1. Proposal

- The phonetic patterns of production in language are best modeled by freely-rankable scalar articulatory constraints (following de Lacy 2002).
- This allows for anti-Paninian rankings, where a more general constraint dominates a less general constraint (see Prince 1997).
- The ranking values of articulatory constraints are language-specific and must be learned (contra Boersma 2006, Boersma and Hamann 2008).

2. Production and Perception of Glottalization in Yucatec Maya

- In Yucatec Maya, GLOTTALIZED vowels (/v̥v/) are distinguished from HIGH TONE vowels (/ṽv/) on the basis of pitch and glottalization
  - GLOTTALIZED vowels have higher initial pitch, a larger pitch span (difference between minimum and maximum pitch), and more glottalization
- See Frazier (2009) for full methodology, results, and discussion of production and perception experiments; only glottalization is discussed here
- I divide glottalization into four categories:
  - **modal**: no glottalization; modal voice only
  - **weak glottalization**: brief period of non-modal voice
  - **creaky voice**: more substantial period of non-modal voice
  - **full glottal stop**: period of glottal closure (at least 20 ms between glottal pulses)

weak glottalization vs. creaky voice
2.1 Production of Glottalization

- Percentage of times a given vowel shape is produced with a specific glottalization type:

<table>
<thead>
<tr>
<th></th>
<th>mod.</th>
<th>w.g.</th>
<th>cr.</th>
<th>g.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLOTTALIZED</td>
<td>56%</td>
<td>15%</td>
<td>26%</td>
<td>2%</td>
</tr>
<tr>
<td>HIGH TONE</td>
<td>97%</td>
<td>1%</td>
<td>1%</td>
<td>0%</td>
</tr>
</tbody>
</table>

- GLOTTALIZED vowels are most often produced without glottalization. When glottalization is produced, there is a preference for creaky voice.
- HIGH TONE vowels are almost always produced without glottalization.

2.2 Perception of Glottalization

- Percentage of times a given vowel shape is heard on the basis of glottalization type:

<table>
<thead>
<tr>
<th></th>
<th>mod.</th>
<th>w.g.</th>
<th>cr.</th>
<th>g.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLOTTALIZE</td>
<td>39%</td>
<td>55%</td>
<td>68%</td>
<td>93%</td>
</tr>
<tr>
<td>HIGH TONE</td>
<td>61%</td>
<td>45%</td>
<td>32%</td>
<td>7%</td>
</tr>
</tbody>
</table>

- A glottal stop is a really good cue for GLOTTALIZED vowel.
- Creaky voice is a decent cue for GLOTTALIZED vowels.
- Modal voice is a decent good cue for HIGH TONE vowels.
- Weak glottalization is not a good cue for this contrast.

† How does the grammar of Yucatec Maya account for the fact that GLOTTALIZED vowels are often produced with modal voice but that modal voice is not a good cue for GLOTTALIZED vowels?

3. The Grammar of Yucatec Maya

3.1 Model of Analysis

- Bidirectional Stochastic OT (Boersma 2006, 2007) is a parallel, multilevel model of phonetics and phonology; the production and perception grammar are defined by the same constraints with the same mean ranking values; stochastic evaluation accounts for variation
- our focus: the relation between a phonological surface form (/SF/) and an articulatorily and acoustically explicit phonetic form ([PF])
- in production, /SF/ is the input and candidate [PF]s are evaluated
  - cue constraints penalize particular /SF/, [PF] pairings
  - articulatory constraints penalize effortful [PF]s

<table>
<thead>
<tr>
<th></th>
<th>/SF1/</th>
<th>*/SF1/, [PF2]</th>
<th>*/SF1/, [PF3]</th>
<th>![PF1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[PF1]</td>
<td></td>
<td></td>
<td></td>
<td>![PF1]</td>
</tr>
<tr>
<td>[PF2]</td>
<td>![PF2]</td>
<td></td>
<td></td>
<td>![PF2]</td>
</tr>
<tr>
<td>[PF3]</td>
<td></td>
<td></td>
<td></td>
<td>![PF3]</td>
</tr>
</tbody>
</table>

