Formalizing the link between opacity and exceptionality

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MOT 2019, York University and University of Toronto

Opacity vs. exceptionality

- Phonological generalizations that are **opaque** (McCarthy 1999, Bakovic 2011) have one of the following properties:
  - *Non-surface apparent* (there are examples in which the rule does apply, but shouldn't; counterbleeding)

    Canadian Raising: /ɹaɪt/ → [ɹʌɪt] /ɹaɪtə˞/ → [ɹʌɪ**ɾ**ə˞]

  - *Non-surface true* (there are examples in which the rule should apply, but doesn't; counterfeeding)

    Bedouin Arabic open syllable raising: /CaCV/ → [Ci.CV] (McCarthy 1999)
    /CaCw/ → [C**a**.Cu]

Opacity vs. exceptionality

- Phonological generalizations that are exceptionful have one of the following properties
  - *Exceptional application*: rule does not apply by default, but some morphemes trigger the rule as an exception

    Yine vowel deletion (triggered by certain following suff., Matteson 1965):
    /heta+lu/ → [hetlu] cf. /heta+nu/ → [hetanu]

  - *Exceptional non-application*: rule applies by default, but some morphemes do not undergo the rule as an exception

    Yine vowel deletion (blocked by certain suffixes):
    /heta+wa+lu/ → [hetawalu], *[hetawlu] cf. /heta+nu+lu/ → [hetanru]

Different explanations

- Despite inherent similarity, opacity and exceptionality traditionally attributed to disjoint sources
- Opacity:
  - Rule/process ordering (McCarthy 2007)
  - Early vs. late phonology (Bermúdez-Otero 2003)
- Exceptionality:
  - Storage of exceptional forms (Zuraw 2000)
  - Indexed constraints/minor rules (Pater 2000)

Why unified model?

- The learning of both phenomena requires the inference of hidden structure (Tesar and Smolensky 2000):
  - Structure necessary for the grammar, but not observable from isolated data points

    Foot structure
    URs
    Derivational intermediate steps
    Exceptionality marking

Why unified model?

- Both exceptionality and opacity require finding generalizations despite contradiction, and attributing this contradiction to some source
  - Divide between opacity and exceptionality is not always sharp
  - Work that has hypothesized opacity may be a form of exceptionality and/or unnaturalness: Mielke et al. (2003), Sanders (2006), Pater (2014)

- Current unified model: no extrinsic rule/process ordering necessary
  - Opacity/transparency is a matter of ranking lexically indexed constraints
  - Exceptionality is a matter of ranking lexically indexed constraints

Proposal

Rethinking indexation

- Pater (2000, 2010): some OT constraints may be **indexed** to a certain morpheme
  - Indices stand for sets of morphemes to which the constraint applies

$*ai_i$	One violation for every [ai] sequence, all or part of which comes from one of the morphemes *i* = {/-i/, /-i/, /-ite/, …}
Ident(voice)j	One violation for every voicing change if the [voice] feature occurs in one of the morphemes *j* = {/anad/, /kimeb/, /boreg/, …}

- SPE: non-phonetic (“alphabet”) features invoked for exceptionality:
  - On a par with all other features, may trigger application of rules
  - May not be manipulated by phonological component

Rethinking indexation

- Proposal (**extended indexation**): indices = alphabet features *à la* SPE
  - Phonetically arbitrary feature dimensions
  - All segments have a + or – specification for these dimensions (cf. Becker 2009 for a similar, binary view of constraint indexation)

  - Phonological GEN has a finite set of phonological operations (e.g., McCarthy 2007, 2008), none of which apply to indices
    - Indices cannot be deleted, even when rest of segment is deleted feature by feature

      $p_{[+i]}$ [-son, +cont, +labial, +i] → $ʔ_{[+i]}$ [-son, +cont, +i] → $H_{[+i]}$ [-son, +i] → $\varnothing_{[+i]}$ [+i]

    - Ergo: indices must stay the same between input and output

Predictions

- This extended view of indices allows a few new possibilities:
  - An index can be on a specific segment
    $tad_{[+i]}a$
  - An indexed segment may have a predictable surface realization
    $tad_{[+i]}a$ $*tat_{[+i]}a$
  - An indexed segment's realization may be non-uniform (either per context or per morpheme)
    $\mathbf{tad_{[+i]}a}$ $*tat_{[+i]}a$ $*tad_{[+i]}$ $\mathbf{tat_{[+i]}}$
- Will show: this allows to represent opaque generalizations with indexed constraints

Indexation of segments

- Previous work: some arguments that indices should be on individual segments, not entire morphemes (see, e.g., Temkin-Martinez 2010 and others)
- If indices are features, segment indexation comes for free:
  - Any individual segment has a surface specification for every feature
  - For indices: surface = underlying
  - Therefore, every segment must have a specification for each type of index

t[-i]a[-i]t[+i]a[-i] a[-i,+k]p[+i-,k]a[-i,-k]

