

Explaining Phonological Typology: Phonetic and Computational Factors

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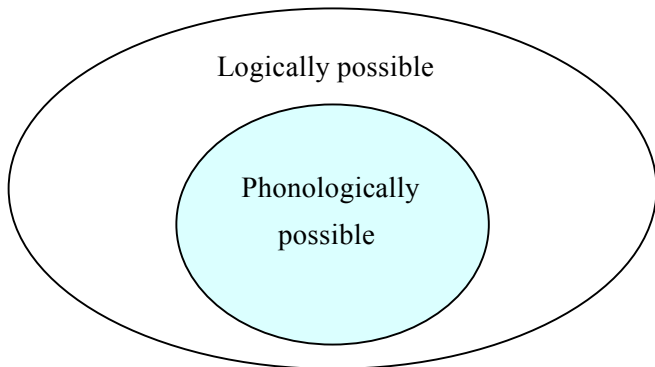
Phonological possibility

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



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.

Phonological possibility

For a given phonological process, we can ask,

- What is the motivation?
 - Articulatory or perceptual (avoidance of a sequence)
 - Prosodic requirements

Phonological possibility

For a given phonological process, we can ask,

- What accounts for the structural change?
 - Why does $A \rightarrow B$ instead of $A \rightarrow C$?

Phonological possibility

For a given phonological process, we can ask,

- What is the nature of the transformation?
 - UR \mapsto SR

Phonological computation

underlying form \mapsto surface form

Phonological computation

underlying form \mapsto surface form

German final devoicing

(1) /bad/ ↦ [bat], 'bath'

German final devoicing

/bad/ ↦ [bat] 'bath'

/sag/ ↦ [sak] 'say'

/wald/ ↦ [walt] 'forest'

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

German final devoicing

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

/bad/ ↦ [bas] 'bath'

/sag/ ↦ [sas] 'say'

/wald/ ↦ [wals] 'forest'

German final devoicing

- Why not string reversal?

/bad/ ↦ [bat] 'bath'

/sag/ ↦ [gas] 'say'

/wald/ ↦ [dalw] 'forest'

Metathesis

- Once a phonological 'outlier', metathesis is now more widely viewed as a systematic process attested in the synchronic grammars of many languages.

(Grammont 1906, Ultan 1978, Blevins and Garrett 1998, 2004, Hume 2000, Buckley 2011)

Metathesis

Rotuman (CV \mapsto VC)
hosa \mapsto **hoas** 'flower'
hula \mapsto **hual** 'moon'
tiko \mapsto **tiok** 'flesh'

(Churchwood 1940)

Metathesis

Leti (VC \mapsto CV)
ukar \mapsto ukra 'finger, toe'
urun \mapsto urnu 'breadfruit'

(Hume 1998)

Metathesis

Faroese ($C_1C_2 \mapsto C_2C_1$)
baiskt \mapsto baikst 'bitter.NEUT'

(Lockwood 1955)

Phonetic factors

baiskt \mapsto **baikst** 'bitter.NEUT'

- Avoidance of fricative-stop-stop sequence.
- No known cases going in the opposite direction: **kst** \mapsto **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) $/nasʏatʃ/ \mapsto [naʃʏatʃ]$ 'I killed them again'
- Why not resolve violations of $*s...ʃ$ with movement?
(3) $/nasʏatʃ/ \mapsto /natʃʏats/$

(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)

Hypothesis

Phonological transformations are computed 'locally'.

Processes as functions

- The map from UR to SR is a *function*.
 - (5) a. $f(\text{hosa}) = \text{hoas}$
 - b. $f(\text{tiko}) = \text{tiok}$
 - c. $f(\text{hos}) = \text{hos}$
 - d. $f(\text{oooo}) = \text{oooo}$
- What class of functions do phonological transformations belong to?

Hypothesis

Phonological transformations are Input Strictly Local functions.

Input Strictly Local functions

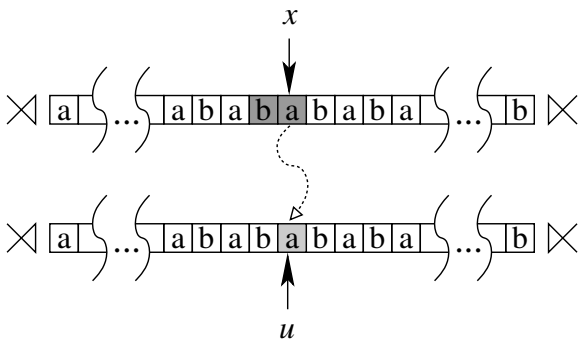


Figure: For every Input Strictly 2-Local function, the output string u of each input element x depends only on x and the input element previous to x .