- in perception, [PF] is the input and candidate /SF/ s are evaluated
  - cue constraints penalize particular /SF/, [PF] pairings
3.2 Constraints for the Analysis of Glottalization

- **structural constraints** penalize ill-formed /SF/s
  
<table>
<thead>
<tr>
<th>[PF1]</th>
<th>*/SF1/, [PF1]</th>
<th>*/SF2/, [PF1]</th>
<th>*/SF3/</th>
</tr>
</thead>
<tbody>
<tr>
<td>/SF1/</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/SF2/</td>
<td></td>
<td>*!</td>
<td></td>
</tr>
<tr>
<td>/SF3/</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

- cue constraints penalize each possible pairing of an underlying form (/GLOTTALIZED/ or /HIGH TONE/) with a surface form ([modal voice], [weak glottalization], [creaky voice], [glottal stop])
- articulatory constraints penalize the production of [adducted vocal folds]
- scalar *[AVF] constraints (modeled after the markedness constraints of de Lacy (2002) and similar to the ‘don’t produce effort amount x’ constraints in Boersma and Hamann (2008)):
  - *[AVF:{wg, cr, gs}]: penalizes weak glottalization, creaky voice, and a glottal stop
  - *[AVF:{cr, gs}]: penalizes creaky voice and a glottal stop
  - *[AVF:{gs}]: penalizes a glottal stop

3.3 Learning Strategies

- the ranking values of **cue constraints** are learned via “lexicon-driven perceptual learning” (Boersma 2006); the learner uses perception tableaux to test the interim grammar, and adjustments are made each time the grammar predicts an incorrect winner
  - example: speaker said [PF1] to mean /SF1/
  - learner checks that grammar predicts [PF1] to be mapped onto /SF1/:
    
    \[ \begin{array}{cccccc}
    \text{[PF1]} & C_1 & C_2 & C_3 & C_4 & C_5 & C_6 \\
    \text{/SF1/} & * & * & * & * & * & * \\
    \text{/SF2/} & * & * & * & * & * & * \\
    \end{array} \]

    \( \text{leads to an incorrect winner}\)

- the grammar has made an incorrect prediction, and so the constraints that distinguish the two candidates are adjusted, as denoted by the arrows

- the ranking values of **articulatory constraints** are based on effort and are (possibly) only lowered for practiced articulations (Boersma 2006, Boersma and Hamann 2008)

- If there is no language-specific learning or if the only language-specific ranking adjustments are those that lower the ranking values of constraints that penalize practiced articulations, we expect the ranking:
  
  * *[AVF:{gs}]  »  * *[AVF:{cr, gs}]  »  * *[AVF:{wg, cr, gs}]
  
  least general » more general » most general

- Is this ranking able to account for the Yucatec Maya data?

3.4 Learning Simulation

- simulation run with PRAAT (Boersma and Weenink 2006)
• a GLA learner (Boersma and Hayes 2001) was trained on the production data associated with 685 tokens (337 with a GLOTTALIZED vowel and 348 with a HIGH TONE vowel) as spoken by Yucatec Maya speakers from Santa Elena, Yucatan, Mexico.

• learning strategy:
  ▪ round one: initial state = all constraints have ranking value of 100
  ▪ learner uses perception tableaux to test and adjust the rankings of cue constraints (= lexicon-driven perceptual learning)
  ▪ round two: initial state = all cue constraints have ranking value reached at end of round one; all articulatory constraints have ranking value of 100
  ▪ learner uses both perception and production tableaux to test and adjust the rankings of cue and articulatory constraints (= new method designed for the learning of articulatory constraints)

3.5 Results of the Learning Simulation

• ranking values learned for each constraint:

<table>
<thead>
<tr>
<th>articulatory constraints</th>
<th>cue constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>*[AVF:{gs}]</td>
<td>*/GL/, [gs]</td>
</tr>
<tr>
<td>*[AVF:{cr, gs}]</td>
<td>*/GL/, [cr]</td>
</tr>
<tr>
<td>*[AVF:{wg, cr, gs}]</td>
<td>*/GL/, [wg]</td>
</tr>
<tr>
<td></td>
<td>*/GL/, [mod]</td>
</tr>
</tbody>
</table>

• The articulatory constraints are in an anti-Paninian ranking; the more general *[AVF:{wg, cr, gs}] dominates the less general *[AVF:{cr, gs}].

