Learnability of Derivationally Opaque Patterns in the Gestural Harmony Model

Caitlin Smith¹ & Charlie O'Hara²
¹Johns Hopkins University, ²University of Southern California

Introduction

Stepwise vs. Salient

- Attested stepwise (chain-shifting) vowel raising:
  - Nonhigh vowels raise one step along narrow height scale in presence of high vowel trigger
  - Unattested salientary (derived-environment) vowel raising:
    - Step in vowel height scale is ‘skipped over’
    - Vowels at ‘skipped’ height do not raise
- Chain shifts and saltations are both examples of underapplication derivational opacity
- Saltations are rare among phonological processes and likely unattested in height harmony
- For a pattern to be robustly attested, it must be derivable within a phonological framework, but also easily learnable within that framework

Proposals

- Partial height harmony via blending in the Gestural Harmony Model (Smith 2016, 2018) generates attested stepwise and salientary height harmonies equally learnable?
- Aspects of learnability of saltatory height harmony explain its lack of attestation

A Gestural Model of Height Harmony

- Gestures (Browman & Goldstein 1986, 1989): dynamically-defined, goal-based units of phonological representation
- Gestural Harmony Model (Smith 2016, 2018): Harmony-triggering gesture extends to overlap gestures of other segments in a word (undergoers)

Undergoer Trigger

- Antagonistic gestures: gestures with conflicting target articulatory states
- Antagonism resolved by blending target articulatory states of concurrently active gestures according to Task Dynamic Model of speech production (Saltzman & Munhall 1989; Fowler & Saltzman 1993)

Target1 • Strength1 + Target2 • Strength2 = Blended Target

- Stepwise height harmony in Nzebi (Guthrie 1968; Smith to appear):
  - Vowel raising harmony due to overlap by anticipatory upper surface narrow gesture of suffix high vowel /i/
  - Vowels of different heights have antagonistic target states for upper surface constriction degree, resulting in gestural blending

The Gestural Gradual Learning Algorithm

- With correct gestural strength settings, Gestural Harmony Model can generate both stepwise and salientary height harmonies
  - Are stepwise and saliency height harmonies equally learnable?
- Task: set constriction degree targets and blending strengths for vowel and dorsal consonant gestures such that learner produces target vowel raising pattern

Patterns tested:
- Four-height stepwise raising before high vowel trigger (Nzebi-like)
- Four-height salientary raising before high vowel trigger
- Ran 100 models of each type until convergence

1. Initialize target constriction degree of 16 mm (i.e., all vowels start as [æ] and random strength (between 1 and 20)
2. On each iteration randomly generate (V,C) sequence
3. If Vx is a trigger of harmony, it overlaps V1, resulting in blending
4. If C is dorsal /g/, following V overlaps it, resulting in blending
5. If learner produces error (segment with target farther than 0.2 mm from teacher’s production): a. Update constriction degree target of learner’s tongue body gesture to produce a constriction degree that better matches teacher’s output
b. In cases of blending: update strength of learner’s tongue body gesture to produce a constriction degree that better matches teacher’s output

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The Gestural Gradual Learning Algorithm

- For assimilation of X to Y, Y’s gestural strength must be exponentially higher than that of X
- For X to resist assimilation to Y, Y’s gestural strength must be exponentially higher than that of Y
- More overpowering relationships in a pattern → more extreme strengths necessary → more strength updates necessary during model training

- Only two overpowering relationships in stepwise height harmony:
  - 1. Dorsal consonant /g/ must overpower the strongest vowel to fully resist lenition (/g/ → /a/)
  - 2. High vowels must overpower mid vowels to trigger their full assimilation (/i/, /l/ → /e/, /i/)

Assumptions:

- Assuming standard feature theory and markedness/faithfulness constraints, neither chain shifts nor saltation are derivable in Harmonic Grammar (Albright, Magri, & Michaels 2008; Farris-Trumble 2008)
- Assuming non-standard features and/or constraint definitions, both opaque patterns are derivable in Harmonic Grammar
- Necessary conditions for each type of pattern:
  - Chain shifts: There exists a constraint C such that C(ε/−[ε]) > C(ε/−[ε]) + C(ε/−[ε])
  - Salutation: There exists a constraint D such that D(ε/−[ε]) > D(ε/−[ε]) + D(ε/−[ε])
- Two possible types of constraint D in approaches to generating salatory patterns:
  - Overlapping and non-overlapping faithfulness

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- Overlapping faithfulness: any change on a scale violates the same faithfulness constraint
- With scalar ID[height] (Gnanadesikan 1997) as constraint D:
  - D(ε/−[ε]) > D(ε/−[ε]) + D(ε/−[ε])
  - Non-overlapping faithfulness: all mappings violate distinct faithfulness constraints, i.e. *MAP constraints (Zuraw 2007; White 2013; Hayes & White 2015)

- With *M[+e,i] as constraint D:
  - D(ε/−[ε]) > D(ε/−[ε]) + D(ε/−[ε])
- Two possible types of constraint D in approaches to generating salatory patterns:
  - Overlapping and non-overlapping faithfulness

Overall Results

- Stepwise raising is substantially easier/faster to learn than saltation raising
- Salutation takes ~5.3 times as many iterations to learn
- Hard-to-learn salatory patterns are more likely to be mislearned across generations and become less frequent

Alternatives

- MaxEnt Generational Stability Model (O’Hara 2020, in prep):
  - Maximum Entropy Harmonic Grammar learner with each trained model used as teacher to train next generation of learner
  - Hard-to-learn patterns are less stable across generations
  - Stability: Proportion of 100 models in which a pattern remains the same for 10 generations
  - Stability of stepwise and salutation harmonies:

- Stepwise pattern learned by this point

Featured frameworks that derive both stepwise and salutation height harmonies predict saltation harmonies to be more stable/better attested, contra the typological facts