Exploring Serial NHG with Eastern Andalusian Harmony

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Introduction

- Noisy Harmonic Grammar: probabilistic implementations of Harmonic Grammar (Jesney 2007; Hayes 2017; Flemming 2017; Zuraw & Hayes 2017).
- Only one member of this family supports an analysis of optionality in Eastern Andalusian Harmony (Kaplan 2018a; Kaplan 2019).
- The harmony-driving constraint in this analysis requires serialism.

A crucial, unaddressed question

How does serial Noisy Harmonic Grammar work?

Eastern Andalusian Harmony

- Jiménez & Lloret (2007); Lloret & Jiménez (2009); Lloret (2018)
- /s/-aspiration (= deletion) causes laxing of word final vowel, which triggers [–ATR] harmony on the stressed syllable:

tesis	ˈtɛsɪ	‘thesis’	*nenes*	ˈnɛnɛ	‘babies’
tienes	ˈtjɛnɛ	‘you have’	*pesos*	ˈpɛsɔ	‘weights’
monos	ˈmɔnɔ	‘monkeys’	*lejos*	ˈlɛhɔ	‘far’
bocas	ˈɔkæ̱	‘mouths’	*asas*	ˈa̱sæ̱	‘handles’

- Harmony on other vowels is optional. . .

Eastern Andalusian Harmony

- Nonfinal post-tonic vowels optionally harmonize in lockstep:

treboles	ˈtrɛβolɛ ∼ ˈtrɛβɔlɛ	‘clovers’
cómetelos	ˈkɔmetelɔ ∼ ˈkɔmɛtɛlɔ	‘eat them (for you)!’
	*ˈkɔmɛtelɔ, *ˈkɔmetɛlɔ	

- Likewise for pretonic vowels; post-tonic harmony is a prerequisite for pretonic harmony:

momentos	moˈmɛntɔ ∼ mɔˈmɛntɔ	‘instants’
relojes	reˈlɔhɛ ∼ rɛˈlɔhɛ	‘watches’
monederos	moneˈðɛrɔ ∼ mɔnɛˈðɛrɔ	‘purses’
	*mɔneˈðɛrɔ, *monɛˈðɛrɔ	
recógelos	reˈkɔhelɔ ∼ reˈkɔhɛlɔ ∼ rɛˈkɔhɛlɔ	‘pick them’
	*rɛˈkɔhelɔ	

Eastern Andalusian Harmony

- But high vowels do not undergo harmony:

crisis	ˈkɾisɪ	‘crisis’
muchos	ˈmuʃɔ	‘many’
ídolos	ˈiðolɔ ∼ ˈiðɔlɔ	‘idols’
cojines	koˈhinɛ ∼ kɔˈhinɛ	‘pillows’
cotillones	kotiˈʒɔnɛ ∼ kɔtiˈʒɔnɛ	‘cotillions’

- When the stressed vowel is high (e.g. *cojines*), harmony becomes derivationally opaque (Kaplan 2020); not dealt with here.

OT Analyses

- Positional Licensing triggers harmony on the stressed syllable (Jiménez & Lloret 2007; Lloret & Jiménez 2009; Lloret 2018; Walker 2011):

/ˈtesis/	License([–ATR], σ́)	*[–ATR]
a. ˈtesɪ	*!	*
☞ b. ˈtɛsɪ		**

- Optionality: using Partial Orders (Anttila 2007), other constraints trigger or block harmony in other positions.

NHG & Serialism

- Standard Positional Licensing is pathological in HG. A replacement (Kaplan 2018b):

LICENSE([–ATR], $\acute{\sigma}$)

Assign +1 for each [–ATR] that coincides with $\acute{\sigma}$ and +1 for each additional syllable that [–ATR] appears in.

- Positive constraints & infinite goodness (Kimper 2011a): epenthesize infinite harmonic vowels to increase LICENSE's reward.
- Serialism's repair: outputs are derived over a series of passes through the grammar, with only one change allowed at a time.
- Epenthesis and harmony occur on separate steps, and there's no motivation for harmony absent epenthesis.

NHG & Serialism

What implementations of serial NHG are possible? Which provide satisfactory accounts of Eastern Andalusian? How does serial NHG compare to parallel NHG?

- What we'll see:
  - Hayes's (2017) "classical NHG" has several possible serial implementations; all account for Eastern Andalusian satisfactorily.
  - Other versions of serial NHG overgenerate.
  - These results match the behavior of parallel NHG.

- Other findings:
  - Our choice of anti-harmony constraint can be crucial in serial NHG.
  - Results aren't affected by whether we treat harmony as a one-step or two-step process.

The Core Constraints

- Positive LICENSE drives harmony, *[–ATR] discourages it.
- CRISPEDGE (e.g. Ito & Mester (1999)) discourages pretonic harmony:
  - CRISPEDGE([–ATR], $\acute{\sigma}$, L): assign -1 for each syllable to the left of the stressed syllable with which it shares a [–ATR] feature (Kaplan 2018c).

Other constraints, effectively undominated

- MAX(–ATR): don't delete [–ATR]
- ANCHOR-R: ensures a lax final vowel (*['tɛsi])
- *[+hi, –ATR]: prevents high vowels from harmonizing. (Outweighed by MAX(–ATR) because final high vowels lax.)

NHG: the Mechanics

Add noise to the computation of harmony scores at various levels (Hayes 2017):

/rekóhelos/	License 11	CrispEdge 0.25	*[–ATR] 11	H
a. re'kohelɔ			−1	−11
(☞) b. re'kɔhelɔ	+2		−2	0
(☞) c. re'kɔhɛlɔ	+3		−3	0
(☞) d. rɛ'kɔhɛlɔ	+4	−1	−4	−0.25
e. rɛ'kɔhelɔ	+3	−1	−3	−0.25

NHG: the Mechanics

Add noise to the computation of harmony scores at various levels (Hayes 2017): constraint ("classical NHG"),

/rekóhelos/	LICENSE 11 +.5	CRISPEDGE 0.25 −.2	*[−ATR] 11 +.3	*H*	
a. re'kohelɔ			−1	~~−11~~	→ −11.3
(☞) b. re'kɔhelɔ	+2		−2	~~0~~	→ 0.4
(☞) c. re'kɔhɛlɔ	+3		−3	~~0~~	→ 0.6
(☞) d. rɛ'kɔhɛlɔ	+4	−1	−4	~~−0.25~~	→ 0.75
e. rɛ'kɔhelɔ	+3	−1	−3	~~−0.25~~	→ 0.55

NHG: the Mechanics

Add noise to the computation of harmony scores at various levels (Hayes 2017): constraint ("classical NHG"), cell,

/rekóhelos/	LICENSE 11	CRISPEDGE 0.25	*[–ATR] 11	H	
a. re'kohelɔ	$+.9$	$-.8$	-1 $-.5$	~~-11~~	→ -10.5
(☞) b. re'kɔhelɔ	$+2$ $+.5$	$-.7$	-2 $-.5$	~~0~~	→ 2
(☞) c. re'kɔhɛlɔ	$+3$ $+0$	$+.6$	-3 $-.9$	~~0~~	→ 2.7
(☞) d. rɛ'kɔhɛlɔ	$+4$ $-.9$	-1 $+.7$	-4 $+.2$	~~-0.25~~	→ -5.35
e. rɛ'kɔhelɔ	$+3$ $+.2$	-1 $-.2$	-3 $+.6$	~~-0.25~~	→ -1.25

NHG: the Mechanics

Add noise to the computation of harmony scores at various levels (Hayes 2017): constraint ("classical NHG"), cell, or candidate.

