

Exploring the Systematicity and Learnability of Language through Artificial Language Learning

In cognitive linguistics, linguistic knowledge is seen as a complex system of constructions, or associations between forms and meanings (Langacker, 1987; Evans & Green, 2006), which are traditionally positioned along a continuum of schematicity (Croft, 2001). We focus here on another dimension along which constructions vary: systematicity, or the regularity of the mappings between meanings and signals. The systematicity of a construction can be defined as the frequency with which form and meaning components reliably co-occur in the language to which a learner is exposed. We use a recent measure of systematicity (Tamariz & Smith, in press) based on information theory (Shannon, 1948) and insights from usage-based techniques such as cross-situational learning (Siskind, 1996; Smith, Smith, Blythe, & Vogt, 2006).

We explore the interactions between the cognitive bias for systematicity and the learnability of language, and the effects these have on the cultural evolution of language over generations. We define the learnability of a language as the fidelity with which regular patterns in the form-meaning mappings are reproduced after the language has been learnt. We have investigated these interactions experimentally, using an artificial miniature language (Esper, 1966; Gómez & Gerken, 2000; Selten & Warglien, 2007). We prepared four artificial languages with different levels of systematicity, and asked participants to learn them. In order to test how well the languages were learnt, participants were given two separate tasks: both to reproduce the form they learnt for each meaning, and to select the meaning corresponding to each form. We analysed how the systematicity of the input language affected the systematicity of the output language produced by the participants. We also examined the relationship between the systematicity of an input language and its learnability.

Our results showed that input systematicity correlated positively with output systematicity: participants were sensitive to the systematicity in the language they were exposed to, though with a high degree of individual variation. Moreover, some participants produced languages which were more systematic than the languages they were exposed to (note that in these experiments, the artificial languages can become perfectly systematic, because there is an even meaning frequency distribution). In addition, the systematicity of the input languages correlated positively with learnability: very systematic languages were learnt much more easily.

These findings suggest that humans have a preference for learning regular mappings between forms and meanings. This preference leads to the proportion of regular patterns in the languages increasing, which in turn makes the language more learnable. This has two separate consequences: the structure of the language becomes more regular, and the task of language learning becomes increasingly easy over generations. This study gives us a window into the cognitive processes at work during language learning, and allows us to link these to the linguistic structure which results from cumulative cultural linguistic evolution.

References

- Croft, W. (2001). *Radical construction grammar: syntactic theory in typological perspective*. Oxford: Oxford University Press.
- Esper, E. A. (1966). Social transmission of an artificial language. *Language*, 42(3), 575–580.
- Evans, V., & Green, M. (2006). *Cognitive linguistics: an introduction*. Edinburgh University Press.
- Gómez, R. L., & Gerken, L. (2000). Infant artificial language learning and language acquisition. *Trends in Cognitive Sciences*, 4(5), 178–186.
- Langacker, R. W. (1987). *Foundations of cognitive grammar: theoretical prerequisites* (Vol. I). Stanford, CA: Stanford University Press.
- Selten, R., & Warglien, M. (2007). The emergence of simple languages in an experimental coordination game. *Proceedings of the National Academy of Sciences*, 104(18), 7361–7366.
- Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27, 379–423 and 623–656.
- Siskind, J. M. (1996). A computational study of cross-situational techniques for learning word-to-meaning mappings. *Cognition*, 61, 39–91.
- Smith, K., Smith, A. D. M., Blythe, R. A., & Vogt, P. (2006). Cross-situational learning: a mathematical approach. In P. Vogt, Y. Sugita, E. Tuci, & C. Nehaniv (Eds.), *Symbol grounding and beyond* (p. 31–44). Springer.
- Tamariz, M., & Smith, A. D. M. (in press). Regularity in mappings between signals and meanings. In A. D. M. Smith, K. Smith, & R. Ferrer i Cancho (Eds.), *The Evolution of Language (EVOLANG 7)* (pp. 315–322). World Scientific.