# COMMUNICATION WITHOUT PRIOR LEARNING INHIBITS THE EMERGENCE OF SYSTEMATIC STRUCTURE

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Previous work suggests that systematically structured languages are adaptive for learning. However, systematic structure is also adaptive for communication. Does communication alone lead to the emergence of systematic structure? Evidence from experiments and an emerging sign language suggests communication alone may inhibit the emergence of systematic structure: learning is necessary in addition for systematic structure to emerge.

## 1. Introduction

Human languages are systematically structured. Variations in form are generally conditioned: e.g., use of a word for multiple referents is conditioned on their semantic similarity, and use of a grammatical marker is conditioned on factors such as the word's syntactic category. Systematicity is adaptive for learning, since it means language can be acquired via generalization from limited input. Systematicity is also adaptive for communication: conditioning form on aspects of semantics and syntax enables a producer to communicate novel meanings. Previous work suggests that iterated learning plus communication leads to systematic structure, with neither learning nor communication alone being sufficient (Kirby et al., 2015). However, other work suggests that interaction alone can lead to efficient communication systems (Galantucci & Roberts, 2012). We investigate the effect of communication and learning on systematic structure in two contexts: an artificial language experiment, and an emerging sign language. In both cases, communication without prior learning appears to inhibit systematic structure, while adding learning leads to its re-emergence.

## 2. Experiment

**Methods.** We designed a set of images varying in similarity (Figure 1). Participants produced a language by labeling these images. In a systematically structured language, label reuse is conditioned on image similarity: i.e., images close together in the space share the same label. We compare the systematicity of languages produced by three groups of participants. *Individuals* simply label the images. *Communicators* produce a language by playing a communication game which rewards participants depending on how similar their guess is to the target (see supplementary materials). *Learners* learn an initially random language, then play the same communication game as Communicators; one participant's language is then passed on as learning input to the next pair in a 5 generation iterated learning chain (Kirby et al. 2014).

**Results.** Communicators' languages are less systematic than Individuals' (Figure 1). Learners' languages approach Individuals' systematicity. We quantify this by averaging how many of an image's neighbours share its label (see supplementary materials). This measure ranges from 0 to 1, where 1 means the language is optimally structured. Individuals average 0.77 (*SD* 0.09), Communicators 0.57 (*SD* 0.28), and Learners 0.71 (*SD* 0.13). A one-way ANOVA finds a main effect of condition, $F(2,53) = 5.8$, $p = .005$. Tukey's post-hoc tests find Individuals and Communicators significantly differ, $p = .005$, and Communicators and Learners marginally differ, $p = .08$. Individuals and Learners do not significantly differ, $p = .63$.

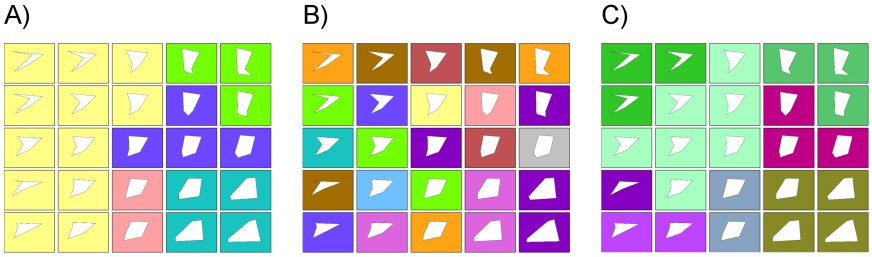


Figure 1. Representative languages from each condition. Images with the same background colour were given the same label. A) Individuals B) Communicators C) Learners at generation 5.

**Discussion.** Communication appears to inhibit the systematicity present in Individuals' languages. On introducing learning, however, systematicity re-emerges. What is it about communication specifically that harms systematic structure? Communicators appear to maximize coordination on individual

images, rather than developing a systematic language across the whole set. The contrast between Communicators and Learners suggests that communication incentivizes the establishment of local conventions; learning is necessary for the induction of system-wide regularities.

## 3. Nicaraguan Sign Language

Nicaraguan Sign Language (NSL) is an emerging sign language that has been observed for the last several decades (see supplementary material). The populations involved in its origin allow us to test whether the experimental results hold in a naturalistic example of language emergence where, unlike in the experiment, communication takes place in the rich context of face-to-face interaction. The first population is *homesigners*, isolated deaf individuals who, like Individuals above, created a system largely on their own. When these first students began communicating with one another in school they formed the *first cohort* of Nicaraguan signers. These first cohort signers, like Communicators, created a system jointly with communication partners. The *second cohort* and *third cohorts* of Nicaraguan signers learned NSL from their older peers: like the Learners, they learn a system, and then used this system to communicate.

**Methods.** Here we investigate whether the same factors that condition linguistic structure in our lab experiments also affect the structure of this new natural language. As a test case, we compared morphological differentiation between nouns and verbs in adult homesigners, first cohort NSL signers, second cohort NSL signers, and third cohort NSL signers. Participants watched and then described clips, inspired by Supalla and Newport's (1987) stimuli, which depicted 19 objects used in typical (e.g., man takes picture with camera) or atypical (e.g., man digs in dirt with camera) actions. Typical action events were designed to elicit signs for actions (verbs); atypical events were designed to elicit signs for objects (nouns). All signs were transcribed; potential action and object signs were identified and coded for several dimensions that mark this distinction in established sign languages. Here we focus on that first reported by Supalla and Newport (1987): repetition of the sign's articulatory movement.

**Results.** We find that all groups except first cohort NSL signers selectively use repetition to mark signs for objects (nouns), and not on signs for actions (verbs) (object/action category by cohort interaction: $\beta = 0.53$, $p < .01$).

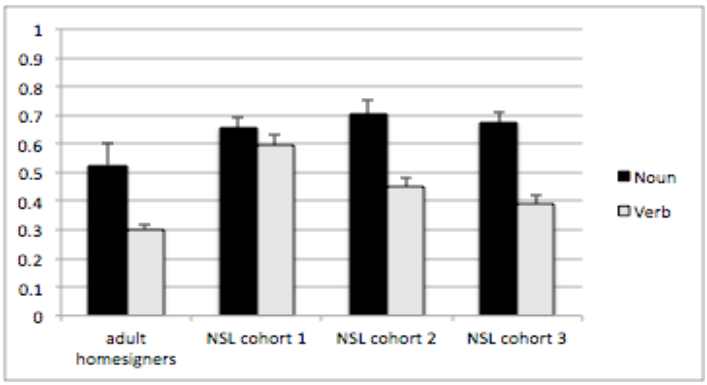


Figure 2. Rates of sign repetition for noun target and verb target items in homesigners and signers.

**Discussion.** The emerging sign language in Nicaragua uses systematic structure to distinguish signs for actions, likely verbs, from signs for objects, likely nouns. The evolution of NSL bears out the findings of our lab study: systematic marking of the noun/verb distinction is present in all participant groups *except* first cohort signers. Systematic use of repetition first emerges in individual, isolated homesigners, but the task of communicating without a language model faced by first cohort NSL signers leads to its elimination. Systematicity is then reestablished by signers who learn their language from older peers: second and third cohort signers. Comparison with the experiment suggests a possible mechanism: the coordination problem faced by first cohort signers may lead them to focus on communicating successfully in local interactions, whereas second and third cohort signers introduce systematicity in the process of inferring a language from input.

## 4. Conclusion

Communicating without a language model may inhibit the emergence of systematic structure, even where the seeds of systematicity are present in individuals. The results invite further work on the differing task demands of communication and learning and their effect on the structure of language.

**References**

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