## Experimental Evidence that Learning of Morphophonological Alternations starts Local

Surface alternation among allomorphs and allophones is often phonologically conditioned, and language learners must discover what in the phonological environment makes the surface form predictable. For example, the surface form of the English PL morpheme—[z], [s], or [əz]—is predictable from the segment left-adjacent to the morpheme. Statistical learning studies have consistently found evidence that learners can track dependencies between adjacent items from a range of linguistic and non-linguistic domains [2, 4, 5], that the ability to track non-adjacent dependencies only emerges later in development [3], and that learners asymmetrically prefer tracking adjacent dependencies over non-adjacent dependencies [3]. Recent work has hypothesized that these facts form the basis of phonological alternation learning, and encoded that hypothesis in an explicit computational model [1]. The model constructs phonological generalizations by localizing its search for the conditioning phonological environment around the alternating segment and expanding the breadth of its search only when unable to sufficiently predict the surface form from adjacent segments. This hypothesis predicts that if both adjacent and non-adjacent segments are equally and fully predictive of an alternating segment's surface form, then learners will construct a generalization based only on the adjacent segments. In this work, we evaluate this prediction using a poverty-of-stimulus artificial-language-learning paradigm [6].

**Method.** We designed an artificial language in which plurals are formed by adding a suffix to the SG form. The PL morpheme has two forms, [-f] and [-ʃ]. Stems are of the form CV.CV or CVC.CV, and the PL morpheme's form is predictable from the final segment V, but also from the penultimate segment C. When the final V is [+back] {u, ɔ}, the PL form is [-f]; when the final V is [-back] {i, ɛ} the PL form is [-ʃ]. Likewise, when the penultimate C is [+voi] {d, b}, the PL form is [-f]; when it is [-voi] {t, p} the PL form is [-ʃ]. The alternation was designed to lack phonetic motivation in order to control for the possibility that a preference for adjacent dependencies results from phonetic pressures like coarticulation. In the exposure phase, the penultimate C is always [+voi] when the final V is [+back] and [-voi] when it is [-back]. Thus, there are three generalizations consistent with the exposure data, written in rule-notation in (1), where "[*]" means "any segment."

(1) (a) PL → [-f] / [+back] __ [-ʃ] elsewhere
(b) PL → [-f] / [+voi][+back] __ [-ʃ] elsewhere
(c) PL → [-f] / [+voi][*] __ [-ʃ] elsewhere

Our description of [-ʃ] as the default/elsewhere PL form is only for ease of presentation. Our evaluation accounts for the possibility that [-f] is treated as default or that neither form is treated as default.

The exposure data underdetermines the generalization. The hypothesis encoded in [1]'s model predicts that learners will construct (1a). Each generalization's predictions for test items that end in [-voi][+back] or [+voi][-back] (unlike the exposure items) are in (2), again using default /ʃ/ only for presentation.

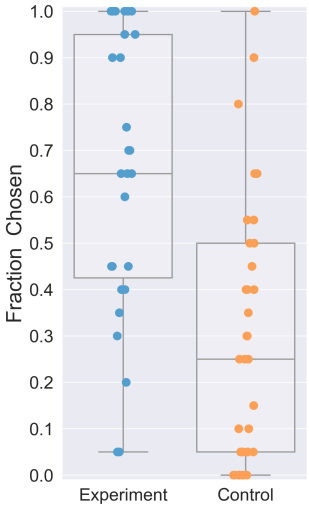
(2)(a) /dupu-ʃ/ → [dupuf]
/pidpɔ-ʃ/ → [pidpɔf]
(b) /dupu-ʃ/ → [dupuʃ]
/pidpɔ-ʃ/ → [pidpɔʃ]
(c) /dupu-ʃ/ → [dupuʃ]
/pidpɔ-ʃ/ → [pidpɔʃ]

Participants—adult L1 speakers of English (avg age 31.5yrs); 27 in Exp group; 33 in Control—were recruited on Prolific and compensated $16/hr. During an exposure phase, participants were presented

SG-PL pairs: each presented auditorily along with a picture of a simple object for the SG and multiple of the same object for the PL. The exposure data consisted of 100 pairs, of which 50 SGs ended in [+voi][+back] (taking [-f]) and 50 ended in [-voi][-back] (taking [-ʃ]). The presentation order was random. A control group was presented the same data, but only the SG forms, and hence no information about how PLs are formed. A test-phase followed with a sequence of two-alternative forced-choice trials. In each trial, participants were presented auditorily with a SG, along with a picture, and then two options for the PL form of the SG, one taking [-f] and one [-ʃ]. The participants chose which form they thought was the "correct" form in the language they had just learned. The order in which the choices were presented was randomized. The test data contained 12 "Train-Like" trials, with test items following the training distribution (ending in [+voi][+back] or [-voi][-back]) and 40 "Novel" trials following the distribution unseen during training (ending in [-voi][+back] or [+voi][-back]).

**Results.** To confirm that a generalization was learned and whether learners treat either PL form as default, we fit a mixed-effects logistic regression model to the responses on Train-Like test trials. Model coefficients along with Z-tests for EMMs reveals that (a) the experimental group effectively constructs a training-consistent generalization—e.g. one of those in (1)—and (b) both groups treat [-ʃ] as the default form, possibly because it is more salient than [-f] and more similar to the english plural [-s].

Since both groups treated [-ʃ] as the default, we evaluated which generalization in (1) Exp group learners constructed. (1a) predicts that Exp group will select [-f] for [-voi][+back] forms more than the Control group, whereas (1b)-(1c) predict that the Exp group will select [-ʃ] for such forms (indistinguishably from the Control group, who treats [-ʃ] as default). The figure below shows, for each participant, the fraction of [-voi][+back] trials where they chose the [-f] form. The Exp group selected the [-f] form much more than Control, consistent with (1a). To evaluate this quantitatively, we fit a mixed-effects log. reg. model to the responses on Novel trials. The model's response variable was whether the [-f] form was chosen; its coefficients are in the table below. The coefficients, together with an ANOVA test comparing the model to its subset without the interaction reveal a significant interaction between Group x Type (both $p < 0.01$). A Z-test for the Estimated Marginal Means between Groups for each Type reveals that the Exp group selected the [-f] form significantly more often than the Control ($p < 0.01$), strongly supporting [1]'s hypothesis (1a).




| Coefficient | Estimate | Std. Err | Pr(> \|z\|) |
|---|---|---|---|
| Intercept | −1.49597 | 0.26077 | < 0.00001*** |
| Group | 1.12214 | 0.37761 | 0.00296** |
| Type | 0.22687 | 0.07582 | 0.00277** |
| Group × Type | 0.80069 | 0.10386 | < 0.00001*** |

**References [1]** Belth, C. (In Press). A learning-based account of local phonological processes. *Phonology*. **[2]** Fiser, J. and Aslin, R. N. (2002). Statistical learning of higher-order temporal structure from visual shape sequences. *Journal of Exp. Psych.: Learning, Memory, and Cog*. **[3]** Gómez, R. and Maye, J. (2005). The developmental trajectory of nonadjacent dependency learning. *Infancy*. **[4]** Saffran, J. R., Aslin, R. N., and Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*. **[5]** Saffran, J. R., Johnson, E. K., Aslin, R. N., and Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition*. **[6]** Wilson, C. (2006). Learning phonology with substantive bias: An experimental and computational study of velar palatalization. *Cognitive Science*.