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Authors

MacDonald, Calen
Christiansen, Morten H

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Feedback Maintains Stability in Cultural Transmission

Calen MacDonald (cmc262@cornell.edu)
Department of Psychology, Cornell University, Ithaca, NY 14853, USA

Morten H. Christiansen (christiansen@cornell.edu)
Department of Psychology, Cornell University, Ithaca, NY 14853, USA

Abstract

Word order tends to be transmitted stably between generations of speakers. This is perhaps because languages typically use one of two strategies to express who-does-what-to-whom: strict word order (e.g. English) or flexible word order with a case marking system (e.g. Russian). Second language learners can destabilize and change the languages they acquire, due in part to competition between their first and second languages. There is reason to think that how one acquires a second language affects this competition. One such way of affecting language learning is feedback. In our preregistered study, 90 native English speakers learned and transmitted an artificial language with flexible word order and case marking across 15 iterated learning chains while receiving positive, negative, or no feedback. The original flexible word order remained most stable across generations of transmission when feedback was given; otherwise English SVO word order was likely to predominate by the final generation. These findings elucidate the role feedback may play in negotiating between competing linguistic variants and ensuring their stable transmission across generations.

Keywords: artificial language; cultural transmission; iterated learning; feedback; word order

Introduction

Human cognition faces the stability-plasticity dilemma (Mermillod, Bugaiska, & Bonin, 2013). Learning demands stable retention of previous knowledge to avoid catastrophic forgetting and enough plasticity to integrate new knowledge to avoid the entrenchment effect. Consequently, language learning is highly local, concerning specific relationships between particular linguistic representations (Christiansen & Chater, 2016). If we model language change as an evolutionary process negotiating among competing linguistic variants (Hruschka et al., 2009), learning one relationship between linguistic representations is less likely to interfere with another when linguistic representations are unchanging. Acquired through lossless transmission, stable language can facilitate the learning of local representations to alleviate the cognitive demands of the stability-plasticity dilemma.

Competition between one's native language and a second language is a clear case of the stability-plasticity dilemma at play. Some languages use word order to convey information about who-does-what-to-whom (i.e., semantic roles or grammatical relations). English uses a strict subject-verb-object (SVO) word order to assign roles. Although the sentences "dog bites cat" and "cat bites dog" are lexically identical, word order changes their meaning. Resultingly, "bites cat dog" and "cat dog bites" are infelicitous and ambiguous in their assignment of roles. Other languages, like Korean, Russian, and Turkish, allow for flexible word orders by using case marking to communicate grammatical roles, leaving word order free to perform pragmatic functions. For example, dog bites cat (SVO) can be translated to Russian as "кошку кусает собака" (SVO) or "собака кусает кошку" (OVS). In both instances -ку marks cat (кош-) with the accusative case to denote it as object and its flexible position at the start or end of the statement pragmatically indicates the speaker's disposition toward the cat.

These two strategies, case marking with flexible word order and strict word order without case marking, are relatively stable and represent different ways of denoting grammatical relationships (Bentz & Christiansen, 2013). In fact, crosslinguistic trends indicate the emergence of case marking tends to entail the emergence of flexible word order (Scherbakova, Tamariz, & Smith, 2024); the strict and flexible strategies have contrastive features and evolutionary origins. Thus, it seems competition between word order strategies might be a source of instability for, for example, heritage Russian speakers acquiring English. However, Laleko (2024) compared the grammaticality judgements of homeland Russian speakers and English-dominant heritage Russian speakers, finding that heritage language word order was not straightforwardly affected by dominant language transfer effects; more important were factors like input frequency and universal constituent placement preferences. So a speaker can stably acquire both a flexible word order and a strict word order language. Rebuschat and Williams (2009) similarly suggest language transfer might not prevent word order learning. They found native English speakers could acquire syntactic knowledge of an artificial language with SVO, VSO, and VOS word orders through exposure alone. But this study was not an iterated learning experiment; though participants learned these word orders, it's unclear if they could transmit them stably. We propose one mechanism allowing for the stable acquisition of different word order strategies is feedback, which the speakers in Laleko (2024) would have received while learning their languages naturalistically.

