Noisy HG Models of Eastern Andalusian Harmony*

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1 Introduction

- Noisy Harmonic Grammar (NHG): depending on when and where noise is added, different patterns of variation are possible (Hayes 2017).

- ATR harmony in Eastern Andalusian as a test of these possibilities: variation is constrained by categorical requirements; depending on the constraint set, some attested forms are harmonically bounded.

- The best model perturbs constraint weights at the outset of the evaluation.
  - This version of NHG cannot produce harmonically bounded forms and therefore requires constraints under which attested forms are not harmonically bounded.

2 Eastern Andalusian Harmony

- /s/-aspiration: word-final /s/ deletes, triggering laxing of adjacent vowel. These lax vowels trigger variable harmony on preceding vowels.


  (1) a. tesis téṣi ‘thesis’
  b. tienes tjéne ‘you have’
  c. nenes néñe ‘babies’
  d. monos móno ‘monkeys’
  e. lejos lého ‘far’
  f. pesos pésco ‘weights’
  g. bocas bókæ ‘mouths’

*I am grateful to participants in the Analyzing Typological Structure workshop at Stanford University (Sept. 22, 2018) for feedback on this work, and thanks especially to Abby Kaplan for assistance with R.
• Other post-tonic vowels optionally harmonize as a group:

(2) a. *treboles trébolı̱c ∼ trébolı̱c ‘clovers’
    b. *cómételos kómételɔ ∼ kómételɔ ‘eat them (for you)’

• Pretonic vowels optionally harmonize as a group, but only with post-tonic harmony:

(3) a. *momentos moméntɔ ∼ moméntɔ ‘instants’
    b. *reloj relı̱ ∼ relı̱ ‘watch’
    c. *relojes relı̱hı̱ ∼ relı̱hı̱ ‘watches’
    d. *monederos moneđerı̱ ∼ moneđerı̱ ‘purses’
    e. *cojines kohı̱ne ∼ kohı̱ne ‘pillows’
    f. *cotillones kotı̱zı̱ne ∼ kotı̱zı̱ne ‘cotillions’
    g. *recógelos rekohı̱lo ∼ rekohı̱lo ‘pick them’

• High vowels lax word finally but do not undergo harmony:

(4) a. *crisis krisı̱ ‘crisis’
    b. *muchos mújɔ ‘many’
    c. *mios mío ‘mine (pl.)’


• Pairing different versions of PL with particular implementations of NHG gives a range of models of Eastern Andalusian.

  – Constraints: negative and positive versions of PL (Kaplan 2018).

• The best model: Hayes’s (2017) “classic NHG” with positive PL

  – Classic NHG: no harmonically bounded outputs. Therefore, no licit output can be harmonically bounded (the case under positive but not negative PL).
  – Other versions of NHG produce harmonically bounded forms, but cannot distinguish “good” ones from “bad” ones.
3 Positional Licensing Analyses

3.1 Candidates of Interest

(5)

<table>
<thead>
<tr>
<th>Input</th>
<th>Candidate</th>
<th>Attested?</th>
<th>Neg. PL</th>
<th>Pos. PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. /monedéros/ ‘purses’</td>
<td>monedéro monedéro monedéro monedéro monedéro monedéro</td>
<td>✓</td>
<td>Bounded</td>
<td>Bounded</td>
</tr>
<tr>
<td>b. /kómetelos/ ‘eat them (for you)!’</td>
<td>kómetelo kómetelo kómetelo kómetelo kómetelo kómetelo</td>
<td>✓</td>
<td>Bounded</td>
<td>Bounded</td>
</tr>
<tr>
<td>c. /rekógelos/ ‘pick them’</td>
<td>rekóhelo rekóhelo rekóhelo rekóhelo rekóhelo rekóhelo</td>
<td>✓</td>
<td>Bounded</td>
<td>Bounded</td>
</tr>
<tr>
<td>d. /krísis/ ‘crisis’</td>
<td>krísi krísi krísi</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Positive PL: no attested candidate is harmonically bounded.

• Negative PL: two attested candidates are harmonically bounded: kómetelo, rekóhelo.

• Both: some unattested candidates are harmonically bounded; other are not.

• NHG with negative PL must produce kómetelo, rekóhelo without producing other harmonically bounded forms.

