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Cooperation and popularity in spatial games

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HIGHLIGHTS

- In spatial games, neighbors strategies are preferentially selected based on their popularity.
- Popularity-driven selection mechanism can enhance the level of cooperation remarkably.
- The effectiveness of such a mechanism is verified by the snowdrift game and the different structures of networks.

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ABSTRACT

Selection of the competition opponent is crucial for the evolution of cooperation in evolutionary games. In this work, we introduce a simple rule, incorporating individual popularity via the single parameter α, to study how the selection of the potential strategy sources influences individual behavior traits. For positive α players with high popularity will be considered more likely, while for negative α the opposite holds. Setting α equal to zero returns the frequently adopted random selection of the opponent. We find that positive α (namely, adopting the strategy from a more popular player) promotes the emergence of cooperation, which is robust against different interaction networks and game classes. The essence of this boosting effect can be attributed to the fact: increasing α accelerates the microscopic organization of cooperator clusters to resist the exploitation of defectors. Moreover, we also demonstrated that the introduction of a new mechanism alters the impact of uncertainty by strategy adoption on the evolution of cooperation. We thus present a viable method of understanding the ubiquitous cooperative behaviors in nature and hope that it will inspire further studies to resolve social dilemmas.

1. Introduction

Understanding the emergence and stability of cooperation among unrelated individuals represents one of the major challenges of evolutionary biology and of behavioral sciences [1–3]. For elucidating this puzzle, researchers have traditionally adopted evolutionary game theory as the common formal framework to study the evolutionary dynamics of behavior traits [4,5]. A simple, paradigmatic model the prisoner's dilemma game in particular, illustrating the social conflict between cooperative and selfish behaviors, has attracted considerable attention both in theoretical as well as experimental fields

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[6–14]. In its basic version, two players simultaneously decide to adopt one of two strategies: cooperation (C) and defection (D). When a population of players has interaction in the well-mixed case, cooperation will disappear soon.

Over the past decades, a great number of scenarios have been identified that can offset the above unfavorable outcome and can lead to the evolution of cooperation [15–23]. Nowak attributed all these to five mechanisms: kin selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection [24], which can be somewhat related to the reduction of an opposing player's anonymity relative to the so-called well-mixed situation. Among these mechanisms, network reciprocity, where players are arranged on the spatially structured topology and interact only with their direct neighbors, has attracted the greatest interest (see Refs. [25–27] for a comprehensive review) because cooperators can survive by means of forming compact clusters, which minimizes the exploitation by defectors and protects those cooperators that are located in the interior of such clusters [28]. In line with this achievement, the effect of spatial topology, and its various underlying mechanisms have been explored extensively. For example, among the proposed scenarios of supporting the sustenance of cooperation, we have the presence of mobile agents [29–33], more complex interaction network [34–39], aspiration-driven ability [40–42], the influence of transferring capability [43,44] and differences in evolutionary time scales [19,20]. Moreover, individual heterogeneity, uncertainty or diversity [42,45,46], asymmetry payoff factor [47,48] and environmental influence [49,50] have also been considered as the potential mechanisms of enhancing cooperation. Other traits involve that coevolutionary selection of dynamical rules, where the strategy property of the population is allowed to evolve together with the network topology or the evolution rule, can have a positive impact on the evolution of cooperation [51–54].

Of particular renown, the influence of individual opinions on learning ability has attracted great attention recently. Looking at some examples more specifically, in a recent research work [55], where Szolnoki et al. assumed that individual learning ability was a function of collective opinion performance in groups, cooperator abundance on the spatial grid was supported due to the dynamical effect. In Ref. [56], it was shown that a conformity mechanism involving a tendency to copy the most frequent nearby strategy could lead to the long-term dominance of cooperation, even if the conditions did not necessarily favor the spreading of cooperators. Meanwhile, other scholars [57–59] reported that when the copying probability directly attenuated through the so-called "letting learning activity level decrease" the evolution of cooperation could also be guaranteed, especially for the co-evolution proposal suggested by Tanimoto et al. [60].

However, while it is undisputable that the transferring capability of strategy is an effective approach to model the evolution of behavior traits, there may exist other potential ways of exploring the influence of individual opinion states. In our society, it is well-known that individuals having higher popularity usually obtain more attention than others. For example, the behaviors of movie or sport stars are often followed by their fans, while in the animal world, the leaders' behaviors are often imitated by subordinative animals. Inspired by these facts, an interesting question poses itself, which we aim to address in what follows. Namely, if the influence of popularity is evolved into the selection of strategy sources, how does cooperation fare? To answer this issue, the popularity can be regarded as a function of behavior opinions.

In the present work, we study the prisoner's dilemma game (and snowdrift game) with a preferential mechanism, where the selection of imitation object needs referring to its popularity. Differentiating from the previous research works [61,62], where an opponent is chosen uniformly at random, the neighbor possessing the higher popularity is more likely to be chosen as the potential strategy donor. Our main aim is to study the impacts of such a simple mechanism on the spreading of cooperation. Through numerical simulations, we unveil that this mechanism can allow for cooperative behavior to prevail even if the temptation to defect is large, irrespective of the potential interaction networks and games. Subsequently, we will show more details.

2. Evolution game model and dynamics

We consider an evolutionary prisoner's dilemma game that is characterized with the temptation to defect T (the highest payoff received by a defector if playing against a cooperator), reward for mutual cooperation $R = 1$, and both the punishment for mutual defection P as well as the sucker's payoff S (the lowest payoff received by a cooperator if playing against a defector) equaling 0. As a standard practice, $1 < T \leq 2$ ensures a proper payoff ranking ($T > R > P \geq S$) and captures the essential social dilemma between individual and common interests [28]. It is worth mentioning that though we choose a simple and weak version (namely, $S = 0$), our observations are robust and can be observed in the full parameterized space as well [63].

Throughout this work, each player x is initially designated either as a cooperator (C) or defector (D) with equal probability. With respect to the interaction network, we choose either the $L \times L$ regular lattice, the triangle network, or the honeycomb lattice with periodic boundary conditions. The game is iterated forward in accordance with the Monte Carlo simulation procedure comprising the following elementary steps. First, a randomly selected player x acquires its payoff P_x by playing the game with its nearest neighbors (the payoffs of all its neighbors are also evaluated in the same way). Then, it chooses a neighbor y according to the following probability:

$$\Omega_y = \frac{\exp(\alpha S_y)}{\sum_z \exp(\alpha S_z)} \quad (1)$$