In the present paper, we employ feedback in an iterated learning experiment to manipulate the stability of word orders competing to express the same meanings. Because feedback improves learning of artificial languages (e.g. Jeuniaux, Dale, & Louwerse, 2009; Monaghan, Ruiz, & Rebuschat, 2021) and second languages (e.g. Carroll & Swain, 1993; Ellis, Loewen, & Erlam, 2006), it may affect

In D. Barner, N.R. Bramley, A. Ruggeri and C.M. Walker (Eds.), *Proceedings of the 47th Annual Conference of the Cognitive Science Society* ©2025 the author(s). This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY).

the stability of word order, narrowly, and language, broadly, across generations of transmission.

If we adopt the notion of *communicative* feedback, proposed by Nikolaus and Fourtassi (2023)., then feedback is both common and effective in natural language. Indeed, they consider such implicit feedback essential to first language acquisition by promoting mutual understanding between children and caregivers. Thus, in conversation, feedback occurs about every eight to ten seconds in the form of backchannels, a type of positive feedback that signals mutual understanding (Dideriksen et al., 2023). Repairs, which constitute requests for clarification, are also frequent, occurring roughly every one and a half minutes (Dingemanse et al., 2015). This kind of communicative feedback, not just mere exposure, might even be necessary to learn certain grammatical structures. In one experiment, learning an artificial language with a double- object dative structure was only possible with feedback and positive feedback produced the best performance (Frinsel, Trecca, & Christiansen, 2024). This suggests that learning some grammatical structures, and thus transmitting them stably, requires feedback, at least for native English speakers.

The iterated learning literature often treats stability as a corollary of linguistic features, not an outcome to be measured in and of itself. Perhaps this is because it can be assumed from computational work that a culturally evolving language adapts to ensure successful transmission, and thus stability, from generation to generation (Smith, Kirby, & Brighton, 2003).

Commonly, iterated learning experiments measure the emergence of structure in an initially unstructured artificial language of form-meaning pairs transmitted along a chain of learners (for reviews see Kirby et al., 2014; Tamariz & Papa, In press). These experiments show that stability and structure do not always correspond. The initially randomly structured languages in Kirby, Cornish, & Smith (2008) converge to different stable strategies in their two experiments, shown by increases in measures of learnability and structure. In the first experiment, lacking a pressure to avoid ambiguity, the languages become systematically underspecified, using just a few labels that can be faithfully replicated but disregard some dimensions of the meaning space—structure is sacrificed for stability. In the second experiment repeated labels are filtered between generations and consequently compositional structure emerges to allow successful generalization of labels without exposure to the entire language; stability and structure arise together. If cultural transmission promotes stability, feedback might affect its instantiation and persistence by facilitating learning. Structure does not guarantee stability if it cannot be learned. We expect feedback will increase learning to maintain the flexibility of the second language.

To show that feedback can facilitate stability we transmit an already-structured artificial language across six generations of learners. Each of the two word orders (VSO, VOS) of our flexible language corresponds to one of two types of scenes (a blue star marks either the subject or the object). In the experimenter-generated language, this correspondence depends on the noun appearing first in the word order (i.e. a VSO sentence corresponds to a scene with the subject marked). We chose VSO and VOS word orders to circumvent the subject-initial, verb-final bias found in silent gesture experiments (Futrell et al., 2015). We also wanted participants to be able to potentially introduce their native English SVO word order into the language through transmission. Thus, participants might destabilize our preformed structure by altering the correspondence of VSO and VOS word orders to scenes and also by introducing SVO word order. We ask, having instantiated structure, how does feedback affect its stability across generations of transmission?

