pə} \rangle$ | Harmonically improving because NO-CODA \gg DEP. |
| $\langle \text{pap}, \text{pa} \rangle$ | Harmonically improving because NO-CODA \gg MAX. |
| $\langle \text{pap}, \text{pa.pə}, \text{pa.bə} \rangle$ | Harmonically improving because $\langle \text{pap}, \text{papə} \rangle$ is harmonically improving and *VC _{VCLS} V \gg ID(voice). |

(23) Some invalid chains for input /pap/ under the grammar in (21)

| | |
|---|---|
| ** $\langle \text{pap}, \text{pab} \rangle$ | Final voicing is not harmonically improving under \mathcal{H} . |
| ** $\langle \text{pap}, \text{pa.bə} \rangle$ | Not gradually divergent. |

How candidate chains are like and unlike derivations in rule-based phonology

- 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 rule-based phonology. 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.

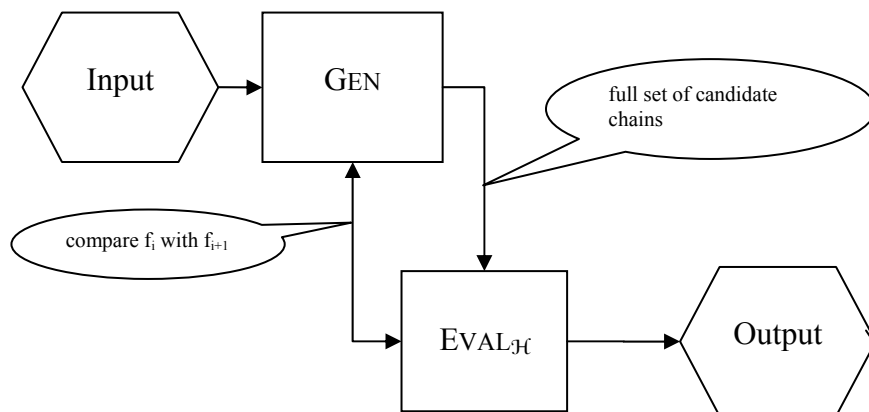
The most important precursor to OT-CC

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

(24)



What's next?

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

11. 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:

- \mathcal{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 \mathcal{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* [ˈɛjdəmˌpɒtənt].

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 \mathcal{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.

You should be able to complete the argument. In light of Moreton's proof, what can we say about the length of chains in OT-CC?

For instance, suppose (implausibly) that $\langle pa, pa\eta, pa\eta\theta, pa\eta\theta\eta, pa\eta\theta\eta\theta, pa\eta\theta\eta\theta\theta, pa\eta\theta\eta\theta\theta\theta \rangle$ was known to be a valid chain. What would it take for the longer chain obtained by adding $[pa\eta\theta\eta\theta\eta\theta]$ also to be valid?

What kinds of constraints, other than markedness or faithfulness, could subvert this result? (Obviously, there's no issue if no such constraints exist.)

Suppose we have two valid chains from the same input, and one chain properly contains the other as its initial sequence: $C = \langle f_1, f_2, \dots, f_n \rangle$ and $D = \langle f_1, f_2, \dots, f_n, f_{n+1}, \dots, f_m \rangle$. Which is more harmonic? Is there enough information to answer?

Chains diverge in finitely many ways

- Suppose we have a valid chain $\langle f_0, \dots, f_n \rangle$, and we want to know whether there is any f_{n+1} that will give a valid chain $\langle f_0, \dots, f_n, f_{n+1} \rangle$.
- 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 ($(\dots[[[dog]_{PwD}]_{PwD} \dots]_{PwD})$ and empty prosodic structure ($([dog]_{\sigma} []_{\sigma} []_{\sigma} []_{\sigma} \dots)$).
- 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 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 at all.)

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.

12. 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 $\mathcal{H}_{\text{Arabic}}$, than [ktub], [uktub], [ʔktub], [kutub], ... (Harmony is relative to input /ktub/, of course.)

(25) 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 $\mathcal{H}_{\text{Arabic}}$, 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>.)

(26) 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 additional ranking 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.

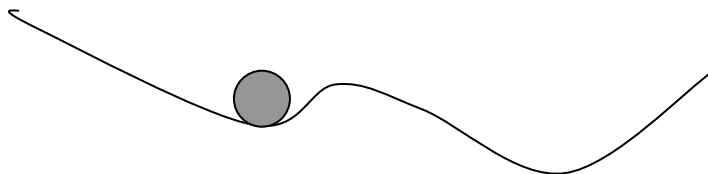
- This means that some mappings that are possible in classic OT are impossible in OT-CC, *ceteris paribus*. In general, these mappings are ruled out because all paths from input to intended output go through local minima (see (27)).

- 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.

(27) 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)).

(28) 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:

- (29) <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 (2003b, 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]).

(30) 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 | *! | * |

Can NO-CODA and/or ONSET compel the /apekto/ → [paketo] unfaithful mapping in OT-CC? Explain.

Example: Obstruent nasalization in Vimeu Picard

- In Vimeu Picard, voiced stop codas become nasals after nasalized vowels: /repõd/ → [repõn] 'to answer' (cf. [repõdy] '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:

(31) Voiced obstruent coda nasalization in Vimeu Picard

| | | |
|---------|-----------------|--------------|
| /repõd/ | *VOICEDOBSTCODA | IDENT(nasal) |
| → repõn | | * |
| repõd | *! | |

•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 2003b, 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).

