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Distinguishing punishing costly signals from nonpunishing costly signals can facilitate the emergence of altruistic punishment

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ABSTRACT

Altruistic punishment is regarded as a solution for the social dilemma, yet the fact that altruistic punishment itself is a type of public good raises the second-order social dilemma. Previous studies have typically explained the emergence of altruistic punishment by recoupling punishers with other public goods or altruistic behaviors, but introducing new public goods would then raise the n-order social dilemma. Costly signaling theory (CST), by viewing public goods as costly signaling, is a potential approach to explain the evolution of cooperation without introducing other public goods because partnering altruistic signalers is not necessarily an altruistic behavior. However, previous studies based on CST have rarely distinguished altruistic punishment as the distinctive costly signal from a nonpunishing contribution. In this study, we explore the rules of transforming payoffs into fitness by differentiating punishing costly signals from nonpunishing costly signals. The results show that, under the condition that the efficacy of costly signaling is incomplete, altruistic punishment can only emerge in the population with transforming rules in which individuals regard altruistic punishment as a distinctive costly signal rather than a nonpunishing contribution.

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1. Introduction

Altruistic punishment is suggested to be an important mechanism for maintaining cooperation among non-kin individuals. Experimental studies have shown that altruistic punishment effectively enforces cooperation in social dilemma situations [1,2]. However, this raises the second-order social dilemma, i.e., how can altruistic punishment emerge under the circumstances where nonpunishing cooperators are better off than punishers?

The effects of group selection and conformism can prevent the invasion of both first-order and second-order free riding when punishers are common [3]. However, how can initially rare punishing behaviors gain a foothold within the group? Computational simulation is an increasingly accepted approach for exploring this question, and there are two main types of studies with simulation methods in this field. The first type is the simulation of evolutionary games in spatial networks

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[4–7]. By being able to depict the influences that spatial factors exerted on social interactions, spatial networks are used as an important complement to analytical approaches. For research on the evolution of cooperation, spatial networks not only provide solutions for the first-order social dilemma [8–11] but also deepen our understanding of the second-order social dilemma. Notably, different mechanisms of punishment have been suggested in the spatial evolution of cooperation, such as adaptive punishment [12], probabilistic punishment [13,14], and conditional punishment [15].

Another type of simulation is the multiagent simulation based on the Moran process. In this approach, there are mainly two types of possible solutions for solving the second-order social dilemma. One possibility is that there is a mechanism that could limit the opportunity of free riders to exploit public goods, thus indirectly reducing the cost of punishment. For example, altruistic punishment can emerge if individuals can choose whether to take part in the joint endeavor [16]. The key to this mechanism lowering the cost of punishment is that those nonparticipants neither contribute (do not give free riders any chance to exploit) nor consume (do not be the new free riders). However, the latter can hardly be achieved since there are several cases in which the collective good is not excludable [17].

If trying to escape from the exploitation of free riders is just “a narrow road to cooperation” [17], is there any mechanism that either directly relieves the burden for punishers or compensates them? One study has shown that by sharing the cost of punishment among all the group members, altruistic punishment can be evolutionarily stable [18]. Other researchers have suggested that, the second-order social dilemma can be solved if nonpunishing cooperators recoup the punishers, which indirectly sanctions the defectors [19]. However, both the enforcement of ensuring the sharing of the punishment cost and the compensation itself is a type of public good as well. In this case, the possibility that noncompensators would be better off than compensators would cause the n-order social dilemma. Thus, the key to accounting for the emergence of altruistic punishment relies on finding the mechanism to provide “selective incentives” [20] for compensators, in other words, having compensators compensated, but not with the public good.

Costly signaling [21,22] seems to be the potential mechanism that provides selective incentives for those who recoup punishers. Signalers contribute to public goods in the form of competitive displays. By doing so, they benefit from being prioritized to potential allies or mates [23–25], considering that the long-run cooperative relationships based on commitment would be more successful than those cooperative relationships based on reciprocity [26]. It would make better sense to understand the provision of public goods as costly signaling because otherwise, it would simply indicate the propensity to divert resources away from families and friends to strangers [27]. Essentially, choosing the costly signalers as allies or mates is another method of compensation for altruism; however, this compensation can give the compensators exclusive benefits because partnering altruistic signalers is not necessarily an altruistic behavior—it can merely be in their personal interest [28,29]. Giving a hero food or money as their compensation might ultimately benefit the freeriders, whereas being the hero’s ally or wife is another story completely. Even though compensators might fail to win the allies or mates they want, selective incentives are already there to overcome the public goods problem. Notably, the costly signaling mechanism is favorable to the emergence of altruistic punishment because the threat of reputation can prevent anti-social punishment or spite and create punishment that is focused on noncooperators [30].

While costly signaling is proposed as one mechanism for maintaining the evolution of altruistic punishment [31], some issues need to be addressed further. Previous studies on social dilemma based on CST have mostly treated altruistic punishment as a general public good. In other words, nonpunishing cooperators and punishers are neutral to the signal receivers. If contributing public goods rather than punishment is adequate to gain allies or mates, why bother to signal with the riskier punishment? As a result, most CST studies seem to solve the first-order social dilemma without the necessity of introducing punishment. The problem here is that previous studies have assumed that the costly signaling system of public goods has absolute efficacy. Indeed, several factors can attenuate the efficacy of a signaling system, e.g., observability, noise, receiver attention and interpretation [32]. In our case, there are at least two dimensions concerned.

