Comparative computational processes underlying coordination learning in a transparent game in macaque and human dyads

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Abstract

The emergence of joint coordination in group-living species constitutes a fundamental aspect of social cognition. The ability to establish and maintain coordination for mutual benefit provides an evolutionary advantage to primates, especially humans. However, the underlying learning mechanisms enabling coordination, and how these differ between humans and nonhuman primates, remain poorly understood. In particular, the computational mechanisms underlying coordination learning in naturalistic face-to-face contexts with real-time action visibility is not well characterized.

Here, we investigated how rhesus macaques and humans solve a transparent coordination task with conflicting preferences, the iterated Bach-or-Stravinsky (BoS) game. Participants (29 human and 9 macaque dyads) sat face-to-face across a transparent touchscreen and physically reached for their chosen target (1). This sensorimotor context resembles real-life situations where cooperation often requires synchronous movement toward a common goal. Human dyads participated in a single session; macaques were first paired with a conspecific ("naïve" condition, 9 pairs), and then 4 macaques were trained for dynamic coordination with a human confederate who alternated between selecting their own or the macaque's preferred target in blocks ("in training" condition). These macaques were subsequently paired with another trained conspecific ("trained" condition, 4 pairs).

Both species achieved high coordination, but in different ways. Humans demonstrated clear within-session learning, as confirmed by a Generalized Linear Mixed-Effects model based on past choices and action visibility, which showed significant improvement in coordination. Similar but weaker within-session effects were observed in both naïve and trained macaque dyads, though there was no significant within-session improvement in macaques coordinating dynamically with the human confederate. Across multiple sessions, macaques exhibited strong learning in the "naïve" and "in training" conditions, and maintained high coordination in the "trained" condition.

Bayesian model comparison among different classes of learning algorithms (2) revealed that

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the computational mechanism best approximating the target-based coordination in most human dyads was consistent with a Partially Observable Markov Decision Process (POMDP). This model exploited movement time-dependent probabilistic action visibility, both in dynamic turn-takers (~half of human dyads) and in dyads coordinating on a fixed target. In contrast, naïve macaques, in addition to POMDP, leveraged simpler mentalizing strategies such as influence reinforcement learning (RL) or fictitious play, and converged to a static coordination favoring a fixed target or a side. During training with a human confederate, all macaques switched to target-based strategies consistent with POMDP or simpler mentalizing models, which predicted actual choices better than in the naïve condition. After such training, when macaques were with each other, in contrast to prior interactions, they consistently converged on the same computational mechanisms (either target- or side-based), relying on POMDP or simpler RL-influence. These results indicate that transparent face-to-face sensorimotor interactions promote reliance on strategies that utilize observing or at least inferring partner's actions in both species, and that partly distinct computational mechanisms are at play in each species.