/rekóhelos/	LICENSE 11	CRISPEDGE 0.25	*[–ATR] 11	H	
a. re'kohelɔ			−1	−11 +.4	→ −10.6
(☞) b. re'kɔhelɔ	+2		−2	0 +.2	→ 0.2
(☞) c. re'kɔhɛlɔ	+3		−3	0 −.8	→ −0.8
(☞) d. rɛ'kɔhɛlɔ	+4	−1	−4	−0.25 −.3	→ −.55
e. rɛ'kɔhelɔ	+3	−1	−3	−0.25 +.4	→ 0.65

Only constraint-level noise accounts for Eastern Andalusian in parallel NHG (Kaplan 2018a; Kaplan 2019); that's where we'll start with serialism.

Serial Versions of Constraint-Level Noise

1. Constant noise: weights are perturbed once at the outset, fixing their values for the whole derivation.

$$\textit{Step 1: } w(C) + i$$
$$\textit{Step 2: } w(C) + i$$

2. Variable Noise: weights are perturbed anew at each step in the derivation.

$$\textit{Step 1: } w(C) + i$$
$$\textit{Step 2: } w(C) + j$$

3. Cumulative variable noise: like variable noise, but the starting point for each step is the perturbed weights from the previous step.

$$\textit{Step 1: } w(C) + i$$
$$\textit{Step 2: } w(C) + i + j$$

Simulations

- Existing software (OTsoft (Hayes, Tesar & Zuraw 2013), OT-Help (Staubs et al. 2010), e.g.) doesn't support serial NHG.
- My own implementations, built in R (R Core Team 2020). Some details:
  - Noise was drawn from a normal distribution with mean of 0 and standard deviation of 1.
  - Negative weights were reverted to 0 (following Hayes (2017)).
  - In the event of tied winners, one is chosen at random.
  - Results from each implementation were aggregated over 10,000 iterations.
  - Weights supplied at the outset.

Weights

/rekóhelos/	License 11	CrispEdge 0.25	*[–ATR] 11
a. re'kohelɔ			−1
(☞) b. re'kɔhelɔ	+2		−2
(☞) c. re'kɔhɛlɔ	+3		−3
(☞) d. rɛ'kɔhɛlɔ	+4	−1	−4
e. rɛ'kɔhelɔ	+3	−1	−3

- Harmony on stressed syllable: $2w(\text{License}) > w(\text{*[–ATR]})$
- Post-tonic harmony:
  - $w(\text{License}) > w(\text{*[–ATR]})$ **or**
  - $w(\text{License}) < w(\text{*[–ATR]})$
- Pretonic Harmony:
  - $w(\text{License}) > w(\text{*[–ATR]}) + w(\text{CrispEdge})$ **or**
  - $w(\text{License}) < w(\text{*[–ATR]}) + w(\text{CrispEdge})$

Weights

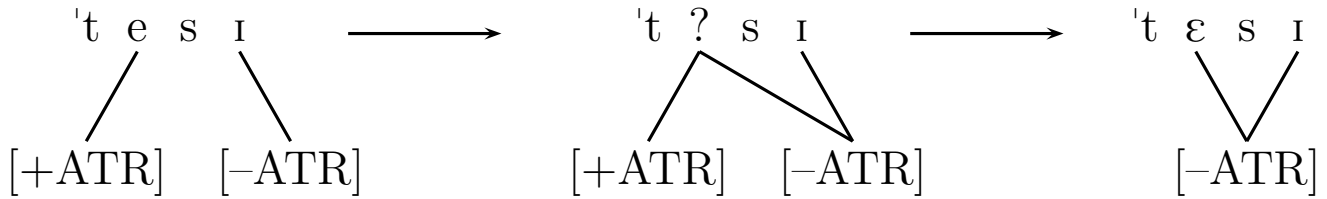
Constraint	Weight
*[–ATR]	11
License	11
CrispEdge	0.25
Max(–ATR)	50
Anchor-R	100
*[+hi, –ATR]	40

Representational Assumptions

- Gradualism: one change at a time. What counts as a change?

