Partial Height Harmony, Partial Transparency, and Gestural Blending

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with support from Microsoft Research AI
Introduction

- Harmony: spreading of some phonological property throughout domain

  /o-a-a/ → [o-o-o]

- Transparency: some segments are apparently skipped by harmony process

  /o-i-a/ → [o-i-o]

- Partial harmony: segment takes on phonological property of trigger to only partial degree
Partial Height Harmony

- Partial height harmony: vowels raise one step along height scale, approaching height of trigger without necessarily reaching it
- Servigliano Italian (Romance; Italy) metaphony (raising harmony targeting stressed vowel; Camilli 1929, Nibert 1998, Walker 2011):

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Difficulties of Analyzing Partial Height Harmony

Servigliano Italian Metaphony

- Different height changes manipulate different vowel features (e.g., [± high] vs. [± low] vs. [± ATR])
- Stepwise harmonies involve chain shifts ($X \rightarrow Y \rightarrow Z$), requiring additional theoretical machinery in constraint-based grammars
- Scalar height features: undesirable predictions about possible direction of feature change (low to high vs. high to low) in stepwise harmony
Proposal: Partial Transparency in a Gestural Model of Harmony

Gestural Harmony Model (Smith 2016, 2017ab, 2018):
- Subsegmental units of phonological representation are goal-based, dynamically-defined *gestures*
- Harmony is result of extension of gesture to overlap gestures of other segments in a word
- Transparency to harmony is result of *blending* gestures with different target articulatory states

**Proposals:**
1) Partial transparency/partial undergoing is result of blending gestures of similar *strengths*
2) Stepwise partial height harmony is type of *partial transparency*
Gestures as Phonological Units
Gestural Parameters

- Gestures: dynamically-defined, goal-based units of phonological representation (Browman & Goldstein 1986, 1989)

- Target articulatory state:
  - Constriction location
  - Constriction degree

- Blending strength (\(\alpha\)): ability to command vocal tract articulators

- Ability to self-activate and self-deactivate (Smith 2016, 2017ab, 2018)
Constriction Location and Degree for Consonantal Gestures

- Constriction location of gesture specifies target point along vocal tract surface

- Constriction degree of gesture specifies distance between active articulator and constriction location point
Constriction Location and Degree for Vowel Gestures

- Each vowel includes two tongue body gestures:
  - Constriction location ‘upper surface’
  - Constriction location ‘back surface’

- Constriction degree of upper surface gesture determines vowel height

- Constriction degree of back surface gesture determines vowel backness
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Harmony and Transparency via Gestural Blending
Gestural Activation and Deactivation
(Smith 2016, 2017ab, 2018)

- **Typical gesture**
  - Starting timepoint, gesture activates
  - Target articulatory state reached, gesture self-deactivates

- **Persistent gesture**
  - Starting timepoint, gesture already activated
  - Target articulatory state reached, gesture does not self-deactivate

- **Anticipatory gesture**
  - Starting timepoint, gesture already activated
Example: Rounding Harmony

Resulting lip position:
Transparency as Gestural Blending

- Transparency: competition between two concurrently active antagonistic gestures (Smith 2016, 2018)

- Gestural antagonism: two concurrently active gestures with opposing target articulatory states
  - Lip protrusion vs. lip spreading
  - Wide upper surface constriction vs. narrow upper surface constriction

![Diagram of intergestural competition/blending](image-url)

Resulting state of vocal tract for some variable:
Gestural Strength and Blending

- 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)

\[
\frac{\text{Target}_1 \times \alpha_1 + \text{Target}_2 \times \alpha_2}{\alpha_1 + \alpha_2} = \text{Blended Target}
\]
Example: Transparency in Rounding Harmony

- Tongue Body upper surface wide
- Tongue Body upper surface narrow
- Tongue Body upper surface wide
- Tongue Body upper surface narrow
- Tongue Body upper surface wide
- Tongue Body back surface narrow
- Tongue Body back surface wide
- Tongue Body back surface narrow
- Lip protrusion
- Lip spread
- α = 10
- α = 1

Resulting lip position:
Advantages of Transparency via Gestural Blending

- Correctly predicts which segments can be transparent within nasal harmony and rounding harmony

- Avoids over-generation of predicted transparent segments (Smith 2016, 2018)

- Harmony is represented locally (without skipping), resulting in gestural antagonism with transparent segments
Prediction: Partial Transparency via Gestural Blending

- Full transparency: overlapped gesture of transparent segment is much stronger than harmonizing gesture (e.g. 10-to-1)
- Identical or similar blending strengths of harmonizing gesture and overlapped gesture predicts partial transparency/partial undergoing of harmony
- Partial transparency attested in Coeur d’Alene Salish faucal (retraction) harmony (Smith 2017c, 2018)

Resulting state of vocal tract for some variable:
Partial Height Harmony in Servigliano Italian
Servigliano Italian Partial Height Harmony
(Camilli 1929, Nibert 1998, Walker 2011)

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Servigliano Italian: Analysis

- Vowel raising harmony due to overlap by anticipatory upper surface narrowing gesture of suffix high vowels /i/ and /u/.
- Vowels of different heights have antagonistic target states for upper surface constriction degree, resulting in gestural blending.