Homework exercise

Prince and Smolensky's (2004) analysis of Lardil augmentation (exemplified in (32)) involves a constraint system similar to (33). The alignment constraint accounts for the fact that augment includes not only epenthetic *a* but also an epenthetic consonant that is homorganic with the preceding consonant. (The epenthetic segments are in boldface.)

The exercise is to figure out whether and how to analyze these facts in OT-CC under the assumption that gradualness limits GEN to epenthesizing one segment at a time.

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

| | | |
|-------|---------------|----------|
| Root | Nominative | |
| /ɾil/ | ɾil ta | 'neck' |
| /ɬal/ | ɬal ta | 'vulva' |
| /maɾ/ | maɾ ɬa | 'hand' |
| /kaŋ/ | kaŋ ka | 'speech' |

(33) FTBIN, ALIGN-R(root, σ) >> DEP

| /ɕil/ | FTBIN | ALIGN-R(root, σ) | DEP |
|----------|----------------|--------------------------|----------------|
| → ɕil.ta | | | 2 |
| a. ɕi.la | | W ₁ | L ₁ |
| b. ɕil | W ₁ | | L |

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) work suggests 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.

13. Phonological Opacity in OT-CC (first pass)

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_abur].

-Crucially dominated faithfulness constraints

DEP — no epenthesis.

IDENT(low) — no raising.

(34) Wrong result in classic OT (=4)

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

(35) Valid chains from /gabr/ in Bedouin Arabic, given ranking in (4)

a. <gabr>

b. <gabr, ga.bur>✓

c. <gabr, ga.bur, gi.bur>

(36) 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.

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

| /gabr/ | *COMPLEX-CODA | PREC(IDENT(lo), DEP) | RAISE | IDENT(lo) | 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 (37)) is the optimal *derivation*, even though its *output* [gabur] would be nonoptimal in classic OT, as (4) 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.

(38) Wrong result in classic OT (=5)

| /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 | *! | | | * |

(39) Valid chains from /ħa:kim-i:n/ in Bedouin Arabic, given ranking in (5)

- <ħa:kimi:n>
- <ħa:kimi:n, ħa:k^jimi:n>
- <ħa:kimi:n, ħa:kmi:n>
- <ħa:kimi:n, ħa:k^jimi:n, ħa:k^jmi:n>✓

(40) Effect of PREC(ID(back), MAX) in OT-CC

| /ħa:kim-i:n/ | *iCV | *ki | MAX | PREC(ID(bk), MAX) | ID(back) |
|---|------|-----|-----|-------------------|----------|
| a. → <ħa:kimi:n, ħa:k ^j imi:n, ħa:k ^j mi:n> <IDENT(back), MAX> | | | * | | * |
| b. <ħa:kimi:n> <> | *! | *! | | | |
| c. <ħa:kimi:n, ħa:k ^j imi:n> <IDENT(back)> | *! | | | | * |
| d. <ħa:kimi:n, ħa:kmi:n> <MAX> | | | * | *! | |

•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 **<thakumin, thak^jumin, thak^jmin>, with palatalization in a nonpalatalizing environment. This chain would wrongly beat the intended winner <thakumin, thakmin> because it satisfies PREC(ID(back), MAX).

(41) Unwanted effect of allowing non-harmonically-improving chains

| /t-ħakum-in/ | *iCV | *ki | MAX | PREC(ID(bk), MAX) | ID(back) |
|--|----------------|-----|-----|-------------------|----------|
| → *thak ^l .min <ID(back), MAX> | | | 1 | | 1 |
| a. th̄a.ku.min <> | W ₁ | | L | | |
| b. th̄ak.min <MAX@5> | | | 1 | W ₁ | L |

14. The Intellectual Roots of OT-CC*Relationship to other work in OT*

- Candidates with multiple forms:
 - Jun (1999), Odden (1997), Bye (2001) revisions of sympathy theory (McCarthy 1999).
 - Paradigms as candidates (see various contributions to Downing, Hall, and Raffelsiefen (eds.) (2005), Rice (2005)).
- GEN/EVAL interaction
 - Harmonic serialism (McCarthy 2000, Prince 1975, Prince and Smolensky 2004).
 - Wilson (2003) theory of constraint application.
- Importance of fully faithful candidate
 - Comparative markedness (McCarthy 2002a, 2003a)
 - “Enriched input” (Inkelas, Orgun, and Sprouse 2002, Sprouse 1997, 1998).

The theory of derivations in the 1960’s and 1970’s

- *The Sound Pattern of English* (Chomsky and Halle 1968) (likewise Chomsky 1951, 1965)
 - Rules are totally ordered.
 - This ordering is language-particular (“extrinsic”). In principle, two languages could have identical rules but different ordering.
 - Except for effects of the cycle and certain rule abbreviatory conventions, rule application is strictly sequential (no going back, no repetition (iteration), no simultaneous application).

- Study of rule interaction (begins with Kiparsky 1968)
 - Look at subsystems of rules that coexist in a grammar (usually only pairs of rules).
 - What are their relations with one another?
 - Feeding and counterfeeding, bleeding and counterbleeding. (To save time, I'll only be discussing feeding and counterfeeding today.)

