LEARNING OPAQUE AND TRANSPARENT INTERACTIONS IN HARMONIC SERIALISM

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It has long been hypothesized that opaque process interactions are less natural and more difficult to learn than transparent interactions (Kiparsky 1968). However, the potential impact on phonological theory of these central debates has been limited by a lack of explicit computational models capable of learning opaque interactions and making precise and testable predictions for language acquisition and change. Building on recent developments in phonological theory and learnability that enable the modeling of opaque interactions in Harmonic Serialism (HS) and the learning of hidden structure in phonology, respectively, this paper presents initial modeling results comparing the relative learnability of four basic types of process interactions: bleeding, feeding, counterfeeding and counterbleeding. The overall findings support an inherent learning bias against opaque interactions; however, the specific patterns of preference depend substantially on the framework and choice of constraints.

The language system used for modeling is a hypothetical system involving potential interactions between a palatalization process (s → ʃ / _i) and a vowel deletion process (V → ∅ / _V). In the transparent interaction (1), vowel deletion applies first and palatalization second, resulting in bleeding (1c) and feeding (1d) interactions, depending on input. In the opaque interaction, palatalization applies before vowel deletion, leading to counterbleeding (2c) and counterfeeding (2d), depending on input.

1) Transparent Interaction

	a. Deletion	b. Palatalization	c. Bleeding	d. Feeding
Underlying	/sa-a /	/si/	/si-a/	/sa-i/
Deletion	sa	—	sa	si
Palatalization	—	ʃi	—	ʃi
Surface	[sa]	[ʃi]	[sa]	[ʃi]

2) Opaque Interaction

	a. Deletion	b. Palatalization	c. Counterbleeding	d. Counterfeeding
Underlying	/sa-a/	/si/	/si-a/	/sa-i/
Palatalization	—	ʃi	ʃia	—
Deletion	sa	—	ʃa	si
Surface	[sa]	[ʃi]	[ʃa]	[si]

The theoretical framework used for modeling these four interactions is a variant of HS called Serial Markedness Reduction (SMR; Jarosz 2014b). In SMR, candidates encode newly satisfied markedness constraints in a list called *mseq* that is initially empty <> and is updated on each pass. As shown in 3, deletion requires *VV ≫ MAX, while Palatalization requires *SI ≫ IDENT. Unlike in OT, in HS, potential feeding interactions (4) require *VV ≫ *SI because the required step of deletion creates a violation of *SI.

3) Crucial Rankings for Individual Processes in HS: Iteration 1

/sa-a/ <>	*VV	MAX
a. sa-a < >	W*	L
☞ b. sa <*VV>		*

/si/ <>	*SI	IDENT
a. si < >	W*	L
☞ b. ʃi <*SI>		*

4) Feeding / Counterfeeding: Iteration 1

/sa-i/ <>	*VV	MAX	*SI	IDENT
a. sa-i < >	W*	L	L	
☞ b. si <*VV>		*	*	

The SMR constraint SM(*SI, *VV), which assigns a violation to an *mseq* in which *SI follows or occurs simultaneously with *VV, is necessary to favor opaque interactions. With these rankings established, on the second iteration of the potential feeding interaction (5), SM(*si, *VV) ≫*si results in counterfeeding, while the opposite ranking results in feeding. In the potential bleeding interaction (6), the choice between transparency and opacity is made on the first iteration: bleeding occurs unless SM(*si, *VV) ≫*VV.

5) Feeding / Counterfeeding: Iteration 2

	/si/ <*VV>	*VV	Max	*si	Ident	SM(*si, *VV)
counterfeeding	a. si <*VV>			*		
feeding	b. ʃi <*VV,*si>				*	*

6) Bleeding / Counterbleeding: Iteration 1

	/si-a/ <>	*VV	Max	*si	Ident	SM(*si, *VV)
faithful	b. si-a < >	*		*		
bleeding	a. sa <*VV+*si >		*			*
counterbleeding	b. ʃi-a <*si>	*			*	

To model learning in this system, the general approach to hidden structure learning developed by Jarosz (2014a) is adapted to an HS framework. In this approach, the grammar is represented in terms of pairwise ranking probabilities (e.g. P(A≫B), P(A≫C), etc.), and it is these parameters that are updated during learning. To compute the update, each pairwise ranking A≫B is tested by sampling the predicted outputs from a temporary grammar that is just like the current grammar except with A≫B categorically set. Updates reward pairwise rankings that succeed in correctly generating the observed output form. In this way, hidden structure is irrelevant to the mechanics of learning, and adapting the approach to HS requires only implementing an HS, iterative EVAL production module – everything else is identical.

The initial grammar for all simulations ranks all constraints equally. The languages in 1 and in 2 were both learned correctly on all runs, confirming that the model is capable of learning both opaque and transparent interactions in SMR. Additionally, to compare the relative learnability of the four process interaction types, learning was examined on four test sets that included only 1a and 1b, plus exactly one of the interaction types (1c, 1d, 2c, or 2d). The number of learning iterations required for the model to converge on the correct grammar on average (out of 20 runs) was used as a proxy for learning difficulty. As shown in 7, bleeding was learned most quickly, feeding next most quickly, and the opaque interactions were learned most slowly and did not differ significantly from one another.

7) Ave (s.d.) of 20 runs	*Bleeding*	*Feeding*	*Counterbleeding*	*Counterfeeding*
Iterations till convergence	56.0 (9.9)	90 (17.2)	153.5 (25.6)	150.5 (30.9)

The results depend only on the ranking requirements of the above SMR analysis: no prior biases of any kind are assumed. Feeding is harder than bleeding because feeding requires an extra crucial ranking (4) be learned. Opaque interactions are harder because they require SM constraints rank above markedness, which must be above faithfulness, requiring more 'spread out' rankings. The paper discusses alternative analyses that result in different predictions. For example, under different constraint formulations, bleeding and feeding become equally easy. In general, predictions for learning difficulty can hinge on minute details of the theory, and a great deal of careful modeling work is needed before any general conclusions can be reached.

SELECT REFERENCES

Jarosz, G. 2014a. Stochastic, reward-based learning of hidden structure in phonology. Paper presented at *11th Meeting of the Old World Conference in Phonology*, Leiden, Holland.

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