Input Strictly Local functions

- (6) Quechua post-nasal obstruent voicing
a. /kampa/ ↦ [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

#	k	a	m	p	a	#
#	k	a	m	b	a	

Input Strictly Local Functions

- How big is the 'window'?
- It's the length of the targeted sequence - for Quechua that's the length of $N\zeta$.
- 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.

ISL Metathesis

- Rotuman metathesis is 3-ISL, because the targeted sequence is CV#.

ISL Metathesis

h u l a #
#

ISL Metathesis

h u l a #
#

ISL Metathesis

h u l a #
□

ISL Metathesis

h u l a #
hu

ISL Metathesis

h u l a #
hu

ISL Metathesis

#	h	u	l	a	#
#			hu		al

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) $s...f \mapsto f...s$

(8) $/nasyatf/ \mapsto /natfɣats/$

LD Metathesis is not ISL

(9) $s...f \mapsto f...s$

(10) $/nasyatf/ \mapsto /natfɣats/$

- What is k ?

LD Metathesis is not ISL

- $k = 5$?

n a s y a t ʃ

LD Metathesis is not ISL

- $k = 5$?

n a s a y a t j

LD Metathesis is not ISL

- $k = 6$?

n a s a y a t ŋ

LD Metathesis is not ISL

- $k = 6$?

n a s t a y a t ŋ

Interim summary

- The UR \mapsto 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.

Interim summary

- Phonetic accounts are needed to explain the segments targeted and the nature of the change.
 - Faroese has $skt \mapsto kst$ but no language has $kst \mapsto skt$
 - 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. /mɛlk/ \mapsto [mɛlək] '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 → -high	ʔile:l
V → -long / — C #	ʔilel
	[ʔilel], 'might fan'

- /ʔili:l/ ↦ [ʔilel] is 3-ISL

Phonological locality

- Intuitions about phonology are driven by ‘locality’.
- The ISL functions establish and formalize the role of locality in phonological transformations.

Non-ISL processes

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
/nasɣatʃ/ ↦ [naʃɣatʃ] 'I killed them again'

(16) Sudanese
/ɲarumbara/ ↦ [ɲalumbara] '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. /nasyatʃ/ ↦ [nasyat]

(18) Long-distance insertion?

Summary: option 1

Substitution: ISL or long-distance

Deletion, insertion, metathesis: ISL

Summary: option 2

Substitution: ISL or long-distance

Deletion, insertion: ISL

Metathesis is actually insertion + deletion:

(19) hosa \mapsto hoasa \mapsto 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:

