Formalizing Iterativity and the Computation of Rule Application Modes

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Rule application modes

$$[-\text{cons}] \rightarrow [+\text{nas}] \;/\; [+\text{nas}] \;\_\_$$

Language A	Language B
NVVV↦NṼṼṼ	NVVV↦NṼVV

Rule application modes

$$[-\text{cons}] \rightarrow [+\text{nas}] \;/\; [+\text{nas}]\ \_\_$$

Language A	Language B
NVVV↦NṼṼṼ	NVVV↦NṼVV
iterative	simultaneous

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Language A	Language B
NVVV↦NṼṼṼ	NVVV↦NṼVV
iterative	simultaneous

One rule, different application modes.

Rule application modes

Language A	Language B
$[-\text{cons}] \rightarrow [+\text{nas}]\ /\ [+\text{nas}]\ \_\_$	$[-\text{cons}] \rightarrow [+\text{nas}]\ /\ [+\text{nas}, +\text{cons}]\ \_\_$
$\text{NVVV} \mapsto \text{N}\tilde{\text{V}}\tilde{\text{V}}\tilde{\text{V}}$	$\text{NVVV} \mapsto \text{N}\tilde{\text{V}}\text{VV}$
iterative	iterative

Different rules, one application mode.

(See Chomsky and Halle, 1968; Johnson, 1972; Howard, 1972, among others)

Optimization

- Optimality Theory (Prince and Smolensky, 1993, 2004) is inherently iterative.

/NVVV/	*[+nas][−nas]	IDENT-NAS
[NVVV]	*!	
[NṼVV]	*!	*
[NṼṼV]	*!	**
☞[NṼṼṼ]		***

Optimization

‘iterative’
*[+nas][−nas] ≫ IDENT-NAS

‘simultaneous/**noniterative**’
*[+nas,+cons][−nas] ≫ IDENT-NAS ≫ *[+nas][−nas]

Optimality Theory

- Emergent Noniterativity Hypothesis (Kaplan, 2008): No formal entity in phonological grammars may require noniterativity.
  - Prediction: 'There is no phenomenon that must be analyzed with a self-feeding rule that is not permitted to apply to its own output' (pg. 4).

In terms of computation

- A computational approach isn't about rules or constraints, but their *extensions*:
    - {(NV, N$\tilde{V}$), (VN, VN), (NVV, N$\tilde{V}$V), ...} ('noniterative')
    - {(NV, N$\tilde{V}$), (VN, VN), (NVV, N$\tilde{V}\tilde{V}$), ...} ('iterative')
- An extension or *map* either has a given computational property, or it doesn't.
    - Can't change the rule or add constraints.

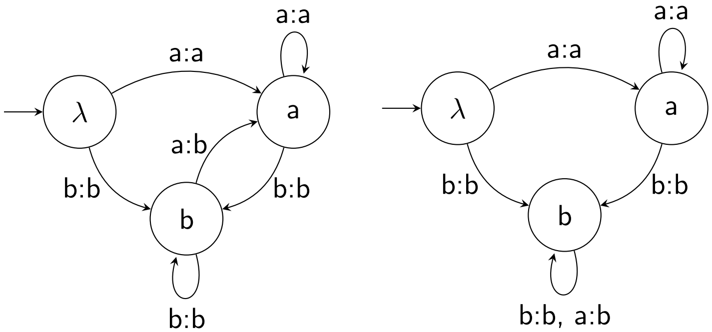
Properties of extensions

- Relevant computational properties for this talk: input strict locality (ISL) and output strict locality (OSL).
- ISL and OSL functions are part of a subregular hierarchy of functions (see Heinz, 2018).

FST characterizations

a → b / b ___

ISL OSL



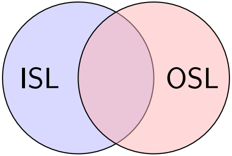
Rule application

$$a \rightarrow b \;/\; b \,\_\_$$

ISL ≈ noniterative	{(baaa, bbaa) ... }
OSL ≈ iterative	{(baaa, bbbb) ... }

Do we need both?

- For many (most?) rules, ISL and OSL are extensionally-equivalent.
    - Final obstruent devoicing: {(bad, bat), (hʊnd, hʊnt), ... }
- Are there any rules that are *necessarily* ISL?



