Paradigm uniformity and neutralization avoidance in phonological learning

We examine two biases previously shown to influence phonological learning: paradigm uniformity and neutralization/homophony avoidance. In terms of paradigm uniformity, adults and children tend to avoid phonological alternations both in artificial language learning and natural language learning, for instance, by failing to apply an alternation in the required context or by choosing alternative constructions (e.g. Tessier 2012, Do 2018). In terms of neutralization avoidance, Yin and White (2018) found that adults were worse at learning a set of palatalization rules in an artificial language when the rules caused neutralization, particularly when the neutralization also created homophony.

In this study, we use the 'mixture-shift' paradigm (Culbertson et al. 2012) to examine how these biases affect learning of a variable pattern. We exposed learners to an artificial language in which the plural was variably marked by one of two prefix forms (*ba-* or *ni-*), one frequent and one infrequent (depending on condition). Crucially, for one group of participants, the *ni-* also triggered palatalization of stem-initial velar stops (e.g. [**g**api] ⟶ [ni**dʒ**api]) whereas the *ba-* form triggered no alternations. For a second group, we altered the phoneme inventory of the language (e.g. adding stem [**dʒ**api]) so that these alternations were neutralizing and homophony-creating. A third group (a control group) saw no alternations during the experiment. We expected participants to shift away from *ni-* (use it less frequently) when it caused alternations, and we expected neutralization to result in an even greater shift away from *ni-* or to inhibit acquisition of the palatalization rule.

Design and Method: Participants were randomly assigned to one of nine groups (25 native English speakers per group; 225 in total), depending on the type of alternations presented in training (no alternations, non-neutralizing alternations, or neutralizing alternations) and the frequency of the two prefix variants in training (frequent *ba-*, frequent *ni-*, or equifrequent).

Participants were told that an alien instructor (who appeared on the screen) would be teaching them an alien language. The experiment consisted of four phases: stem learning, stem testing, affix learning, and affix testing.

(1) *Stem learning*: Participants heard 10 nonce CVCV noun stems (e.g. *gapi*) paired with images of singular objects. Each stem was repeated 10 times (100 total trials).

(2) *Stem testing*: Participants were asked to produce the correct word aloud after seeing an image. They received feedback by hearing the correct word after each response. Each stem occurred 5 times (50 total trials). Responses were coded in real time by the experimenter (seated in an adjacent room). Participants were given two chances to pass the test at a criterion of 70% accuracy; those who failed the second test were excluded.

(3) *Affix learning*: Participants saw plural images and heard CV-CVCV plural forms (e.g. *ba-gapi*) for the stems they had previously learned. The frequency of *ba-* and *ni-* depended on the frequency condition: *ba-* in 2/3 of the trials and *ni-* in 1/3 for the frequent *ba-* group, *vice versa* for the frequent *ni-* group, and a 50-50 split in the equifrequent group. Each stem was presented 6 times (60 total trials). The prefix *ni-* triggered palatalization in velar-initial stems in the appropriate conditions, changing [k, g] to [tʃ, dʒ]. Four of the ten stems were velar-initial.

(4) *Affix test*: The procedure was identical to the stem test, but participants produced prefixed forms (in response to plural pictures). Participants were instructed that there was more than one correct way to say words in the language. After participants responded, the alien instructor produced one of the two correct forms (the *ba-* or *ni-* form, with palatalization where appropriate)

following the same proportions used in training.

Results and Discussion: Results were analyzed using mixed effects logistic regression models. First, we examine how often participants chose the frequent prefix in the final test phase according to condition (Table 1, left). In most conditions, we found frequency matching, meaning output frequency matched input frequency (shaded cells); setting aside the 50-50 control conditions, modelling found no significant difference between any of the shaded cells. There was one exception: participants trained with frequent *ba-* and non-neutralizing alternations used the frequent variant significantly more often compared to the other five groups ($p < .01$). To state the finding in a more helpful way: when *ni-* caused alternations and *ni-* was infrequent, participants shifted away from it in favor of *ba-*.

Curiously, the shift away from *ni-* was not found when it caused neutralizing alternations, but this could be because participants did not robustly learn the alternations when they were neutralizing. Thus, we next examine how often participants actually applied the palatalization to velar-initial stems after *ni-* in each condition (Table 1, right). When the alternations were non-neutralizing, participants applied the palatalization at a high rate, and relatively equally across frequency conditions. However, when the alternations were neutralizing, participants were significantly less successful at applying the palatalization ($p < .01$), particularly in the frequent *ba-* condition where they had the least exposure to it in the input ($p=.05$ for the interaction).

Table 1. Proportion of frequent prefix used (left) and proportion of palatalization applied where appropriate (right), according to condition. *Ba-* was arbitrarily chosen as the frequent variant in the 50-50 conditions. Numbers in parentheses show how often the frequent variant was presented in training.

	Proportion frequent prefix variant chosen				Proportion palatalization applied with *ni-* (velar-initial stems only)		
	50-50	Freq *ba-*	Freq *ni-*		50-50	Freq *ba-*	Freq *ni-*
No alternations	.47 (.50)	.59 (.67)	.65 (.67)		--	--	--
Non-neutralizing alternations	.51 (.50)	.76 (.67)	.67 (.67)		.73	.74	.72
Neutralizing alternations	.49 (.50)	.67 (.67)	.66 (.67)		.60	.46	.62

To summarize, we found that paradigm uniformity and neutralization avoidance both affected learning, but they did so in distinct ways. Paradigm uniformity caused learners to shift away from infrequent variants that caused alternations (making them even less frequent). Neutralization made it more difficult for learners to acquire the alternations in the first place. These results support and bolster recent findings, for instance Do's (2018) finding that Korean children use alternative constructions to avoid applying alternations in Korean (even though they know the alternations) and Yin and White's (2018) finding that adults struggle to learn neutralizing and homophony-creating rules in an artificial language. This study also emphasizes that the influence of these biases is highly dependent on input frequency.

References:

Culbertson, J., Smolensky, P., & Legendre, G. (2012). Learning biases predict a word order universal. *Cognition, 122,* 306–329.

Do, Y. (2018). Paradigm uniformity bias in the learning of Korean verbal inflections. *Phonology, 35*(4), 547–575.

Tessier, A.-M. (2012). Testing for OO-Faithfulness in the acquisition of consonant clusters. *Language Acquisition*, *19*(2), 144–173.

Yin, S. H., & White, J. (2018). Neutralization and homophony avoidance in phonological learning. *Cognition*, *179*, 89-101.