We hypothesized that flexible word order would only remain stable when learned with feedback and, following Frinsel et al. (2024), that positive feedback would maintain the most accurate transmission.

Pre-registration: https://aspredicted.org/FZV_KK3.

Methods

Participants

Ninety native English-speaking Cornell University undergraduate students (60 self-identified as female, 22 male, 8 non-binary; mean age = 19.8, SD = 1.21) participated in the study for course credit. We organized them into 15 transmission chains, each six generations in length, allocating five chains per feedback condition (POS, NEG, or NO Feedback). This study was approved by the Cornell University IRB (Protocol #IRB0147874) and all participants provided informed consent prior to participation.

Materials

We created an artificial language with 24 transitive sentences comprising a verb, a subject, and a case-marked object, corresponding each to one of 24 reversible scenes. The initial experimenter-designed language represented a flexible word order with 12 verb-object-subject (VOS) and 12 verb-subject-object (VSO) sentences. Through transmission the word order was subject to change; each participant had the option to map each scene to a VOS, VSO, or SVO word order. Though the first participant in each chain never saw SVO sentences, English language transfer might introduce SVO sentences to the language. We expect feedback to offset this effect and its amplification through cultural transmission.

Meanings (scenes) Each scene pictured a red arrow (signifying action denoted by the verb *poox*) with a subject animal to its left and an object animal to its right.

Two sentences in each set contained the same words in VSO and VOS word orders (e.g. *poox cat-ma fox* and *poox fox cat-ma*) and expressed the same meaning (e.g. a fox to the left of the arrow and a cat to the right). To visually distinguish these scenes, and because VSO and VOS convey different pragmatic emphases in natural language (recall the Russian

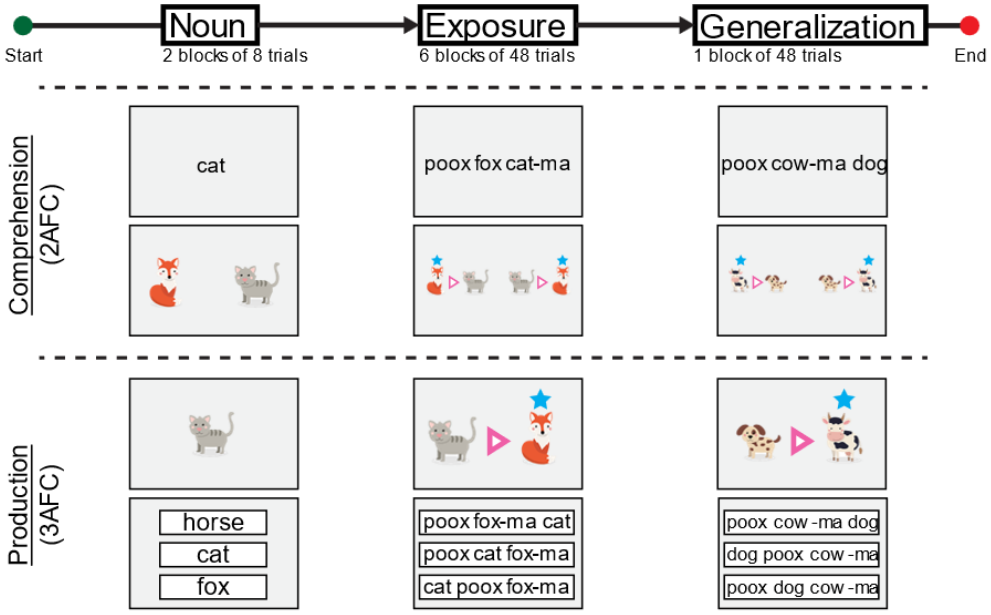


Figure 1: Overview of the experiment. Feedback was given after each Exposure trial, except for the production trials of the sixth block. The scene-sentence mappings made by participant *n* in the production trials of Exposure block six became the input language for participant *n + 1*.

speaker's flexible disposition toward the biting cat), a blue star marked the referent foregrounded in the sentence by being mentioned first. Thus, there were 12 scenes with subject-emphasis (corresponding to 12 VSO sentences in the initial language) and 12 scenes with object-emphasis (corresponding to 12 VOS sentences in the initial language).

