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Aspiration-induced dormancy promotes cooperation in the spatial Prisoner's Dilemma games

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An interesting phenomenon is often observed in realistic systems. In the process of games, if the expected payoff from game interactions is not achieved, players would refuse to participate in the games. Inspired by this fact, we propose an aspiration-induced dormant mechanism, in which players quit the games and become dormant if their payoffs are less than the aspiration level. After a dormant period, they continue to play the game with others. Our results indicate an intermediate aspiration value, leading to the highest cooperation level in the spatial prisoner's dilemma games. The effects of the dormant period are also studied.

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I. INTRODUCTION

The emergence and maintenance of cooperation among nonrelated individuals are among the fundamental problems in biology and social sciences [1]. The evolutionary prisoner's dilemma game (PDG) [2] has long been established as a paradigm in studying cooperative behavior under different conditions. The original PDG describes the interaction between two players whose incomes depend on their choices. The players can simultaneously make two choices, namely, to cooperate or to defect. They both receive payoffs R and P upon mutual cooperation and defection, respectively. Once a cooperator meets a defector, the cooperator receives the sucker's payoff S, whereas the defector gains the temptation T. These payoffs satisfy the ranking $T > R > P > S$ and $2R > T + S$. We simplify the payoff matrix in accordance with common practice: let $T = b, R = 1$, and $P = S = 0$ [3], where b represents the temptation to defect, and being typically constrained to the interval $1 < b < 2$. Thus, defection is dominant because it brings higher individual income when the co-player chooses either defection or cooperation. This result is at odds with the ubiquitous observations of cooperative behaviors in human and animal societies.

Considering the rapid development of complex network theory [4–9], much effort has been devoted to the evolutionary game on complex networks in the past decade [10–22]. To explain the emergence of cooperation, researchers have proposed many important mechanisms, such as the direct and indirect reciprocity [23–25], kin-selection [26], memory effects [27, 28], noise [29–31], punishment and reward [32–34], migration [35, 36], social diversity [37, 38], reputation [39, 40] and network reciprocity [41, 42], and aspiration [43–51], to name but a few. Among them, voluntary participation is considered as an effective approach to avoid deadlocks in states of mutual defection [52–58]. Under this setup, the loner, as the novel strategy which can be imitated by other players, does not engage in any interaction yet obtain a fixed and small payoff.

In the original PDG, individuals are forced to participate in the game regardless of their payoffs. However, in reality, when individuals are not satisfied with their present situation, they will be temporarily out of the game. For example, in the Texas Holdem game, when the player has judged that his/her hand is not good, he/she will choose "fold" which mean that he/she will give up the chance to profit. He/she will be back in the game in order to earn back the cost or to get more profit. Inspired by this finding, we propose an aspiration-induced dormancy model, in which individuals quit the game and become dormant if their payoffs are lower than their aspiration levels, and then, they continue to participate in the game after a certain period. In contrast to the previous voluntary model, the dormant individuals' strategies are unchanged and cannot be imitated by others during such period.

Using the Monte Carlo simulations, we found that the dormant mechanism introduction affects the cooperation evolution. An intermediate aspiration level which can lead to the maximum cooperation level is shown in this study. Moreover, the dormant period significantly affects the evolution of cooperation.

The rest of this paper is organized as follows. First, we will describe the aspiration-induced dormancy model. Second, we will present the main results and interpretations of the observed phenomena. Finally, we will present our conclusions.

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