First, in some cases, people might not regard altruistic propensity as the prior standard for choosing allies or mates. For example, several studies have shown that women have two mate-choice mechanisms: one gives the sexually desirable men a higher score, while the second one appreciates those men who are willing and able to invest in her and her children. Experimental evidence suggests that the former would be more salient when women are within their ovulatory cycle, which is the most fertile period within each month [33,34].

Second, even though individuals realize the importance of signals indicating altruistic propensity, they may not receive them substantially. Although the reason why individuals signal with public goods is to make the signals salient, this is not necessary to guarantee the effect of the signals. Without mass media (if it is credible), the observation on altruistic behaviors is limited, thus our ancestors highly relied on gossip to spread costly signaling with public goods. However, the information in social life that is spread by gossip may suffer distortions and attenuation due to the expansion of group size [35]. In addition, the specific social relationship an individual has or her/his position in a social network may also affect whether or to what extent costly signaling with public goods could spread substantially and receive the reward deserved.

All of these factors above can be regarded as noises in the costly signaling system of public goods. Studies have shown that introducing noise into the game might change otherwise neutral strategies [36–38]. Thus, distinguishing the two types of costly signals, i.e., nonpunishing public goods and altruistic punishment is not trivial under the condition that the efficacy of the costly signaling system of public goods is limited.

In this study, we apply simulation to explore two questions. First, can the costly signaling mechanism still solve the first-order social dilemma without introducing punishment if the efficacy of costly signaling is incomplete? Second, what are the effects of regarding altruistic punishment as a distinctive costly signal rather than the contribution of nonpunishing public goods,on the evolution of cooperation, especially on the emergence of altruistic punishment? To answer these questions, in this study, we explore the rules of transforming payoffs into fitness via costly signaling with simulation.

2. Methods

We consider three strategies. The defectors are those who do not contribute and exploit the public goods. The cooperators contribute but do not punish. The punishers not only contribute but also punish defectors. The interaction of the three types of individuals in a public goods game (PGG) is simulated with the five stages explained below.

The first stage is setting a random sample to participate in the game. We randomly choose N individuals from a well-mixed finite population of constant size M to take part in a PGG.

Among the N individuals, there will be N_x cooperators, N_y defectors, and N_z punishers. Then we have $N= N_x + N_y + N_z$.

The second stage is calculating the payoff for the individuals from the sample. According to the model in previous studies [16], the payoffs of cooperators, defectors, and punishers in each period of the PGG, namely, P_x, P_y, and P_z, are as follows:

$$P_x = \frac{1}{N}\sum_{i=1}^{x+z} cr - c \tag{1}$$

$$P_y = \frac{1}{N}\sum_{i=1}^{x+z} cr - \sum_{i=1}^{z}\delta \tag{2}$$

$$P_z = \frac{1}{N}\sum_{i=1}^{x+z} cr - c - \sum_{i=1}^{y}\gamma \tag{3}$$

where c is the contribution cost for cooperators and punishers ($c > 0$); r is the multiplier of return ($r > 1$); δ and γ denote the strength and the cost of punishment, respectively.

The third stage is calculating the evolutionary fitness. Previous studies assume that individuals with higher payoffs generally have higher fitness; thus, payoffs are directly transformed into fitness with an algorithm such as $F = exp\ (\omega P)$, where F is fitness, P is the payoff, and ω denotes selection strength ($0 < \omega \le 1$) [39]. However, from the perspective of costly signaling theory, what indeed enhances the fitness of individuals is the success of mating or allying. In this case, payoffs alone cannot determine the result of the competition on fitness. The success, instead, hinges on transforming payoffs into positive social attention as much as possible. In essence, what potential allies or mates care about is not payoffs per se, but how likely or how much of the payoffs would benefit him or her. This is, by a large extent, a hidden quality for each individual. As a result, if individuals want to gain a mate or gain allies to help them gain a mate, they need to send a signal not only telling these individuals how much they have, but also how much they are able and willing to give. Thus, we define the effect of costly signaling τ as a conversion rate between payoffs and positive social attention ($0 < \tau < 1$), and we discounted P by τ. Then, $P\tau$ represents the social attention holding power (SAHP) which is deemed significant for individuals to be successful in the evolutionary history of humans [40,41]. Accordingly, the algorithm of fitness changes to the following:

$$F = e^{\omega P \tau (c, \gamma,\ \ N_y; \alpha)} \tag{4}$$

We assume that the rules of transforming payoffs into fitness via costly signaling are as follows: the effect of costly signaling is the function of altruistic behaviors, including contributing to public goods and altruistic punishment. The more agents contribute or punish, the more their payoffs will be transformed into SAHP. More importantly, the altruistic punishment would be much starker than the nonpunishing contributions, which means it would transform payoffs much more substantially into the attention of potential mates or allies. Note, too, that the costly signaling system which regardspunishment and nonpunishing contributions as neutral has incomplete efficacy. Thus, we have the following:

$$\tau(c, \gamma,\ N_y; \alpha) = 1 - e^{-[1-\alpha+\alpha\lambda(\gamma N_y)(c+\gamma N_y)]} \tag{5}$$

where α depicts the efficacy of the costly signaling system ($0 \le \alpha < 1$), and the smaller α represents the stronger noise. Two main factors might contribute to the noise. First, individuals may choose their mates or allies based on factors other than altruism. For example, Studies show that women change dynamically between their two mate-choice mechanisms (either someone who is handsome or someone who is a good husband) across their ovulatory cycle [33,34]. Also, the heterogeneity in weight assigned to the two mechanisms for different women can be another source of noise. In addition, the observation of altruistic behaviors is limited, and any distortion or receding in the spreading of the gossip on altruistic behaviors can damp the efficacy of the costly signaling system. As a result, defectors (with $c = \gamma = 0$) might still get chance to prevail in the population even under the costly signaling system that favors those who provide public goods, with $\tau = 1 - exp\ [-(1 - \alpha)]$.

When $\alpha = 0$, providing public goods as costly signaling has few effects on enhancing fitness. In this case, τ for either defectors, cooperators or punishers is $1 - exp\ (-1)$, which means the calculation of fitness would be directly based on payoffs. Then the algorithm would be the same as the simulations in which fitness directly transformed from payoffs [16]. When

$\alpha \to 1$, τ for defectors is 0, and for contributors, including both nonpunishing contributors and punishers, it is $\tau = 1 - exp(-c)$. This is the situation, as assumed by most previous CST studies on the evolution of cooperation, where altruistic punishment would have no difference with nonpunishing contributions. Thus, this study can be viewed as a tentative attempt to synthesize the two mechanisms to maintain cooperation, i.e., altruistic punishment and costly signaling, into a general frame.

Thus, we use a Heaviside unit step function $\lambda(\gamma N_y)$ to denote the effect of altruistic punishment as a costly signal. We specifically define: $\lambda(\gamma N_y) = 1$ if $\gamma N_y = 0$ and κ if $\gamma N_y > 0$ ($\kappa > 1$). The bigger $\lambda(\gamma N_y)$ is, the more distinctive the altruistic punishment as a costly signal than a nonpunishing public good is. When $\lambda(\gamma N_y) = 1$, the costly signaling system of public goods would change to the scenario in which altruistic punishment would just be seen as an ordinary public goods, without differences with those nonpunishing contributions.

Then, we have the algorithm of fitness in the simulation as follows:

$$F = \exp\ \{\omega P[1 - exp(-(1 - \alpha + \alpha\lambda(\gamma N_y)(c + \gamma N_y)))]\} \tag{6}$$

The fourth stage is replication or strategy updating. In this stage, we adopt a Moran process in which an individual is first chosen for replication with a probability proportional to their fitness, and then the clonal offspring replace a randomly selected individual from the population M [42]. The replication can be interpreted as either reproduction or imitation.

The fifth stage is mutation. We assume that any individual in the population could randomly switch to either of the other two types with a small probability μ irrespective of its payoff. The parameter μ is called the mutation rate.

The pseudocode for the simulation is as follows:

Algorithm The pseudocode for the simulation

```
Initialize M agents
for each time do
  N_rand ←Simple(M) agents
  Play PGG
  For i=1 to N agents do
    P_i ← payoff(N_i)
    F_i ← fitness(N_i)on SAHP
  end for
  Max(F_i) of agents to reproduce one offspring
  if F_i of all agents == 0 then
    Reproduce none
  end if
  If number of agents ≥ N then
    agent_rand from agents to die
  end if
  Mutates
end for
```

3. Results

The simulation result under the weak efficacy of the costly signaling system is shown in Fig. 1. As shown in Fig. 1(a), defectors dominate if there is no punishment (here punishers and cooperators are identical). In Fig. 1(b), altruistic punishment is present, but it is regarded as a costly signal without any difference from nonpunishing contributions. In this case, the simulation shows that, after some oscillations, cooperation can hardly be established in the population. Then, we can see that punishers gain a foothold in Fig. 1(c) which depicts the situation in which altruistic punishment is seen as a more valuable costly signal than is nonpunishing cooperation.

One set of model runs, however, is not enough to confirm the result; thus, we run the model multiple times and calculate the mean of each data series (Fig. 2). We can see that the result is consistent with the result shown in Fig. 1. Additionally, we can find a divergence between the frequencies of punishers in the simulations where $\lambda > 3$ and those with $\lambda < 3$.

To further test the robustness of the simulation results, we explore how those results varied under different parameter values. The strategy frequencies here are the averaged proportion (over 20 times) in the population in the 100,000th period. We find that if individuals regard altruistic punishment as an ordinary costly signal, without altruistic punishment, cooperation can only be maintained when the efficacy of the costly signaling system is strong (Fig. 3(a)). Meanwhile, the range of parameters for establishment of cooperation widens after introducing altruistic punishment (from [0.7, 0.9] in Fig. 3(a) to [0.5, 0.9] in Fig. 3(b)). However, cooperation can only be maintained under the strong efficacy of the costly signaling system. Fig. 3(c) shows that cooperation can be established even under the weak efficacy of the costly signaling system (the range extends to [0.3, 0.9]) if altruistic punishment is seen as a distinctive costly signal.