Predictable realization of indices

- Indexed Markedness constraint above all relevant Faithfulness constraints: the segment will change to satisfy the M constraint
  - The index cannot change!
  - This means that we know what an index will “sound” like

/tat$_{[+i]}$a/	***[-voice]$_{[+i]}$**	**Faith**
[tat$_{[+i]}$a]	*!	
☞[tad$_{[+i]}$a]		*

Non-uniform realization of indices

- We can regulate how uniformly indices will be realized through constraint ranking
- For example, if an index [+i] normally requires [+voice], this could still be subject to final devoicing:

/tat$_{[+i]}$a/	***D#**	***[-voice]$_{[+i]}$**	**Faith**
[tat$_{[+i]}$a]		*!	
☞[tad$_{[+i]}$a]			*

/tat$_{[+i]}$/	***D#**	***[-voice]$_{[+i]}$**	**Faith**
☞ [tat$_{[+i]}$]		*	
[tad$_{[+i]}$]	*!		*

Non-uniform realization of indices

- We can regulate how uniformly indices will be realized through constraint ranking
- We can also let the surface realization of indexed segments be arbitrary (and just let such segments influence the realization of other segments)

/tat$_{[+i]}$a/	***D#**	**Faith**	***[-voice]$_{[+i]}$**
☞ [tat$_{[+i]}$a]			*
[tad$_{[+i]}$a]		*!	

/tad$_{[+i]}$a/	***D#**	**Faith**	***[-voice]$_{[+i]}$**
☞ [tad$_{[+i]}$a]			*
[tat$_{[+i]}$a]		*!	

Canadian Raising case study

Canadian Raising

- Well-known opaque pattern (Joos 1942, Chambers 1973, Idsardi 2000, Bermúdez-Otero 2003)
- Diphthongs with *low nucleus* (aJ) raised to have a *mid-low nucleus* (ʌJ) before voiceless C (in the same word)

/aɪs/ → ʌɪs ‘ice’ /aɪz/ → aɪz ‘bridle’
/laɪf/ → lʌɪf ‘life’ /laɪ/ → laɪ ‘lie’
/ɹaɪt/ → ɹʌɪt ‘write’ /ɹaɪd/ → ɹaɪd ‘ride’

Opacity

- Opaque whenever tapping (/t,d/ → [ɾ]) applies to a sequence /aJt/
  - /t/ becomes a voiced [ɾ], but still motivates raising of a preceding /aJ/
  - Non-surface apparent application of raising (counterbleeding)

[tʌɪɾl] ‘title’ (instead of expected *[tʌɪrl]) cf. [bɹaɪrl] ‘bridle’
[ɹʌɪɾɚ] ‘writer’ (instead of expected *[ɹaɪrɚ]) cf. [ɹaɪrɚ] ‘rider’

	/ɹaɪt-ɚ/	/ɹaɪd-ɚ/
Raising	ɹʌɪtɚ	-------
Tapping	ɹʌɪɾɚ	ɹaɪɾɚ
	[ɹʌɪɾɚ]	[ɹaɪɾɚ]

Representational solution

- Extended indexation allows for a representational solution:
  - Voiceless consonants are always indexed with an index [+i]
  - Voiced consonants are always indexed with an index [-i]

    $t_{[+i]}$ $*d_{[+i]}$ $*t_{[-i]}$ $d_{[-i]}$

  - Except when tapping applies

    $t_{[+i]} \rightarrow ɾ_{[+i]}$ $d_{[-i]} \rightarrow ɾ_{[-i]}$

Representational solution, cont'd

- Raising is conditioned by [+i], not [-voice]
  - This means that ɾ[+i] derived from t[+i] will trigger raising, but not ɾ[-i] derived from d[-i]

aJ$t_{[+i]}$ → ʌJ$ɾ_{[+i]}$ aJ$d_{[-i]}$ → aJ$ɾ_{[+i]}$

/ɹaɪ$t_{[+i]}$-ɚ/ → [ɹʌɪ$ɾ_{[+i]}$ɚ] /ɹaɪ$d_{[-i]}$-ɚ/ → [ɹaɪ$ɾ_{[-i]}$ɚ]

  - So [+i] acts like a regular segmental feature – but one unaffected by GEN
  - Reminiscent of other representational approaches: Goldrick (2001), Boersma (2007), van Oostendorp (2008)

OT analysis: constraints

- Indexed constraints

  *aJC$_{[+i]}$: * for each sequence [+low] + glide + C$_{[+i]}$ (promotes raising)

  *[+voice, +i]: * for each voiced segment with the index [+i]
  *[-voice, -i]

- General constraints

  *VTV: don't have VTV (promotes tapping; simplified)
  Ident(son): don't change /t,d/ to [ɾ] (or *vice versa*)
  Ident(low): don't change /a/ to [ʌ] (or *vice versa*)
  Ident(voice)