3.2 Negative PL

• To avoid pathologies in HG, PL must be gradient: Negative Gradient PL (NG-PL; Kaplan 2018):

(6) LICENSE(−ATR, σ): assign −1 for each [−ATR] that does not coincide with σ and −1 for each syllable that intervenes between [−ATR] and the nearest σ.

• This accounts for harmony up to the licensor.
- Pretonic harmony: Maximal Licensing (Walker 2011) requires \([-\text{ATR}]\) to appear in every syllable.

- IDENT(\text{ATR}) disfavors harmony.

- These constraints produce post-tonic and pretonic harmony, but forms with no post-tonic harmony are harmonically bounded.

- LICENSE penalizes unharmonized post-tonic vowels in \(\text{kömêtel}\), \(\text{rekôhel}\) to avoid pathologies (Kaplan 2018).

- \(\text{feito}\) = attested; \(\times\) = harmonically bounded

\[(7)\]

<table>
<thead>
<tr>
<th>(7) a.</th>
<th>/\text{monedêros}/</th>
<th>LICENSE</th>
<th>MAXLic</th>
<th>IDENT</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\text{moneôêrc})</td>
<td>(-1)</td>
<td>(-3)</td>
<td>(-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) b. (\text{moneôêrc})</td>
<td>(-2)</td>
<td>(-2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) c. (\text{moneôêrc})</td>
<td></td>
<td></td>
<td>(-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) d. (\text{moneôêrc})</td>
<td>(-1)</td>
<td>(-3)</td>
<td></td>
<td>collectively bounded(^1) by (b) &amp; (c)</td>
<td></td>
</tr>
<tr>
<td>(\times) e. (\text{moneôêrc})</td>
<td>(-1)</td>
<td>(-3)</td>
<td></td>
<td>collectively bounded by (b) &amp; (c)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(7) b.</th>
<th>/\text{kömêtel(\hat{e})}/</th>
<th>LICENSE</th>
<th>MAXLic</th>
<th>IDENT</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\text{kömêtel})</td>
<td>(-3)</td>
<td>(-3)</td>
<td>(-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) b. (\text{kömêtel})</td>
<td>(-2)</td>
<td>(-2)</td>
<td>(-2)</td>
<td>collectively bounded by (a) &amp; (c)</td>
<td></td>
</tr>
<tr>
<td>(\times) c. (\text{kömêtel})</td>
<td></td>
<td></td>
<td>(-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) d. (\text{kömêtel})</td>
<td>(-1)</td>
<td>(-1)</td>
<td>(-3)</td>
<td>collectively bounded by (a) &amp; (c)</td>
<td></td>
</tr>
<tr>
<td>(\times) e. (\text{kömêtel})</td>
<td>(-1)</td>
<td>(-1)</td>
<td>(-3)</td>
<td>collectively bounded by (a) &amp; (c)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(7) c.</th>
<th>/\text{rekôhel(\hat{e})}/</th>
<th>LICENSE</th>
<th>MAXLic</th>
<th>IDENT</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\text{rekôhel})</td>
<td>(-2)</td>
<td>(-3)</td>
<td>(-1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) b. (\text{rekôhel})</td>
<td>(-1)</td>
<td>(-2)</td>
<td>(-2)</td>
<td>collectively bounded by (a) &amp; (c)</td>
<td></td>
</tr>
<tr>
<td>(\times) c. (\text{rekôhel})</td>
<td></td>
<td></td>
<td>(-3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) d. (\text{rekôhel})</td>
<td></td>
<td></td>
<td>(-4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\times) e. (\text{rekôhel})</td>
<td>(-1)</td>
<td>(-1)</td>
<td>(-3)</td>
<td>bounded by (c)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Collective harmonic bounding: Samek-Lodovici & Prince (1999)
• High vowels: *[+hi, −ATR] prevents harmony, MAX(−ATR) forces laxing word-finally.

\[(8)\]

<table>
<thead>
<tr>
<th>/krísis/</th>
<th>*[+hi, −ATR]</th>
<th>MAX(−ATR)</th>
<th>LICENSE</th>
<th>MAXLic</th>
<th>IDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. krísi</td>
<td></td>
<td>−1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. krísi</td>
<td>−1</td>
<td>−1</td>
<td>−1</td>
<td>−1</td>
<td>−1</td>
</tr>
<tr>
<td>c. krísi</td>
<td>−2</td>
<td></td>
<td></td>
<td></td>
<td>−2</td>
</tr>
</tbody>
</table>

• What to do about the harmonically bounded attested forms?
  – Nothing: let NHG deal with them.
  – Revise PL: Positive Gradient PL (PG-PL; Kaplan 2018)

3.3 Positive PL

\[(9)\] LICENSE([−ATR], σ): assign +1 for each [−ATR] that coincides with σ and +1 for each additional syllable that [−ATR] appears in.

