(Non)iterativity and Input/Output Locality

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10 March 2023
“In general a major step in coming to understand something new consists in formulating it in terms of concepts and notations that we already understand:

Understanding is translation from the unknown to the known.”

(Keenan and Moss, 2016, ix)
“In general a major step in coming to understand something new consists in formulating it in terms of concepts and notations that we already understand:

Understanding is translation from the unknown to the known.”

- The unknown: phonological iterativity
- The known: strict locality
Theory-based definitions

Johnson (1972, 35): an iterative rule keeps applying until the string can no longer be changed.

(1) Sanskrit nasal retroflexion: targets /n/ before another sonorant when it is preceded by a retroflex continuant without an intervening coronal

<table>
<thead>
<tr>
<th>uṣṇataraanaaам</th>
<th>uṣṇataraanaam</th>
</tr>
</thead>
<tbody>
<tr>
<td>uṣṇataraanaam</td>
<td>uṣṇataraanَاam</td>
</tr>
<tr>
<td>uṣṇataraanَاam</td>
<td>uṣṇataraanَاam</td>
</tr>
</tbody>
</table>
Theory-based definitions

- Alternatively, rules apply strictly left-to-right or right-to-left
- Linear rules (Johnson, 1972): direction is stipulated
- Directional rules (Howard, 1972): direction is determined by the rule’s form (X __ or __ X)
Theory-based definitions

- In practice, iterative means ‘not simultaneous’ (Chomsky and Halle, 1968) or ‘reapplies to its own output’.

\[(2) \quad [-\text{cons}] \rightarrow [+\text{nasal}] / [+\text{nasal}] \]

a. NVVV → ÑVVV
b. NVVV → Ñ̃VṼ
**Optimization and iteration**

<table>
<thead>
<tr>
<th>/NVVV/</th>
<th>*[+nas][−nas]</th>
<th>IDENT-NAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[NVVV]</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>[NĨVV]</td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>[NĨṼV]</td>
<td>*!</td>
<td>**</td>
</tr>
<tr>
<td>⧿[NĨṼṼ]</td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>
Emergent noniterativity

- Emergent Noniterativity Hypothesis (Kaplan, 2008): No formal entity in phonological grammars may require noniterativity.
- Noniterativity is always epiphenomenal and can be explained by other means.

(3) Lango (Western Nilotic; Noonan, 1992; Kaplan, 2008)
  a. /ɓɔŋɔ̥-ni/ [ɓɔŋɔni] ‘your dress’
  b. /amɔŋ-ni/ [amɔŋki] ‘your shoe’
  c. /mɔtɔkə-e/ [mɔtɔkə-e] ‘cars’

- Positional licensing: suffix [ATR] needs to be linked to the root.
‘True noniterativity’

- Not all cases of noniterativity can be reanalyzed as emergent (Ampofo and Rasin, 2021; McCollum and Kavitskaya, 2022).
- True noniterativity = counterexample to emergent noniterativity.
Extensions of rules

- Extension: \{(NV, N\~\nu), (NV\nu, N\~\nu\nu), (NV\nu\nu, N\~\nu\nu\nu), \ldots \}\n- Intensional descriptions:

(4) 

a. \([-\text{cons}] \rightarrow [+\text{nasal}] / [+\text{nasal}] \quad \text{(simultaneous/\(-\text{iterative})}

b. \([-\text{cons}] \rightarrow [+\text{nasal}] / [+\text{nasal}] \quad \text{(right-to-left)}

c. \([-\text{cons}] \rightarrow [+\text{nasal}] / [+\text{nasal}, +\text{cons}] \quad \text{(left-to-right, right-to-left, simultaneous/\(-\text{iterative})}
In finite-state phonology, different application modes are implemented by matching the rule’s context on either the input or output string (Kaplan and Kay, 1994; Hulden, 2009; Gorman and Sproat, 2021).

\[
\begin{align*}
A & \rightarrow B \ | \ | \ L \ _ \ R \ ; \quad \text{simultaneous} \\
A & \rightarrow B \ \| \ L \ _ \ R \ ; \quad \text{right-to-left} \\
A & \rightarrow B \ \// \ L \ _ \ R \ ; \quad \text{left-to-right}
\end{align*}
\]
Matching context on input