Additionally, the effect of altruistic punishment as costly signaling is shown as robust in different initial compositions (Fig. 4). We can see that altruistic punishment gains a foothold if it is seen as a more valuable costly signal, even if the population consisted initially of 100% defectors. In addition, there is a threshold value of λ located at 3.0. Once λ is larger than 3.0, altruistic punishment can emerge, and as a result, cooperation can be established in the population. Other robustness

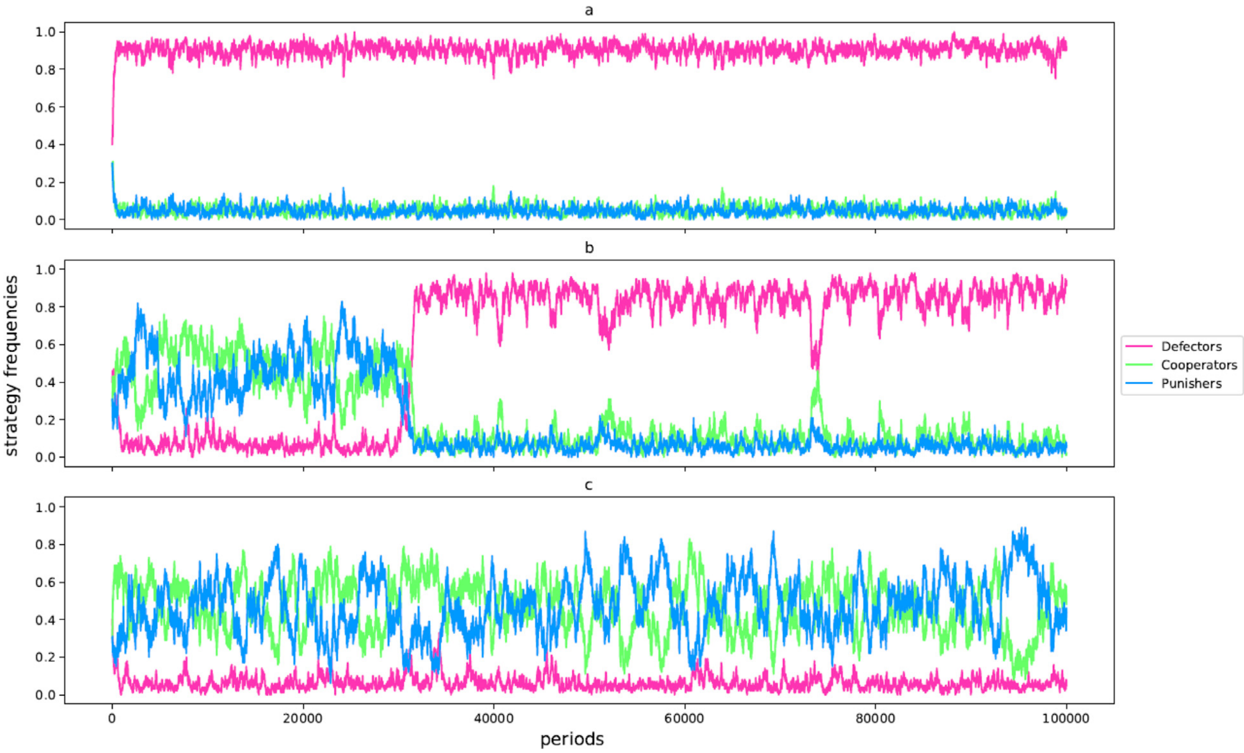

Fig. 1. Evolution of cooperation in a PGG. In the simulations, the parameter values are $M = 100$, $N = 5$, $X = 30$, $Y = 40$, $Z = 30$, $c = 1$, $r = 3$, $\delta = 1$, $\alpha = 0.3$, $\omega = 0.5$, $\mu = 0.001$. (a) With $\gamma = 0$, $\lambda = 1$. (b) With $\gamma = 0.3$, $\lambda = 1$. (c) With $\gamma = 0.3$, $\lambda = 5$.