1. A vowel harmonizes in one fell swoop:

2. Harmony is a two-step process (e.g. McCarthy (2008)):



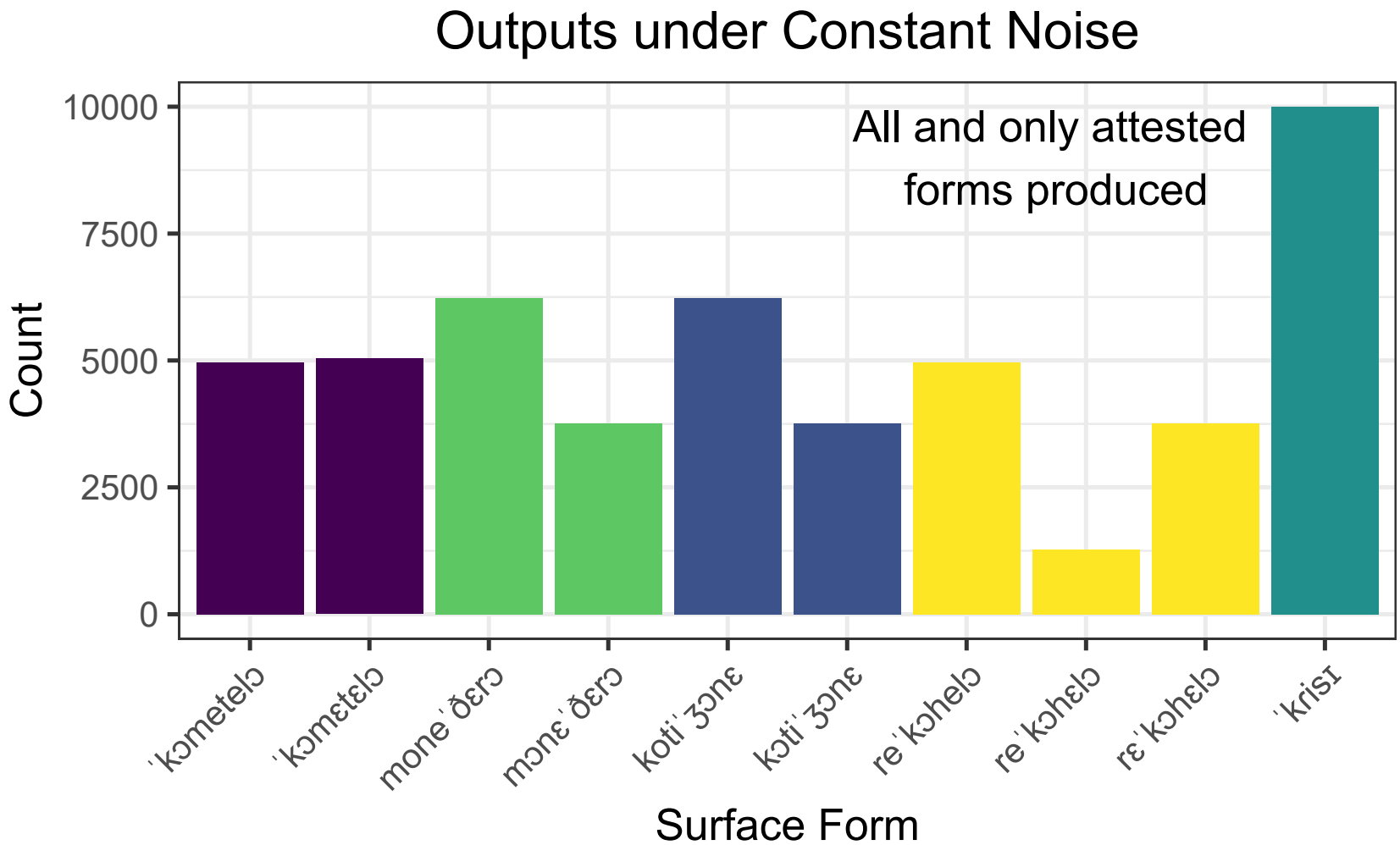
- Fell-swoop harmony for now; revisit this later.

Configurations to Test

- /ˈkometelos/ ‘eat them (for you)!’: 2 non-final post-tonic vowels; harmonize both or neither.
- /moneˈderos/ ‘purses’: 2 pretonic vowels; harmonize both or neither.
- /kotiˈʒones/ ‘cotillions’: high V doesn’t stop other pretonic V from optionally harmonizing.
- /reˈkohelos/ ‘pick them’: pretonic V can’t harmonize without the post-tonic V.
- /ˈkɾisis/ ‘crisis’: 2 high vowels; only licit realization: [ˈkɾisɪ]

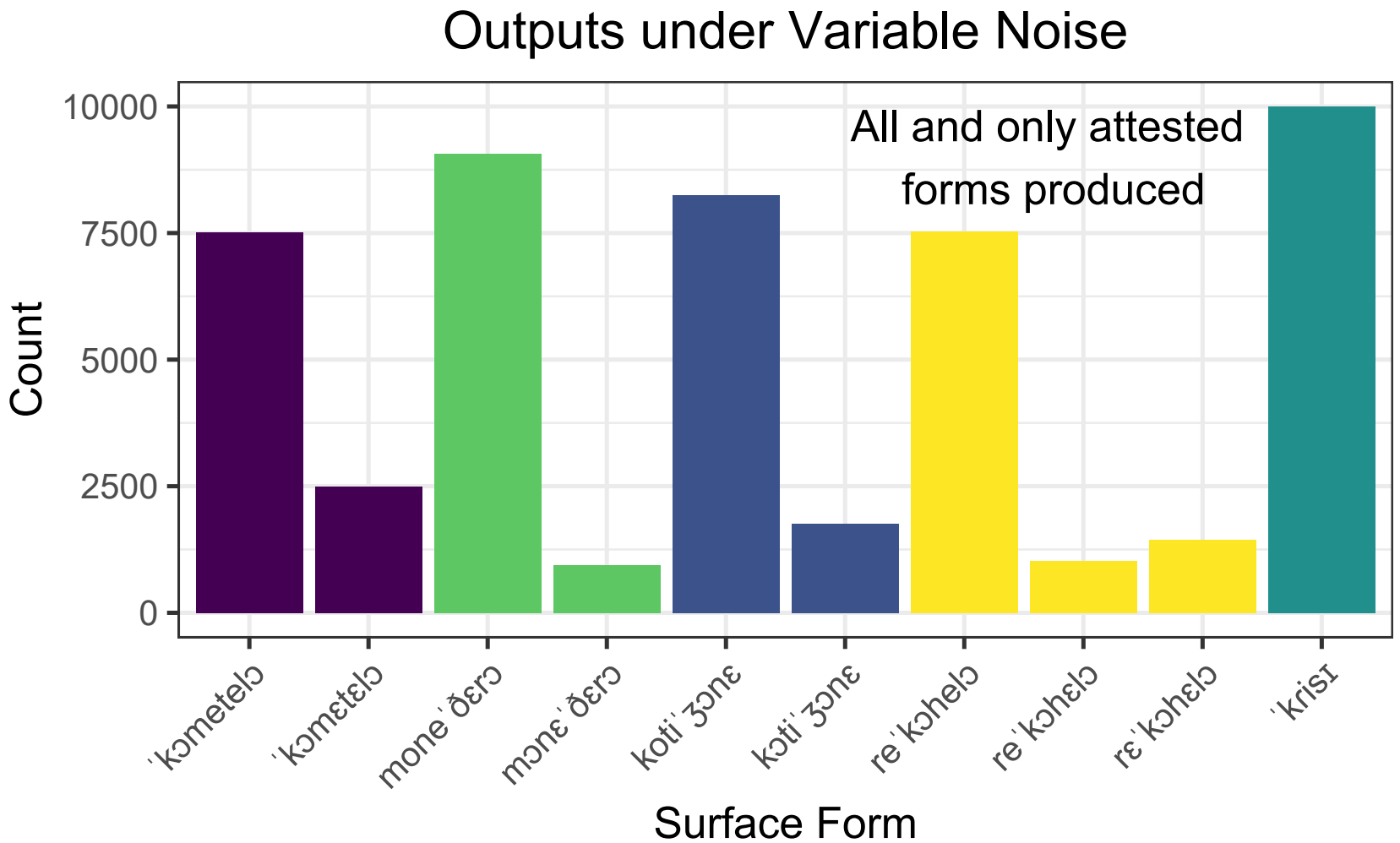
Constant Noise

- Weights perturbed once and for all at the outset.