<table>
<thead>
<tr>
<th>N</th>
<th>V</th>
<th>V</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Ñ</td>
<td>V</td>
<td>V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N</th>
<th>V</th>
<th>V</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Ñ</td>
<td>V</td>
<td>V</td>
</tr>
</tbody>
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<tr>
<th>N</th>
<th>V</th>
<th>V</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Ñ</td>
<td>V</td>
<td>V</td>
</tr>
</tbody>
</table>
Matching context on output
Strictly local functions

Input Strictly Local

\[
\begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & & \\
\end{array}
\quad \begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & V & \\
\end{array}
\quad \begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & V & V \\
\end{array}
\]

Output Strictly Local

\[
\begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & & \\
\end{array}
\quad \begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & \tilde{V} & \\
\end{array}
\quad \begin{array}{ccc}
N & V & V & V \\
N & \tilde{V} & \tilde{V} & \tilde{V} \\
\end{array}
\]

(Berstel, 1982; Vaysse, 1986; Lind and Marcus, 1995; Sakarovitch, 2009; Chandlee, 2014)
Previously...

- 94% of the processes in P-Base (Mielke, 2008) are Input Strictly Local (ISL) for some $k$ (Chandlee, 2014, p. 138).
- OSL is available if you need to iterate.
Incomparable but not disjoint
An ISL classification is ambiguous
Proposal: recast ‘noniterative’ as necessarily ISL and ‘iterative’ as necessarily OSL.

Most(?) maps are in the intersection.
  • Gorman and Sproat (2021, p. 53): ‘directionality of application has no discernable effect for perhaps the majority of rules, and can often be ignored’.
<table>
<thead>
<tr>
<th></th>
<th>ISL</th>
<th>ISL $\cap$ OSL</th>
<th>OSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>substitution (one-sided)</td>
<td>output-nondistinct single target</td>
<td>output-distinct</td>
<td>output-nondistinct multiple targets</td>
</tr>
<tr>
<td>dissimilation (one-sided)</td>
<td>identical span</td>
<td>single target</td>
<td>alternating pattern</td>
</tr>
<tr>
<td>deletion (one-sided)</td>
<td>anchored single target</td>
<td>overlap</td>
<td>anchored multiple targets</td>
</tr>
<tr>
<td>epenthesis (one-sided)</td>
<td></td>
<td>everything</td>
<td></td>
</tr>
<tr>
<td>epenthesis (two-sided)</td>
<td>both contexts longer than 1</td>
<td>at least one context of length 1</td>
<td></td>
</tr>
<tr>
<td>other two-sided</td>
<td></td>
<td></td>
<td>everything</td>
</tr>
</tbody>
</table>
Deletion maps

(5) \( V \to \emptyset / \# \)

- Simultaneous and right-to-left application: \( VVVC \to VVC \)
- Left-to-right application: \( VVVC \to C \)
Deletion maps

(6) \( V \rightarrow \emptyset \) / \( V \) __

Simultaneous: \( \text{aeiou} \rightarrow \text{a} \)
Left-to-right: \( \text{aeiou} \rightarrow \text{aiou} \rightarrow \text{aou} \rightarrow \text{au} \rightarrow \text{a} \)
Right-to-left: \( \text{aeiou} \rightarrow \text{aeio} \rightarrow \text{aei} \rightarrow \text{ae} \rightarrow \text{a} \)
‘Anchored’ deletion

(7) \[ V \rightarrow \emptyset / \# \]
‘Overlap’ deletion

(8) \( V \rightarrow \emptyset / V \_ \)

\[
\begin{align*}
\lambda & \quad \xrightarrow{C:C} \quad C \\
V & \quad \xrightarrow{C:C} \quad C \\
V & \quad \xrightarrow{V:V} \quad V \\
\end{align*}
\]

ISL \cap OSL
### Anchored deletion

(9) \[ V \rightarrow \emptyset / \# \_ \_ \]

<table>
<thead>
<tr>
<th>/VVVC/</th>
<th>*#V</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>[VVVC]</td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>[VVC]</td>
<td>*!</td>
<td>*</td>
</tr>
<tr>
<td>[VC]</td>
<td>*!</td>
<td>**</td>
</tr>
<tr>
<td>[C]</td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>
Overlap deletion

(10) \( V \rightarrow \emptyset \ / \ V \ ____ \)

<table>
<thead>
<tr>
<th>( /VVVV/ )</th>
<th>*VV</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>[VVVV]</td>
<td><em>!</em> **</td>
<td></td>
</tr>
<tr>
<td>[VVV]</td>
<td><em>!</em></td>
<td>*</td>
</tr>
<tr>
<td>[VV]</td>
<td>*!</td>
<td>**</td>
</tr>
<tr>
<td># [V]</td>
<td></td>
<td>***</td>
</tr>
</tbody>
</table>
# Deletion (summary)

<table>
<thead>
<tr>
<th>ISL</th>
<th>ISL ∩ OSL</th>
<th>OSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>anchored</td>
<td>overlap</td>
<td>anchored</td>
</tr>
<tr>
<td>single target</td>
<td></td>
<td>multiple targets</td>
</tr>
<tr>
<td>noniterative</td>
<td></td>
<td>iterative</td>
</tr>
</tbody>
</table>
Theoretical implications

- For rule-based theories, we have a prediction for when the non-default application mode will be required.