Principal conclusion emerging from this body of research: Feeding order is natural

- Two possible rationales:
 - -Feeding order maximizes rule application (Anderson 1969, 1974, Kiparsky 1968, Koutsoudas, Sanders, and Noll 1974). (Cf. Minimalist economy of derivation (Chomsky 1995).)
 - -Counterfeeding order in (2) denies raising an opportunity to apply.
 - -Feeding order maximizes *transparency* and minimizes *opacity* (Kiparsky 1973). Transparency: phonological rules state surface-true generalizations (and their contextual conditions are also met at surface structure).
 - -Raising is opaque in (2) because surface form [gabur] looks like it should have undergone this process but didn't.
- Choice of rationale depends on whether you think the other natural order is bleeding or counterbleeding.

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).

Lower-ranked restrictions or principles come into play only when higher-ranked ones don't decide.

E.g., “maximize application” won't decide stress-epenthesis interaction in colloquial Arabic:

/katab-l-ha/ →_{Epenthesis} [katabilha] →_{Stress} [kata'bilha] (Iraqi)

/katab-l-ha/ →_{Stress} [ka'tablha] →_{Epenthesis} [ka'tabilha] (Palestinian)

Transparency favors Iraqi [kata'bilha], since independently required “stress heavy penult” generalization is surface-true. In Palestinian Arabic, a language-particular absolute ordering restriction Stress > Epenthesis would be required, and it would take precedence over “maximize transparency”.

- 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, and Anderson (1974: 218) cites a couple of unobtainable works that might present real-life examples of interactions that can only be decided by considering >2 rules at a time.)
- Work along these lines led to complaints that have a highly familiar sound to them:

“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.)

(Ringen (1976) and Phelps and Brame (1973) point out that the number is actually infinite, and not just $n!$, since rules can reapply in a derivation.)

What happened with the study of rule ordering in phonology after about 1975? What happened to rule ordering in syntax?

15. A restriction on ranking PREC constraints

(42) Metaconstraint on the ranking of PREC constraints

$B \gg \text{PREC}(A, B)$

(43) Effect of $\text{PREC}(\text{ID}(\text{back}), \text{MAX})$ in OT-CC (= (40))

| | /hɑ:kim-i:n/ | *iCV | *ki | MAX | PREC(ID(bk), MAX) | ID(back) |
|------|--|------|-----|-----|-------------------|----------|
| a. → | <hɑ:kimi:n, hɑ:k ^j imi:n, hɑ:k ^j mi:n> <IDENT(back), MAX> | | | * | | * |
| b. | <hɑ:kimi:n> <> | *! | *! | | | |
| c. | <hɑ:kimi:n, hɑ:k ^j imi:n> <IDENT(back)> | *! | | | | * |
| d. | <hɑ:kimi:n, hɑ:kmi:n> <MAX> | | | * | *! | |

(44) Effect of reranking PREC(ID(back), MAX) above *iCV (and therefore above MAX)

| /ħa:kim-i:n/ | PREC(ID(bk), MAX) | *ki | *iCV | MAX | ID(back) |
|---|-------------------|-----|------|-----|----------|
| a. → <ħa:kimi:n, ħa:k ^j imi:n, ħa:k ^j mi:n> <IDENT(back), MAX> | | | | * | * |
| b. <ħa:kimi:n> <> | | *! | *! | | |
| c. <ħa:kimi:n, ħa:k ^j imi:n> <IDENT(back)> | | | *! | | * |
| d. <ħa:kimi:n, ħa:kmi:n> <MAX> | *! | | | * | |

No problem in (44), but think about this: What does the grammar in (44) do to the input /ʃarib-at/ 'he drank'? (I've given you a blank tableau to practice on.) What pattern of behavior does the grammar in (44) describe? Is this a reasonable prediction, or do we need (42) to rule it out?

(45) Practice tableau with PREC(ID(back), MAX) above *iCV (and therefore above MAX)

| /ʃarib-at/ | PREC(ID(bk), MAX) | *ki | *iCV | MAX | ID(back) |
|------------|-------------------|-----|------|-----|----------|
| a. → | | | | | |
| b. | | | | | |

16. Localized unfaithful mappings (LUMs)

How big is a LUM?

- The unit of maximal disparity between successive forms in a candidate chain is the *localized unfaithful mapping* or LUM. (The LUM notion was introduced in the context of a different theory of opacity in McCarthy (2003c).)
- Every form in a chain must accumulate the LUMs of all its predecessors, and it must add exactly one LUM to those of its immediate predecessor.
- Intuitively, a LUM is a change that brings a single violation of a single faithfulness constraint. But this intuition is not precise enough, because some individual changes can bring single violations of several faithfulness constraints at once.

- The *basic faithfulness constraints* are limited to the following: MAX(x) and DEP(x) constraints, which militate against deletion and insertion of elements of type x that stand in correspondence; IDENT(f) (abbreviated ID(f)) constraints, which forbid changing particular attributes f of these elements; and perhaps one or two others, such as LINEARITY.
- A LUM is a mapping that brings exactly one violation of exactly one basic faithfulness constraint.

What does “localized” mean?