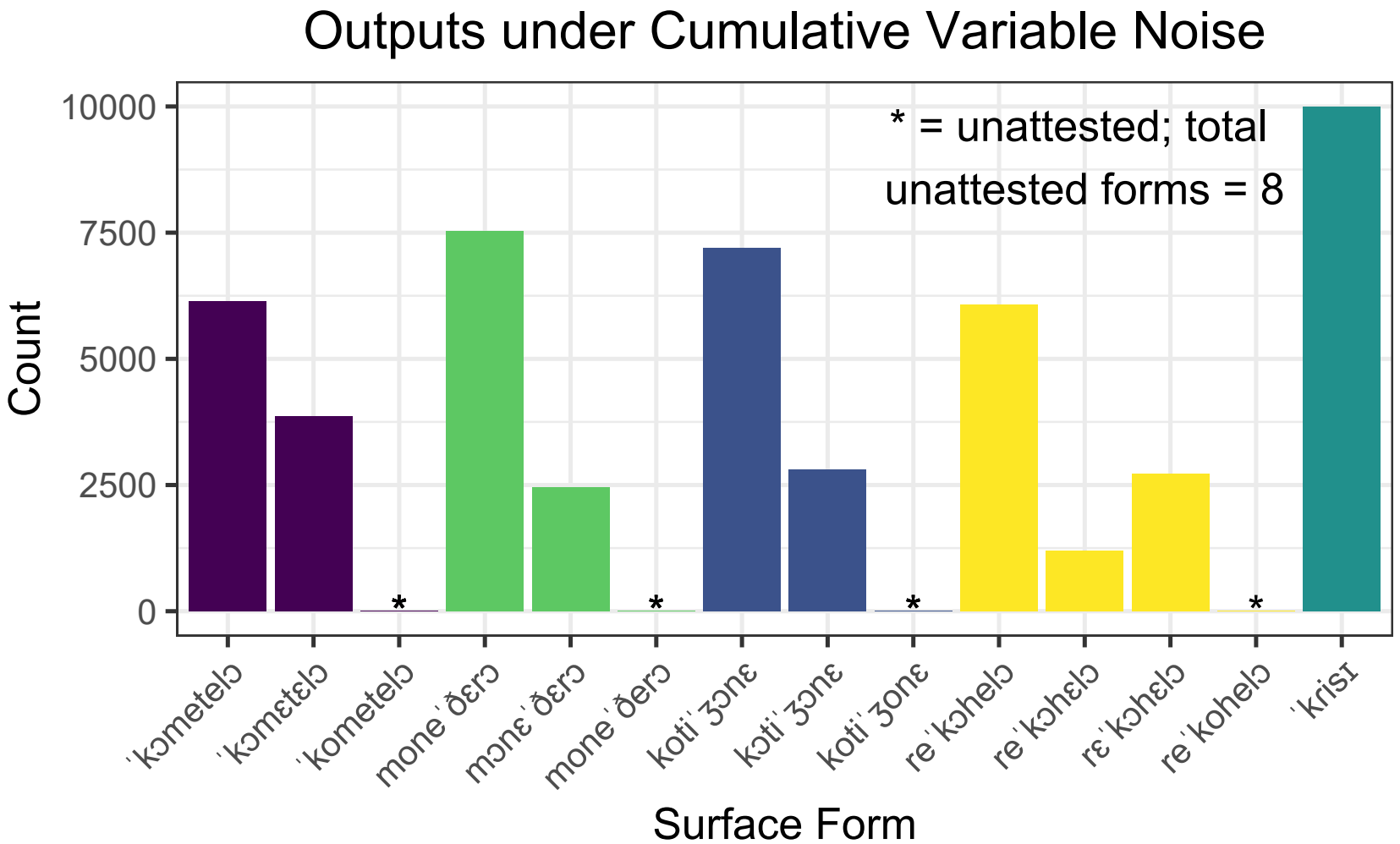
Variable Noise

- New noise on each step.



Cumulative Variable Noise

- New noise each step, beginning with previous step's weights.