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>Other mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPE</td>
<td>simultaneous</td>
<td>parenthesis-star</td>
</tr>
<tr>
<td>Linear rules</td>
<td>iteration</td>
<td>reverse direction</td>
</tr>
<tr>
<td>Directional rules</td>
<td>iteration</td>
<td>simultaneous</td>
</tr>
<tr>
<td>Parameterized rules</td>
<td>+iterative</td>
<td>−iterative</td>
</tr>
</tbody>
</table>

(Chomsky and Halle, 1968; Johnson, 1972; Howard, 1972; Archangeli and Pulleyblank, 1994)
Deletion (summary)

<table>
<thead>
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<th>ISL</th>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>noniterative</td>
<td></td>
<td>iterative</td>
</tr>
</tbody>
</table>
Theoretical implications

- For constraint-based theories, the category of ‘necessarily ISL’ offers a principled means of deciding when to relax the otherwise output-oriented assumptions of markedness.
- Noniterativity, but also opacity:
  - McCarthy (1996): markedness constraints are specified as holding at the underlying or surface level (or either).
  - Hyman (2021): HTS - A syllable following an input /H/ should be followed by H in the output.
Computational implications

- *Most* maps are in the intersections of ISL and OSL.
  - Only under certain conditions does the difference matter, and even then it may be difficult to observe.
- The three-way partition matters—ISL, OSL, or ISL $\cap$ OSL—for our understanding of the computational nature of maps.
Locality and iterativity

- Why local functions?
- Locality and iterativity are inextricably linked.
Locality and iterativity

• Search and Copy model of vowel harmony (Mailhot and Reiss, 2007; Nevins, 2010).

• e.g., Turkish back harmony:
  • Searching left-to-right, find the first vowel that is specified for the feature back. Copy that vowel’s specification for back to the suffix vowel.

• Relativized locality ("find the first") = no formal difference between local and long-distance maps.

• Each ‘recipient’ initiates its own search for a donor = no iteration.
Hierarchy of functions

- Left Subsequential
- Left Output TSL
- Left Output SL
- Input TSL
- Input SL
- Finite
- Right Subsequential
- Right Output TSL
- Right Output SL
Current work: Rhythmic syncope

- Deletion of every other vowel (often schwa)
- This map is not tier-based strictly local (Hao and Bowers, 2019; Bowers and Hao, 2020).

\[
\begin{array}{cccc}
V & V & V & V \\
V & V & V & V \\
V & V & V & V \\
\end{array}
\]

- (This is just overlap deletion again: \( V \to \emptyset \) / \( V \mapsto \) )
- To preserve locality, they introduce the tier-based synchronized strictly local (TSSL) functions.
Hierarchy of functions

- Left Subsequential
  - Left TSSL
  - Left Output TSL
  - Left Output SL
- Right Subsequential
  - Right TSSL
  - Right Output TSL
  - Right Output SL
- Input TSL
- Input SL
- Finite
However, (part 1)

- If we don’t ignore the consonants, they can be used to distinguish vowel targets from non-targets.
- 3-OSL

```
  C  V  C  V  C  V  C  V  C  V  C  V
  C  V  C  C  V  C  V  C  C  C  V
```
However, (part 2)

- This only works if the deletion rule has a left or right context, not both.

(11)  
   a. $V \rightarrow \emptyset / VC __$
   b. $V \rightarrow \emptyset / __ CV$
   c. $V \rightarrow \emptyset / VC __ CV$

- OSL (needed for iteration) cannot model rules with both contexts.
Conclusions

- Recasting *noniterative* and *iterative* as requiring access to input or output structure, respectively, enables the use of these terms as properties of maps rather than grammars.
- A theory of phonology that embraces the notion of locality must deal with both of these categories one way or another.
Thank you!
Substitution (non-dissimilatory)

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

A phonological map is

1. output-nondistinct if Outputs \( \cap \) Triggers \( \neq \) \( \emptyset \).
2. output-distinct if Outputs \( \cap \) Triggers \( = \) \( \emptyset \).
Bengali ATR harmony

\{ɛ, ɔ\} → \{e, o\} before a high vowel (Mahanta, 2007).