OT analysis: raising and tapping

- Raising: *aJC$_{[+i]}$ >> Ident(low)

/ɹaɪt[+i]/	***aJC[+i]**	**Id(low)**
[ɹaɪt$_{[+i]}$]	*!	
☞[ɹʌɪt$_{[+i]}$]		*

- Tapping: *VTV >> *[+voice, +i], Ident(son), Ident(voi)

/bʌt[+i]ɚ/	***VTV**	***[+voice, +i]**	**Id(son)**	**Id(voi)**
[bʌt$_{[+i]}$ɚ]	*!			
☞[bʌr$_{[+i]}$ɚ]		*	*	*

OT analysis: interaction

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

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

OT analysis: Richness of the Base

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

/aɪd[+i]/	*VTV	*[+voice, +i]	*[-voice, -i]	*aJC$_{[+i]}$	Ident(low)	Ident(son)	Ident(voi)
aɪt				*!			*
☞ ʌɪt					*		*
aɪd		*!		*			
ʌɪd		*!			*		
aɪɾ		*!		*		*	
ʌɪɾ		*!			*	*	

OT analysis: Richness of the Base

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

/aɪt[-i]/	*VTV	*[+voice, +i]	*[-voice, -i]	*aJC$_{[+i]}$	Ident(low)	Ident(son)	Ident(voi)
aɪt			*!				
ʌɪt			*!		*		
☞ aɪd							*
ʌɪd					*!		*
aɪɾ						*!	*
ʌɪɾ					*!	*	*

OT analysis: Richness of the Base

- A segment with [+i] in the tapping environment always triggers raising

/aɪd[+i]-ɚ/	*VTV	*[+voice, +i]	*[-voice, -i]	*aJC$_{[+i]}$	Ident(low)	Ident(son)	Ident(voi)
aɪtɚ	*!			*			*
ʌɪtɚ	*!				*		*
aɪdɚ	*!	*		*			
ʌɪdɚ	*!	*			*		
aɪɾɚ		*		*!		*	
☞ ʌɪɾɚ		*			*	*	

- High, but not undominated ranking of *[+vce,+i] leads to consistent and opaque raising before voiceless consonants or tapped /t/s

Alternative rankings

- If *[+voice, +i] above Tapping constraint: [+i] = [-voice]; transparent raising

/aɪt[+i]-ɚ/	*[+voice, +i]	*[-voice, -i]	*VTV	*aJC$_{[+i]}$	Ident(low)	Ident(son)	Ident(voi)
aɪtɚ			*	*!			*
☞ ʌɪtɚ			*		*		*
aɪdɚ	*!		*	*			
ʌɪdɚ	*!		*		*		
aɪɾɚ	*!			*!		*	
ʌɪɾɚ	*!				*	*	

Alternative rankings

- If *[+voice, +i] below Faithfulness: raising occurs in lexically specific environments

/aɪd[+i]/	*VTV	*aJC$_{[+i]}$	Ident(low)	Ident(son)	Ident(voi)	*[+voice, +i]	*[-voice, -i]
aɪt		*!			*		
ʌɪt			*		*!		
aɪd		*!				*	
☞ ʌɪd			*			*	
aɪɾ		*!		*		*	
ʌɪɾ			*	*!		*	

Discussion

Indices as bearers of contrast

- Extended indexation: indices are non-phonetic features (SPE)
- Phonetically arbitrary markers of contrast
  - [+i] and [-i] segments contrast, but their phonetic realization is dependent on the lexical and on constraint ranking
- Contrast can motivate both exceptions and opacity
  - See Lubowicz (2003) for an explicitly contrast-based account of opacity
- Phonetically arbitrary contrast motivated empirically (Pater 2000, Mullin 2011, Osadcha 2019)

Cases of opacity

- Here, only applied to one case:
  - Raising conditioned by [+i] feature
  - Tapping changes [voice] feature
  - [+i] and [voice] related indirectly, through constraints (“differential classification”)

- However, general strategy should apply to other cases:
  - Opaque deletion: [+i] feature remains despite deletion of phonetic features
  - Multi-level opacity: multiple indices; undesired combinations of indices may be mapped onto empty parse (ineffability)

Learning

- If opacity and exceptionality are linked in this way, can extended-indexed constraints be learned?
  - Becker (2009), Nazarov (2018): learners for indexation
  - Mayer (2018), Nazarov (2016): learners for phonetically arbitrary features
  - Combination of techniques from these may yield good results
- Broader issue: interaction and interplay between opacity and exceptionality (historical and synchronic) can be modelled more easily with extended indexation

Thank you!

Acknowledgments

- Elan Dresher
- Peter Jurgec
- Nathan Sanders
- Marc van Oostendorp
- John McCarthy
- Gaja Jarosz
- Joe Pater
- Participants of the Mass Storage Workshop @ U of T
- Students and auditors in LIN1222, Fall 2018

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