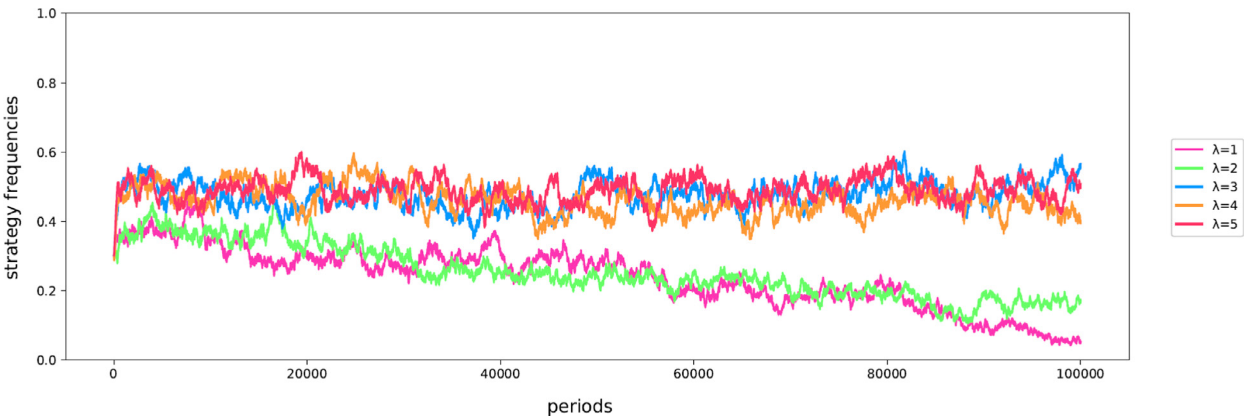

Fig. 2. Average frequencies of punishers(over 20 times) under different conditions. In the simulations, the parameter values are $M = 100$, $N = 5$, $X = 30$, $Y = 40$, $Z = 30$, $c = 1$, $r = 3$, $\delta = 1$, $\alpha = 0.3$, $\omega = 0.5$, $\mu = 0.001$.

tests are shown in Fig. 4. We can see that altruistic punishment can emerge over a considerably wide range of values on different parameters (see Fig. 5).

Considering that r in Fig. 5(e) cannot solely represent dilemma strength or weakness in evolution and cooperation and that r/N has been increasingly regarded as the real dilemma strength or weakness [10,43], it is necessary to check the emergence of altruistic punishment with different values of r/N. For this purpose, we run the model multiple times to obtain the contour plots of the frequencies of altruistic punishers in the 100,000th period versus α, λ, ω with r/N (Fig. 6). We can see from Fig. 6(a) that a high r/N and the relatively complete efficacy of costly signaling can support a high frequency of altruistic punishers; however the high level of r/N can still maintain the emergence of altruistic punishment even under lower α. Fig. 6(b) shows that when the λ is lower than 0.5, $r/N > 0.5$ is needed to maintain the emergence of altruistic punishment. When λ is lower than 0.2, r/N needs to be at least 0.7 to support the emergence of altruistic punishment. The result of Fig. 6(c) is consistent with the result shown in Fig. 5(d), in which the effect of the strength of natural selection can be moderated by social selections which are represented by the transforming rule in this study.

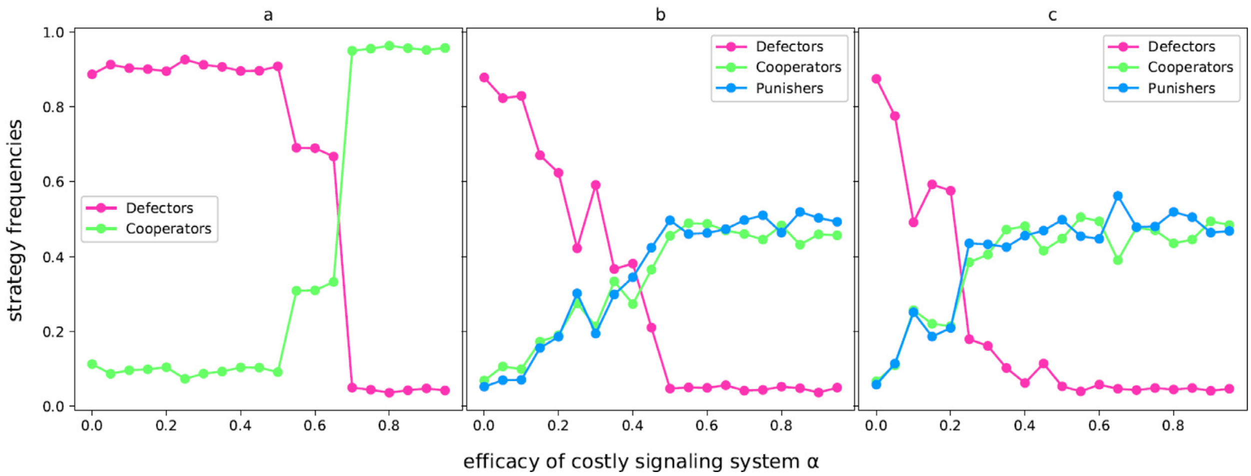

Fig. 3. The efficacy of a costly signaling system that does not distinguish nonpunishing public goods and altruistic punishment under different conditions. The parameter values are $M = 100$, $N = 5$, $c = 1$, $r = 3$, $\omega = 0.5$, $\mu = 0.001$. (a) With $X = 60$, $Y = 40$, $\gamma = 0$. (b) With $X = 30$, $Y = 40$, $Z = 30$, $\gamma = 0.3$, $\delta = 1$, $\lambda = 1$. (c) With $X = 30$, $Y = 40$, $Z = 30$, $\gamma = 0.3$, $\delta = 1$, $\lambda = 5$.

