Raising and Flapping in Canadian English: grammar and acquisition

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AIMS

§1  This paper argues for a stratal solution to the problem of phonological opacity in OT. Stratal OT is shown to possess significant advantages over its competitors:

• Stratal OT imposes tight formal restrictions on the space of possible opacity effects: all opacity effects arise from the interaction between cycles; there is no cycle-internal opacity.

• In Stratal OT, therefore, the interaction between phonological processes can be deduced from their morphosyntactic domain of application.

• Because of this, Stratal OT supports a learning model that is capable of accounting for the acquisition of opacity effects even in nonalternating items.

§2  The advantages of Stratal OT are illustrated with a case study of the classic counterbleeding interaction between Diphthong Raising and Flapping in Canadian English:

• The relative order of Raising and Flapping need not be stipulated, but can be deduced from the fact that Raising is stem-level, whereas Flapping is phrase-level;

• The proposed learning model shows how children can use evidence from alternations such as write [wrait] ~ writer [wairə] and ride [raid] ~ rider [raɪə] to assign correct underlying representations to the flaps in nonalternating items such as mitre [miɪə] and spider [spaɪə].

THE PROBLEM OF PHONOLOGICAL OPACITY

Definition

§3  Kiparsky’s (1982 [1971]: 75; 1973: 79) rule-based definition:

A rule \( R \) of the form \( α → β / γ__δ \) is opaque if there are surface representations in the language having

either (i) \( α \) in the environment \( γ__δ \) (underapplication)

or (ii) \( β \) derived by \( R \) in an environment other than \( γ__δ \) (overapplication)

§4  Rule-ordering approach:

Rule \( R \) is ordered before another rule \( S \) such that

either (i) \( S \) creates the target of \( R \) (viz. \( γaδ \)) (counterfeeding)

or (ii) \( S \) destroys the environment of \( R \) (viz. \( γ__δ \)) (counterbleeding)
The problem for OT

§5 A large set of phonological phenomena previously modelled by means of opaque rules cannot be described in the original version of OT (Prince & Smolensky 1993):

The signature of underapplication:
• a language has grammatical output forms containing [γαδ],
• yet there is independent evidence requiring the ranking *γαδ $\gg$ FAITH-a.

The signature of overapplication:
• a language has expressions where input /α/ is unfaithfully mapped onto output [β],
• yet there is no markedness constraint M ranked above FAITH-α such that the mapping /α/$\rightarrow$[β] in these expressions increases harmony with respect to M.

How significant is the problem?

§6 Opacity is one of the clearest instances of Plato’s Problem (Chomsky 1986) in phonology, as learners must acquire generalizations that are not true on the surface.

⇒ The ability to explain the acquisition of opaque grammars should be regarded as one of the main criteria by which generative theories of phonology are to be judged.

APPROACHES TO OPACITY IN OT: STRATAL OT

The common ground to the main approaches

§7 Opaque generalizations are true of some representation different from, but related to, the output.

§8 Stratal OT (e.g. Bermúdez-Otero 1999, 2003, etc.; Kiparsky 2000, 2002, etc.):
the opaque generalization holds true of a phonological cycle associated with a subdomain of the expression.

§9 Transderivational correspondence:
• paradigmatic opacity (e.g. writer [wri่าง]) ⇒ OO-correspondence (e.g. Benua 1997) the opaque generalization holds true of the output representation of a grammatically related expression (e.g. write [writ]);
• nonparadigmatic opacity (e.g. mitre [måiɾɾə]) ⇒ sympathy (McCarthy 1999, 2003) the opaque generalization holds true of the output selected (for the same input) by a related constraint hierarchy.

Sympathy is invoked where an analysis based on OO-correspondence is not available.

Stratal OT

§10 Cyclic application
Given a linguistic expression e with a phonological input representation I, the phonological function P applies recursively from the inside out within a nested
hierarchy of phonological domains associated with the morphosyntactic constituent structure of $e$:

\[ I = [[x]] [[y]z] \]

then  \( P(I) = P(P(x), P(y), z) \).