Forms (sentences) All sentences contained the same verb (*poox*) and two nouns, one with an object case marker (*-ma*). The language's eight nouns were English words. We divided these into sets for Exposure (*goat, cat, fox, horse*) and Generalization (*dog, sheep, pig, cow*). Sentences were only presented in written form, not auditorily. For example sentences and scenes, see Figure 1.

Procedure

The experiment was programmed in PsychoPy2 version 1.90.3 (Peirce et al., 2022). It had three parts (i.e., Noun, Exposure, and Generalization) consisting of two- and three-alternative forced-choice tasks representing language comprehension (2AFC) and production (3AFC). Participants saw all stimuli in each part, randomized within blocks and trial types. In any given block of trials, the first half involved comprehension and the second half production. Participants completed the experiment on a computer in the lab and were offered a two minute break after the third and sixth blocks of Exposure trials. To begin each trial, participants clicked a fixation cross. Figure 1 illustrates the experiment's three parts.

Noun (2 blocks of 8 trials – see Figure 1, left column) In comprehension trials, participants viewed an English noun for two seconds, then selected one of two animal images: a target and a randomized foil. In production trials, participants viewed an animal image, then selected one of three English nouns: a target and two randomized foils. This initial part familiarized participants with the experiment using recognizable stimuli. Feedback was not given.

Exposure (6 blocks of 48 trials – see Figure 1, center column) In this part of the experiment, for both comprehension and production trials, the target answer was the scene-sentence mapping made by the previous participant, or, in the first generation, the experimenter-generated language. In comprehension trials, participants viewed a sentence from the artificial language for two seconds, then selected one of two scenes. The subject and object roles were reversed between target and foil, while the blue star marked the same referent in both target and foil. Thus, to correctly answer a comprehension trial for the experimenter-generated language required participants understand the role of the case marker.

In production trials, participants viewed for two seconds a scene consisting of two animals, a red arrow, and a blue star, then selected one of three sentences from the artificial language. Always the three answer options contained the same words and varied only in word order: VOS, VSO, and SVO. This means two scenes (differentiated only by the placement of the blue star on the subject or object) always had the same three answer choices; the target answer in the experimenter-generated language required understanding the blue star and its expression of pragmatic emphasis.

Feedback was provided throughout this part of the experiment, except for the production trials of the sixth and final block. The scene-sentence mappings made by participant n in the production trials of Exposure block six became the input language for participant n + 1.

Feedback consisted of a thumbs up (in the POS condition) or a thumbs down (in the NEG condition) received upon answering a trial correctly or incorrectly respectively. After the thumb, participants in both conditions saw the correct scene and sentence mapping together for two seconds. In the No Feedback condition, participants saw the scene-sentence pair they picked after every trial to ensure equivalent language exposure across conditions. Participants only received one type of feedback.

At the end of each of the first five blocks, participants completed an attention check. This was a single production trial with two foil answers and a target answer that read "Click this answer." We planned to exclude participants who failed 30% or more of these trials, but all participants succeeded on the majority of the attention checks.

Generalization (1 block of 48 trials – see Figure 1, right column) The comprehension and production trials of this part were identical to those of the Exposure part, but the scenes and sentences contained novel referents and nouns. Notably, the targets in these trials corresponded to the original experimenter-generated language with 12 VSO and 12 VOS sentences mapped to 12 subject-emphasis and 12 object-emphasis scenes. Feedback was not given.

Data Analysis

For data analysis we used R version 4.4.1 (R Core Team, 2023) and RStudio version 1.4.1106 with the packages lme4 1.1-27 (Bates et al., 2015) and emmeans 1.10.0 (Lenth, 2024). To assist in the convergence of our models we used a Bound Optimization BY Quadratic Approximation (BOBYQA) algorithm (Powell, 2009). We ran Type II Wald Chi-square tests to detect significant differences and the *emmeans* function was used to investigate those differences.

