CUMULATIVE CULTURAL EVOLUTION, POPULATION STRUCTURE AND THE ORIGIN OF COMBINATORIALITY IN HUMAN LANGUAGE

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1. Introduction

The emergence of combinatoriality (or duality of patterning) in human language is a central question for evolutionary linguistics. Combinatoriality is absent only in a handful of natural languages, such as ABSL, an emergent sign language that developed in a village setting (Sandler et al. 2011). The emergence of another design feature of language, compositionality, has been explained as a trade-off between learning biases for compressibility and communication pressure against ambiguity operating over cultural transmission (Kirby et al. 2015). We test two hypotheses: (H1) Combinatoriality also results from a similar trade-off. (H2) Population structure explains differences in combinatoriality across languages.

2. Methods

We constructed minimal languages that could nevertheless show combinatoriality. Each language had four atomic meanings, each mapped onto a 2-unit signal from the set *{ac, bd, ad, bc, pr, ps, qr, qs}*. The 4096 possible languages included 8 *Degenerate* languages, with the same signal for all meanings; 1632 *Holistic* languages with all distinct signals, and no reuse of units across signals; and 48 *Combinatorial* languages with all distinct signals, and maximum reuse of units across signals.

During learning, agents computed a Bayesian posterior probability distribution over the set of possible languages. The compressibility bias was modelled as a higher prior probability for languages with lower coding length. The disambiguation pressure was modelled as a bias against ambiguous languages during communication (Goodman & Frank 2016).

Two population dynamics were modelled. During a communicative interaction, with Vertical dynamics, akin to the situation in village sign language emergence, agents learn from the oldest agent in the population. With Horizontal dynamics, agents learn from other agents who are themselves learners. This is more like the situation in deaf-community sign languages, such as the case of emergence in schools for the deaf (Meir et al., 2010). The oldest agent was removed and a new one added every 20 interactions.

3. Results and discussion

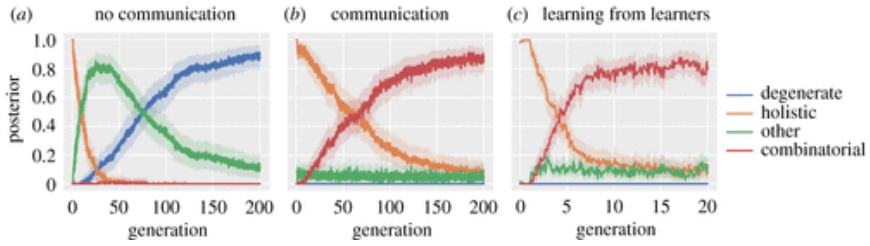

Figure 1. Posterior probability of each language type. In all cases agents have a bias for compressibility. (a) Vertical dynamics, no disambiguation pressure (200 generations). (b) Vertical dynamics, disambiguation pressure (200 generations). (c) Horizontal dynamics, disambiguation pressure (20 generations only).

With Vertical dynamics, under Compressibility bias alone (Fig. 1a), degenerate languages spread in the population; however, under Compressibility plus Disambiguation (Fig. 1b), combinatorial languages win out. This supports H1 that combinatoriality emerges as from a trade-off between compressibility and disambiguation pressures.

When learning from the oldest agent, combinatoriality evolves much slower than when agents learn from other learners. This supports H2 and suggests that population dynamics modulates the rate of evolution of combinatoriality, offering a new candidate explanation for why combinatoriality emerges more rapidly in deaf-community rather than in village sign languages.

References

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