§11 Level segregation

The phonology of a language does not consist of a single function $P$, but of a set of distinct functions or ‘levels’ \{\( P_1, P_2, \ldots, P_n \)\}, such that the specific function $P_i$ applying to domains of type $\delta_i$ is determined by the type of morphosyntactic construction associated with $\delta_i$.

Bermúdez-Otero (in preparation) and Kiparsky (2000, 2003, etc.) acknowledge three levels (the stem level, word level, and phrase level), roughly corresponding to the cyclic, postcyclic, and postlexical strata of classical ruled-based Lexical Phonology.

§12 Cycle-internal transparency

Each cycle involves a single pass through Gen and Eval:

\[ P_\delta = \text{Eval}(\text{Gen}(\delta)) \]

Within cycles, computation is parallel; seriality only arises from the interaction between cycles.

§13 Key predictions

- Within each cycle, the input-output mapping is transparent; opacity arises only from the serial interaction between cycles.
- The complexity of opacity effects is bounded by the number of cycles, which is in turn independently constrained by the morphosyntactic structure of the linguistic expression.
- The only criterion that determines the level ascription of a phonological process (i.e. a ranking of constraints) is the morphosyntactic domain where the process applies: e.g. a process cannot be assigned to the word level if it does not apply transparently in word-level domains.

RAISING AND FLAPPING IN CANADIAN ENGLISH: GRAMMAR

A classic case of opacity

§14 • Raising  /ai, aʊ/ → [si, ʌʊ] / __ [-voice] under certain prosodic conditions

• Flapping  /t, d/ → [ɾ] / \[\begin{array}{c} 1 \\ V \end{array} \] __ V under certain prosodic conditions

• Flapping counterbleeds Raising, so that Raising appears to overapply.

\[
\begin{array}{l|llll}
\text{UR} & \text{writing} & \text{riding} & \text{mitre} & \text{spider} \\
/aiənt-ɪŋ/ & /aiənd-ɪŋ/ & /maɪtə/ & /spaɪdər/ \\
\text{Raising} & aɪtɪŋ & — & mɪtər & — \\
\text{Flapping} & aɪrɪŋ & aɪrɪŋ & mɛɪrə & ɛʊrdə
\end{array}
\]

§15 The opacity effect is psychologically real: evidence from repetition-priming experiments in Luce et al. (1999: 1892):

Our results suggest that — at least in the recognition of flapped items in American English — recovery processes do indeed map the surface manifestation of the flap onto representations in which underlying abstract voicing categories are well specified.

Raising

§16 Raising is triggered by a following voiceless segment (henceforth Ç):

\begin{align*}
\text{e.g.} & \quad \text{write} \ [\text{rait}] \quad \text{cf.} \quad \text{ride} \ [\text{raid}] \\
& \quad \text{knife} \ [n\text{ai}f] \quad \text{cf.} \quad \text{knives} \ [n\text{ai}vz]
\end{align*}

§17 Raising is bounded by the prosodic word (ω):

\begin{align*}
\text{e.g.} & \quad \text{high school} \ [\omega_1^{\text{h}}\text{hat}]^{\omega_2}[\text{sku}]^{\omega_2}\text{[l]} \quad \text{cf. univerbated} \ [\omega_1^{\text{h}}\text{oi},\text{sku}]:[\text{l}] \\
& \quad \text{tie shop} \ [\omega_1^{\text{t}}\text{ai}]^{\omega_2}[\text{ap}]^{\omega_2}
\end{align*}

§18 Within ω, the trigger Ç may belong to a following weaker foot:

\begin{align*}
\text{e.g.} & \quad \text{nitate} \ [\omega_1^{\Sigma_1}\text{ai}]^{\omega_2}[\Sigma_1\text{t}e\text{ert}]^{\omega_2}\text{[l]}
\end{align*}

But the trigger Ç must not belong to a stronger foot:

\begin{align*}
\text{e.g.} & \quad \text{syphonic} \ [\omega_1^{\Sigma_1}\text{ai}]^{\omega_2}[\Sigma_1^t\text{a}n\text{ik}]^{\omega_2}\text{[l]}
\end{align*}

\begin{align*}
\text{citation} & \quad [\omega_1^{\Sigma_1}\text{ai}]^{\omega_2}[\Sigma_1^t\text{ei}n]\text{[l]}
\end{align*}