- An unfaithful mapping is localized in a form if it includes sufficient information to apply unambiguously to that form.
- There is a difference, for example, between epenthesis a [ə] after the [t] versus after the [k] of /patrakla/, just as there is a difference between inserting a [ə] or a [i] after the [t]. Therefore, DEP-violating LUMs must include information about which segment is inserted and where it is inserted.
- Similarly, MAX-violating LUMs must indicate which segment is deleted.
- IDENT-violating LUMs must specify the affected segment and the changed feature-value.
- Localization can be indicated with indices pointing to positions in the input (which is constant across all candidates).

17. Chain convergence

The issue

- Consider an input like /kætaki/, with two potential loci of palatalization because there are two /k/+front vowel sequences.
- We want /kætaki/ → [k^jæ.tak^j], with transparent palatalization of the first [k] and opaque palatalization of the second.
- The potential problem comes from the chain *⟨kæ.ta.ki, k^jæ.ta.ki, k^jæ.tak⟩, which looks like it satisfies PREC(ID(back), MAX). The presence of transparent palatalization elsewhere in the word is fooling the PREC constraint.
- If the PREC constraint doesn't discriminate between opaque [k^jæ.tak^j] and transparent *[k^jæ.tak], the choice falls to lower-ranking constraints. Both markedness and faithfulness favor the wrong form, *[k^jæ.tak].

The intuition

- *⟨kæ.ta.ki, k^jæ.ta.ki, k^jæ.tak⟩ shouldn't satisfy PREC(ID(back), MAX) because it doesn't matter whether the ID(back)-violating LUM precedes or MAX-violating LUM: the outcome is the same either way.

Chain convergence

- Chains are convergent if they have the same output form and the same LUMs, but in different orders.
- Convergent chains are collapsed into a single candidate by combining their sequences of LUMs (their “LUMSeqs”) so that all that's left are the orderings that are common to all of them. (This is called “intersection of total orders”, and it produces a partial order.)

- For instance, the merger of $\langle A, B, C \rangle$ and $\langle C, A, B \rangle$ is the a properly partial order where A precedes B and C is unordered with respect to A and B.
- Partial orders are cumbersome to write out without diagrams, so I use the trick of dividing the information in a partial order into two parts:
 - The \mathcal{L} -set is just a list of all the elements that enter into the ordering — e.g., $\{A, B, C\}$. The \mathcal{L} -set, then, is simply a list of all the LUMs violated in a chain or set of convergent chains.
 - The rLUMSeq ('r' for 'reduced') is a list of all the pairwise orders other than the reflexive ones — e.g., $\{\langle A, B \rangle\}$.

Chain convergence applied (hypothetical example)

- (46) Chains converging on $*[k^j\text{æ.tak}]$ and their LUMSeqs
- | | |
|---|--|
| $\langle k\text{æ.ta.ki}, k^j\text{æ.ta.ki}, k^j\text{æ.tak} \rangle$ | $\langle \text{ID}(\text{bk})@1, \text{MAX}@6 \rangle$ |
| $\langle k\text{æ.ta.ki}, k\text{æ.tak}, k^j\text{æ.tak} \rangle$ | $\langle \text{MAX}@6, \text{ID}(\text{bk})@1 \rangle$ |
- (47) \mathcal{L} -set and rLUMSeq for (46)
- \mathcal{L} -set = $\{\text{ID}(\text{bk})@1, \text{MAX}@6\}$
- rLUMSeq = \emptyset
- (48) Chains converging on $[k^j\text{æ.tak}^j]$
- | | |
|---|--|
| $\langle k\text{æ.ta.ki}, k^j\text{æ.ta.ki}, k^j\text{æ.ta.k}^j, k^j\text{æ.tak}^j \rangle$ | $\langle \text{ID}(\text{bk})@1, \text{ID}(\text{bk})@5, \text{MAX}@6 \rangle$ |
| $\langle k\text{æ.ta.ki}, k\text{æ.ta.k}^j, k^j\text{æ.ta.k}^j, k^j\text{æ.tak}^j \rangle$ | $\langle \text{ID}(\text{bk})@5, \text{ID}(\text{bk})@1, \text{MAX}@6 \rangle$ |
| $\langle k\text{æ.ta.ki}, k\text{æ.ta.k}^j, k\text{æ.tak}^j, k^j\text{æ.tak}^j \rangle$ | $\langle \text{ID}(\text{bk})@5, \text{MAX}@6, \text{ID}(\text{bk})@1 \rangle$ |
- \mathcal{L} -set = $\{\text{ID}(\text{bk})@1, \text{ID}(\text{bk})@5, \text{MAX}@6\}$
- rLUMSeq = $\{\langle \text{ID}(\text{bk})@5, \text{MAX}@6 \rangle\}$

18. Definitions, etc.

(49) Definition: Candidate Chain

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

- a. Initial form: f_0 is the faithful parse of /in/ that is most harmonic according to \mathcal{H} .
- b. Gradualness: In every pair of immediately successive forms in C , $\langle \dots, f_i, f_{i+1}, \dots \rangle$ ($0 \leq i < n$), f_{i+1} has all of f_i 's localized unfaithful mappings relative to /in/, plus one more.
- c. Local optimality (harmonic improvement + best violation): For every pair of immediately successive forms in C , $\langle \dots, f_i, f_{i+1}, \dots \rangle$ ($0 \leq i < n$), where F is the basic faithfulness constraint violated by the LUM that distinguishes f_{i+1} from f_i , f_{i+1} is more harmonic according to \mathcal{H} than f_i and every other form that differs from f_i by a different F -violating LUM.