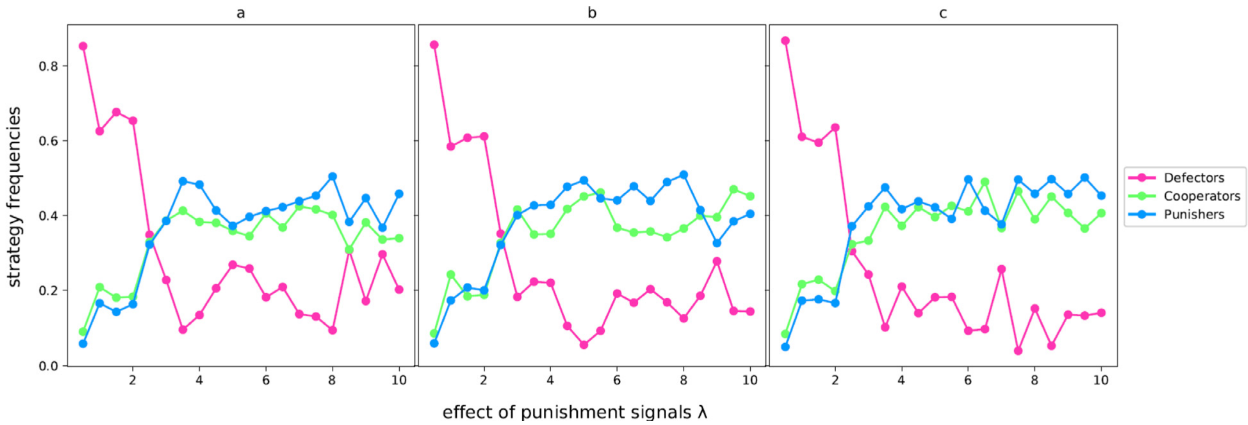

Fig. 4. The effect of altruistic punishment as costly signaling in different initial compositions. The parameter values are $M = 100$, $N = 5$, $c = 1$, $r = 3$, $\delta = 1$, $\alpha = 0.3$, $\gamma = 0.3$, $\omega = 0.5$, $\mu = 0.001$. (a) With 100% defectors. (b) With 100% cooperators. (c) With 100% punishers.

Finally, to further check the role that λ play in the establishment of cooperation, we run the model multiple times to obtain the contour plots of the frequencies of the cooperators (both nonpunishing cooperators and punishers) and altruistic punishers in the 100,000th period versus α and λ (Fig. 7). The results shown in the contour plots are consistent with the analysis above. In the region where both α and λ are relatively small, cooperation can be hardly established. In contrast, when λ is no longer 1, which means that individuals regard altruistic punishment as more valuable costly signals than the nonpunishing costly signals, altruistic punishment emerged even with small α.

4. Discussion

Our results are mainly based on a PGG. However, considering that dyadic interactions are the fundamental forms of social interactions and are broadly regarded as archetypes for studying the evolution of cooperation, it is important to reconsider the results by checking the relation between twoplayer and multiplayer games [43]. One important dimension to consider in this relation is scaling parameters that indicate dilemma strength or weakness. A PGG, by its nature, can be viewed as a multiplayer prison dilemma (PD) game. From this perspective, a PGG is equivalent to a donor & recipient (D&R) game, which is a specific form of 2 × 2 PD, in the sense that both have equivalent universal scaling parameters indicating dilemma strength or weakness. In a PGG, the dilemma strength is represented by a multiplier of return *r*; in a D&R game, *r* is equivalent to D_g’ and D_r’, where D_g’= D_g/R-P=T-R/R-P, D_r’= d_r/R-P=P-S/R-P. Here, T and S denote the temptation payoff and the sucker’s payoff in a PD game, respectively; R and P denote the reward from cooperation and the punishment from mutual defection, respectively [10,44].

The memory of the agents is an important dimension for studying the evolution of cooperation [45]. One assumption of this simulation is that agents have no memory about costly signals, which means that individuals would completely