Possible analysis: the prosodic domain of Raising is the colon (κ), defined as a sequence of a (strong) foot plus any weaker feet following it within ω:

\begin{align*}
\text{e.g.} & \quad \omega \quad \omega \\
& \quad | \\
& \quad \kappa \\
& \quad \Sigma_1 \quad \Sigma_w \quad \Sigma_w \quad \Sigma_1 \\
\text{nai} & \quad \text{teert} & \text{sai} & \text{fa:nik}
\end{align*}

§19 Raising underapplies before word-level suffixes (Bermúdez-Otero 2003):

\begin{align*}
\text{e.g.} & \quad \text{eyeful} \ [\text{arful}], *[\text{ai}f\text{ul}] \quad \text{cf.} \quad \text{Eiffel} \ [\text{ai}f\text{al}]
\end{align*}

\begin{align*}
\text{Frauship} & \quad [\text{fra}u\text{ip}], *[\text{fra}u\text{ip}]
\end{align*}

Implication: Raising applies at the stem level.

Why not pursue a prosodic, rather than morphophonological, analysis?

\begin{align*}
\text{e.g.} & \quad \text{eyeful} \ [\omega_1^{\text{e}}\text{ai}]^{\omega_2}\text{ful}?
\end{align*}

Because there is no independent phonetic evidence for an ω-boundary intervening between a word-level suffix and its base:

\begin{align*}
\text{e.g.} & \quad \text{sensitivity of gradient duration rules to boundaries (Sproat 1993: 178)}
\end{align*}
For no speaker is it the case that the + [e.g. +ic; RB-O] or # [e.g. #ing; RB-O]
boundary contexts show a significant difference from each other or from the no-
boundary context (0). On the other hand, for every speaker […] the difference
between the compound boundary cases and the other lexical cases [sc. 0, +, #; RB-O]
is significant. […] While there is no evidence of sensitivity to weaker lexical
boundaries (+ and #), duration rules are sensitive to the edges of other domains,
including compound boundaries.

Raising and Prefortis Clipping

§20 A connection between Canadian Raising and Prefortis Clipping has long been surmised
(e.g. Trudgill 1986, McMahon 2000).

Strong position: the environments of Canadian Raising and Prefortis Clipping are in
fact identical.

§21 Evidence:

• Prefortis Clipping underapplies before word-level suffixes:

e.g. awe-some Wells (1990) /əʊ: səm/ i.e. [əʊsəm], *[əʊsəm]
law-ful Wells (1990) /lɔ: fl/ i.e. [lɔ:f], *[lɔ:f]
cf. gruesome Wells (1990) /gruːs əm/ i.e. [ɡruːsəm], *[ɡruːsəm]
waffle Wells (1990) /wɔːfl əl/ i.e. [wɔːfl], *[wɔːfl]

• Prefortis Clipping overapplies before flapped /t/, i.e. is counterbled by Flapping:

e.g. /ˈʌtər/ /ˈʌdər/ utter udder
Clipping
Flipping
SR

[Phonetic evidence (Zue & Laferriere 1979, Patterson & Connine 2001, etc.):
(i) no significant difference in mean duration between flapped /d/ and flapped /t/;
(ii) on average, vowels 9ms longer before flapped /d/ than before flapped /t/;
(iii) near merger —difference maintained in production but not exploited in lexical
recognition.

⇒ A gradient, nonneutralizing phonetic process of durational adjustment reduces, but
does not eliminate, the categorical length difference between clipped and
unclipped vowels before flaps.]

§22 Conclusions: Raising applies at the stem level to clipped diphthongs.

§23 Rankings for Raising:

• **CLEARDIPH** » IDENT[mid],
  • **CLIPDIPH** » IDENT[low],
  and • **CLIPDIPH** » CLEARDIPH,

where

• **CLEARDIPH**

  Maximize the distance between diphthongal elements.