\texttt{kɔtʰa} \hspace{1cm} \textquote{spoken words} \hspace{1cm} \texttt{kɔlpo} \hspace{1cm} \textquote{resembling}
\texttt{kɔtʰito} \hspace{1cm} \textquote{uttered} \hspace{1cm} \texttt{kolpito} \hspace{1cm} \textquote{invented}
\texttt{kɔthoniyo} \hspace{1cm} \textquote{speakable} \hspace{1cm} \texttt{kɔlponiyo} \hspace{1cm} \textquote{imaginable}

/ɔɔi/ → [ɔɔi]
Bengali ATR harmony

- \textbf{Triggers} = \{i, u\} (only high vowels can trigger harmony)
- \textbf{Outputs} = \{e, o\}
- Output-distinct
- \textbf{ISL} \cap \textbf{ROSL}
Akan serial verbs

[+ATR] spreads leftward to the next vowel, but no further (Ampofo and Rasin, 2021).

/to fæ di/ [to fæ di] ‘buy, take, and eat’
/to fa bo di/ [to fa bo di] ‘buy, take, crack, and eat’
/to di su/ [to di su] ‘buy, eat, and cry’
Akan serial verbs

- \( \text{TRIGGERS} = \text{OUTPUTS} = \{i, e, æ, o, u\} \)
- Output-nondistinct
- ISL only
Dissimilation

(12) \( L \rightarrow R / L \) __

- ISL (and simultaneous application): LLLL \( \rightarrow \) LRRR
- LOSL (and iterative application): LLLL \( \rightarrow \) LRLR
Tianjin tone sandhi

\[
R \rightarrow H / \_ R \quad RRR \rightarrow HHR
\]

\[
F \rightarrow L / \_ F \quad FFF \rightarrow FLF
\]

\[
L \rightarrow R / \_ L \quad LLL \rightarrow LRL
\]

(Chen, 1986; Zhang, 1987; Tan, 1987; Hung, 1987; Chen, 2000; Wee, 2010)
(13) \( V : \rightarrow V / V : C_0 \quad \_ \_ \_ \)

Slovak (Indo-European; Slovakia)

\( /\text{čít}-a:\text{m}/ \quad [\text{čít}-\text{am}] \quad \text{‘read-1S’} \)
\( /\text{čít}-a:\text{v}-a:\text{m}/ \quad [\text{čít}-\text{av}-\text{am}] \quad \text{(frequentive)} \)

Githabal (Australian)

\( /\text{nu}:\text{n}-\text{da}:\text{ŋ}/ \quad [\text{nu}:\text{n}-\text{daŋ}] \quad \text{‘too hot’} \)
\( /\text{djalum}-\text{ba}:\text{da}:\text{ŋ}-\text{be}:/ \quad [\text{djalum}-\text{ba}:\text{daŋ}-\text{be}:] \quad \text{‘is certainly right on the fish’} \)

(Kenstowicz and Kisseberth, 1979)
Rules with two-sided contexts

(14) \( a \rightarrow b / a \_ a \)

aaaa \( \rightarrow \) abba
Rules with two-sided contexts

- These rules are necessarily ISL, but do they ever iterate?
- Survey of PBase (Mielke, 2008):

<table>
<thead>
<tr>
<th></th>
<th>Potentially iterative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitution</td>
<td>8</td>
<td>672</td>
</tr>
<tr>
<td>Deletion</td>
<td>37</td>
<td>207</td>
</tr>
<tr>
<td>Epenthesis</td>
<td>—</td>
<td>287</td>
</tr>
</tbody>
</table>
(15) Mundari (Austro-Asiatic; India; Cook, 1965, pg. 61)

a. \{u, o\} \rightarrow [w] / V \_\_ V
b. /kiũa/ [kiwa] ‘chin’
c. /he دقa/ [hewa] ‘accustom’

- Need to see what happens to /euua/
References I


Cook, W. A. (1965). A descriptive analysis of Mundari: A study of the structure of the Mundari language according to the methods of the linguistic science, with particular attention to the units of sound, the units of meaning, the units of grammar, and their mutually contrastive arrangement patterns. PhD thesis, Georgetown University.


