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Learning restrictive analyses of Canadian Raising in OT using exceptionality diacritics

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Opacity (restrictive analysis)

- Canadian English: low diphthongs /aɪ aʊ/ raise before:
  - Voiceless consonants (*transparent*)

    rʌɪt ‘write’, mʌʊs ‘mouse’
  - Voiced [ɾ] only if derived from /t/ (“overapplication” opacity) (*opaque*)

    rʌɪɾɚ ‘writer’ (← raɪt-ɚ)

    BUT raɪɾɚ ‘rider’ (← raɪd-ɚ)
- Restrictive analysis of such an opaque pattern:
  - Ensures no word has unraised diphthong + voiceless C

    *klaɪt
  - Ensures no word has raised diphthong + voiced C ↚ /t/

    *flʌɪd, *(flʌɪɾɚ ~ fla/ʌɪd), ✓(flʌɪɾɚ ~ flʌɪt)

Serial vs. Parallel analyses

- Serial analysis (traditional; Chomsky 1964, Bermudez-Otero 2003):
  1. Raising applies before voiceless consonants
  2. t is “flapped” (→ ɾ) in certain V_V environments
  - ➢ Learnable (Nazarov & Pater 2017), but reintroduces serialism into Optimality Theory (Prince & Smolensky 1993/2004)

- Parallel analysis that acknowledges phonological opaque interaction (cf. Hayes 2004, Pater 2014) and does not assume extra representational levels (cf. Boersma 2007):
  - o Raising applies before consonants indexed *i* (Pater 2000, Round 2017)
  - o Consonants indexed *i* are either voiceless, or flaps derived from /t/ (see next slide)
  - ➢ Avoids conceptual disadvantages, but is it learnable? Under which circumstances?

Local indexation analysis

- Indexed constraints only apply to items marked by a particular index (Pater 2000, 2010)
  - Round (2017): individual segments may have an index
  - Indices stay the same between input and output (cf. Chomsky & Halle 1968)

/bab/	*[+voice]$_i$	*[+voice]
bab		**
/b$_i$ab/		
b$_i$ab	*	**

- Restrictive analysis of Canadian Raising:
  - No consonant indexed ***i*** follows an unraised diphthong

    * C$_i$ /aɪ_ >> Ident(low) — *raɪt$_i$, ✓rʌɪt$_i$

  - Segments indexed ***i*** must be voiceless by default

    *[+voice]$_i$ >> Ident(voice) — *rʌɪd$_i$, ✓rʌɪt$_i$

  - Except when flapping applies: it turns ***i*** segments voiced

    *ɾ̥, *V{t,d}V >> *[+voice]$_i$ >> Ident(voice), Ident(son) — *rʌɪɾ̥$_i$ɚ, *rʌɪt$_i$ɚ ✓rʌɪɾ$_i$ɚ

Learning (local) indexation

- To learn indexation analysis:
  - Start with universal constraints and unindexed inputs
  - Determine which constraints & which input segments have which index
  - Rank all constraints
- Here: Round's (2017) algorithm:
  - Operates within Biased Constraint Demotion (BCD; Prince & Tesar 2004)
  - When BCD gets stuck, finds most generally applicable indexed constraint & corresponding indexed segments – add constraint to analysis and continue BCD (cf. Pater 2010)
  - Algorithm categorical, but makes random guesses when it cannot decide between analyses based on the data

Simulation setup

Constraints used:

*[+voice], *[-voice]
*aɪ, *ʌɪ
*C̥/aɪ_, *C/aɪ_
*C̬/ʌɪ_, *V/ʌɪ_
*ɾ, *ɾ̥, *l̥
*V{*t*,*d*}V
IDENT(voice)
IDENT(son)
IDENT(low)

- Three data sets (what does learner need to see?):

D_1
(no transparent CR)
[flʌɪɾɚ] 'flighter'
[glaɪɾɚ] 'glider'
[saɪɚ] 'sigher'
[vaɪɚ] 'vier'

