

COMMUNICATION, COOPERATION AND COHERENCE

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Evolutionary game theory and related mathematical models from evolutionary biology are increasingly seen as providing the mathematical framework for modeling the evolution of language (Benz, Jäger, & Van Rooij, 2005; Nowak, Komarova, & Niyogi, 2002). Two crucial, general results from this field are (i) that altruistic communication is, in general, evolutionary unstable (Maynard Smith, 1982), and (ii) that there is a minimum value on the accuracy of genetic or cultural transmission to allow linguistic coherence in a population (Nowak, Komarova, & Niyogi, 2001). Both results appear to pose formidable obstacles for convincing scenarios of the evolution of complex language. Because language and communication did obviously evolve, finding solutions for both problems is a key challenge for theorists. Work in “honest signaling theory” (e.g. (Lachmann, Szamado, & Bergstrom, 2001)) and the evolution of Universal Grammar (e.g. (Komarova, Niyogi, & Nowak, 2001)) can be seen as addressing issues (i) and (ii) respectively.

In this paper we argue that both problems might be directly due to some of the mathematical idealizations used in the theoretical analysis, and disappear when those idealizations are relaxed. We present a very simple, computational model where two idealizations are avoided: (i) we allow for individuals to interact and reproduce in a local neighborhood, avoiding the more common mean-field approximations; (ii) we allow languages to have different similarity relations to one another, avoiding the uniform compatibility function used to derive the coherence threshold. We show that in this model, predictions from the game-theoretic models do not hold, and communication can evolve under circumstances thought to exclude that. Our model and results are not entirely novel: the model is inspired on (Oliphant, 1994), and the results relate to work in mathematical population genetics such as e.g. (Cavalli-Sforza & Feldman, 1983), (Wiehe, 1997); however, we believe our simple and intuitive model might be useful to clarify many of these issues in the Evolang community.

In our model^a a population of 400 agents shares a finite set of signals used

^aAvailable at staff.science.uva.nl/~fsangati/language_evolution.html

to convey a corresponding amount of meanings. Each individual has a transmitting and a receiving system specifying which signal is associated with a specific meaning and vice versa (we thus consider the very general case where the reception doesn't necessarily mirror production). We show that the incorporating a spatial distribution of agents allows the emergence of linguistic cooperation: even when speakers are not rewarded, an optimal communication is able to emerge and be maintained, although suboptimal communications are able to survive above chance frequency in small subareas.

To compare our model to the mathematical models of (Nowak et al., 2001, 2002), we study a number of models at intermediate levels of abstraction. We find that their *coherence threshold* phenomenon depends on the assumption of uniform distances between the possible languages, an assumption which is not valid in models such as ours (as well as the real world), where languages can be more or less similar to each other (figure 1).

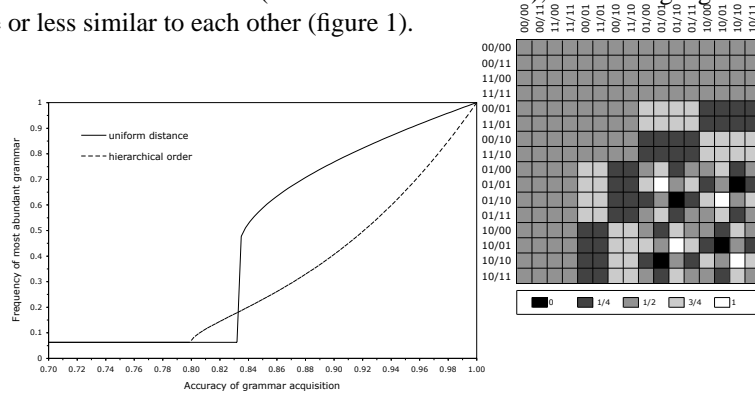


Figure 1. (left) Linguistic coherence in a population with 16 different languages, having uniform distance of 0.5 as in (Nowak et al., 2001) and according to the distances derived from the meaning-symbol mappings of our model. (right) Similarity matrix of the 16 languages derived from the possible mapping between 2 meanings (0/1) and 2 symbols (0/1). Each mapping is fully defined with a 2×2 transmitting and receiving system.

References

- Benz, A., Jäger, G., & Van Rooij, R. (Eds.). (2005). *Game theory and pragmatics*. Palgrave.
- Cavalli-Sforza, L., & Feldman, M. (1983). Paradox of the evolution of communication and of social interactivity. *Proc. Nat. Acad. Sci. USA*, *80*, 2017–2021.
- Komarova, N., Niyogi, P., & Nowak, M. (2001). The evolutionary dynamics of grammar acquisition. *J. Theor. Biology*, *209*(1), 43–59.
- Lachmann, M., Szamado, S., & Bergstrom, C. T. (2001). Cost and conflict in animal signals and human language. *Proceedings of the National Academy of Sciences USA*, *98*, 13189–13194.
- Maynard Smith, J. (1982). *Evolution and the theory of games*. Cambridge University Press, Cambridge, England.
- Nowak, M. A., Komarova, N., & Niyogi, P. (2001). Evolution of universal grammar. *Science*, *291*, 114–118.
- Nowak, M. A., Komarova, N. L., & Niyogi, P. (2002). Computational and evolutionary aspects of language. *Nature*, *417*, 611–617.
- Oliphant, M. (1994). The dilemma of Saussurean communication. *BioSystems*, *37*(1–2), 31–38.
- Wiehe, T. (1997). Model dependency of error thresholds: The role of fitness functions and contrasts between finite and infinite sites models. *Genetical Research Cambridge*, *69*, 127–136.