Explaining Phonological Typology: Phonetic and Computational Factors

Jane Chandlee

University of Delaware | Nemours Biomedical Research

April 17, 2015
What is a *possible* phonological process?

Answering this question,

1. Predicts what will and will not be attested cross-linguistically.
2. Characterizes the nature of human language phonology.
Phonological possibility

Logically possible

Phonologically possible
Objectives

- Using metathesis as a case study, demonstrate how both computational and phonetic factors contribute to our understanding of phonological possibility.
- Extend the computational analysis to show that a significant range of processes are restricted in the same way.
- Discuss the relevance of these findings for phonological learning and their implications for phonological theory.
For a given phonological process, we can ask,

- What is the motivation?
  - Articulatory or perceptual (avoidance of a sequence)
  - Prosodic requirements
For a given phonological process, we can ask,

- What accounts for the structural change?
- Why does A → B instead of A → C?
For a given phonological process, we can ask,

- What is the nature of the transformation?
- $\text{UR} \leftrightarrow \text{SR}$
Phonological computation

underlying form $\rightarrow$ surface form
underlying form $\mapsto$ surface form
German final devoicing

(1) /bad/ $\rightarrow$ [bat], ‘bath’
German final devoicing

/bad/ $\mapsto$ [bat] ‘bath’
/sag/ $\mapsto$ [sak] ‘say’
/wald/ $\mapsto$ [walt] ‘forest’

- Motivation: avoidance of *[+voice, -son]#
German final devoicing

- Why not substitute [s] for all word-final voiced obstruents?

/bad/ $\rightarrow$ [bas] ‘bath’
/sag/ $\rightarrow$ [sas] ‘say’
/wald/ $\rightarrow$ [wals] ‘forest’
German final devoicing

- Why not string reversal?

/bad/ \[\rightarrow [bat] \quad \text{‘bath’}

/sag/ \[\rightarrow [gas] \quad \text{‘say’}

/wald/ \[\rightarrow [dalw] \quad \text{‘forest’}
Once a phonological ‘outlier’, metathesis is now more widely viewed as a systematic process attested in the synchronic grammars of many languages.

Metathesis

Rotuman (CV $\leftrightarrow$ VC)

- hosa $\leftrightarrow$ hoas ‘flower’
- hula $\leftrightarrow$ hual ‘moon’
- tiko $\leftrightarrow$ tiok ‘flesh’

(Churchwood 1940)
Metathesis

Leti (VC $\rightarrow$ CV)

\begin{align*}
\text{ukar} & \leftrightarrow \text{ukra} & \text{‘finger, toe’} \\
\text{urun} & \leftrightarrow \text{urnu} & \text{‘breadfruit’}
\end{align*}

(Hume 1998)
Metathesis

Faroese \((C_1C_2 \leftrightarrow C_2C_1)\)

bai\text{iskt} \leftrightarrow \text{baikst} 'bitter.NEUT'

(\text{Lockwood 1955})
Phonetic factors

\[ \text{baiskt} \leftrightarrow \text{bai\textsc{kst}} \quad \text{‘bitter.NEUT’} \]

- Avoidance of fricative-stop-stop sequence.
- No known cases going in the opposite direction: \text{kst} \leftrightarrow \text{skt} (Hume 2004).
Computational factors

What is the nature of the transformation?

- Phonological movement is available to avoid certain sequences, but this movement is computationally restricted.
LD metathesis?

- Sarcee prohibits s...ʃ, but ʃ...s is permitted.

  (2)  /nasʃatʃ/ → [nafcʃatʃ] ‘I killed them again’

- Why not resolve violations of *s...ʃ with movement?

  (3)  /nasʃatʃ/ → /natʃyats/

(Cook 1978, Heinz 2010)
LD metathesis?

- Long-distance phonological movement does not appear to be an option in the synchronic grammar.

(Buckley 2011, Chandlee et al. 2012, Chandlee 2014)
LD metathesis?

- Long-distance metathesis does not appear to be an option, at least for the synchronic grammar.

(4) Latin > Gascon

a. capra > craba  ‘goat’
b. cambra > cramba  ‘bedroom’
c. tendru > trendo  ‘tender’

(Dumenil 1987)
Phonological transformations are computed ‘locally’.
Processes as functions

- The map from UR to SR is a *function*.

\[(5)\]
\[
a. \quad f(\text{hosa}) = \text{hoas} \\
b. \quad f(\text{tiko}) = \text{tiok} \\
c. \quad f(\text{hos}) = \text{hos} \\
d. \quad f(\text{oooo}) = \text{oooo}
\]

- What class of functions do phonological transformations belong to?
Phonological transformations are Input Strictly Local functions.
Input Strictly Local functions

Figure: For every Input Strictly 2-Local function, the output string $u$ of each input element $x$ depends only on $x$ and the input element previous to $x$. 
(6) Quechua post-nasal obstruent voicing
   a. /kampa/ $\mapsto$ [kamba] ‘yours’

(Pater 2004)
Input Strictly Local Functions

# k a m p a #
Input Strictly Local Functions

# k a m p a #
# k
Input Strictly Local Functions

# k a m p a #
# k a
Input Strictly Local Functions

# k a m p a #
# k a m
Input Strictly Local Functions

# k a m p a #
# k a m b #
Input Strictly Local Functions
Input Strictly Local Functions

- How big is the ‘window’?
- It’s the length of the targeted sequence - for Quechua that’s the length of NČ.
- This length is the $k$-value of the function: a given ISL function is more specifically $k$-ISL.
- Post-nasal obstruent voicing is 2-ISL.
Rotuman metathesis is 3-ISL, because the targeted sequence is CV#. 
ISL Metathesis