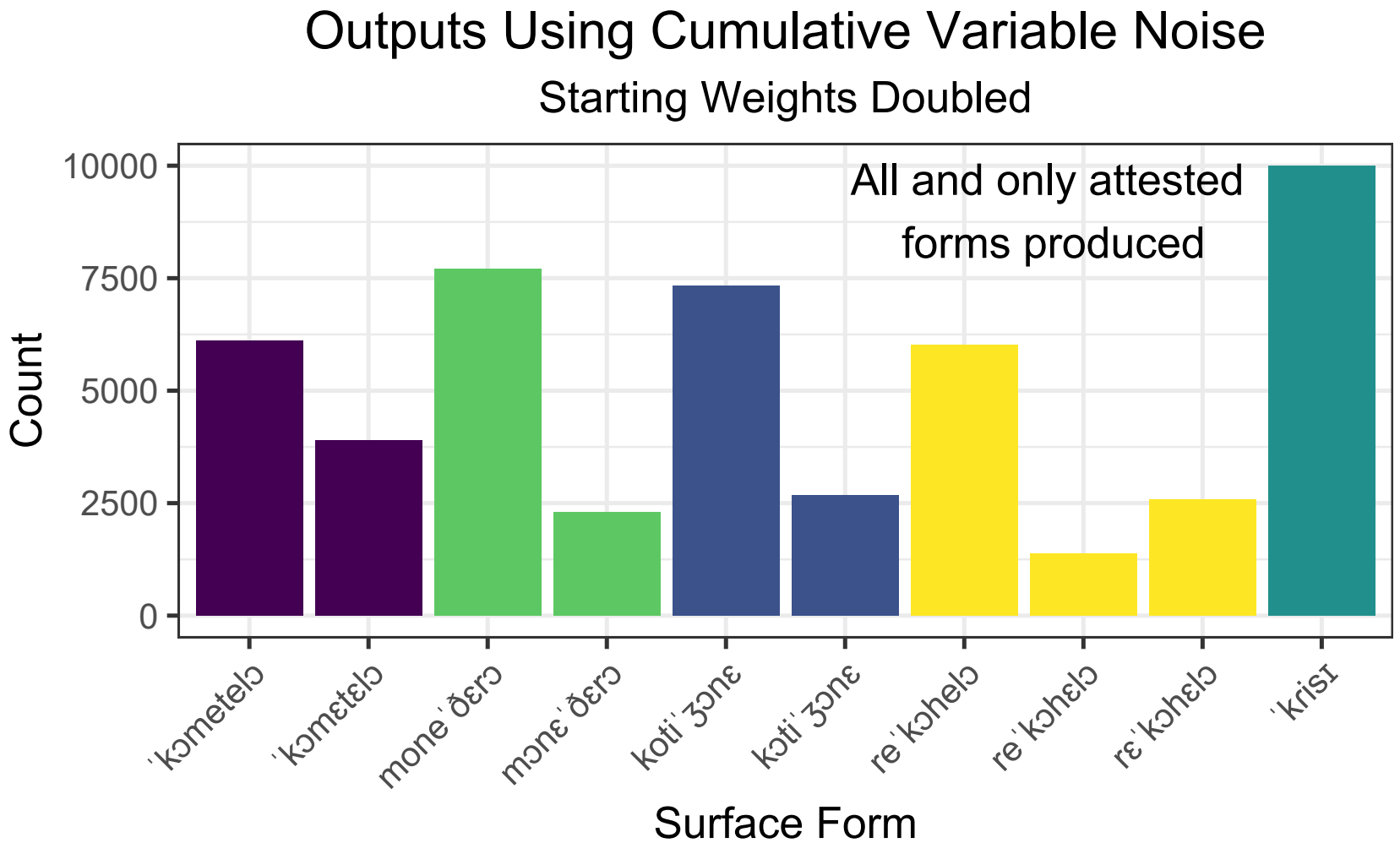


Cumulative Variable Weight

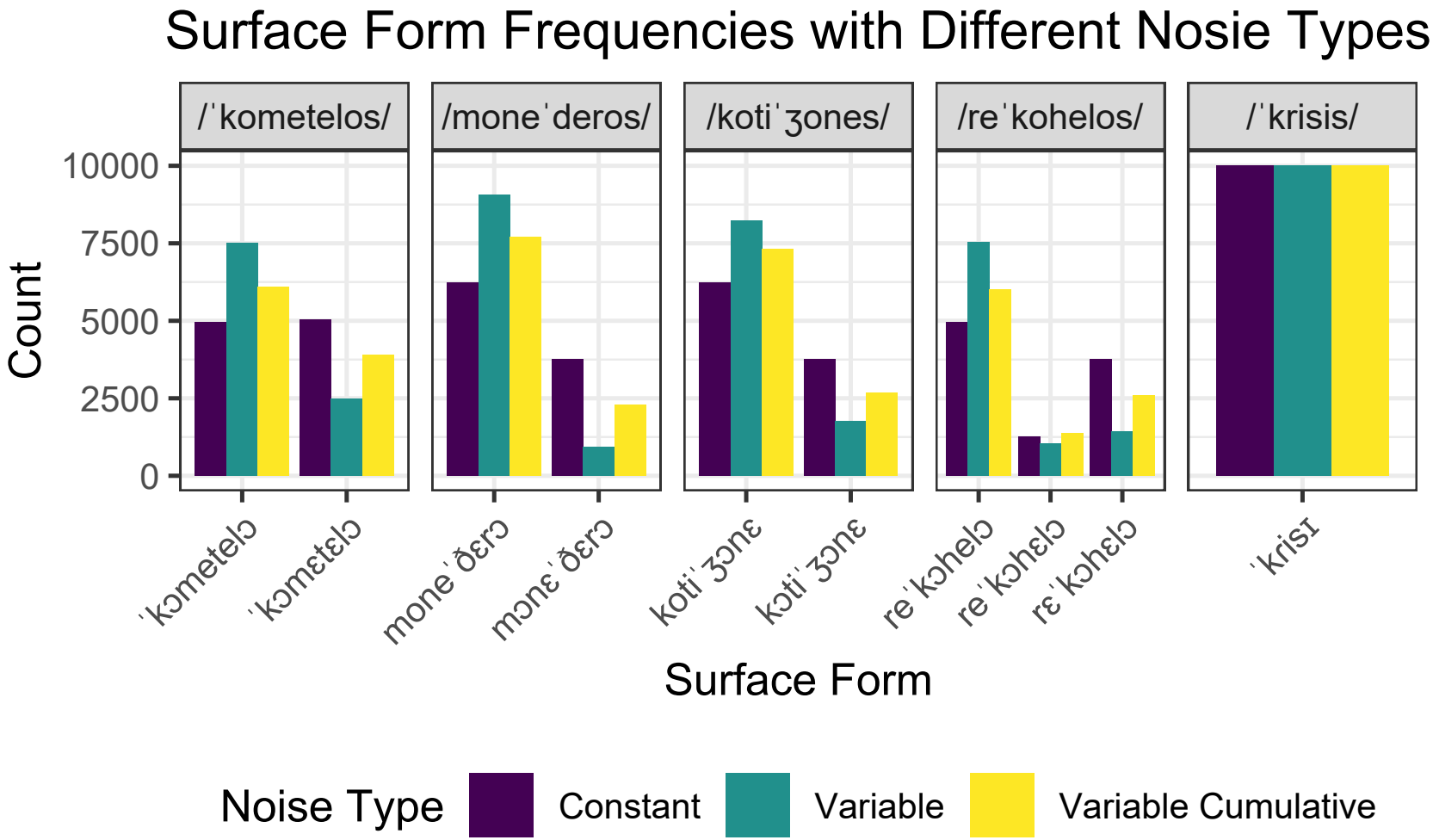
- Bad outcomes result when the accumulation of noise causes a constraint's weight to stray too far.
- E.g. in one derivation yielding *[ˈkometelɔ], License and *[–ATR]'s final weighs are 4.62 and 14.4, respectively. No harmony can happen.
- Cf. constant noise: the greatest such deficit for License is -4.98 (w(License) = 8.77; w(*[–ATR] = 13.8))

Cumulative Variable Weight

- Doubling the weights prevents this:



Comparison of Frameworks



- Variable noise makes harmony harder: perturbation must consistently favor harmony.
- Pretonic harmony is rarer than post-tonic harmony (CrispEdge!).

How Long Until Convergence?

Noise Type	Mean Steps	Maximum Steps
Constant	2.40	4
Variable	3.01	30
Variable Cumulative	2.53	14

- Constant noise: the maximum number of steps is constrained by the number of vowels.
- Variable noise: potential for infinite loop if weights cycle between $w(\textsc{License}) > w(*[\text{–ATR}])$ and the reverse.