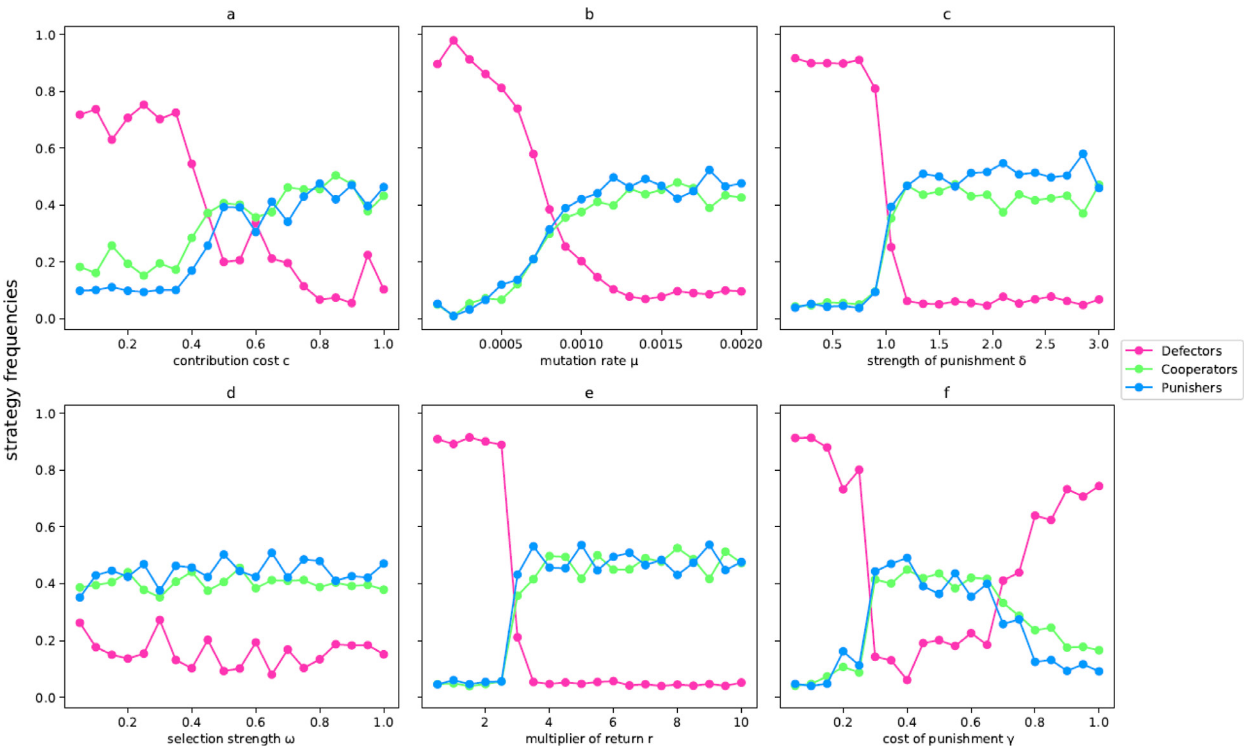

Fig. 5. The effect of different parameter values on the evolution of cooperation in PGG. (a) contribution cost c; (b) mutation rate μ; (c) strength of punishment δ; (d) selection strength ω; (e) the multiplier of return r; (f) cost of punishment γ. The parameter values are $M = 100$, $N = 5$, $X = 30$, $Y = 40$, $Z = 30$, $\alpha = 0.3$, $\lambda = 5$, $c = 1$(except for Fig. a), μ=0.001(except for Fig. b), $\delta = 1$(except for Fig. c), $\omega = 0.5$(except for Fig. d), $r = 3$(except for Fig. e), $\gamma = 0.3$(except for Fig. f).

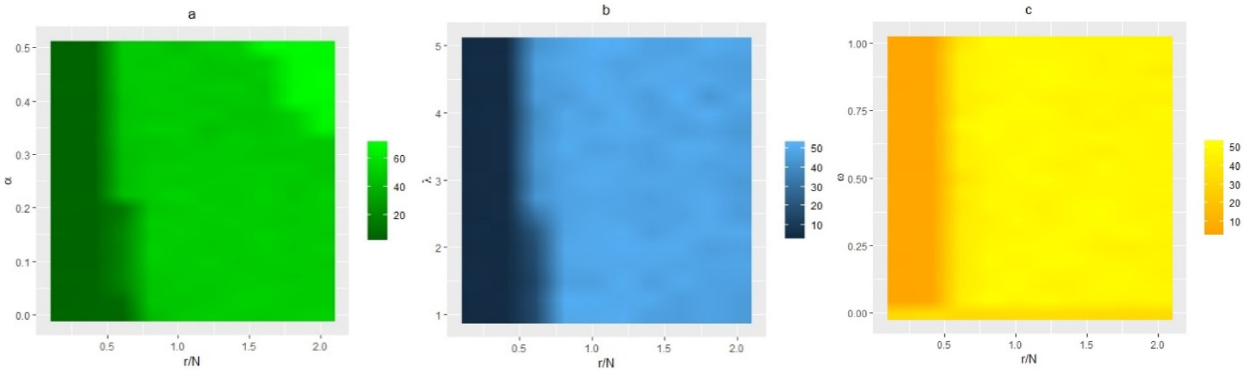

Fig. 6. Contour plot of the frequency of altruistic punishers (a) versus α with r/N and (b) versus λ with r/N and (c) versus ω with r/N over multiple times. The simulation is repeated, with $M = 100$, $X = 30$, $Y = 40$, $Z = 30$, $c = 1$, $r = 3$, $\delta = 1$, $\gamma = 0.3$, $\alpha = 0.3$(except for Fig. a), $\lambda = 5$(except for Fig. b), $\omega = 0.5$(except for Fig. c), $\mu = 0.001$, over 100 times. The frequencies are the average proportion in the 100,000th period, and the range of r/N is [0.2, 2].

ignore or forget what punishers have contributed in the last round. This is a demanding assumption that is unfavorable to the evolution of cooperation, whereas altruistic punishment can still emerge even under such an assumption if individuals regard it as a distinctive signal rather than a nonpunishing contribution.