To measure the systematic correspondence between forms and meanings we calculated RegMap, an information-theoretic measure (Tamariz & Smith, 2008; Cornish, Tamariz & Kirby 2009). This measure uses conditional entropy to aggregate partial regularities between forms and meanings in comprehension and production. Well-established in the iterated learning literature, it quantifies the extent to which forms and meaning predict one another on a continuous scale (0 – no predictability, 1- completely predictable) and offers a point of comparison to the emergent systematicity in other studies.

Results

Stability

Word Order (see Figure 2, top half) To compare the production of SVO sentences across conditions we used a generalized binomial mixed-effects model encoding output word order as a binary variable (VSO, VOS = 0 | SVO = 1) with fixed effects for feedback condition, generation, scene emphasis, input word order, and experiment part, plus random effects for participant and scene.

A chi-squared test investing main effects within the binomial mixed effects model found significant differences in SVO production based on condition ($\chi^2(2) = 96.09$, $p < .0001$), generation ($\chi^2(5) = 24.86$, $p = .0001$), scene emphasis ($\chi^2(1) = 33.09$, $p < .0001$) and input word order ($\chi^2(2) = 331.39$, $p < .0001$), but not experiment part ($\chi^2(1) = 0.0126$, $p = 0.91$).

Participants in the NO condition were significantly more likely to produce SVO sentences (52.69%) compared to those in the NEG (1.36%) and POS (6.73%) conditions. Participants in the NO condition produced significant more SVO sentences than participants in the POS (Odds Ratio (OR) = 15.445, SE = 6.62, $z = 6.386$, $p < .0001$) or NEG (OR = 80.701, SE = 37.10, $z = 9.552$, $p < .0001$) conditions. Fewer SVO sentences were produced in the NEG condition than the POS condition (OR = 0.191, SE = 0.0881, $z = -3.591$, $p = 0.001$). For both Exposure and Generalization, the initial word orders were most stable in feedback conditions; participants produced more SVO sentences without feedback.

Regardless of feedback condition, participants were significantly less likely to produce SVO sentences in response to a subject-emphasis scene than an object-emphasis scene (OR = 0.687, SE = 0.0448, $z = -5.752$, $p < 0.0001$). In other words, scenes marking the object animal with the blue star, originally with VOS word order, were more often assigned SVO word orders.

Regularity (see Figure 2, bottom half) We calculated RegMap twice to represent two dimensions of our meaning space: the 12 subject- 12 object-emphasis scenes marked by the blue star and the 24 distinct scenes (or items). In order to compare the systematic correspondences of form and meaning across conditions, we used a linear mixed-effects model with fixed effects for feedback condition, generation, and experiment part, plus a random effect for participant. We created two models, one for each dimension of the meaning space (emphasis and item).

For emphasis RegMap, a chi-squared test investing main effects within the linear mixed-effects model found significant differences based on feedback condition ($\chi^2(2) = 33.0$, $p < .0001$) and experiment part ($\chi^2(1) = 9.93$, $p = .002$) but not generation ($\chi^2(5) = 4.02$, $p = .55$). For item RegMap, a chi-square test showed significant differences based on feedback condition ($\chi^2(2) = 13.62$, $p = .001$) but not experiment part ($\chi^2(1) = .97$, $p = .32$) or generation ($\chi^2(5) = 1.75$, $p = .088$).

