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Imitating winner or sympathizing loser? Quadratic effects on cooperative behavior in prisoners' dilemma games

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HIGHLIGHTS

- Investigates the effect of sympathy on cooperation, which is not adequately revealed before.
- Sympathy has a quadratic effect on cooperation, and it promotes cooperation beyond its threshold.
- Temptation has a quadratic effect as well, and it even promotes cooperation beyond a threshold.
- Although cooperation falls at earlier stages, the resilience is strong enough to promote cooperation later on.

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ABSTRACT

Cooperation is vital in human societies and therefore is widely investigated in the evolutionary game theory. Varieties of mechanisms have been proposed to overcome temptation and promote cooperation. Existing studies usually believe that agents are rational, but irrationalism such as emotions and feelings matters as well. Winner and loser are defined by their payoffs. In addition to admiring and imitating winners, the mechanism of sympathizing and imitating losers is introduced into the model as an alternative action rule, and each one plays the prisoners' dilemma game with eight neighbors under the influence of both irrationalism and rationalism. Rationalism refers to imitating winner to get highest payoff, and irrationalism means that people sympathize and adopt the actions of losers. As it is widely recognized that temptation reduces cooperation, this study focuses on the effect of sympathy on cooperation within a certain group or society. If it overcomes temptation that leads to defection, sympathy will be a powerful mechanism to promote cooperative behavior. Simulation results indicate that sympathy and temptation shares similar quadratic relationships with cooperation. Both sympathy and temptation undermine cooperation below their thresholds, and they both promote cooperation above their thresholds. Temptation not only reduces cooperation but also promote it as temptation goes beyond the threshold. Although sympathy is a good merit or human nature that is beneficial to society, a crisis or collapse of cooperation is inevitable when the sympathy propensity is relatively smaller. After cooperation reaches a minimal bottom, it then rises increasingly and dramatically, which brings a much brighter future of the society.

1. Introduction

Cooperation is vital and therefore widespread in the real world, which can be observed at biological groups as well as human society [1–3]. Human society is based on cooperation, but the puzzle of cooperation [3] indicates that cooperators

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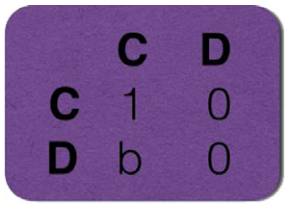

Fig. 1. *The payoff matrix.* Each individual who cooperates gets 1 if the partner is cooperating. Each one who defects obtains b ($b > 1$) if the partner is cooperating. She or he obtains 0 otherwise.

receive less while selfish defectors are rewarded. Then the question is raised that how cooperation can be enhanced under this paradox. Cooperation is widely studied in various fields including game theory [4–6]. The goal of this paper is to solve this puzzle and promote cooperative behaviors among a certain society.

The core issue is to promote cooperation via applications or designs of certain mechanisms [3,7–9] to countervail temptation of defection. Spatial and evolutionary game theory provides multiple solutions to promoting cooperation. Two types of games, prisoners' dilemma game [5,6,9,10] and public goods game [7,11–31], are generally applied. In game theory, temptation is the core mechanism that seduces agents to defect and undermines cooperation, as defection provides higher payoffs than cooperation [1,3,5]. Therefore, mechanisms that are able to overcome temptation are needed to promote cooperation. Varieties of anti-temptation mechanisms are proposed, such as reputation [3,5,7,8,12,23,24], influence [28], tolerance [32], punishment [21,29,32,33], recommendation [25], and expectation [10,34]. It suggests that they all enhance cooperation at certain extents.

It is commonly assumed in the classical game theory that each individual is rational or selfish [2,3,8,9,13,15,20,24,35,36], trying to maximize the payoff, income, or welfare while interacting with the partners or neighbors [3,8]. However, it cannot be denied that not all the agents are rationalized; instead, some of them are irrational for the existence of heterogeneity [24,28,31] or diversity [6,17,27,31] in reality. Irrational agents make choices under the influence of irrational considerations, such as emotions or feelings. They may sympathize losers with lowest payoff for the sake of values [37,38], emotion [2], altruism [11,39], commitment [39], voluntarism [30,36,40], etc. while rational agents admire and imitate winners with highest payoffs.

We aim to investigate the effect of sympathy on cooperation. The fraction of cooperation in game theory interprets collective action [41–47] in the real world where sympathy is common phenomenon and effective mechanism that triggers the rise of collective action and therefore enhances cooperation. One reason is that perceived injustice could increase one's sympathy with a certain collective action and enhances the potential for mobilization and participation [48–50]. As well the feeling of discontent may lead to sympathy and participation in collective action [51].

Under the paradigm of spatial game theory [5,6,14,15,17,20,21,52], this study proposes two action rules: each rational agent admires and imitates the winner who is his or her neighbor with highest payoff, and each irrational agent sympathizes and imitates the loser who is the neighbor with lowest payoff. This study is important as it covers both rational and irrational parts of human nature. As people are interacting with each other, both of the two mechanisms exert influences. Therefore, this model fits reality better than previous ones. Macroscopically speaking, the real society is a mixture of rational and irrational agents; microscopically speaking, each agent owns both propensities of rationalism and irrationalism. Evaluating their effects via numerical simulations and statistical evaluations, this study inspects the evolution of the cooperative behavior and how rationalism and irrationalism influence it.

2. Model

Like previous work [3,5,53], each agent interacts with eight neighbors, playing the prisoners' dilemma game in an $L \times L$ square lattice. Each one has two strategy or options, cooperate (C) and defect (D). The payoff matrix in Fig. 1 has only one parameter b that satisfies $b \in (1,\ 2]$. If one cooperates with a neighbor who cooperates he or she receives one unit of payoff, if he or she defects with a neighbor who cooperates then the payoff is b, and the payoff would be zero otherwise.

There is a probability p that indicates each agent's propensity of irrationalism, and $(1 - p)$ therefore represents the propensity of rationalism for each individual. In Fig. 2, each one plays games with eight neighbors, and each agent in the center imitates action of the neighbor with lowest payoff with the probability p. Meanwhile, each one imitates the neighbor who has largest payoff with the probability of $(1 - p)$. Besides, if there exist more than one neighbor who has the highest or lowest payoff, i.e. m_1 and m_2 neighbors respectively, these neighbors are chosen with the same probability of $(1 - p)/m_1$ or p/m_2, which satisfies that $m_1,\ m_2 \in [1,\ 8]$. It is assumed that agent merely imitates neighbors other than himself, in order to investigate the imitating effects and the influence of environment.

The initial cooperation rate is 50%, which means that half people play C and the other half play D. As the first round of game begins, agents play given strategies and acquire their payoffs. After that, they calculate and compare payoffs of eight neighbors. Each agent adopts the neighbor with lowest payoff (loser) with the probability p, and imitates the neighbor with highest payoff (winner) with the probability $1 - p$. Then, the second round of game begins and agents follow exactly the