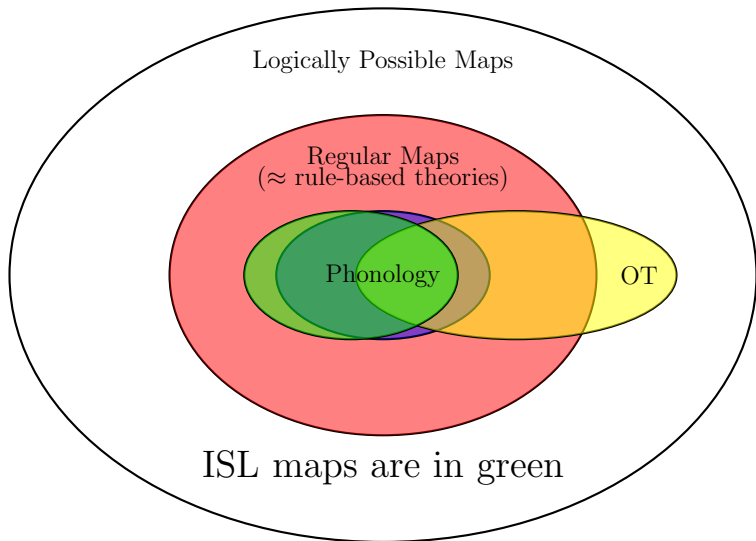
(20) *s...ʃ

- 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



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

- Bennett, W. (2013). Dissimilation, consonant harmony, and surface correspondence. Ph.D. thesis, Rutgers.
- Blevins, J. and Garrett, A. (1998). The origins of consonant-vowel metathesis. *Language*, 74(3):508-556.
- Blevins, J. and Garrett, A. (2004). The evolution of metathesis. In Hayes, B., Kirchner, R., and Steriade, D., editors, *Phonetically Based Phonology*, pages 117-156. Cambridge, Cambridge University Press.
- Buckley, E. (2011). Metathesis. In van Oostendorp, M., Ewen, C., Hume, E., and Rice, K., editors, *The Blackwell Companion to Phonology*, volume 3. Wiley-Blackwell.
- Chandlee, J. (2014). Strictly Local Phonological Processes. PhD thesis, University of Delaware.
- Chandlee, J., R. Eyraud, and J. Heinz. (2014). Learning Strictly Local subsequential functions. *Transactions of the Association for Computational Linguistics* 2, 491-503.

Selected references

- Chandlee, J. and J. Heinz. (to appear). Strict Locality and Phonological Maps. *Linguistic Inquiry*, under revision.
- Chandlee, J., A. Jardine, and J. Heinz. (2015). Learning repairs for marked structures. *Proceedings of the Annual Meetings on Phonology 2014*, MIT, October 2014.
- Churchward, C.M. (1940). *Rotuman Grammar and Dictionary*. Sydney, Methodist Church of Australasia, Department of Overseas Missions.
- Cohn, A. C. (1992). The consequences of dissimilation in Sundanese. *Phonology* 9:199-220.
- Cook, E. (1978). Palatalizations and related rules in Sarcee. In *Linguistic studies of native Canada*, ed. by Eung-Do Cook and Jonathan Kaye, 1935. Vancouver: University of British Columbia Press.
- Dumenil, A. (1987). A rule-account of metathesis in Gascon. *Lingvisticae Investigationes* 11:81-113.

Selected references

- Gerdemann, D. and M. Hulden (2012). Practical Finite State Optimality Theory. In *Proceedings of the 10th International Workshop on Finite State Methods and Natural Language Processing*, Donostia-San Sebastian, pp. 10-19. Association for Computational Linguistics.
- Grammont, M. (1906). La mtathse dans le parler Bagneres-de-Luchon. *Memoires de la Socit de Linguistique de Paris 13*, 73-90.
- Heinz, J. (2010). Learning long-distance phonotactics. *Linguistic Inquiry* 41(4):623-661.
- Hume, E. (1998). Metathesis in phonological theory: The case of Leti. *Lingua* 104, 147-186.
- Hume, E. (2000). Metathesis website.
<http://www.ling.ohiostate.edu/ehume/metathesis/>.
- Hume, E. (2004). The indeterminacy/attestation model of metathesis. *Language* 80(2), 203-237.

Selected references

- A. Jardine, J. Chandlee, R. Eyraud, and J. Heinz. Very efficient learning of structured classes of subsequential functions from positive data. In Alexander Clark, Makoto Kanazawa, and Ryo Yoshinaka (eds.) *Proceedings of the 12th International Conference on Grammatical Inference*.
- Johnson, C. Douglas. (1972). *Formal Aspects of Phonological Description*. The Hague: Mouton.
- Kaplan, R. M. and M. Kay (1994). Regular models of phonological rule systems. *Computational Linguistics* 20, 371-387.
- Koskeniemi, K. (1983). *Two-Level Morphology: A general computational model for word-form recognition and production*. University of Helsinki, Department of General Linguistics.
- Mielke, J. (2008). *The Emergence of Distinctive Features*. Oxford: Oxford University Press.
- McCarthy, J.J. (1999). Sympathy and phonological opacity. *Phonology* 16: 331-399.

Selected references

- Pater, Joe (2004). Austronesian nasal substitution and other NC effects. McCarthy, John (ed.), *Optimality Theory in Phonology: A Reader*, Oxford and Malden, MA: Blackwell, 271-289.
- Ultan, R. (1978). A typological view of metathesis. In Greenberg, J. H., editor, *Universals of human language*, Vol. 2, Phonology, pages 367-402. Stanford, CA, Stanford University Press.

Optimization and non-regular maps

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

IDENT, DEP \gg **ab* \gg MAX

Non-regular relation:

$a^n b^m \mapsto a^n$, if $m < n$

$a^n b^m \mapsto b^m$, if $n < m$