Based on the estimated marginal means (EMM), participants in the NO condition expressed significantly less pragmatic emphasis than participants in the NEG (EMM = –0.46, SE = 0.08, $t = –5.7$, $p < 0.0001$) and POS (EMM = –0.27, SE = 0.08, $t = –3.4$, $p = 0.003$) conditions. There were no significant differences in emphasis RegMap between the

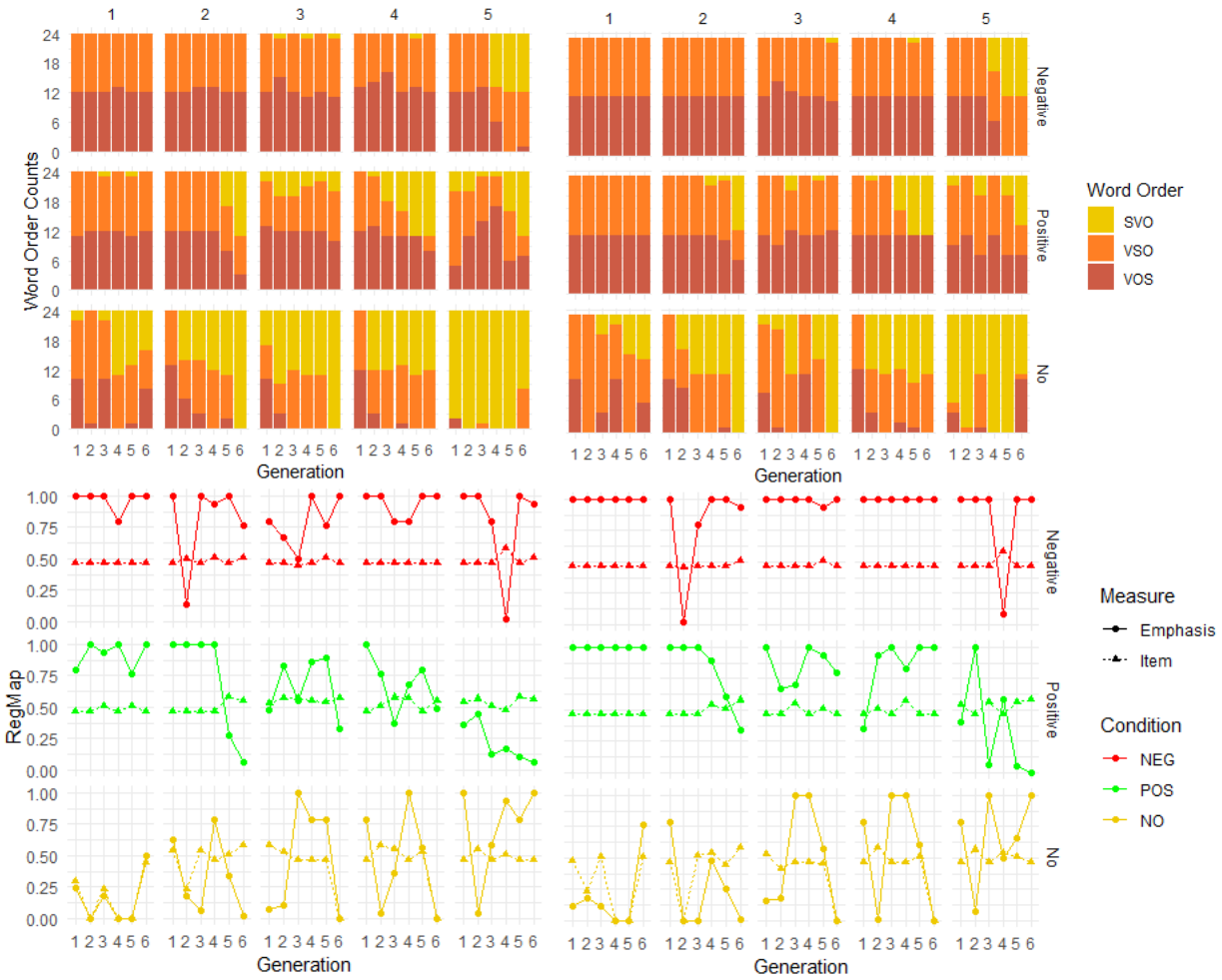


Figure 2: Stability of output languages in Exposure (left) and Generalization (right) production (3AFC) trials. Each graph represents a chain of six participants. Exposure data come from the production trials of the sixth and final block, the language iterated to participant *n + 1*. Word order counts (top) and RegMap (bottom) show stability across generations of forms and form-meaning mappings respectively. Meanings did not change throughout the experiment. RegMap is calculated for word order-pragmatic emphasis and word order-scene (item) mappings.