Nasal spreading/assimilation

/NVVV/ $\mapsto$ [NṼṼṼ]		iterative
/NVVV/ $\mapsto$ [NṼVV]		noniterative

Nasal spreading/assimilation

$$/\text{NVVV}/ \mapsto [\text{N}\tilde{\text{V}}\tilde{\text{V}}\tilde{\text{V}}] \quad \text{OSL}$$

$$/\text{NVVV}/ \mapsto [\text{N}\tilde{\text{V}}\text{VV}] \quad \text{ISL}$$

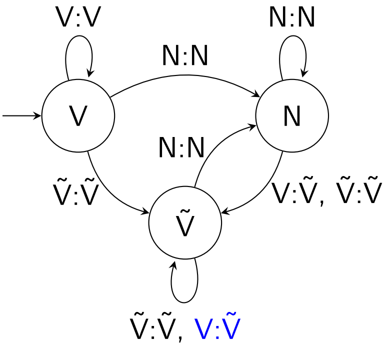
Nasal spreading/assimilation

$/\text{NVVV}/ \mapsto [\text{N}\tilde{\text{V}}\tilde{\text{V}}\tilde{\text{V}}]$ OSL

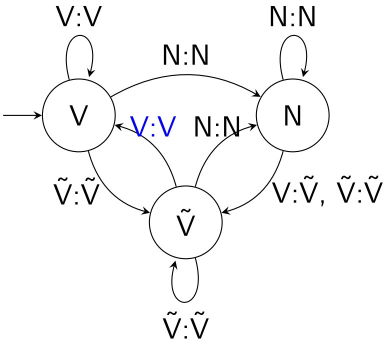
$/\text{NVVV}/ \mapsto [\text{N}\tilde{\text{V}}\text{VV}]$ ISL (and OSL?)

Noniterative OSL map

OSL (iterative)



OSL (noniterative)



OSL and (non)iterativity

- Goal: define (phonologically-intuitive) conditions for when OSL will enforce iteration.

Triggers and Outputs

Let TRIGGERS be the set of segments that trigger a process, and let OUTPUTS be the set of segments that result from that process.

(1) A phonological map is

a. *output-nondistinct* if $\text{OUTPUTS} \cap \text{TRIGGERS} \neq \varnothing$.

b. *output-distinct* if $\text{OUTPUTS} \cap \text{TRIGGERS} = \varnothing$.

Triggers and Outputs

/NVVV/ $\mapsto$ [NṼṼṼ]	/NVVV/ $\mapsto$ [NṼVV]
TRIGGERS = {N, Ṽ}	TRIGGERS = {N}
OUTPUTS = {Ṽ}	OUTPUTS = {Ṽ}
output-nondistinct	output-distinct

ISL and OSL

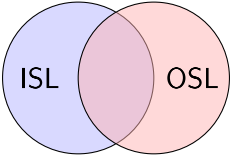
	output-nondistinct	output-distinct
OSL	iterative	noniterative

ISL and OSL

	output-nondistinct	output-distinct
OSL	iterative	noniterative
ISL	noniterative	noniterative

ISL and OSL

	output-nondistinct	output-distinct
OSL	iterative	noniterative
ISL	noniterative	noniterative



What are we looking for?

- ‘True noniterativity’ (i.e., necessarily ISL) would be an output-nondistinct noniterative map.
- Vowel harmony is a great place to look.

A note on local versus long-distance

- If we assume vowel harmony rules include C_0, they are trivially neither ISL nor OSL.

(2) $V_{-\alpha} \rightarrow +\alpha \;/\; V_{+\alpha}\; C_0$ ___

- Will instead use strings of vowels, which can be interpreted in two ways:
  1. The map applies on a vowel tier.
  2. The number of consonants is bounded by syllable structure and can be ignored (for presentation purposes).

Bengali ATR harmony

In Bengali, {ɛ, ɔ} → {e, o} in nouns when they precede a high vowel (Mahanta, 2007).

kɔt^{h}a	'spoken words'	kot^{h}ito	'uttered'	kɔthoniyo	'speakable'
kɔlpo	'resembling'	kolpito	'invented'	kɔlponiyo	'imaginable'

Noniterative: /ɔɔi/ ↦ [ɔoi]

Bengali ATR harmony

- TRIGGERS = {i, u} (only high vowels can trigger harmony)
- OUTPUTS = {e, o}
- ✓output-distinct
- Both ISL and OSL.

Crimean Tatar labial harmony

Initial [+rd] vowels trigger labial harmony on the next high vowel (McCollum and Kavitskaya, 2018).

(3) Central Crimean Tatar (NMZR-POSS.3S)

a.	/tuz-lɯɣ-ɯ/	[tuz-luɣ-ɯ]	‘salt’
b.	/kyz-lig-i/	[kyz-lyg-i]	‘autumn’
c.	/toz-lɯɣ-ɯ/	[toz-luɣ-ɯ]	‘dust’
d.	/køz-lig-i/	[køz-lyg-i]	‘eye’

Crimean Tatar labial harmony

- TRIGGERS = {y, ø, u, o}
- OUTPUTS = {y, ø, u, o}

Crimean Tatar labial harmony

- TRIGGERS = $\{y^i, ø^i, u^i, o^i\}$ (only initial vowels can trigger)
- OUTPUTS = {y, ø, u, o}
- ✓output-distinct
- Both ISL and OSL.