![Diagram showing tongue body height blending](image)

Resulting tongue body height:

- Raised
- Lowered
Relatively weak narrow-mid vowels /ɛ/ and /ɔ/ do not resist raising and surface as narrow.

Wide-mid vowels /ɛ/ and /ɔ/ surface as narrow-mid, partially resisting raising to narrow due to strength equal with trigger gesture.
## Gestural Blending Strength Calculations

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<td>4 mm</td>
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</tr>
<tr>
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<td>8 mm</td>
<td>1</td>
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<tr>
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<td>12 mm</td>
<td>10</td>
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\[
\begin{align*}
4 \times 10 + 8 \times 1 &= 4.36 \text{ mm} \\
4 \times 10 + 12 \times 10 &= 8 \text{ mm}
\end{align*}
\]
Narrow-mid vowels /e/ and /o/ fully undergo harmony
Relative gestural blending strengths favor target constriction degree (narrow upper surface constriction) of high vowels

Resulting tongue body height:
### Gestural Blending Strength Calculations

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- $4 \times 10 + 8 \times 1 = 4.36 \text{ mm}$
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Servigliano Italian: Analysis

- Overlap between gestures of wide-mid vowels /ɛ/ and /ɔ/ and narrow /i/ produces narrow-mid [e] and [o]
- Intermediate blended articulatory state due to equal gestural strengths

![Diagram](image)

Resulting tongue body height:

- Raised
- Lowered
Featural Approaches to Partial Height Harmony
In vowel inventory with more than two heights, multiple binary features must be used to distinguish them (e.g., \([\pm \text{high}], [\pm \text{low}], [\pm \text{ATR}]\))

- Stepwise height harmony may involve spreading/assimilation of two or more different features in a single harmony process.
In vowel inventory with more than two heights, multiple binary features must be used to distinguish them (e.g., $[\pm \text{high}]$, $[\pm \text{low}]$, $[\pm \text{ATR}]$)

- Stepwise height harmony may involve spreading/assimilation of two or more different features in a single harmony process.
Stepwise Partial Height Harmony as Chain Shift

- Stepwise height harmony produces apparent chain shifts:
  
  \( \varepsilon \rightarrow e \rightarrow i \) \hspace{1cm} \( \mathcal{C} \rightarrow o \rightarrow u \)

- Non-derivational frameworks (Optimality Theory, Harmonic Grammar) encounter difficulty with chain shifts and other derivationally opaque phonological patterns
Stepwise Partial Height Harmony as Chain Shift

- Synchronic chain shifts in Optimality Theory via conjunction of faithfulness constraints (Kirchner 1996, Moreton & Smolensky 2002)

- Servigliano Italian (Walker 2011): conjoined constraint IDENT(high)&IDENT(ART) prevents $\varepsilon \rightarrow i$ and $\sigma \rightarrow u$

- Independently motivated individual constraints can produce unattested patterns when conjoined (Itô & Mester 1998, Fukazawa & Lombardi 2003, Pater 2009)

- Ganging of weighted constraints in Harmonic Grammar does not produce chain shifts (Magri 2018)
Underlying and Derived Vowels

- Underlying mid-high vowel /e/: 

  Tongue Body  
  back surface wide$_1$

  Tongue Body  
  upper surface narrow-mid$_1$

- Mid-high vowel [e] derived by blending /ɛ/$_1$ and /i/$_2$:

  [  
  Tongue Body  
  back surface wide$_1$  

  Tongue Body  
  upper surface wide-mid$_1$  
  ]

  [  
  Tongue Body  
  back surface wide$_2$  

  Tongue Body  
  upper surface narrow$_2$  
  ]
Conclusion
Conclusion

- Stepwise/partial height harmony can be analyzed as case of partial transparency to harmony

- Partial transparency is predicted by gestural model of harmony in which transparency is modeled as competition/blending of gestures with antagonistic target states

- Avoids issues that arise in analyses that rely on binary or scalar height features and additional grammatical mechanisms