POS and NEG conditions (EMM = 0.19, SE = 0.08, t = 2.31, p = 0.06).

Similarly for item RegMap, participants in the NO condition were less likely to maintain correspondences between scenes and sentences than in the NEG condition (EMM = –.074, SE = .03, t = –2.49, p = .039) and the POS condition (EMM = –.033, SE = .2150, z = -1.508, p = .2870). There were no significant differences between the POS and NEG conditions (EMM = –.033, SE = .03, t = –1.11, p = .51).

Learnability (see Figure 3)

To compare learning across conditions we ran a generalized binomial mixed-effects model with fixed effects for feedback condition, generation, scene emphasis, input word order, and experiment part, plus random effects for participant and scene. The model assessed performance on comprehension trials.

Accuracy significantly differed based on feedback condition ($\chi2(2) = 64.45$, $p < .0001$), scene emphasis ($\chi2(1) = 11.13$, $p = .0008$), input word order ($\chi2(2) = 540.13$, $p < .0001$), and experiment part ($\chi2(1) = 8.93$, $p = 0.0028$), but not generation ($\chi2(5) = 2.57$, $p = 0.77$). Learning in the NO condition was significant less than in the NEG (OR = 0.16, SE = 0.041, z = –7.24, $p < .0001$) or POS (OR = 0.19, SE = 0.048, z = –6.64, $p < .0001$) conditions. Learning did not differ between NEG and POS feedback conditions (OR = 1.17, SE = 0.21, z = 0.61, p = 0.81). Participants learned scene-sentence mappings best when feedback was given.

SVO sentences offered an improvement in performance over VOS (OR = 18.12, SE = 2.41, z = 21.76, $p < .0001$) and VSO sentences (OR = 3.75, SE = 0.43, z = 11.45, $p < .0001$). VOS sentences were not learned as well as VSO (OR = 0.21, SE = 0.018, z = -18.23, $p < .0001$).

The oscillation patterns in our aggregated data are explained by individual outliers, a consequence of each data point representing only five participants.

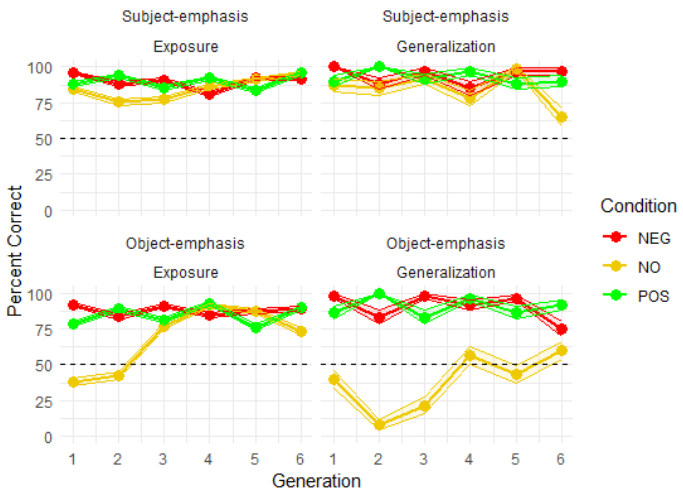


Figure 3: Performance in comprehension (2AFC) trials across Exposure (left) and Generalization (right) parts split by scene emphasis. Exposure performance is averaged across all six blocks. Generalization consisted of only one block. Dotted lines show chance performance. Ribbons are standard error across participants.