Constraint-Level Noise: Summary

- All three kinds of constraint-level noise permit accurate models of Eastern Andalusian.
- Cumulative noise is more brittle: weights can stray far from original settings.
- Major differences lie in frequency predictions (which can be adjusted somewhat by changing initial weights), but without frequency data, we can't say which is more accurate.

Candidate- & Cell-Level Noise

- Candidate-level noise: noise added directly to candidates' harmony scores:

/rekóhelos/	LICENSE 11	CRISPEDGE 0.25	*[–ATR] 11	*H*
a. re'kohelɔ			−1	~~−11~~ +.4 → −10.6
(☞) b. re'kɔhelɔ	+2		−2	~~0~~ +.2 → 0.2
(☞) c. re'kɔhɛlɔ	+3		−3	~~0~~ −.8 → −0.8
(☞) d. rɛ'kɔhɛlɔ	+4	−1	−4	~~−0.25~~ −.3 → −.55
e. rɛ'kɔhelɔ	+3	−1	−3	~~−0.25~~ −.4 → 0.65

- Cell-level noise: different noise for each cell in a tableau:

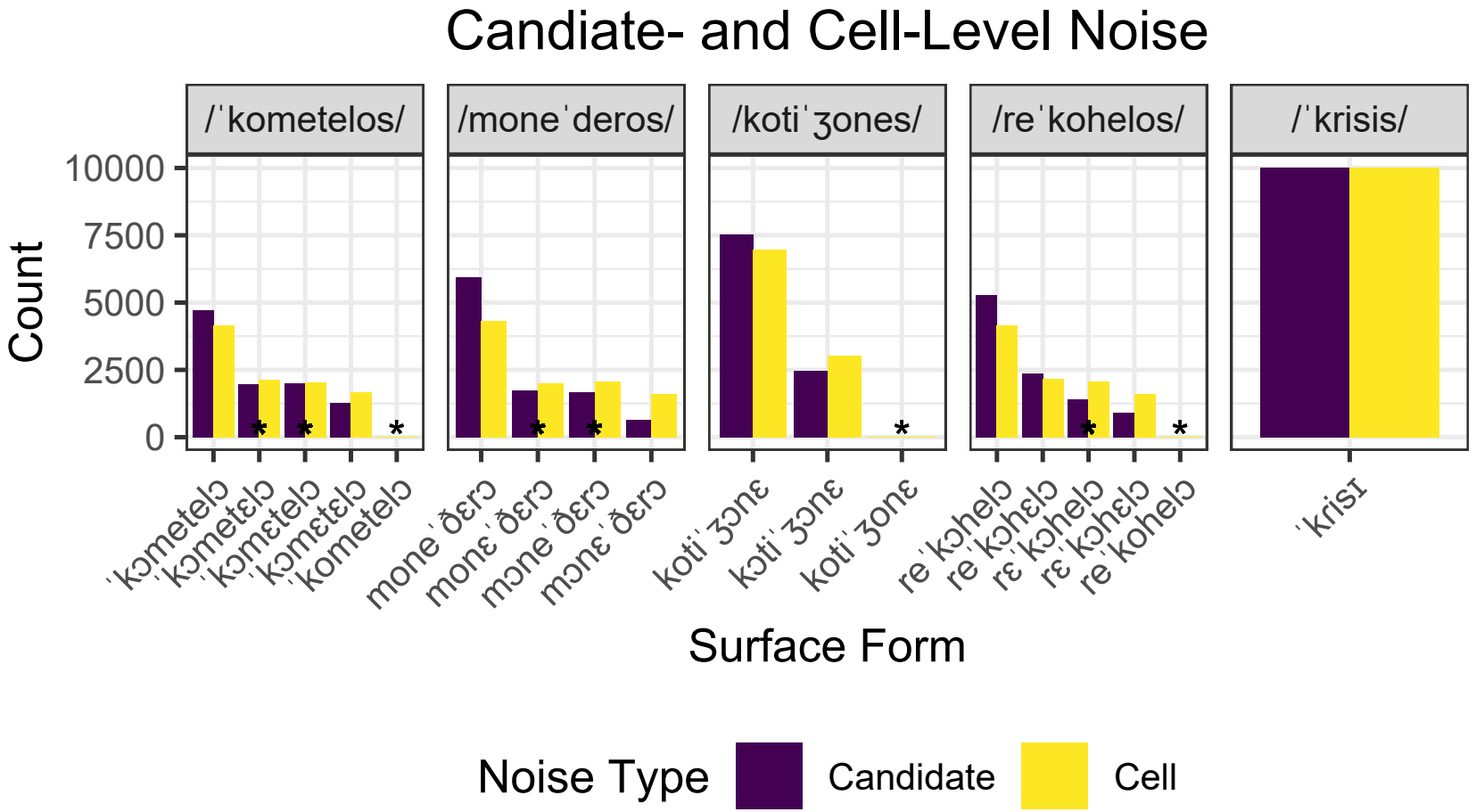
/rekóhelos/	LICENSE 11	CRISPEDGE 0.25	*[–ATR] 11	*H*
a. re'kohelɔ	+.9	−.8	−1 −.5	~~−11~~ → −10.5
(☞) b. re'kɔhelɔ	+2 +.5	−.7	−2 −.5	~~0~~ → 2
(☞) c. re'kɔhɛlɔ	+3 +0	+.6	−3 −.9	~~0~~ → 2.7
(☞) d. rɛ'kɔhɛlɔ	+4 −.9	−1 +.7	−4 +.2	~~−0.25~~ → −5.35
e. rɛ'kɔhelɔ	+3 +.2	−1 −.2	−3 +.6	~~−0.25~~ → −1.25

Candidate- & Cell-Level Noise

- Weights used:

Constraint	Weight
*[–ATR]	11
License	11
CrispEdge	0.25
Max(–ATR)	50
Anchor-R	100
*[+hi, –ATR]	40

Candidate- & Cell-Level Noise



* = unattested; those with near-zero frequencies (6 tokens) all come from cell-level noise.

- It is impossible for *[monɛˈdɛrɔ]/*[mɔneˈdɛrɔ] to be less frequent than both [moneˈdɛrɔ] and [mɔnɛˈdɛrɔ].

Candidate- & Cell-Level Noise

- Why? A contradiction:

/monɛˈdɛrɔ/	License	*[–ATR]	CrispEdge
a. monɛˈdɛrɔ	+3	−3	−1
(☞) b. mɔnɛˈdɛrɔ	+4	−4	−2
(☞) c. moneˈdɛrɔ	+2	−2	

- To be less harmonic than [mɔnɛˈdɛrɔ]:
  $w(\text{License}) > w(\text{*[–ATR]}) + w(\text{CrispEdge})$
- To be less harmonic than [moneˈdɛrɔ]:
  $w(\text{License}) < w(\text{*[–ATR]})$
- Similarly for *[ˈkɔmetɛlɔ]/*[ˈkɔmɛtelɔ].