• This subsumes MaxLic; we need Ident(−ATR)-pretonic to block pretonic harmony.

• All attested forms are now possible winners.

\[(10)\] a. /monedéros/

<table>
<thead>
<tr>
<th></th>
<th>LICENSE</th>
<th>IDENT-pretonic</th>
<th>IDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. moneðéρo</td>
<td></td>
<td>−1</td>
<td></td>
</tr>
<tr>
<td>b. moneðéρo</td>
<td>+2</td>
<td>−2</td>
<td></td>
</tr>
<tr>
<td>c. moneðéρo</td>
<td>+4</td>
<td>−2</td>
<td>−4</td>
</tr>
<tr>
<td>d. moneðéρo</td>
<td>+3</td>
<td>−1</td>
<td>−3</td>
</tr>
<tr>
<td>e. moneðéρo</td>
<td>+3</td>
<td>−1</td>
<td>−3</td>
</tr>
</tbody>
</table>

b. /kómetelos/

<table>
<thead>
<tr>
<th></th>
<th>LICENSE</th>
<th>IDENT-pretonic</th>
<th>IDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. kómetelo</td>
<td></td>
<td>−1</td>
<td></td>
</tr>
<tr>
<td>b. kómetelo</td>
<td>+2</td>
<td>−2</td>
<td></td>
</tr>
<tr>
<td>c. kómetelo</td>
<td>+4</td>
<td>−4</td>
<td></td>
</tr>
<tr>
<td>d. kómetelo</td>
<td>+3</td>
<td>−3</td>
<td></td>
</tr>
<tr>
<td>e. kómetelo</td>
<td>+3</td>
<td>−3</td>
<td></td>
</tr>
</tbody>
</table>
c. \begin{tabular}{|l|c|c|c|}
  \hline
  /rekóhelos/ & LICENSE & IDENT-pretonic & IDENT \\
  \hline
  a. rekóhelο & & $-1$ & \\
  \hline
  b. rekóhelο & +2 & & $-2$ \\
  \hline
  c. rekóhelο & +3 & & $-3$ \\
  \hline
  d. rekóhelο & +4 & $-1$ & $-4$ \\
  \hline
  e. rekóhelο & +3 & $-1$ & $-3$ \\
  \hline
\end{tabular}

d. \begin{tabular}{|l|c|c|c|c|c|}
  \hline
  /krísis/ & *[+hi, –ATR] & MAX(–ATR) & LICENSE & IDENT-pretonic & IDENT \\
  \hline
  a. krísi & & $-1$ & \\
  \hline
  b. krísi & & $-1$ & \\
  \hline
  c. krísi & $-2$ & $+2$ & $-2$ \\
  \hline
\end{tabular}

(11) Core weighting requirements:

a. Harmony on $\hat{\delta}$ only: $2w$(LICENSE) > $w$(IDENT) > $w$(LICENSE)

b. Full post-tonic harmony: $w$(IDENT) + $w$(IDENT-pre) > $w$(LICENSE) > $w$(IDENT)

c. Maximal harmony: $w$(LICENSE) > $w$(IDENT) > $w$(LICENSE-pretonic)

d. High vowels: $w$(MAX(–ATR)) > $w$(*[+hi, –ATR]) + $w$(IDENT) > 2$w$(LICENSE)

• **Summary:** 2 ways to account for Eastern Andalusian:

1. NG-PL: NHG responsible for variation and relieving harmonic bounding.

2. PG-PL: NHG responsible for variation only.

4 **Simulations**

• Monte Carlo simulations following Hayes (2017) using OTSoft (Hayes et al. 2013): 8 variants of NHG; NG-PL and PG-PL.

