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# Rational conformity behavior can promote cooperation in the prisoner's dilemma game

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ABSTRACT

In this paper, we explore the effects of rational conformity behavior on the evolution of cooperation in prisoner's dilemma. In general, we think individual updates strategy is based on the difference in income between himself and his neighbors. In real life, in order to avoid risks, they may be consistent with most individuals in the group, because they are not the worst. Therefore, we divide the players into two categories, one is traditional players and the other is rational conformists who update their strategies are based on the two factors: payoffs and the behavior of most individuals in their nearest neighbors. Through a large number of simulations, we find that, rational conformity behavior can promote cooperation in the prisoner's dilemma game, and the greater the proportion of rational players, the more obvious the promotion of cooperation. Our work may provide further insight in understanding the evolution of cooperation, players selectively follow others and make some adjustments according to the current environment to make their own situation better.



## 1. Introduction

It is not uncommon phenomenon nowadays. For example, violent conflicts in some areas and the extinction of some animals and plants and so on. Therefore, cooperative behavior, ranging from biological, economical to human social systems, is increasingly required to alleviate these social dilemmas. Understanding the emergence and maintenance of cooperation is a meaningful and arduous challenge in the real world [1–3]. Evolutionary game theory provides a simple and effective theoretical framework for understanding the evolution of cooperation [4–6]. As a classical and general model, the prisoner's dilemma game (*PDG*) has been widely concerned by many scholars [7,8]. In the classical *PDG*, two players simultaneously decide whether to cooperate (*C*) or defect (*D*). They will receive the reward *R* (punishment *P*) if both players choose cooperation (defection). While a player chooses cooperation and the other chooses defection, the cooperator will get a sucker's payoff *S* and the defector will receive a temptation to defect *T*. These payoffs satisfy the ranking: $T > R > P > S$ and $2R > T + S$ [9–11]. As we all know, for rational individual, defect is his best choice, no matter what strategy his opponent chooses. However, only two sides choose to cooperate to maximize the collective interest. Obviously, players will inevitably fall into the social dilemma of pursuing individual and collective benefits.

At present, many approaches, including theoretical and experimental aspects [12,13], have been proposed to solve the social dilemma mentioned above. Nowak made a pathbreaking contribution in 2006, he summed up five rules for the evolution of cooperation which are kin selection, direct reciprocity, indirect reciprocity, network reciprocity, and group selection [14,15]. Specially, network reciprocity is playing an increasing important role in order to promote cooperation [16,17]. Along this line, a lots of spatial structures in evolutionary games was explored. Such as small-world network [18,19], scale-free network [20–22], hierarchical network [23], multilayer networks [24–27] and other heterogeneous networks [28,29] strongly promote cooperation. In addition, some scenarios can stimulate the evolution of cooperation, like memory [29,30], preference selection [31], aspiration [32–34], social diversity [35,36] and so on [37,38,43].

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It is noteworthy that humans and other animals in nature often exhibit some group behavior, in general, act in line with others can survive better, that is in some cases they belong to conformists. Along this line, scholars have conducted many in-depth studies. Szolnoki and Perc showed an appropriate fraction of conformists within the population introduces an effective surface tension around cooperative clusters and ensures smooth interfaces between different strategy domains in 2015 [39], and leaders must be able to create a following for network reciprocity to be optimally augmented by conformity in 2016 [40]. These results suggest that conformity might have had an evolutionary origin in that it promotes prosocial behavior.

Inspired by the aforementioned, we think that individuals are clever, their behavior may be affected by many factors, not only concerned about payoffs of their own or neighbors, but also the behavior of most neighbors. Therefore, we divide the players into two categories, one is traditional players and the other is rational conformists who update their strategies are based on the above two factors. Through numerical simulation, we found that rational conformists play a very important role in promoting the evolution of cooperative behavior. In the following, we will first describe the modified prisoner's dilemma game in Section 2, later show the numerical simulation results in Section 3, and last summarize our conclusions.

## 2. Model

We consider the prisoner's dilemma game with players located on a square lattice of size of $L \times L$ with periodic boundary conditions, in which each lattice site represents a game player. In particular, we will divide all players into two categories: type $A$ (Called rational conformists: players with rational conformity behavior) and type $B$ (Called ordinary players). At the same time, we introduce a parameter $u$ ($u \in [0, 1]$) that represents the proportion of type $A$ players. Initially, each individual in each type is allowed to choose one of two strategies: cooperate ($C$) or defect ($D$) with equal probability. For simplicity, but without loss of generality, we consider the weak prisoner's dilemma: $R = 1, P = S = 0$ and $T = b$. Thus the prisoner's dilemma game with the payoff matrix:

$$M = \begin{bmatrix} & C & D \\ C & 1 & 0 \\ D & b & 0 \end{bmatrix}, \quad (1)$$

where the parameter $b (1 < b \le 2)$ is the temptation to defect.