• *[AVF:{wg, cr, gs}] conflates all categories of glottalization; lower-ranking constraints decide among the candidates (see de Lacy (2002) for importance of category conflation in phonology)

4. Why the Anti-Paninian Ranking is Necessary for Yucatec Maya

• high-ranking */GL/, [mod] accounts for the fact that modal voice is not a good cue for the perception of GLOTTALIZED vowels; high-ranking *[AVF:{wg, cr, gs}] accounts for the fact that GLOTTALIZED vowels are often produced with modal voice

• when *[AVF:{wg, cr, gs}] » */GL/, [mod], GLOTTALIZED vowels are produced with modal voice; when */GL/, [mod] » *[AVF:{wg, cr, gs}], GLOTTALIZED vowels are produced with some form of glottalization

• if the constraints are ordered according to their mean ranking value, a GLOTTALIZED vowel (/GL/) is produced with [modal voice]:

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</thead>
<tbody>
<tr>
<td>(56%)</td>
<td>![mod]</td>
<td>![wg]</td>
<td>![cr]</td>
<td>![gs]</td>
<td>![!*]</td>
<td>![!*]</td>
<td>![!*]</td>
</tr>
</tbody>
</table>

• if, due to stochastic evaluation, *[AVF:{wg, cr, gs}] falls below */GL/, [mod], the winning
candidate is determined by the ranking of */GL/, [wg] and *[AVF:{cr, gs}]:

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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[mod]</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(15%) [wg]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(26%) [cr]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[gs]</td>
<td>*!</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- if there is no language specific learning with regard to articulatory constraints, *[AVF:{wg, cr, gs}] must be ranked below *[AVF:{cr, gs}]:

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(56%) [mod]</td>
<td>*(!)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(15%) [wg]</td>
<td></td>
<td>*(!)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(26%) [cr]</td>
<td></td>
<td></td>
<td>*(!)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[gs]</td>
<td>*!</td>
<td></td>
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</tbody>
</table>

- here, the ranking of */GL/,[mod]; */GL/, [wg]; and *[AVF:{cr, gs}] determines the winning candidate

- in order for [mod] to be the winner 56% of the time, */GL/,[mod] must be ranked below both */GL/,[wg] and *[AVF:{cr, gs}]

- but low-ranking */GL/,[mod] would negatively affect the perception grammar by making modal voice a good cue to GLOTTALIZED vowels (and making it an even better cue than weak glottalization!)

- the analysis of pitch in Yucatec Maya also requires anti-Paninian rankings (see Frazier 2009: ch. 5)

5. Why the Anti-Paninian Ranking Matters for Phonological Theory

- **learning**: the ranking values of articulatory constraints are language-specific and not solely tied to the quantification of effort
  - de Lacy’s claims about markedness in phonology cannot be applied to articulatory constraints if Boersma’s assumptions about the learning of articulatory constraints is correct; these assumptions predict that articulatory constraints are not freely rankable and that category conflation is not necessary in production grammars
  - learning models must account for the ranking values of articulatory constraints and allow for anti-Paninian rankings

- **defining articulatory constraints**: anti-Paninian rankings cannot be mimicked with MINIMIZE EFFORT, a type of weighted articulatory constraints introduced by Flemming (2001)
  - a MINEFF constraint penalizes some effortful phonetic dimension
  - the penalty assigned by this constraint equals the weight of the constraint times (some quantified value of) the amount of effort produced
  - more effort always equates with a larger penalty
  - a grammar that uses MINEFF-style articulatory constraints cannot account for Yucatec
6. Conclusions

- Anti-Paninian rankings of articulatory constraints are necessary to account for phonetic patterns of production.
- The ranking values of articulatory constraints are language-specific and must be learned.
- MINIMIZE:EFFORT articulatory constraints undergenerate.

References


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