The dichotomy of knowledge: Evolutionary dynamics with game transitions on social networks

Keywords: Cooperation, Evolutionary game theory, Game transitions, Structured population

Extended Abstract

Individual behaviors strongly influence environmental change, which subsequently may feedback on how individual behaviors evolve. The feedback between behavior and environment can be studied using the model of evolutionary dynamics with game transitions, wherein an individual's strategic choice in one game determines the subsequent game to be played [1]. Recent studies suggest that game transitions can promote cooperation significantly in a structured population[2]. In particular, if mutual cooperation is rewarded by transitioning to a valuable state, while any defection is punished by leading to a less valuable game, cooperation can be favored by selection—even if it is disadvantaged within each game. Knowledge of the environmental state, when available, can often modulate individual choices to act altruistically or selfishly in a particular state [3]. However, previous studies in structured populations failed to capture the effect of state-dependent behavior predicated on environmental knowledge. Here, we investigate how knowledge about environmental states can affect the evolution of cooperation in a structured population and compare this with scenarios where such knowledge is scarce. Using both theoretical analysis and numerical simulations, we systematically analyze all types of game transitions of a given complexity to assess whether environmental knowledge promotes cooperation. In structured populations using one-shot donation games, we find that under weak selection, cooperation is favored over defection if the benefit-to-cost ratio of an altruistic act, b/c, exceeds $k-\bar{k}$, where k is the average number of interaction partners of an individual, and $\bar{k}$ captures the effect of game transitions and depends on the availability of environmental-state knowledge. For a broad class of game transition rules, we find that the value of $\bar{k}$ can be negative when individuals lack knowledge of the environmental state, thus increasing the critical threshold of benefit-to-cost ratio for the evolution of cooperation under game transitions; however, when individuals posses full knowledge of the state, the value of $\bar{k}$ can become positive. Thus, for these transition rules, the barrier to cooperation under game transitions is reduced only when individuals have accurate knowledge of the environmental state. Surprisingly, we also find that greater knowledge about the environmental state doesn't always confer an advantage for the evolution of cooperation; instead, for a few game transitions, it can yield neutral or even detrimental effects on the collective cooperation level. By comprehensively analyzing all game transition patterns and strategy update rules, our study delineates when environmental knowledge facilitates the spread of cooperation in structured populations—or, paradoxically, gives rise to a ”knowledge curse”.

References

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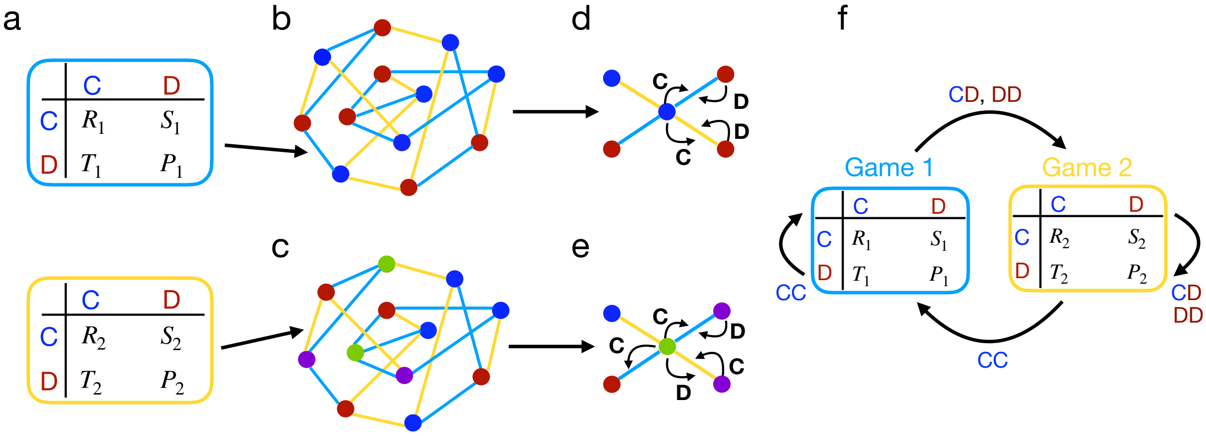

Figure 1: **Game transitions on graphs with and without knowledge of the environmental state.** **a** We study game transitions between two states represented by two payoff matrices, where the transition between states depends on players' actions. **b** Each individual is represented by a node on the graph, and follows a state-independent behavior when they lack environmental knowledge, blue ("cooperate" in all games) or red ("defect" in all games), used in interaction with neighbors. **c** In the presence of knowledge about the current state, individuals can adopt state-dependent behavior, green (cooperate in game 1 and defect in game 2) or purple (defect in game 1 and cooperate in game 2), when interacting with neighbors. Games in different interactions can be distinct, represented by the color of the edges; sky blue edges indicate game 1, and yellow edges denote game 2. **d** An unconditional cooperator (defector) cooperates (defects) in all game states, whereas **e** game state conditional cooperator (green or purple) cooperates depending on the state an edge currently in. At each time step, all individuals interact with their neighbors and accumulate their payoffs. In every time step, all games are updated based on the players' actions along each edge. **f** Example of a game transition rule, where only mutual cooperation leads to game 1 and all other actions lead to game 2.