1. Noise at the constraint level

   (a) **Classic NHG:** Noise added before multiplication of penalties by weights: 
   \( \text{penalty} \times (weight + noise) \)

   (b) Noise added after multiplication of penalties by weights, no noise allowed if 
   penalty = 0: \( (\text{penalty} \times \text{weight}) + \text{noise} \)

   (c) Noise added after multiplication of penalties by weights, noise allowed if 
   penalty = 0: \( (\text{penalty} \times \text{weight}) + \text{noise} \)

2. Noise at the cell level

   (a) Noise added before multiplication of penalties by weights: \( \text{penalty} \times (weight + noise) \)

   (b) Noise added after multiplication of penalties by weights, no noise allowed if 
   penalty = 0: \( (\text{penalty} \times \text{weight}) + \text{noise} \)
(c) Noise added after multiplication of penalties by weights, noise allowed if penalty = 0: \((\text{penalty} \times \text{weight}) + \text{noise}\)

3. Noise at the candidate level

- 100,000 trials per simulation. Negative constraint weights were disallowed.
- Most successful arrangement: Hayes's classic NHG (variety 1a) with PG-PL:

![Diagram showing results of simulations under variety 1a](image-url)

**Figure 1: Results of simulations under variety 1a**

- In particular simulation shown here, all and only attested forms produced. Not a minor accomplishment: some illicit forms are not harmonically bounded.
- Subsequent simulations: unattested forms produced rarely. Worst result: krísi produced 38 times out of 100,000 trials. 2 other illicit forms produced: kóméteslo, moneðério

- The same simulation with NG-PL is less successful: classic NHG effectively does not produce harmonically bounded candidates.\(^2\)
  - Attested [kóméteslo], [rekóhelO] cannot be produced.
  - Unattested [moneðério], [kóméteslo], [rekóhelO] appear at a \(\sim 22%\) rate.

\(^2\)With only positive constraint weights, a harmonically bounded candidate is selected under classic NHG only when it ties with a rival (Hayes 2017). Ties occurred very rarely in my simulations (for the PG-PL simulation in Figure 1: 125 ties in 66,565,284 chances), so I take it to be a reasonable approximation to say that classic NHG does not produce harmonically bounded candidates. Indeed, in none of my simulations with classic NHG did a harmonically bounded candidate win.
• Classic NHG succeeds only when no attested form is harmonically bounded. Under those conditions, it performs very well on Eastern Andalusian.

4.1 Constraint-Level Noise

Figure 2: Results of simulations under variety 1b

Figure 3: Results of simulations under variety 1c
4.2 Cell-Level Noise

Figure 4: Results of simulations under variety 2a

Figure 5: Results of simulations under variety 2b
4.3 Candidate-Level Noise

Figure 6: Results of simulations under variety 2c

Figure 7: Results of simulations under variety 3
4.4 MaxEnt

![Figure 8: Results of simulations under MaxEnt](image)

5 Discussion

- /krísis/: no variation here, so weights approximating “Max(–ATR) ≫ *[+hi, –ATR] ≫ everything else” can be established.

- For this reason, forms with no lax vowels (e.g. *moneðéro*) never win.

- The nature of Eastern Andalusian’s optionality is tailor-made for classic NHG:
  - Many unattested candidates are harmonically bounded and therefore inaccessible to classic NHG.
  - Remaining unattested forms: no lax vowels (e.g. *moneðéro*), ruled out by high-weighted Max(–ATR); no harmony (moneðéro), ruled out if IDENT does not outweigh LICENSE by too much.
  - The weights found under this simulation reflect these criteria:

\[
\begin{align*}
46.000 & \quad \text{Max}(-\text{ATR}) \\
27.000 & \quad *[+\text{hi}, -\text{ATR}] \\
11.655 & \quad \text{LICENSE} \\
11.345 & \quad \text{IDENT}(\text{ATR}) \\
0.251 & \quad \text{IDENT}(\text{ATR})\text{-pretonic}
\end{align*}
\]

- Other implementations of NHG make it easier to subvert these arrangements: harmonically bounded candidates can win, or crucial weighting relationships can be reversed (e.g. by adding noise unequally to candidates).
• NHG cannot relieve the harmonic-bounding problem on its own: opening the door to one bounded candidate opens the door to others.

• Better to let the constraints identify viable candidates that NHG can choose from.

6 Conclusion

• These results provide support for classic NHG and positive constraints.

• The differences between versions of NHG can be subtle, but it is possible to distinguish them empirically.

• Small changes make a big difference.

References


Hayes, Bruce, Bruce Tesar, & Kie Zuraw (2013) OTSoft 2.5. software package, http://www.linguistics.ucla.edu/people/hayes/otsoft/.


