Mechanisms of Coordination for Cooperative and Competitive Interactions

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Abstract

How do individuals coordinate in dynamic social contexts that require switching between cooperative and competitive modes? We developed a two-player Social Foraging Task (SFT) where participants, without direct communication, freely choose between cooperative, competitive, or independent islands to coordinate and collect resources. Analysis revealed four key behaviors influencing coordination: value sensitivity, persistence, their interaction, and leader–follower dynamics. Clustering participants' choices revealed three distinct strategies: economic, sticky, and mixed which each linked to different coordination patterns. To capture these, we built a computational model with two parameters: value sensitivity and persistence. In well-coordinated pairs, these parameters were more similar, suggesting strategic alignment supports stable interaction. Notably, uncoordinated choices were common but often purposeful, serving to re-establish coordination. These findings shed light on how people achieve, lose, and recover coordination in dynamic social settings.

Keywords: Coordination, Social foraging task; Social decision making, Cooperation, Competition.

Introduction

Cooperation and competition are two fundamental modes in social decision-making. In real-world situations, such as foraging, animals often cooperate to locate resources and then compete to consume them (Stephens & Krebs, 1986). Both mechanisms rely on Theory of Mind (ToM), the ability to build a mental model of another agent's behavior when making decisions (Rusch, Steixner-Kumar, Doshi, Spezio, & Gläscher, 2020). In dynamic situations where cooperation and competition shift rapidly, it remains unclear how individuals navigate these transitions. People have different preferences, and how they coordinate depends on how these preferences interact. Some may prefer to lead, others to follow. Some prioritize stability, while others adapt to their partner's behavior [3]. These differences influence how coordination emerges or breaks down in dynamic contexts, highlighting the behavioral mechanisms that support joint decision-making. While ToM plays a role in guiding interaction, real-world behavior is also shaped by stable preferences for different interaction styles. Individuals in competitive environments may favor self-interest, while those in cooperative roles may prefer mutual alignment. These preferences shape how people coordinate.(Henrich et al., 2005) To investigate this, we designed a Social Foraging Task (SFT) with rapid switches between cooperative, competitive, and independent contexts. This allows us to observe how players coordinate to maximize rewards, how coordination breaks down, and how it is re-established. By analyzing these patterns, we aim to uncover the mechanisms that shape coordination in flexible social environments.

Methods

SFT: We designed the SFT with five structured steps per trial using the Otree platform ((Chen, Schonger, & Wickens, 2016)). In the first step, participants choose between three islands, which they could play a matrix game if both player chose the same island: Cooperative (stag hunt), Competitive (hide and seek), and Independent. Selecting an island decreases its resources, while those of unchosen islands regrow. These changes simulate a natural foraging environment and encourage participants to switch between islands to benefit from other sources over time. Choosing different islands incurs a point loss for both players, making coordination a key factor in performance. In the second step, participants view a payoff matrix tailored to the selected island. The third step requires them to predict their partner's next move. In the fourth step, they make their own choice. The final step reveals both players' decisions and the resulting scores. We collected data from 74 participant pairs in an online setting.

Behavioral Observation: Analysis of choice patterns across participant pairs revealed four recurring behavioral tendencies that appeared to guide patch selection (figure 1). 1. Orientation to the relative value of the islnad's resources 2. Persistence of previous choices 3. Consistent avoidance of a specific interactional style (e.g. competition) 4. Stable Leader-Follower dynamics when switching to another island

Clustering of Participants: To examine the prevalence o participant strategies we applied k-means clustering based on four features (Figure 1): both player's previous choices, selection of the island with the maximum score, and exploratory behavior (defined as deviation from both prior choices). This revealed three distinct behavioral clusters. Sticky behavior (yellow): Participants stayed on the same island for long blocks. Economic behavior (red): Participants consistently chose the island with the highest resource. Diverse/Mixed behavior (blue): Participants showed variable behaviors, including avoidance of the competitive island and switching between the other two. Across clusters, well-coordinated pairs often resolved non-coordination (divergent trials) through leader–follower dynamics: one player (leader) switched to another island while the other player (follower) followed suit, enabling rapid re-alignment.