⇒ *ɔi, *ɔu.
• **CLIPDIPH**
  In clipped diphthongs, minimize the distance between elements.
  \[ \Rightarrow \ast a \text{r}, \ast a \text{u}. \]

• **IDENT[\text{mid}]**
  Let \( \alpha \) be an input segment, and let \( \beta \) be its output correspondent; if \( \alpha \) is [\text{mid}] then \( \beta \) is [\text{mid}].
  \[ \Rightarrow /\\text{s}1, \text{\lowercase{a}u}/ \ast \rightarrow [\text{a}1, \text{\lowercase{a}u}]. \]

• **IDENT[\text{low}]**
  Let \( \alpha \) be an input segment, and let \( \beta \) be its output correspondent; if \( \alpha \) is [\text{low}] then \( \beta \) is [\text{low}].
  \[ \Rightarrow /\text{a}1, \text{\lowercase{a}u}/ \ast \rightarrow [\text{\lowercase{s}i}, \text{\lowercase{a}u}]. \]

**Flapping**

§24 I assume the Kiparsky-Jensen analysis:

• Stops are tensed at the word level if foot-initial (in certain dialects, if colon-initial); otherwise, they are lax.

• At the phrase level, lax [\text{t}] and lax [\text{d}] are flapped between in the environment \( \text{V} / \text{\_V} \).

§25 Flapping must be phrase-level because its domain straddles word boundaries:

\begin{align*}
\text{e.g.} & \quad \text{He hit Ann} & [\text{hi h\text{\_r} \text{\_a}n}] & \quad \text{cf. hit} & [\text{h\text{\_t}}] \\
& \quad \text{He hid Ann} & [\text{hi h\text{\_r} \text{\_a}n}] & \quad \text{cf. hid} & [\text{h\text{\_d}}]
\end{align*}

Support for Stratal OT

§26 The counterbleeding interaction between Raising and Flapping follows, as predicted by the theory, from their level ascription, which is independently determined by their morphosyntactic domain:

Raising precedes Flapping because Raising is stem-level and Flapping is phrase-level.

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**Learnability**

**Restrictiveness ≠ learnability**

§27 • If two theories of grammar \( T_1 \) and \( T_2 \) define the grammar spaces \( S_1 \) and \( S_2 \) respectively, and if both \( S_1 \) and \( S_2 \) are too large for convergence to be guaranteed by brute-force searching, then the prime determinant of learnability will be the relative efficiency of the learning algorithms associated with \( T_1 \) and \( T_2 \), rather than the relative size of \( S_1 \) and \( S_2 \) (Tesar & Smolensky 2000: 2-3).

• A phonological model cannot achieve explanatory adequacy in respect of opacity simply by restricting the space of possible opaque effects; one must show that the learner is able to search that space effectively.
The acquisition of opacity in Sympathy Theory

§28 • There is, at present, no algorithm for acquiring sympathy-theoretic grammars (McCarthy 1999: 340).

• Proposal: Assume a $\otimes$O-IDENT » IO-FAITH bias (Dinnsen et al. 2000).

• Problem: Historically, opaquely derived surface properties are reanalysed as underlying, not vice versa.

• Conclusion: Sympathy Theory cannot account for the acquisition of opacity.

The acquisition of opacity in Stratal OT

§29 Iterative stratum construction

input to level $n$ = output of level $n-1$

URs = input to stem level

$\textit{Stem-level hierarchy}$

output of stem level = input to word level

$\textit{Word-level hierarchy}$

output of word level = input to phrase level

$\textit{Phrase-level hierarchy}$

output of phrase level = SRs

§30 Emergence of opacity

• Let a process $p$ apply at level $n$ and become opaque at level $n+1$.

• Assume an ordinary constraint ranking algorithm that only acquires output-true rankings.

Then:

• Ex hypothesi, $p$ is not output-true at $n+1$. Accordingly, the ranking algorithm will not set up the hierarchy for $p$ at $n+1$.

• Assume that the learner assigns input representations correctly at $n+1$; see §32 and §33 below. Now, input to $n+1$ = output of $n$. Ex hypothesi, $p$ is output-true at $n$. Accordingly, the ranking algorithm sets up the hierarchy for $p$ at $n$.

