PROSOCIALITY IN SWARM ROBOTICS: A MODEL TO STUDY SELF-DOMESTICATION AND LANGUAGE EVOLUTION

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1. Introduction

Swarm Robotics, which studies collective behaviors of large populations of interacting robots with simple embodied cognition, is an ideal testbed for studying the cultural evolution of language. Beyond simple communication processes, past experiments in swarm robotics have explored the potential of language games in an embodied agent context (Trianni, De Simone, Reina, & Baronchelli, 2016; Cambier, Frémont, & Ferrante, 2017; Cambier, Albani, Frémont, Trianni, & Ferrante, 2021; Miletitch, Reina, Dorigo, & Trianni, 2019).

The current study expands on existing simulations in order to explore a dominant theory in evolutionary linguistics, namely, that the evolution of present-day languages might have resulted in part from the self-domestication of the human species (Thomas & Kirby, 2018; Benítez-Burraco & Progovac, 2020). According to this human self domestication (HSD) hypothesis, humans' distinctiveness is, to a large extent, the outcome of an evolutionary process similar to animal domestication (Hare, 2017). At the heart of this view lies the idea that HSD resulted in less aggressive individuals, who are more prone to interact with others (and particularly, with their kin, but also with strangers). This increased prosociality and reduced aggressiveness would have in turn promoted more social contacts within a community, and supported the emergence of more sophisticated forms of language (Tamariz & Kirby, 2016; Steels, 2017). Our goal is to create an embodied model of the effects of prosociality on the formation of language using swarm robots, in order to investigate the self-domestication hypothesis and the process of language evolution in general.

Current swarm robotics models, however, lack several crucial features that are considered prerequisites for this process. Swarm robots are typically collaborative, but homogeneous, and have little to no memory, not to mention social memory (who did what to whom). In order to mimic the effects of self-domestication properly, an evolutionary advantage for prosociality first needs to be introduced, and robots need to be treated as distinct individuals. To this end, we designed a novel version of the naming game with swarm robots.

2. The current model

In our model, robots in multiple nests are engaged in a foraging task (i.e., gathering resources in their environment) while playing a naming game (Steels & Loetzsch, 2012). Foraging and resource collection are typical animal activities, which has been widely studied in the field of swarm robotics (e.g. (Miletitch, Dorigo, & Trianni, 2018)) and constitutes an obvious marker of evolutionary fitness, which is highly relevant to an investigation of the HSD. Crucially, we include two novel features in the model: (1) robot individuation: robots have a partner-specific memory, keeping track of the outcomes of past interactions with specific robots; (2) parametrizable prosociality: robots' tendency to interact is based on (a) an innate factor and (b) experience: successful communication between robots reduces their aggression toward each other and increases their chances of interacting again.

We examine the evolution of communicative alignment and foraging behavior within and between nests as a function of prosociality and geographic distance, which are two key factors accounting for language diversity and impacting on language complexity (Padilla-Iglesias, Gjesfjeld, & Vinicius, 2020; Bickel & Nichols, 2009). First, we ask whether increased prosociality leads to more efficient foraging, and whether this pattern is affected by the geographical proximity of nests (seeing as closer nests result in more competition over the same resources). Second, we ask whether our manipulation of initial prosociality affects classic convergence patterns (i.e., where all robots end up aligning on the same word variant), leading to differential divergence depending on nest and past history. That is, does initial prosociality affect the degree and/or speed of convergence within and between nests, and does it result in a distinction between in-group robots (belonging to the same nest) and out-group robots (belonging to different nests)?

3. Results

First, we show that these manipulations lead to the formation of a classic "in-group bias" where robots favor interaction with some robots over others - a bias which is highly common in social animals in nature but that was so far absent from swarm robotics models. Second, we observe that higher prosociality values result in the collection of more resources, potentially indicating an evolutionary advantage. Finally, we show that prosociality modulates the effect of physical distance on lexical convergence, such that low values of innate prosocially lead to more stable sub-swarm divergence, even in relative proximity (i.e., different nests robustly converge on different lexical variants despite being close to each other).

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