SFT model: We implemented a computational model to

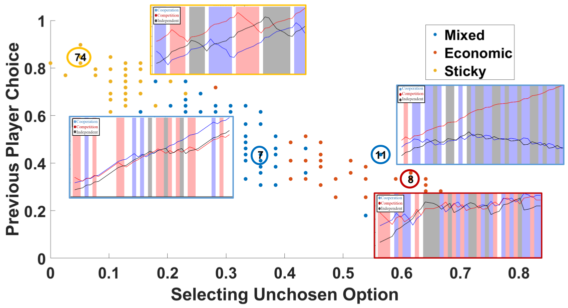

Figure 1: Behavioral patterns in patch selection. Each subfigure shows one participant pair. Background colors indicate jointly chosen islands (red = competitive, blue = cooperative, gray = independent); white = divergent trials of non-coordinated choices. Colored lines show island resource changes.

capture participants' island-selection decisions by estimating subjective values for both themselves and their co-player. The value function for selecting island κ at trial t is defined as:

$$V_i^t(\kappa) = \beta_{1,i} \cdot \mathrm{WIS}^t(\kappa) + \beta_{2,i} \cdot a_i^{t-1} \quad \text{(eq.1)}$$

where $V_i^t(\kappa)$ denotes the subjective value assigned by agent i (self or opponent), $\mathrm{WIS}^t(\kappa)$, is the Weighted Island Score based on resource value and historical preferences, and a_i^{t-1} represents the previous choice, modeling stickiness. To compute final valuations, we used a leader-weighted mixture:

$$V^t_{\text{self,final}}(\kappa) = \omega \cdot V^t_{\text{self}}(\kappa) + (1-\omega) \cdot V^t_{\text{op}}(\kappa) \quad \text{(eq.2)}$$

The weight ω adjusts dynamically during divergent trials. The player who repeats their previous choice is considered the leader; the one who switches is the follower. This asymmetry determines how much participants rely on their own versus their partner's preferences. The model captures how players balance resource maximization with behavioral persistence to maintain coordination

Results

Figure 2 shows four participant pairs representing different behavioral patterns. Rows indicate opponent choices, self-choices, and model predictions; lines show model-predicted action probabilities. The model captures economic, sticky, and avoidance behaviors well, but performs poorly in the top-left pair, where frequent divergence reflects unpredictable strategies. Figure 3 shows model parameters across behavioral clusters. Sticky pairs had higher (β_2) values, reflecting persistence. Economic pairs showed elevated (β_1) values, indicating value sensitivity. Mixed pairs had lower and similar (β_1) and (β_2) values, suggesting no clear strategic bias. Coordination success negatively correlated with parameter differences between partners, indicating that strategic alignment supports more stable joint behavior.

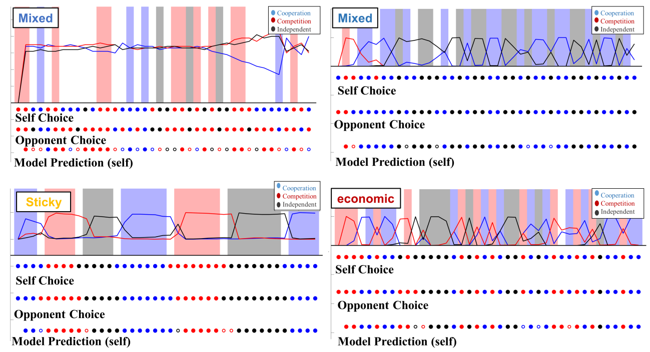

Figure 2: Model predictions vs. actual choices for three behavioral clusters. Top dots = opponent, middle dots = self, bottom dots = model prediction. lines show the Action probability for each island.

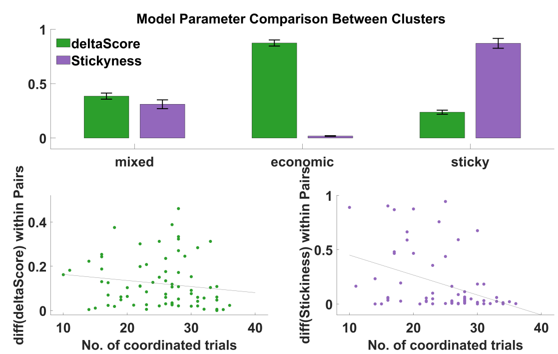

Figure 3: Model parameters across clusters and correlation of difference in parameters in both players of a pair with successful coordination.

Discussion

This study provides insight into how people coordinate in dynamic social environments where interaction modes shift between cooperation and competition. We found that successful coordination does not rely solely on explicit reasoning about the other player, but emerges when both individuals adopt compatible strategies. Pairs that weighted task-relevant features such as island value and past choices, more similarly were more likely to stay coordinated. Flexible role-taking, particularly through leader–follower dynamics, further supported recovery from uncoordinated states. These findings align with existing literature suggesting that coordination often depends on mutual adaptation and shared behavioral tendencies rather than complex recursive reasoning. Prior work on joint action and strategy alignment highlights the importance of predictability and complementary behavior. Our results extend these ideas by showing that stable coordination can emerge from simple, parameterizable patterns, and that discoordination itself can serve as a functional part of the coordination process.

Acknowledgments

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