D_2
(transp CR, no alternations)

flʌɪɾɚ	flʌɪt
glaɪɾɚ	glaɪd
saɪɚ	saɪ
vaɪɚ	vaɪ

D_3
(transp CR and alternations)
flʌɪɾ-ɚ ~ flʌɪt
glaɪɾ-ɚ ~ glaɪd
saɪ-ɚ ~ saɪ
vaɪ-ɚ ~ vaɪ

- Three UR hypothesis sets (what does learner need to assume?):

UR_1
(all surf cands = URs)
/{f, v}{l̥, l}{a, ʌ}ɪ{t, d, ɾ̥, ɾ}ɚ/

UR_2
(uncertainty wrt voicing)
/flaɪ{t, d}ɚ/

UR_3
(canonical URs only)
/flaɪtɚ/

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For multiple URs during learning, see Jarosz (2006)

Results

- For each condition (data set x UR hypothesis), 20 runs
  - All runs lead to some consistent analysis of the data
  - Table: number of times **restrictive** analysis is found for each condition

	UR_1: all surf cands = URs	UR_2: uncertainty wrt voicing	UR_3: “correct” URs
D_1: no transparent CR	0	0	0
D_2: transp CR, no alternations	0	0	0
D_3: transp CR and alternations	15 (/20)	7 (/20)	0

- Restrictive analysis found for dataset D_3 and UR_1/UR_2
  - True alternation between **t** and **ɾ** necessary
  - Uncertainty about UR of [t ~ ɾ] necessary (present in UR_1/UR_2 but not in UR_3)

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Discussion & Conclusion

- Learning indexation analysis of Canadian Raising: possible
  - Based on Round's (2017) segmentally local indexation learner
- Conditions:
  - learner has access to transparent instances of process and alternations
  - learner has not yet finished determining URs of crucial segments
- Possible to analyze at least this case of opacity without serialism (cf. McCarthy 2007) and without additional levels of representation (cf. Boersma 2007)
- This analysis is learnable and discoverable from data given a universal constraint set
- Other types of opacity? Probabilistic learner? Other assumptions about URs, data, constraints, etc.?

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Thank you!

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Appendix

Indexation

- Indexation: universal constraints may have variants specific to some inputs (morphemes/words) only (Pater 2000)

  *[+voice]: no voiced segments
  *$[+voice]_i$: no voiced segments in *i* words

- *Extended indexation*: indices are local to specific segments (Round 2017) and represented as binary; <u>basically same as SPE diacritics</u>

  *$[+voice]_{[+i]}$: no voiced [+i] segments ✓$[d]_{[-i]}$ *$[d]_{[+i]}$

Canadian Raising with indexation

- Raising: $*C_{[+i]}$/aɪ_ >> Ident(low)

All underlying segments are [-i] unless specified otherwise

/ɹaɪt[+i]/	$*C_{[+i]}$/aɪ_	Id(low)
[ɹaɪ$t_{[+i]}$]	*!	
☞[ɹʌɪ$t_{[+i]}$]		*

- Flapping: *V{t,d}V >> $*[+voice]_{[+j]}$, Ident(son), Ident(voi)

/bʌt[+i]ɚ/	*V{t,d}V	$*[+voice]_{[+i]}$	Id(son)	Id(voi)
[bʌ$t_{[+i]}$ɚ]	*!			
☞[bʌ$ɾ_{[+i]}$ɚ]		*	*	*

Canadian Raising with indexation

- The surface voicing of a [+i] segment does not influence raising

/ɹaɪt[+i]-ɚ/	*V{t,d}V	*[+voice]$_{[+i]}$	*C$_{[+i]}$/aɪ_	Ident(low)	Ident(son)	Ident(voi)
ɹaɪt$_{[+i]}$ɚ	*!		*			
ɹʌɪt$_{[+i]}$ɚ	*!			*		
ɹaɪd$_{[+i]}$ɚ	*!	*	*			*
ɹʌɪd$_{[+i]}$ɚ	*!	*		*		*
ɹaɪɾ$_{[+i]}$ɚ		*	*!		*	*
☞ ɹʌɪɾ$_{[+i]}$ɚ		*		*	*	*