(50) Chain convergence

A nonempty set of chains \mathbb{C} derived from input /in/ is convergent if and only if

- (i) there exists a form [out] such that, for any chain $c_i \in \mathbb{C}$, $c_i = \langle \dots, \text{out} \rangle$

and

- (ii) there exists a set of LUMs, L , such that, for any $c_i \in \mathbb{C}$, c_i is associated with a LUMSeq l_i that is an ordering of L .

- (51) Definition: Candidate
 A candidate is an ordered 4-tuple (*in*, *out*, \mathcal{L} -set, rLUMSeq), where
in is a linguistic form, the input;
out is a linguistic form, the output;
 \mathcal{L} -set is a set of LUMs on $in \rightarrow out$;
 and rLUMSeq is a partial ordering on a subset of \mathcal{L} -set.
- (52) $PREC(A, B)(cand)$
 Let A' and B' stand for LUMs that violate the faithfulness constraints A and B , respectively.
 Let $cand = (in, out, \mathcal{L}, rL)$.
 (i) $\forall B' \in \mathcal{L}$, if $\exists A' \in \mathcal{L}$, where $\langle A', B' \rangle \in rL$, assign a violation mark.
 and
 (ii) $\forall B' \in \mathcal{L}$, if $\exists A' \in \mathcal{L}$, where $\langle B', A' \rangle \in rL$, assign a violation mark.

19. Specimen analysis: Opacity in Levantine Arabic

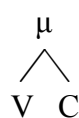
The opaque processes

- (53) Stress-epenthesis interaction I
 a. Stress falls on heavy penult
 /katab-na/ ka'tab.na 'we wrote'
 /katab-l-ak/ ka'tab.lak 'he wrote to you (m. sg.)'
 b. But not if the penult's vowel is epenthetic
 /katab-l-ha/ ka'ta.bi.l.ha 'he wrote to her'
 c. Unless the epenthetic vowel breaks up a CCCC cluster
 /katab-t-l-ha/ ka.tab'ti.l.ha 'I wrote to her'
- (54) Stress-epenthesis interaction II
 a. Stress skips a light penult
 /katab-u/ 'ka.ta.bu 'they wrote'
 b. Unless the final syllable has an epenthetic vowel
 /katab-t/ ka'ta.bi't 'I wrote'
- (55) Interaction with syncope
 a. Short high vowels delete in nonfinal open syllables
 /fihim-it/ 'fi.h.mit 'she understood'
 b. Even when the resulting cluster requires epenthesis and opaque stress
 /ji-ktib-u/ 'ji.ki't.bu 'they write'

Analysis: Stress

(56) Syllable structure (apart from the obvious)

- a. CV:C syllables b. CVCC syllables c. Final CVC syllables



(57) Stress and assumptions about foot structure

- a. da¹ras.na L(¹H)L
 sa¹ma:.na L(¹H)L
 ka¹tab.lak L(¹H)L
 ma¹ka:.tib L(¹H)L
 mak¹tab.na (H)(¹H)L
 ka.ta¹bu:.ha (LL)(¹H)L
- b. ¹?a.na (LL)
 ¹ka.tab (LL)
- c. ¹ka.ta.bu (LL)L
 ¹mad.ra.sa (H)LL
 ¹ʕal.la.mat (H)LL
 ʕal¹la.ma.to (H)(¹LL)L

(58) Evidence for polypedalism

- /ba:b-e:n/ [ba¹be:n] ‘two doors’ (cf. [‘ba:b] ‘door’)
- vs.. [ʕa:.la¹me:n] ‘two worlds’.
- [ma ʕa:f¹ni:f] ‘he didn’t see me’.

(59) FOOT-BINARITY, NONFINALITY >> *LAPSE, LAPSE-AT-PEAK, LAPSE-AT-END

| | FTBIN | NF | *LPS | LPSPK | LPSEND |
|--|----------------|----------------|------|-------|--------|
| /katabu/ | | | | | |
| → ¹ katabu (x .) . | | | 1 | | |
| a. ka ¹ tabu . (x .) | | W ₁ | L | | |
| /madrasa/ | | | | | |
| → ¹ madrasa (x .) . . | | | 2 | 1 | 1 |
| b. mad ¹ rasa (x .)(x) . | W ₁ | | L | L | L |
| c. mad ¹ rasa (x .)(x .) | | W ₁ | L | L | L |

(60) Source of polypedalism: Minimal violation of *LAPSE

| /katabu:ha/ | *LPS | LSPK | LPEnd |
|------------------------------|----------------|------|----------------|
| → kata'bu:ha (x .) (x.) . | 1 | | |
| kata'bu:ha . . (x.) . | W ₂ | | W ₁ |