The game is iterated forward in accordance with the Monte Carlo simulation procedure comprising the following elementary steps. First, in each time step, a randomly selected player $x$ acquires its accumulated payoff $P_x$ by interacting only with his four nearest neighbors (self-interactions are excluded). Then individual $x$ have to randomly choose one neighbor, say $y$, who also gets his payoff $P_y$ in the same way. Next, the player $x$ will update his strategy according to the following rules:when player $x$ belongs to the ordinary player, type $B$, he will change his strategy $s_x$ and adopt the strategy $s_y$ from the selected player $y$ with a probability $W$ given by the Fermi function as follows:

$$W(s_x \leftarrow s_y) = \frac{1}{1 + \exp[(P_x - P_y)/K]}, \quad (2)$$

where $K$ denotes the amplitude of noise or its inverse ($1/K$), the so-called intensity of selection [41,42]; When player $x$ belongs to the rational conformist, type $A$, it means that he will consider various factors rather than one to update his strategy. Specifically, He gives priority to his own earnings. If $P_x \ge preP_x$, he will use the traditional Fermi update rule determined by Eq. (2), where $preP_x$ denotes the player $x$'s earnings for the last time step; If $P_x < preP_x$, as a rational conformist, player $x$ will maintain his strategy with a probability $W_1$ as follows, otherwise, he will change his strategy according to the Fermi rule.

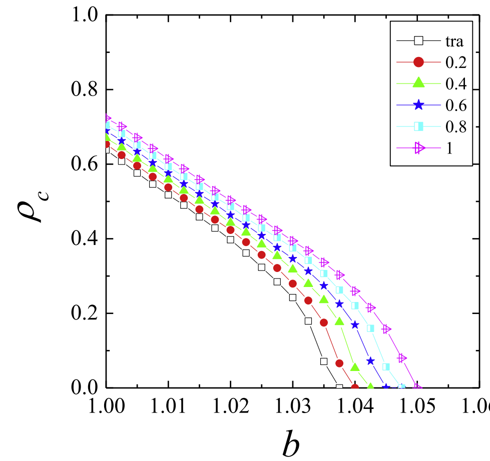


**Fig. 1.** Fraction of cooperators ($\rho_c$) at the stationary state as a function of $b$ for several different values of $u$. All the results are obtained for $K = 0.1$, and $L = 300$.

$$\begin{cases} W_1(s_x \leftarrow C) = \frac{1+preCountC}{5} & s_x = C, \\ W_1(s_x \leftarrow D) = \frac{1+preCountD}{5} & s_x = D. \end{cases} \quad (3)$$

where $preCountC$ and $preCountD$ represent the number of cooperators and defectors in his nearest neighbors in the previous time step, respectively. It shows that rational conformists only take the conformity behavior when they are not satisfied with their payoffs. Obviously, when $u = 0$, all players belong to type $B$, it will go back to the traditional prisoner's dilemma game. Besides, the larger the value of $u$, the greater the proportion of type $A$, the more rational conformists in the group.

During one full Monte Carlo step ($MCS$) each player is selected once on average to change his strategy. Simulation results presented below were carried out on populations comprising $300 \times 300$ individuals. Besides, the key quantity the fraction of three strategies are determined within the last $10^3$ full $MCS$ over the total $10^4$ steps. Moreover, to avoid additional disturbances, the final results were averaged over up to 10 independent realizations for each set of parameter values in order to assure suitable accuracy.

## 3. Results

First, we study the influence of the number of rational conformists in the group on the cooperative behavior in the prisoner's dilemma game. In Fig. 1, we plot the fraction of cooperators ($\rho_c$) at the stationary state as a function of $b$ for several different values of $u$. When $u = 0$, it returns to the traditional situation. All players belong to type $B$, as ordinary players, they only consider the difference between themselves and their neighbors in payoff. We can see that cooperation decreases monotonically as $b$ increases, and cooperation dies out when $b$ is 1.0375 around. Subsequently, with increase of $u$, there are two types of players in the group. It is clear that players with rational conformity behavior (type $A$ players) can promote cooperation, and the greater the proportion of rational players, the more obvious the promotion of cooperation. The greater the value of $u$, the larger the threshold for cooperators become extinct. Thus rational conformity behavior can promote cooperation in the prisoner's dilemma game.

Then we depict the final density of cooperators on $b$-$u$ panel in Fig. 2 in order to complete a clear understanding about the impact of the proportion of rational conformity behavior on cooperative behavior. It shows that as $b$ increases, cooperation gradually de-