All segments are [-i]
unless specified otherwise

Richness of the Base

- Anything with [+i] always shows up as voiceless and triggers raising unless it's in the flapping context

/aɪd[+i]/	*V{t,d}V	*[+voice]$_{[+i]}$	*[-voice]$_{[-i]}$	*C$_{[+i]}$/aɪ_	Ident(low)	Ident(son)	Ident(voi)
aɪt				*!			*
☞ ʌɪt					*		*
aɪd		*!		*			
ʌɪd		*!			*		
aɪɾ		*!		*		*	
ʌɪɾ		*!			*	*	

All underlying segments are [-i] unless specified otherwise

Richness of the Base

- Anything with [-i] always shows up as voiced and never triggers raising

/aɪt[-i]/	*V{t,d}V	*[+voice]$_{[+i]}$	*[-voice]$_{[-i]}$	*C$_{[+i]}$/aɪ_	Ident(low)	Ident(son)	Ident(voi)
aɪt			*!				
ʌɪt			*!		*		
☞ aɪd							*
ʌɪd					*!		*
aɪɾ						*!	*
ʌɪɾ					*!	*	*

All underlying segments are [-i] unless specified otherwise

Round’s (2017) learner in more detail

- Round (2017): model to learn segmentally local indexation from winner-loser pair data
    1. Based on Biased Constraint Demotion (BCD, Tesar and Smolensky 2004)
    2. Whenever two inputs in the data have conflicting ranking requirements (= inconsistency): induce some indexed constraint (Pater 2010)
    3. Which indexed constraint assigned to which segments? *(new contribution)* Selected based on number and location of Winner-preferring violation loci

Biased Constraint Demotion

- Version of Recursive Constraint Demotion (Tesar 1995) with a Markedness-over-Faithfulness bias
  - Start with no ranking
  - At each step, select only those constraints that prefer no losers = PNL
  - Out of PNL, take just the Markedness constraints and install them at the bottom of the ranking
    - If there are no Markedness constraints, select the smallest set of Faithfulness constraints that will “free up” a Markedness constraint at the next step
  - Remove from consideration all winner-loser pairs that have a W mark for one of the freshly installed constraints

Inconsistency

- BCD is dependent on constraints without L marks
- When there are no such constraints, this means something's wrong
  - Cues mutually **inconsistent** rankings, e.g.,
    input 1 wants A >> B, input 2 wants B >> A: mutually incompatible

- Pater (2010): when you encounter inconsistency, induce some indexed constraint
  - Gets you out of inconsistency:
    input 1 wants A*i* >> B, input 2 wants B >> A: mutually compatible!

Indexed constraint selection

- Round (2017) wants model that infers segmentally local indices
- Therefore: violations track segment instances ("loci")

  **[+voice] has a W violation in the second "b" for W-L pair 1, but a L violation in the first "v" for W-L pair 2*

- For each constraint, compute:
  - Φ_W: Set of segment instances that get a W violation of that constraint
  - Φ_L: Set of segment instances that get a L violation of that constraint
  - $\Phi_W - \Phi_L$: Set of segment instances that get a W violation but never a L violation of that constraint

Indexed constraint selection

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- For each constraint, compute:
  - Φ_W: Set of segment instances that get a W violation of that constraint
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  - $\Phi_W - \Phi_L$: Set of segment instances that get a W violation but never a L violation of that constraint
- Make [+i] indexed version of constraint that has the greatest $\Phi_W - \Phi_L$:
  - $\Phi_W - \Phi_L$ become [+i], all other segments instances become [-i] *(binarity: AN)*

Restrictiveness

- Grammars were evaluated on whether they were potentially **restrictive**
  - The consonants before which /aɪ,aʊ/ raise are the same consonants that alternate with a voiceless segment
- Learner had no way of assigning the same index to two different indexed constraints
  - Restrictiveness assessed by seeing if Raising constraint indexed to subset of segments indexed to *[+voice]

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