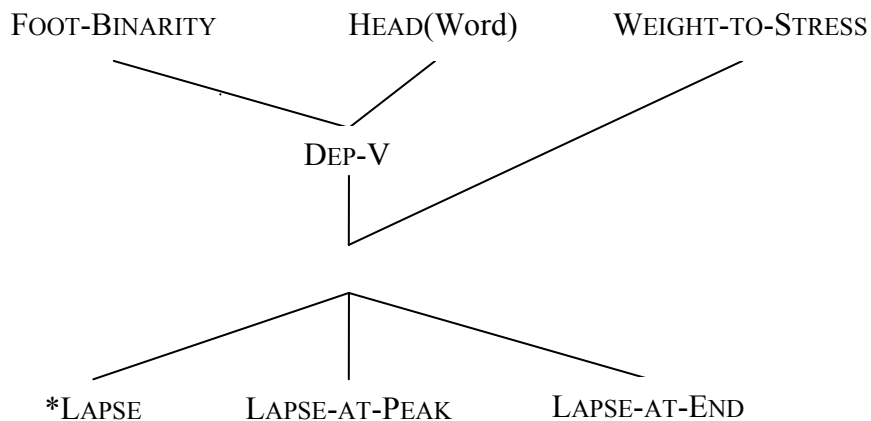
(61) Word minimality: HEAD(Word), FOOT-BINARITY >> DEP-V

| /'bas ^f / | HD(WD) | FTBIN | DEP-V | NF |
|--------------------------------|----------------|----------------|-------|----|
| → 'bas ^f i (x .) | | | 1 | 1 |
| a. 'bas ^f (x) | | W ₁ | L | 1 |
| b. bas ^f | W ₁ | | L | L |

(62) Final stress: WEIGHT-TO-STRESS >> NONFINALITY

| /dukka:n/ | WTSTR | NF |
|---------------------------|----------------|----|
| → duk'ka:n (x .) (x .) | | 1 |
| 'dukka:n (x .) . . | W ₁ | L |

(63) Levantine ranking summary I



(64) Stress assignment is an unfaithful mapping: *LAPSE >> DEP-PROM

| | /ʕallamato/ | *LPS | DEP-PR |
|----|----------------------------|----------------|----------------|
| → | ʕal'lamato (x.) (x .) . | 1 | 2 |
| a. | ʕal'lamato .. (x .) . | W ₂ | L ₁ |
| b. | 'ʕallamato (x.) . . . | W ₃ | L ₁ |

Analysis: Epenthesis in ...C__C# and its interaction with stress

(65) CLUSTER-CONDITION >> DEP-V

| | CL-CND | DEP-V |
|-------------|----------------|----------------|
| /ʔibn/ | | |
| → ('ʔi.bi)n | | 1 |
| ('ʔibn) | W ₁ | L |
| /kalb/ | | |
| → ('kalb) | | |
| ('ka.li)b | | W ₁ |

(66) Valid chains for input /katabt/ and their LUMSeqs

| Chain | LUMSeq | Description |
|---------------------------------------|-------------------|------------------------|
| a. <ka.tabt> | <> | Faithful. |
| b. <ka.tabt, ka('tabt)> | <DEP-PR@4> | Stress, no epenthesis. |
| c. <ka.tabt, ka.ta.bit> | <DEP-V> | Epenthesis, no stress. |
| d. <ka.tabt, ka('tabt), ka('tabit)> ✓ | <DEP-PR@4, DEP-V> | Opaque winner. |
| e. <ka.tabt, ka.ta.bit ('ka.ta)bit> | <DEP-V, DEP-PR@2> | Transparent loser. |

(67) Picking the best DEP-PROM violator (necessary for chain validity)

| | /katab-t/ | FTBIN | WTSTR |
|----|--------------------|----------------|----------------|
| → | ka'tabt .(x.) | | |
| a. | 'katabt (x . .) | | W ₁ |
| b. | 'katabt (x) . . | W ₁ | W ₁ |

(68) PREC(DEP-PR, DEP-V) >> NONFINALITY

| /katabt/ | CL-CND | HD(Wd) | DEP-V | PREC(DEP-PR, DEP-V) | NF | *LPS | DEP-PR |
|--|----------------|----------------|-------|---------------------|----|----------------|--------|
| d. → <ka.tabt, ka('tabt), ka('tabit)> <DEP-PR@4, DEP-V> | | | 1 | | 1 | | 1 |
| a. <ka.tabt> <> | W ₁ | W ₁ | L | | L | W ₂ | L |
| b. <ka.tabt, ka('tabt)> <DEP-PR@4> | W ₁ | | L | | 1 | | 1 |
| c. <ka.tabt, ka.ta.bit> {DEP-V} ∅ | | W ₁ | 1 | W ₁ | L | W ₂ | L |
| e. <ka.tabt, ka.ta.bit ('ka.ta)bit> <DEP-V, DEP-PR@2> | | | 1 | W ₂ | L | W ₁ | 1 |

Analysis: Medial epenthesis and its interaction with stress

(69) Valid chains for input /katab-l-ha/ and their LUMSeqs

| | | |
|--|-------------------------------|----------------|
| a. <ka.tabl.ha> | <> | Faithful. |
| b. <ka.tabl.ha, ka('tabl)ha> | <DEP-PR@4> | No epenthesis. |
| c. <ka.tabl.ha, ka.ta.bil.ha> | <DEP-V@5> | No stress. |
| c'. <ka.tabl.ha, ka.tab.li.ha> | <DEP-V@6> | No stress. |
| d. <ka.tabl.ha, ka('tabl)ha, ka('ta.bil)ha>✓ | <DEP-PR@4, DEP-V@5> | Opaque winner. |
| e. <ka.tabl.ha, ka.ta.bil.ha, kata('bil)ha> | <DEP-V@5, DEP-PR@6> | Transparent. |
| e'. <ka.tabl.ha, ka.tab.li.ha, ka('tab)li.ha> | <DEP-V@6, DEP-PR@4> | Transparent. |
| f. <ka.tabl.ha, ka.ta.bil.ha, ka.ta('bil)ha, (,ka.ta)('bil)ha> | <DEP-V@5, DEP-PR@6, DEP-PR@2> | Transparent. |

