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Merging sociality and robotics through an evolutionary perspective

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Abstract

Robotics, using social mechanisms like hormonal modulation, may accelerate our understanding of core sociality principles.

The field of social robotics has grown into a successful interdisciplinary endeavor to provide solutions to worldwide societal issues. The prevailing perspective in social robotics uses a "top-down" approach, emphasizing the modeling of either complex social behaviors or, sporadically, lower-level behaviors, but often in the context of human-robot interactions *(1, 2)*. Although important insights are gained from such perspectives, we propose directing attention toward a "bottom-up" framework focused on interaction among robots. Such an approach not only offers a fresh perspective on the emergence of spontaneous social behaviors in robotic entities but also sheds light on the core principles underpinning sociality itself. Our intention is not to provide guidelines on the hard-wired implementation of socialness in robots. Rather, we aim to inspire interdisciplinary collaboration to uncover the emergence of social behaviors: By looking at social robotics through an evolutionary lens, we propose this field as a promising framework to investigate the fundamental bricks of sociality from an evolutionary perspective and for further development of social robots.

What determines sociality? What are the simplest units that have led to the evolution of complex social behavior? The intricacy of these questions lies in the many facets of social behavior. Sociality can rely on different mechanisms, as evidenced by its independent emergence in distantly related organisms (e.g., primates, birds, and ants)

(3). From the microscopic world of asexual bacteria to the complicated social structure of vertebrates, the urgency to interact with conspecifics reverberates across taxa (4). Whether there is an underlying common core that fosters sociality across or among species remains an unsolved question in neuroscience and neuroethology. Unique evolutionary trajectories have triggered different social behaviors, influenced by complex, bottom-up dynamic processes. As actors engaged in repeated interactions in unstructured, ever-changing environments bursting with input and obstacles, these processes ultimately culminated in social interactions (5).

Gathering empirical data on these dynamics from humans, and particularly from nonhuman animals in the wild, is challenging. The extended timescales of evolution further complicate the narrative. In this context, evolutionary robotics represents a compelling facilitator, offering the potential to accelerate evolutionary time and streamline our understanding of complex social dynamics. There have been attempts to model bioinspired social behavior in robot-robot interactions within an evolutionary framework. For instance, Eiben developed a simulated ecosystem called EvoSphere where robots reproduce spontaneously via self-assembly (6). If the robot successfully performs a series of user-defined tasks to adapt to the environment, then it is allowed to survive and potentially reproduce. By recombining its genotype with that of another robot, it will pass the new genotype to subsequent generations, thereby continuing its lineage. Although the real-life implementation is now far beyond our technological capabilities, yet open to attempts (7), this approach might offer interesting perspectives on the emergence of impromptu behaviors in robotic entities.

However, this direction in evolutionary robotics still says little about the core of sociality. We argue that basic mechanisms of sociality should fulfill three criteria: They should be observable across taxa; they should be present in some form in phylogenetically distant species; and they should regulate complex social behavior and promote adaptability. One potential core mechanism meeting these criteria is the endocrine (hormone) system (3). For instance, oxytocin and vasopressin are molecules with great evolutionary conservation, with their precursors found in ancient protosocial creatures like nematodes (4). Throughout vertebrate evolution, the effects of oxytocin/vasopressin-like molecules have played a vital role in survival and reproduction in microorganisms, humans, and nonhuman animals. Oxytocin, extensively associated with social attention, was found to enhance social contact and foster selective social preferences (4). Adversely, vasopressin's relevance lies in social adaptation in challenging environments, shaping behaviors linked to attachment, self and family defense, and social network connections (4).

Some researchers in cognitive and social robotics have ventured into experimenting with multiagent hormonal modulation, yielding promising results. In a simulated environment, Lones and colleagues showed the emergence of complex individual- and group-level robot behavior through a simple control model based on hormones that dynamically adjust in response to the environment *(8)*. For instance, in a competitive environment, a morphologically large agent always adopted a dominant-like behavior (Alpha). Although the behavior of smaller agents was avoidant, the dominant behavior of the Alpha sometimes mutated into a more aggressive phenotype: Rather than simply push smaller agents out of its way, it would actively seek them out to continuously push them. Interestingly, the smaller agents learned that they had more chances to get to resources when grouping. When grouped, the agents became emboldened, which translated into an increased concentration of the neurohormone responsible for suppressing the fear of collision. Consequently, on a few occasions, these agents, when grouped, attempted to push the Alpha out of the way.

Other authors have brought this research to the physical realm, showing how new environmental complexity introduces a new form of dyadic interaction between robots and proposing a “synthetic hormone” to cope with these extra layers of complexity *(9, 10)*. Variation in the hormone levels regulated the level of persistence and the approach-avoidance behavior toward obstacles. Notably, the robot equipped with the hormonal mechanism outperformed the other in terms of life span and physiological balance. By modeling specific properties of biological hormones, the authors imbued robots with the ability to form and maintain social bonds, leading to emergent social behavior within the robotic group *(9)*. Such models may allow robots to share information, provide assistance, and collaborate more effectively, even in changing environments *(8)*.

In summary, modeling of social behavior in robots, driven by environmental pressures and hormonal modulation, reveals changes in behavioral dynamics akin to those in natural systems. Concurrent efforts in robot reproduction and self-replication may contribute to a deeper understanding of the evolutionary processes governing the selection and preservation of complex behaviors. In navigating the crossroads of evolutionary robotics, social robotics, and sociality, the synergy of impromptu behavioral adaptations and reproductive strategies emerges as a key frontier. Combining these facets presents a promising avenue for understanding not only the emergence of diverse social behaviors under environmental challenges but also the evolutionary forces shaping and perpetuating these behaviors. In an attempt to understand sociality through the lens of robotics, this holistic approach emphasizes the potential of evolutionary social robotics and paves the way for future breakthroughs in the field.

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