Candidate- & Cell-Level Noise

Noise Type	Mean Steps	Maximum Steps
Candidate	3.09	29
Cell	3.25	23

- Consecutive steps can favor different candidates, hence slower convergence.

Interim Summary

- Only constraint-level noise accurately models Eastern Andalusian (in all its forms).
- In this respect, serial NHG resembles parallel NHG (Kaplan 2018a; Kaplan 2019).

Revisiting Analytical Assumptions

1. Harmony involves a competition between LICENSE and *[–ATR]; why not use IDENT as the anti-harmony constraint?
2. Fell-swoop harmony vs. stepwise harmony

Ident

- Eastern Andalusian has no ATR contrast, indicating w(*[–ATR]) $>$ w(Ident), so License must compete with *[–ATR].
- But using Ident reveals interesting properties of serial NHG...

Ident

- In parallel NHG, the choice of *[–ATR] or Ident is inconsequential because all vowels are [+ATR] underlyingly:[1]

/rekóhelos/	*[–ATR]	Ident(ATR)
a. reˈkohelɔ	−1	−1
(☞) b. reˈkɔhelɔ	−2	−2
(☞) c. reˈkɔhɛlɔ	−3	−3
(☞) d. rɛˈkɔhɛlɔ	−4	−4
e. rɛˈkɔhelɔ	−3	−3

[1] Setting aside rich-base inputs, of course.

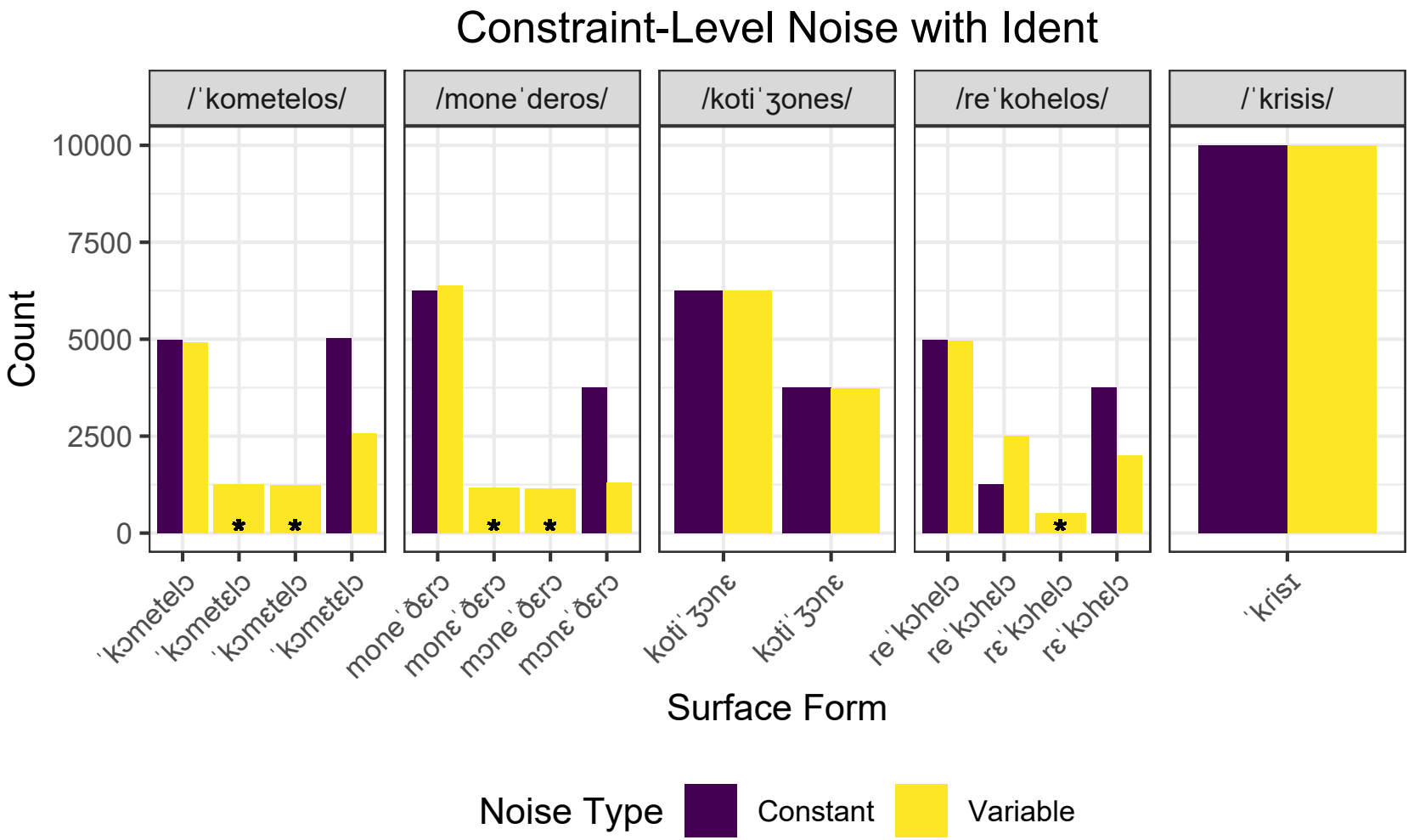
Ident

- Serially, the constraints diverge: if one step creates a lax vowel, on the next step Ident and *[–ATR] conflict.
  - Step 1: /rekóhelos/ → [reˈkohelɔ]
  - Step 2:

/reˈkohelɔ/	*[–ATR]	Ident(ATR)
a. reˈkohelɔ	−1	
b. reˈkohelo		−1
c. reˈkɔhelɔ	−2	−1
d. reˈkohɛlɔ	−2	−1
e. rɛˈkohelɔ	−2	−1

- On any step:
  - w(*[–ATR]) > w(License) → undo harmony (no convergence unless there's nothing to undo).
  - w(Ident) > w(License) → stop right here (convergence!).

Ident



- Constant noise: either License gives maximal harmony, or Ident gives minimal harmony.
- Variable noise: harmony proceeds until either all vowels are harmonized or Ident gets the upper hand.