Discussion

Our results suggest feedback can overcome language transfer effects to maintain stable linguistic representations across generations of transmission, at least in the case of word order. Compared to the feedback conditions, the languages produced in the NO condition were significant more likely to have SVO word order. These languages also conveyed less information about the meaning space in the form of pragmatic emphasis, indicating they were more unlike the experimenter-generated language than the languages in the feedback conditions. Furthermore, they were less likely to maintain correspondences between scenes and sentences.

Because performance on comprehension trials improved when feedback was given, the familiarity with native SVO sentences was less likely to interfere with the stability of the experimenter-generated language. Even though a strict SVO word order was highly learnable, feedback could maintain the flexible word order. If, as Nikolaus and Fourtassi (2024) argue, we consider feedback to be an important aspect of the linguistic environment, our results experimentally affirm the work of Levshina (2020, 2021) arguing trade-offs between word order strategies are better explained by sociolinguistic factors than efficient linguistic behavior. Stability need not arise from any particular linguistic structure so long as the structures that are present can be learned.

Silent gesture experiments demonstrate a general cognitive bias toward representing reversible transitive events with SVO word order (Futrell et al., 2015; Gibson et al., 2013; Hall, Mayberry, & Ferreira, 2013; Meir et al., 2017). However, this bias can be offset by interactional factors, such as interactive alignment, allowing other word orders to persist (Christensen, Fusaroli, & Tylén, 2016). Adding horizontal transmission to these experiments results in more stable word orders over time (Schouwstra, Naegeli, & Kirby, 2022). Interaction, the feedback it entails, and cognitive biases interact to shape the evolution of word order; languages aren't shaped by cognition alone but evolve in and as part of a complex social environment (Beckner et al., 2009).

Corpus analyses reveal a historical trend toward regularization of flexible word order languages acquired by L2 learners, often associated with a simplification of morphological patterning (Lupyan & Dale, 2010)—including case marking (Bentz & Winter, 2013)—possibly due to L2 production constraints (Bentz & Christiansen, 2013). This challenges the findings of Laleko (2024) regarding heritage speakers and their relative lack of language transfer effects. Perhaps this contrast is motivated by differences in the acquisition of L2 and heritage languages. Our methodology suggests experimental manipulations using feedback might be able to explore these differences. Particularly within the iterated learning literature, feedback might be useful in clarifying how certain linguistic properties, such as structure and stability, and the relationships between them emerge.

Precious few aspects of language are truly stable in an absolute sense. The idiolect is both highly variable between speakers of the same language (Mufwene, 2001) and across the lifespan of the individual (Louwerse, 2004; Seminck et al. 2022). Grammaticalization continually creates syntactic markers from lexical items (Christiansen & Chater, 2016), such as the English future tense formed by the *going to* construction (Poplack & Tagliamonte, 2000). Connectionist modeling shows the necessarily incomplete nature of language learning can make morphological change inevitable (Hare & Elman, 1995).

Considering every natural language is distributed and varies across a population, word order is better understood as a gradient of orders based on use rather than a selection of canonical and noncanonical possibilities (Levshina et al., 2023). Our experiment necessarily simplifies the natural complexity of word order to capture the effects of the flexible and strict strategies. Word order need not even necessarily be formulated in the six orderings of subject, verb, and object. Dryer (1997) argues for a typology of word orders based on binary relations of nouns to verbs (i.e. OV vs. VO and SV vs. VS).

The evolutionary pressures at play in iterated learning experiments can represent population-level amplifications of cognitive constraints and sociolinguistic factors. Implemented in this paradigm, feedback was able to maintain flexibility. Considering word order is typically transmitted stably between learners, even second language learners, we conclude feedback in this experiment maintained more realistic languages by transmitting stable word order patterns. Without feedback, word order changed often across generations until a new stable strategy could be found—and that strategy tended to rely on the participant's native English word order. We conclude that feedback can resist the ever-present influence of native language transfer.

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