§31 Constraint ranking by pure phonotactic learning under the identity map

• To find the constraint hierarchy of a level $n$, given output forms:

(i) assume the identity map ($I = O$),

(ii) assume a MARKEDNESS » FAITHFULNESS bias,

(iii) demote markedness constraints and promote faithfulness constraints just enough to derive the output from identical input.

See e.g. Prince & Tesar (1999), Hayes (1999).
• Alternations normally conspire to bring collocations in line with output phonotactics (Kisseberth 1970).

Accordingly, purely distributional evidence will normally suffice to find the constraint rankings driving not only phonotactics but also alternations.

§32 Input assignment (I): alternations prompt departures from the identity map

• Learners only depart from the identity map when faced with alternations (Yip 1996; cf. Alderete & Tesar 2002).

In line with Input Optimization (Prince & Smolensky 1993: §9.3), departures from the identity map are minimal.

• Input optimality (Bermúdez-Otero in preparation)

An input representation is optimal iff it has no competitor that
- (i) generates an identical set of output alternants,
- (ii) generates all output alternants no less efficiently,
- (iii) generates some output alternant more efficiently
[where efficiency = satisfaction of high-ranking faithfulness constraints].

• Where more than one input representation is optimal, follow one of the following heuristics:
  (i) Hale’s heuristic (after Hale 1973: 420)
      Prefer inputs that are well-formed outputs.
  (ii) Heuristic for asymmetric paradigms
      In an asymmetric paradigm, prefer those inputs that generate the morphologically unmarked member most efficiently.

§33 Input assignment (II): Archiphonemic Prudence

Dealing with opacity in non-alternating items:

• Let the following situation of contextual neutralization obtain at level n:

\[ /\alpha/ \quad /\beta/ \quad \{\alpha, \beta\} \rightarrow \gamma /[_f] \quad \text{level } n \]

\[ [\alpha]_e \quad [\gamma]_f \quad [\beta]_e \]

• If the archiphonemic string \([\gamma]_f\) occurs in the output representation of a non-alternating item \(i\) level \(n\), then
  (i) assume that, in \(i\) too, \(/\alpha/\quad /\beta/\) either \(\downarrow\) or \(\uparrow\)

\[ [\gamma]/_f \quad [\gamma]/_f \]

(ii) put the two possible input representations for \(i\) at level \(n\) in ‘quarantine’ by excluding them from the data set triggering acquisition at level \(n-1\);

(iii) when the constraint hierarchy for \(n-1\) is known, discard any input representation for \(i\) at level \(n\) that is not a well-formed output at level \(n-1\).

§34 Interim evaluation of the model

• It makes the most of the assets of the synchronic theory, fully exploiting the serial interaction between strata (§29) and the intimate connection between the domain of a process and its stratal ascription (§30).
• It adopts independently motivated solutions to the problem of acquiring constraint rankings (§31) and input representations for alternating items (§32).

• Only stipulation: Archiphonemic Prudence (§33).

### RAISING AND FLAPPING IN CANADIAN ENGLISH: ACQUISITION

**Acquiring the phrase-level cophonology**

§35 Constraint rankings

• Flapping is output-true ⇔ The ranking for Flapping is set up by pure phonotactic learning.

• Raising misapplies ⇔ The ranking for Raising is not established:

<table>
<thead>
<tr>
<th>Datum</th>
<th>Triggered ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>/mitre/</td>
<td>IDENT[mid] &gt; CLEARDIPH</td>
</tr>
<tr>
<td>-writing/</td>
<td>CLEARDIPH &gt; CLIPDIPH</td>
</tr>
</tbody>
</table>

| arful > iful  | eyeful |

§36 Input assignment for alternating items

• [hit] hit ~ [hir æn] hit Ann  
  optimal input: /hɪt/

• [hid] hid ~ [hir æn] hid Ann  
  optimal inputs: /hɪd/ and */hɪd/; Hale’s heuristic and the heuristic for asymmetric paradigms select /hɪd/.