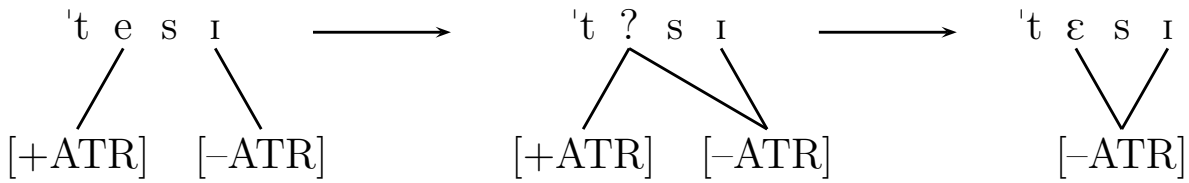
- This replicates Kimper (2011b): in Serial Variation (= Harmonic Serialism whose ranking can change on each step):
  - Markedness vs. markedness → lockstep/global optionality
  - Markedness vs. faithfulness → local optionality

- Prediction (not, I believe, noted by Kimper):
  - Local optionality occurs with contrastive features (because that implies FAITH(F) ≫ *F, making FAITH(F) the constraint participating in a variable ranking).
  - Lockstep optionality occurs with non-contrastive features (because that implies *F ≫ FAITH(F)).
- Eastern Andalusian bears this out: lockstep harmony within the pretonic and post-tonic domains, and [ATR] is not contrastive.

Ident

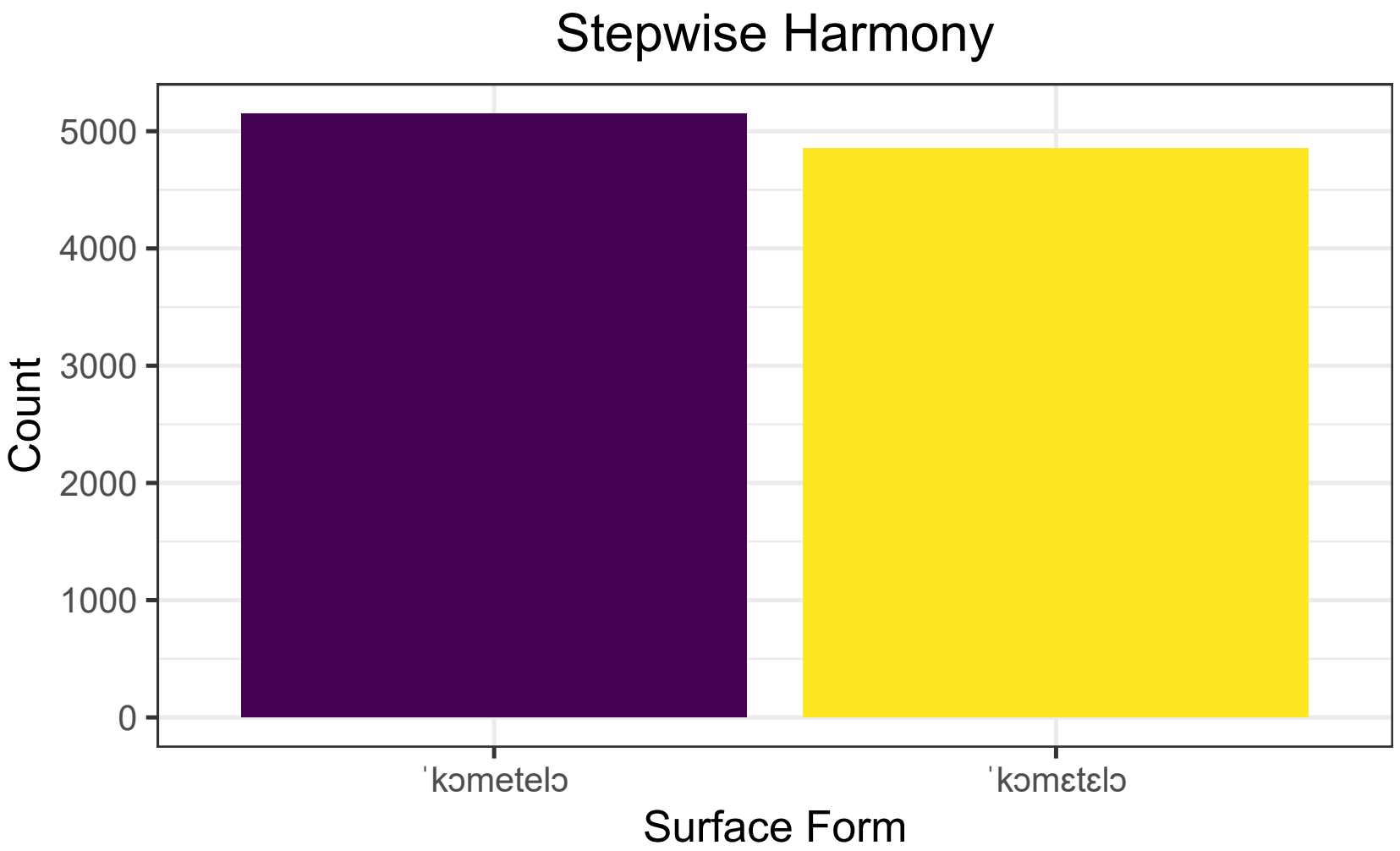
- Independent evidence suggests *[–ATR] is the active constraint, not Ident, but:
  - Constraint-level constant noise still gives good results with Ident (until we consider rich-base inputs).
  - Using Ident reveals that at least one version of serial NHG closely resembles Serial Variation.

Stepwise Harmony



- Potential pitfall: weights trigger the first change (spreading) but not the second change (deletion of [+ATR]) on the next step. Can we avoid convergence on *[ˈtʔsɪ]?
- Yes: weight the constraint responsible for second step high enough so it's unlikely to be crucially dominated.
  - I.e. $w(*\textsc{DoubleAssociation}) > w(\textsc{Ident})$
    - *DoubleAssociation: -1 for each segment bearing two instances of one feature.

Stepwise Harmony



- Only /ˈkometelos/ used here to keep things simple.

Stepwise Harmony

- Weights giving this result:

Constraint	weight
*Double	8
Ident	1
*[–ATR]	8
License	17
Max(–ATR)	50
Anchor	50

Conclusion

- Serial NHG is broadly similar to related frameworks:
  - Like parallel NHG, constraint-level noise models Eastern Andalusian, but candidate- and cell-noise do not.
  - With variable noise, the choice between markedness and faithfulness resembles Serial Variation.
- As far as Eastern Andalusian is concerned, constant and variable (cumulative or not) noise are roughly comparable.
- Stepwise harmony is compatible with serial NHG.
- Maybe we can draw reasonable conclusions about serial NHG from work done in parallel NHG.

- MaxEnt (Goldwater & Johnson 2003)?
- The simulations shown here use only premultiplicative noise: add noise to weight, then multiply by violations. What about post-multiplicative noise?
- Do these conclusions hold beyond Eastern Andalusian?

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