Crimean Tatar labial harmony

$$V_{-rd} \rightarrow [+\text{rd}] \;/\; \#\, V_{+rd} \;\_\_$$

*#[+rd, −rd] (McCollum and Kavitskaya, 2018)

Kazakh labial harmony

[+rd] vowel triggers harmony on following vowel (McCollum and Kavitskaya, 2018):

a.	/mojən-də/	[mojʊn-də]	‘neck-ACC’
b.	/tʊr-məs-ə-nəŋ/	[tʊr-mʊs-ə-nəŋ]	‘live-NMZR-POSS.3-GEN’
c.	/kino-m-əz-dəŋ/	[kino-m-ʊz-dəŋ]	‘movie-POSS.1-PL-GEN’

OSL and (non)iterativity

- Whether a ‘potential’ trigger gets to actually be a trigger is an empirical question.
- As long as something distinguishes underlying triggers from derived ones, OSL will not enforce iteration.
- Computational support for ‘emergent noniterativity’, but we still need ISL too!

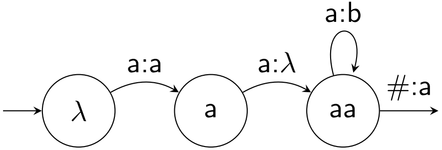
Two additional reasons we need ISL

1. Rules with two-sided contexts are also necessarily ISL.

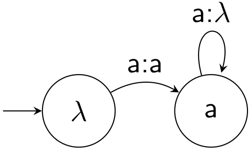
Delaying output

$$a \rightarrow b \ / \ a \ \_\_ \ a$$

ISL



OSL



Two additional reasons we need ISL

1. Rules with two-sided contexts are necessarily ISL (except epenthesis).
2. ISL provides a straightforward solution to:
   - Opacity (Chandlee et al., 2018)
   - Ordering/ranking paradoxes (Oakden and Chandlee, 2020; Oakden, 2021)
   - Nonderived environment blocking (Chandlee, to appear)

Dissimilation

(4) L → R / L __

- TRIGGERS = {L}
- OUTPUTS = {R}
- ✓output-distinct
- Predicts both ISL and OSL will produce a noniterative map.

Dissimilation

- What is a noniterative dissimilation map?

(5) /LLLL/ $\mapsto$ [LRLL]?

- Simultaneous application gives:

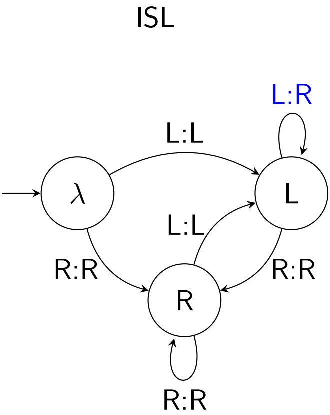
(6) /LLLL/ $\mapsto$ [LRRR]

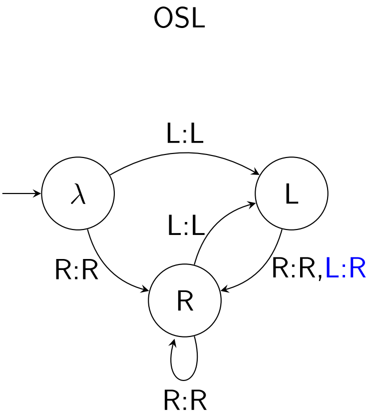
Dissimilation

- Tianjin tone sandhi (Chen, 1986; Hung, 1987; Tan, 1987; Zhang, 1987; Chen, 2000; Lin, 2008; Wee, 2010)

(7) a. R → H / __ R
    b. RRR → HHR

Dissimilation





LLLL ↦ LRRR

LLLL ↦ LRLR

Dissimilation: future work

- Modify definitions to predict iterativity in OSL dissimilation maps.
- Iterative dissimilation is actually self-*bleeding*.
- Highlights the problem of using rule-based terms like iterativity/noniterativity to describe extensions.

Conclusions

- Computational ('theory independent') support for the idea that phonology is iterative and output-oriented, just not exclusively.
- We can't dispense with ISL, but we have a better understanding of when we need it and why.
    - Noniterativity does not necessitate ISL.
    - Connection to rule application modes overgeneralizes.
- The original goal of restricting the theory is maintained as a restriction on computational complexity via subregular functions.

Acknowledgements

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