§37 Input assignment for non-alternating items

• The analysis of alternations shows that there is an archiphonemic string [r] with two possible input correspondents /t/ or /d/.

• Accordingly, by Archiphonemic Prudence:

<table>
<thead>
<tr>
<th>Quarantined item</th>
<th>Phrase-level input candidates</th>
</tr>
</thead>
<tbody>
<tr>
<td>/mitre/</td>
<td>/mitər/, /mitər/</td>
</tr>
<tr>
<td>/spider/</td>
<td>/spaɪdər/, /spaɪdər/</td>
</tr>
<tr>
<td>/writing/</td>
<td>/ˈwriːtɪŋ/, /ˈwridiŋ/</td>
</tr>
<tr>
<td>/riding/</td>
<td>/ˈraɪdɪŋ/, /ˈraɪdɪŋ/</td>
</tr>
</tbody>
</table>

**Acquiring the word-level cophonology**

§38 Constraint rankings (I)

• Raising does not overapply in the output of the word level:
  (i) surface [mitre] ‘mitre’ is under quarantine;
  (ii) at the phrase level, [mitr æp]→/[mitr æp] ‘write up’.

• Raising underapplies in the output of the word level:
  e.g. [arful] eyeful.
• Triggered ranking: \textsc{ident}[low] \textsect{clipdiph} \textsect{cleardiph} \textsect{ident}[mid].

\S 39 \textit{Quarantine lifting (I)}

\begin{tabular}{|c|c|c|c|}
\hline
\textsc{ident}[low] & \textsc{clipdiph} & \textsc{cleardiph} & \textsc{ident}[mid] \\
\hline
\textsc{t`epem} & \textsc{t`epem} & \textsection & \\
\textsc{malt`em} & \textsection & \\
\textsc{t`epem} & \textsc{t`epem} & \textsection & \\
\textsc{malt`em} & \textsection & \\
\textsc{gi`iter} & \textsc{gi`iter} & \textsection & \\
\textsc{gi`iter} & \textsection & \\
\textsc{gi`iter} & \textsc{gi`iter} & \textsection & \\
\hline
\end{tabular}

\S 40 \textit{Constraint ranking (II)}

Flapping does not apply in the new word-level outputs [m`eit`a] and [`eit`i`n]
\implies The constraint ranking for Flapping is blocked.

\S 41 \textit{Input assignment}

Trivial (no alternations): [\textipa{a/-}] \textit{eye} \sim [\textipa{a/-f`ul}] \textit{eyeful} \leftarrow /a/-/ \textit{eye}
[\textipa{e/-}] \textit{write} \sim [\textipa{e/-i`n}] \textit{writing} \leftarrow /e/-/-/wri/-/ \textit{write}

\textbf{Acquiring the stem-level cophonology}

\S 42 \textit{Constraint ranking}

• Raising does not overapply in the output of the stem level. Recall that surface
[m`eit`a] \textit{mitre} and [`eit`i`n] \textit{writing} have been correctly assigned the phrase-level
input representations /m`eit`a/ and /`eit`i`n/ by Archiphonemic Prudence.

• Raising does not underapply in the output of the stem level:
[\textipa{a/-f`ul}] \leftarrow /a/-/-/-/-/-/f`ul/ \textit{at the word level}

• The normal application of Raising triggers the ranking \{\textsect{cleardiph} \textsect{ident}[mid]\},
\{\textsect{clipdiph} \textsect{ident}[low]\}, and \{\textsect{clipdiph} \textsect{cleardiph}\}; see \S 23 above.

\S 43 \textit{Quarantine lifting (II)}

\begin{tabular}{|c|c|c|c|c|}
\hline
\textsc{sp`art`e} & \textsc{sp`art`e} & \textsection & \\
\textsc{sp`art`e} & \textsection & \\
\textsc{sp`ats`e} & \textsection & \\
\textsc{sp`ats`e} & \textsection & \\
\textsc{li`iter} & \textsc{li`iter} & \textsection & \\
\textsc{li`iter} & \textsection & \\
\textsc{li`iter} & \textsc{li`iter} & \textsection & \\
\hline
\end{tabular}


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