(70) <ka.tabl.ha, ka('tabl)ha, ka('tab)liha> is invalid because WEAK<i>>> WEIGHT-TO-STRESS

| /ka('tabl)ha/ | WK<i> | WTSTR |
|----------------|----------------|-------|
| → ka'ta.bil.ha | | 1 |
| ka'tab.li.ha | W ₁ | L |

(71) CLUSTER-CONDITION >>> WEIGHT-TO-STRESS also required for chain validity

| /katab-l-ha/ | CLCND | WTSTR |
|---------------------------|----------------|-------|
| → ka'tab/lha . (x .) . | | 1 |
| ka'tablha . (x .) . | W ₁ | L |

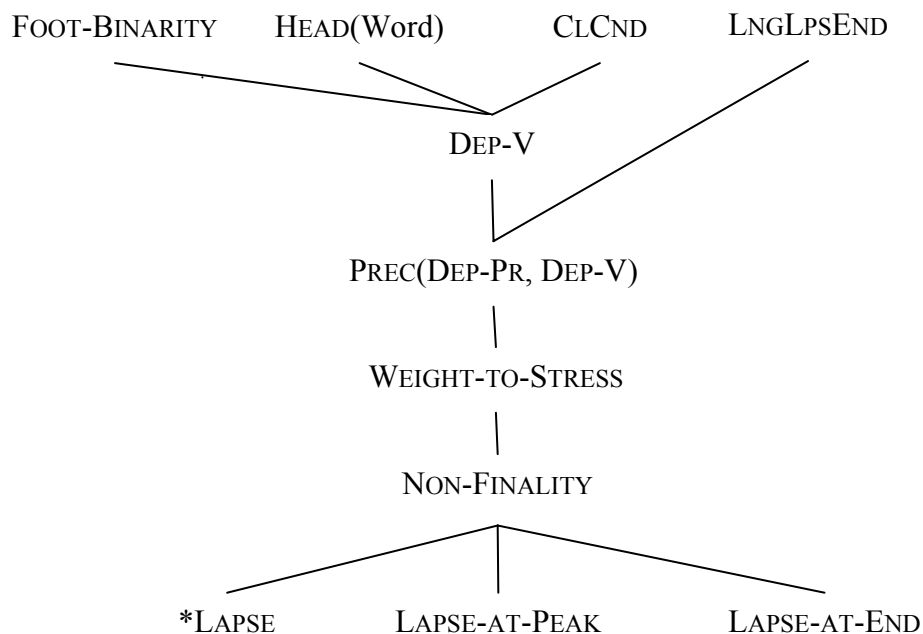
(72) PREC(DEP-PR, DEP-V) >> WEIGHT-TO-STRESS

| | /katab-l-ha/ | DEP-V | PREC | WTSTR | *LPS | DEP-PR |
|------|--|-------|----------------|-------|----------------|----------------|
| d. → | <ka.tabl.ha, ka('tabl)ha, ka('ta.bil)ha> <DEP-PR@4, DEP-V@5> | 1 | | 1 | 2 | 1 |
| e. | <ka.tabl.ha, ka.ta.bil.ha, ka.ta('bil)ha> <DEP-V@5, DEP-PR@6> | 1 | W ₂ | L | 2 | 1 |
| e' | <ka.tabl.ha, ka.tab.li.ha, ka('tab)li.ha> <DEP-V@6, DEP-PR@4> | 1 | W ₂ | L | 2 | 1 |
| f. | <ka.tabl.ha, ka.ta.bil.ha, ka.ta('bil)ha, (,ka.ta)('bil)ha> <DEP-V@5, DEP-PR@6, DEP-PR@2> | 1 | W ₂ | L | L ₁ | W ₂ |

(73) Transparent stress in VCC CCV: LONG-LAPSE-AT-END >> PREC(DEP-PR, DEP-V)

| | /katab-t-l-ha/ | LNGLPSEEND | PREC(DEP-PR, DEP-V) |
|---|----------------------------|----------------|---------------------|
| → | katab'tilha (x.) (x.) . | | 2 |
| | ka'tabtilha (x.) . . . | W ₁ | L |

(74) Levantine ranking summary II



Entailment relation on opaque vs. transparent stress.

Syncope and its interaction with stress and epenthesis

(75) Syncope

| | | | |
|----|-----------------|-------------|----------------------|
| a. | /ʕimil-u:/ | ʕim.lu | ‘they did/made’ |
| | /ʕimil-it/ | ʕim.lit | ‘she did/made’ |
| | /ʕimil-na:/ | ʕmil.na | ‘we did/made’ |
| | /j-darris-u:/ | j'darr.su | ‘they teach’ |
| | /ta:ʒir-e:n/ | ta:ʒ're:n | ‘two merchants’ |
| | /sa:hib-u:/ | sa:hibu | ‘his friend (m.)’ |
| b. | /ji-ktib-u:/ | ji.kit.bu | ‘they write’ |
| | /bi-ti-drus-i:/ | b'tu.dur.si | ‘you (f. sg.) study’ |

(76) WEAK<*i* (WK<*i*)

Assign a violation mark for every weak syllable with a nucleus whose sonority is equal to or greater than that of a [+high] vowel.

