The emergence of categorical and compositional structure in an open-ended meaning space

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Language facilitates the division of the world into discrete, arbitrary categories. This categorical structure reduces an intractable, infinite space of meanings to a tractable, finite set of categories. By sufficiently aligning on a particular system of meaning distinctions, two members of a population can rely on this shared categorical structure to successfully communicate. Language also makes use of compositional structure: the meaning of the whole is derived from the sum of its parts and the way in which those parts are combined. Compositional structure allows languages to be maximally expressive and maximally compressible. Although the emergence of each of these properties has previously been studied in isolation, we show that compositional structure can evolve where no categories have been defined in the meaning space by the experimenter (or, conversely, that categorical structure can evolve where no set of words has been defined in the signal space). We show this using the experimental paradigm of iterated learning using a meaning space that is open-ended.

The meaning space consisted of randomly generated triangle stimuli. The space is continuous and the dimensions of the space are not determined by the experimenter. In addition, the set of stimuli that participants are tested on changes at each generation, such that no two generations are ever exposed to the exact same stimulus. In our first experiment, categorical structure emerged to arbitrarily divide the space into a small number of categories. However, there was no evidence of compositional structure in this experiment. In two additional experiments, we added expressivity pressures: the first of these used an artificial pressure and the second used dyadic communication. Only in the experiment with communication did we find evidence of compositional structure, suggesting that communicative pressures are required for compositionality to arise under more complex, higher-dimensional meaning spaces.