Complexity as a solution to GLA-style learning challenges

This paper investigates the learning challenges encountered when using stringency scale-referring markedness constraints (de Lacy, 2002) to account for vowel harmony (VH). Antagonistic constraints can cause problems for the Gradual Learning Algorithm (GLA; Boersma & Hayes, 2001) when learning a VH language. This effect is exacerbated by reference to stringency scales, as the scale-referring markedness constraints can introduce a surfeit of antagonistic constraints. Illustrated using a typology of vowel phonotactics in Balto-Finnic (BF) languages, I show how introducing additional complexity into the constraint set can decouple antagonistic constraints, offsetting their potential adverse effects on the GLA's learning of such grammars.

Background: Each BF language (Uralic family) uses a subset of the vowel inventory /i, e, æ, y, ø, ɨ, ɤ, ɑ, u, o/. These languages define a typological landscape of monophthong phonotactics that includes various degrees of positional restrictions and/or progressive back-front VH. The varieties exhibiting VH may include harmonic alternations, neutral transparent vowels, and/or neutral opaque vowels. See Table 1.

Language	Inventory	Restrictions in σ_{2+}	Vowel harmony			
			Back	Front	Transp.	Opaque
N Estonian	i,e,æ,y,ø,ɤ,ɑ,u,o	* æ,y,ø,ɤ	-	-	-	-
Finnish	i,e,æ,y,ø,ɑ,u,o	-	ɑ,u,o	æ,y,ø	i,e	-
S Seto	i,e,æ,y,ø,ɨ,ɤ,ɑ,u,o	* ø,ɨ	ɨ,ɤ,ɑ,u,o	e,æ,y,ø	i,e[1]	o

Table 1: Selected BF vowel patterns (Metslang, 2022; Laakso, 2022; Pajusalu, 2022)

Framework for analysis: To account for this broad landscape of vowel patterns, I use a combination of stringency scales (de Lacy, 2002) and no-disagreement constraints (Pulleyblank, 2002); hence the constraint set is quite large (74 total). Sample constraints:

(1) ***F$_3$**: Assign a violation mark for each output segment that is in F$_3$={ø,æ,y}.

(2) ***F$_3$...B$_5$**: Assign a violation for each instance of a back vowel from set B$_5$={ɨ,ɤ,o,u,ɑ}, preceded at any distance by at least one front vowel from set F$_3$={ø,æ,y}.

I use positive evidence as input to the GLA (implemented in OTSoft (Hayes et al., 2013)), running a learner with two widely-used biases: low initial faithfulness (Gnanadesikan, 1995) and specific over general faithfulness (Hayes, 2004).

Learning challenges: Vesik (2022) shows that antagonistic constraints such as ***F**$_m$ and ***B**$_n$ can cause problems for the GLA when learning a VH language. The antagonistic constraints oscillate (when one is promoted the other is demoted), staying near their initial values along with unviolated no-disagreement constraints, while faithfulness constraints rise unchecked. Since oscillation in constraints antagonistic for [±back] is caused primarily by attempting to repair disharmony via changes in [±back], I decouple these issues by introducing a second potential repair strategy (specifically, deletion) to address harmony violations.

Success of increased complexity: Adding breadth to the potential ways in which to be unfaithful provides the GLA with enough flexibility to separate the trajectories of the ***F**$_m$ and ***B**$_n$ constraints that would otherwise oscillate relative to each other. (3) and (4) show selected final constraint values under both frameworks, after simulations with Finnish learning data as input.

[1] /e/ is transparent only in initial syllables.

(3) With only change in [±back] as a repair for disharmony:

Idσ_1(Bk)	136.200
Id(Bk)	116.200
*F_3...$\underline{B_5}$	110.000
*$\underline{B_5}$...F_3	108.200
*B_5	103.800
*F_3	102.200

(4) With deletion and change in [±back]:

Maxσ_1	114.248
Idσ_1(Bk)	114.200
*F_3...$\underline{B_5}$	100.000
*$\underline{B_5}$...F_3	100.000
Max	94.248
Id(Bk)	94.200
*F_3	74.180
*B_5	41.578

The cyan- and green-highlighted constraints are unviolated by the learning data and should end up at the top of the final ranking. In an ideal situation, approximately antagonistic pairs (e.g. orange ***B**$_5$ and ***F**$_3$) should drop from their initial value of 100, leaving space for rising (yellow) general faithfulness constraints to settle in between. In (3) they are unable to do so, tied fairly close to both each other and their original value, whereas in (4) they are able to move independently, resulting in greater movement both with respect to each other as well as downward overall. Tableaux (5) and (6) show that an underlyingly disharmonic input to each potential grammar for Finnish produces an incorrectly faithful result in the grammar from (3), but a harmonic result in the grammar from (4), respectively.

(5) Not including deletion as a repair option results in disharmonic vowel sequences incorrectly surfacing.

/æ..o/	Idσ_1(Bk)	Id(Bk)	*F_3...$\underline{B_5}$	*$\underline{B_5}$...F_3
a. ☞ æ..o			*	
b. ☹ æ..ø		*!		

(6) Including deletion as a repair option results in disharmonic vowel sequences being correctly banned.

/æ..o/	Maxσ_1	Idσ_1(Bk)	*F_3...$\underline{B_5}$	*$\underline{B_5}$...F_3	Max	Id(Bk)
a. æ..o			*!			
b. ☞ æ..ø						*
c. æ.._					*!	

This addition, although adding yet more complexity to an already very-large constraint set, has dual benefits: (1) It allows the GLA to acquire a much better grammar to account for its learning data, while considering the breadth of vowel patterns attested in the BF languages; (2) it reflects the complexity of reality via incorporation of dimensions other than only identity of feature [back] into the constraint set.

Selected references: de Lacy, P. (2002). *The formal expression of markedness.* Doctoral diss., UMass Amherst. ROA 542. | Gnanadesikan, A. (1995). Markedness and faithfulness constraints in child phonology. ROA 67. | Hayes, B. (2004). Phonological acquisition in optimality theory: The early stages. Cambridge University Press. | Laakso, J. (2022). Finnish, Meänkieli, and Kven. In *The Oxford Guide to the Uralic Languages [OGUL].* | Metslang, H. (2022). North and Standard Estonian. In *OGUL.* | Pajusalu, K. (2022). Seto South Estonian. In *OGUL.* | Pulleyblank, D. (2002). Harmony Drivers: No Disagreement Allowed. In *Proceedings of the 28th Annual Meeting of the BLS*, 249-267. | Vesik, K. (2022). The Calibrated Error-Driven Ranking Algorithm as a Solution to Oscillation in Antagonistic Constraints: A Necessary Bias for Algorithmic Learning of Kihnu Estonian. In *Supplemental Proceedings of the 2022 AMP.*