(77) MAX-A

Assign a violation mark for every input low vowel that has no output correspondent.

(78) MAX-I

Assign a violation mark for every input nonlow vowel that has no output correspondent.

(79) High-vowel syncope: MAX-A >> WEAK<*i* >> MAX-I

| /ʕimil-it/ | MAX-A | WK< <i>i</i> | MAX-I |
|---------------|----------------|----------------|----------------|
| /ʕimil-it/ | | | |
| → 'ʕim.lit | | | 1 |
| a. 'ʕi.mi.lit | | W ₁ | L |
| /katab-it/ | | | |
| → 'ka.ta.bit | | 1 | |
| b. 'kat.bit | W ₁ | L | W ₁ |

(80) Valid chains for input /ji-ktib-u/ and their (r)LUMSeqs

| | | |
|--|--|----------------|
| a. <jik.ti.bu> | <> | Faithful. |
| b. <jik.ti.bu, ('jik)ti.bu> | < DEP-PR@2> | No syncope. |
| c. <jik.ti.bu, jikt.bu> | <MAX-I> | No stress. |
| d. <jik.ti.bu, ('jik)ti.bu, ('jikt)bu> | ℒ-set = {DEP-PR@2, MAX-I} | No epenthesis. |
| <jik.ti.bu, jikt.bu, ('jikt)bu> | rL = <> | |
| e. <jik.ti.bu, ('jik)ti.bu, ('jikt)bu, ('ji.kit)bu>✓ | ℒ = {DEP-PR@2, DEP-V, MAX-I} | Opaque. |
| <jik.ti.bu, jikt.bu, ('jikt)bu, ('ji.kit)bu>✓ | rL = {<DEP-PR@2, DEP-V>, <MAX-I, DEP-V>} | |

- (81) WEAK<i>> CLUSTER-CONDITION from chain validity

| /ji-ktib-u:/ | WK<i> | CLCND |
|--------------|----------------|-------|
| → 'jikt.bu | | 1 |
| 'jik.ti.bu | W ₁ | L |

Vowel shortening interacts opaquely with epenthesis

- (82) No closed syllable shortening

| | | |
|------------|----------|----------------------|
| /ʒa:b-ha/ | 'ʒa:b.ha | 'he brought her' |
| /ʒa:b-l-u/ | 'ʒa:b.lu | 'he brought for him' |

- (83) Pre-/CCC/ and /CC#/ shortening

| | | |
|-------------|------------|----------------------|
| /ʃa:f-l-ha/ | 'ʃa.fil.ha | 'he saw for her' |
| /ʒa:b-l-ha/ | 'ʒa.bil.ha | 'he brought for her' |
| /ma ʒa:b-ʃ/ | ma 'ʒa.biʃ | 'he didn't bring' |

- (84) Some chains from /ʃa:f-l-ha/ and their (r)LUMSeqs

a. Opaque stress and shortening.

| |
|--|
| <ʃa:f(l)ha, ʃafl.ha, 'ʃafl.ha, 'ʃa.fil.ha>✓ |
| <ʃa:f(l)ha, 'ʃa:f(l)ha, 'ʃafl.ha, 'ʃa.fil.ha>✓ |
| ℒ-set = {DEP-PR@2, ID(long), DEP-V} |
| rLUMSeq = {<ID(long), DEP-V>, <DEP-PR@2, DEP-V>} |

b. Transparent stress, no shortening.

| |
|------------------------------------|
| <ʃa:f(l)ha, ʃa:fil.ha, ʃa:'fil.ha> |
| LUMSeq = <DEP-V, DEP-PR@4> |

c. Opaque stress, no shortening.

| |
|-------------------------------------|
| <ʃa:f(l)ha, 'ʃa:f(l)ha, 'ʃa:fil.ha> |
| LUMSeq = <DEP-PR@2, DEP-V> |

d. Transparent stress, opaque shortening.

| |
|--|
| <ʃa:f(l)ha, ʃafl.ha, ʃa.fil.ha, ʃa'fil.ha> |
| LUMSeq = <ID(long), DEP-V, DEP-PR@4> |

- (85) *WORD-APPENDIX >> IDENT(long), CLUSTER-CONDITION from chain validity

| /ʃa:f-l-ha/ | *WDAPP | ID(long) | CLCND |
|-------------|----------------|----------|-------|
| → ʃafl.ha | | 1 | 1 |
| ʃa:f(l)ha | W ₁ | L | L |

(86) PREC(ID(long), DEP-V) >> IDENT(long)

| | /ʃa:f-l-ha/ | PREC(ID(long), DEP-V) | ID(long) |
|------|--|-----------------------|----------|
| a. → | <ʃa:f(l)ha, ʃafl.ha, 'ʃafl.ha, 'ʃa.fil.ha> <ʃa:f(l)ha, 'ʃa:f(l)ha, 'ʃafl.ha, 'ʃa.fil.ha> { DEP-PR@2, ID(long), DEP-V } { <ID(long), DEP-V>, <DEP-PR@2, DEP-V> } | | 1 |
| b. | <ʃa:f(l)ha, ʃa:.fil.ha, ʃa:'fil.ha> <ʃa:f(l)ha, ʃa:.fil.ha, ʃa:'fil.ha> | W ₁ | L |

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