Jane Chandlee
Explaining Phonological Typology
ISL Metathesis

# h u l a #

Jane Chandlee
Explaining Phonological Typology
ISL Metathesis

# h u l a #

#
ISL Metathesis

# h u l a #
# hu #
ISL Metathesis

# h u l a #

# hu #
ISL Metathesis

Jane Chandlee
Explaining Phonological Typology
ISL Metathesis

- The SR can be computed by considering the UR a bounded number of segments at a time.
- This won’t work for a long-distance version of metathesis.
LD Metathesis is not ISL

(7)  s...ʃ  ⟷  ʃ...s

(8)  /nasʃatʃ/  ⟷  /natʃΧats/
LD Metathesis is not ISL

(9)  s...ʃ → ʃ...s

(10)  /nasʃatʃ/ ↔ /natʃyats/

- What is $k$?
LD Metathesis is not ISL

$k = 5$?
LD Metathesis is not ISL

\[ k = 5? \]

\[
\# \ n \ a \ s \ a \ y \ a \ t \ \#\]
LD Metathesis is not ISL

- $k = 6$?

```
# n a s a y a t j #
```
LD Metathesis is not ISL

- $k = 6$?

$\# n a s t a y a t \#$
The UR $\leftrightarrow$ SR function of an ISL phonological process can be computed by only considering the most recent input...

...where ‘most recent’ is quantified as the length of the target (e.g., CV) and the triggering context (e.g., ___#).
Interim summary

- Requiring metathesis to be ISL rules out the unattested long-distance version.
- The nature of the transformation is explained with a computational account.
Phonetic accounts are needed to explain the segments targeted and the nature of the change.

- Faroese has skt $\rightarrow$ kst but no language has kst $\rightarrow$ skt
- Both of these are ISL!
Beyond metathesis

- What other processes are ISL?

(11) Quechua post-nasal obstruent devoicing ($k = 2$)
  a. /kanpa/ $\mapsto$ [kampa] ‘yours’

(12) Dutch schwa-epenthesis ($k = 2$)
  a. /meldk/ $\mapsto$ [meldek] ‘milk’

(13) Tagalog deletion ($k = 4$)
  a. /bukasin/ $\mapsto$ [buksin], ‘was opened’

(Pater 2004, Warner et al. 2011)
Beyond metathesis

- What other processes are ISL?

- A review of P-Base (v1.95, Mielke 2008), which includes approximately 5500 patterns from 500 languages, revealed that 95% are ISL functions (Chandlee 2014, Chandlee & Heinz to appear).
Opaque maps are ISL

- Opaque UR-SR maps are also ISL (Chandlee et al. 2015)

(14) Yokuts (McCarthy 1999)

/ʔili:l/ → +long \rightarrow -high ?ile:l
V \rightarrow -long / __ C # ?ilel

[ʔilel], ‘might fan’

/ʔili:l/ \leftrightarrow [ʔilel] is 3-ISL
Intuitions about phonology are driven by ‘locality’.
The ISL functions establish and formalize the role of locality in phonological transformations.
Which phonological processes *aren’t* ISL?
Non-ISL processes

- No LD movement, but assimilation and dissimilation (i.e., substitution) can occur long-distance.

(15) Sarcee
\[\text{/nas}y\text{atʃ}/ \rightarrow [\text{naʃ}y\text{atʃ}] \text{ ‘I killed them again’} \]

(16) Sudanese
\[\text{/n}ar\text{umbara}/ \rightarrow [\text{n}al\text{umbara}] \text{ ‘go abroad (pl.)’} \]

- These are not ISL.

(Cook 1984, Cohn 1992, Bennett 2013)
Long-distance phonology

- Long-distance phonological functions appear to be limited to substitution.

(17) Long-distance deletion?
  a. /nasɣatʃ/ \rightarrow [nasɣat]

(18) Long-distance insertion?
Summary: option 1

Substitution: ISL or long-distance
Deletion, insertion, metathesis: ISL
Substitution: ISL or long-distance

Deletion, insertion: ISL

Metathesis is actually insertion + deletion:

(19) hosa ↔ hoasa ↔ hoas

(Blevin & Garrett 1998, Heinz 2005, Chandlee & Heinz 2012)
Future work

- Why are long-distance transformations limited to substitution?
- Why is substitution possible long-distance?
Long-distance phonology

- Long-distance substitution corresponds to markedness constraints against non-contiguous sequences:

  \[(20) \quad *s...\] 

- Work on long-distance phonotactics indicates that these patterns are still computationally restricted when locality is interpreted as *precedence* (Heinz 2010).

- A comparable but distinct functional class based on precedence could model long-distance substitution.
Implications for phonological learning

- Algorithms exist that provably learn the class of ISL functions from positive data (Chandlee et al. 2014, Jardine et al. 2015).

- The phonological learner can use the defining properties of ISL functions as learning biases when generalizing from positive examples.
Implications for phonological theory

Logically Possible Maps

Regular Maps
(≈ rule-based theories)

Phonology

OT

ISL maps are in green
Conclusions

- Locality has been an implicit guideline for phonological formalisms (rules and constraints), but it is also a defining property of phonological transformations.
- The ISL functions make precise the role of locality in phonological computation and combined with phonetic explanations help characterize the nature of phonology.


Selected references


Selected references


Selected references


Selected references


Optimization and non-regular maps

- Optimization is known to generate non-regular UR-SR maps, even with simple constraints (Gerdemann & Hulden 2012).

\[ \text{IDENT, DEP} \gg *ab \gg \text{MAX} \]

Non-regular relation:

\[ a^n b^m \mapsto a^n, \text{ if } m < n \]
\[ a^n b^m \mapsto b^m, \text{ if } n < m \]