Altruistic punishers, in some previous studies, would end with dominating the whole population, and nonpunishing cooperators would nearly die out if it were not for mutation [16,46]. However, a substantial part, if not the majority, of our society are noncooperators; thus, the results in this simulation, in which both altruistic punishers and nonpunishing contributors coexist, fit reality better.

Several pieces of experimental evidence show that punishers would be less rewarded than helpers [47]. There are two things to note in these results. First, punishers in the experiment do not help, whereas the main reason why altruistic punishment is so costly and what makes its emergence puzzling is that punishers are supposed to punish as well as to help. Secondly, some researchers think that punishers might benefit from being chosen as a long-run partner instead of being

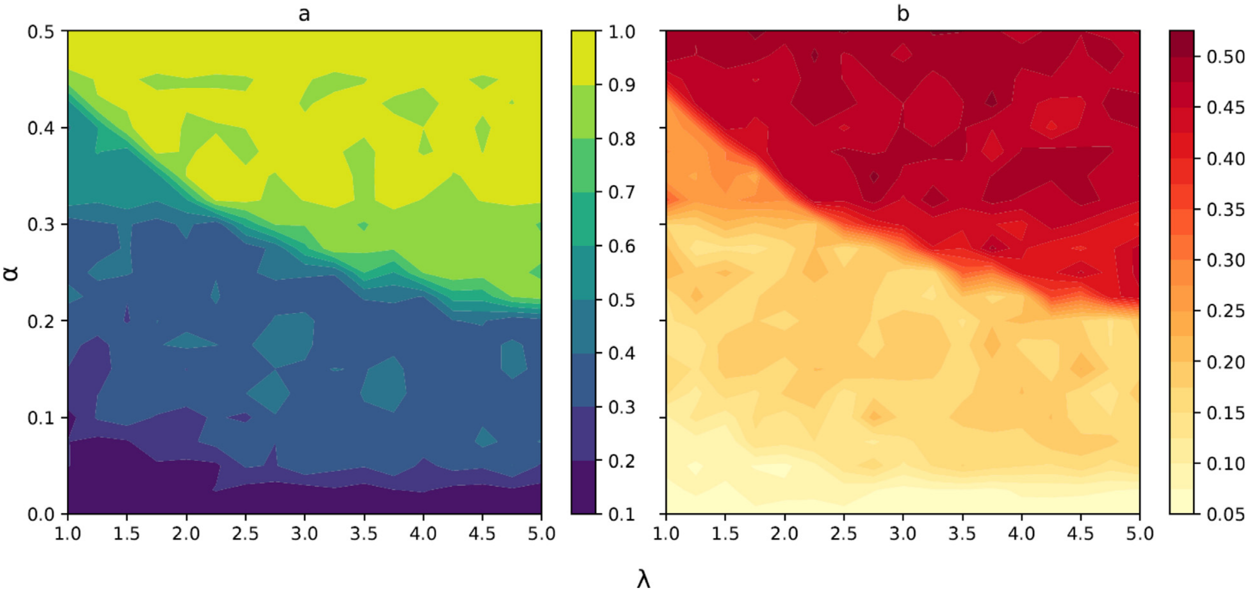

Fig. 7. Contour plot of the frequency of cooperators (including both nonpunishing cooperators and punishers(a) and the frequency of altruistic punishers(b) versus α and λ over multiple times. The simulation is repeated, with $M = 100$, $N = 5$, $X = 30$, $Y = 40$, $Z = 30$, $c = 1$, $r = 3$, $\delta = 1$, $\gamma = 0.3$, $\omega = 0.5$, $\mu = 0.001$, over 100 times. The frequencies are the average proportion in the 100,000th period, and the ranges of α and λ are [0, 0.5] and [1, 5], respectively.

rewarded in real-world settings; thus, more naturalistic experimental conditions are needed [47]. For example, although punishers are less frequently chosen as a temporary partner for a trust game [48], they are chosen more frequently as a partner who charges in resources [49]. Considering the experimental evidence above, which suggests that the adaptive advantage of punishers lies in their likelihood of being chosen as long-run partners instead of being chosen as recipients of a reward, we think that the algorithm of fitness that directly transforms payoffs into fitness might be not appropriate to explain why altruistic punishment can evolve. Thus, we emphasize in the simulation, from the perspective of costly signaling, that what dictates the fitness is not the payoff per se, but rather to what extent these payoffs can be transformed into the social attractiveness that brings aboutallies and mates.

We believe that altruistic punishment indeed contains at least two types of distinctive information that make them more valuable costly signals. First, altruistic punishment indicates that individuals are able and willing to become involved in social conflicts for others, which cannot be expressed by nonpunishing contributions. This might be the ultimate origin of the distinction between punishing costly signals and nonpunishing costly signals. In the early evolution of humans, only premature infants could be born successfully through the contracted pelvises of women, which is one of the consequences of upright walking [50]. On the one hand, premature infants have high level of brain plasticity, which is the basis for the evolution of complex cognition. On the other hand, it is impossible for human babies to survive without long-term parental care due to their lengthy postnatal development [51]. As a result, women prefer those men who are willing and able to providing food and protection. Since the latter would be more fundamental in conditions for survival, the costly signals that indicate the willingness and capacity to become involved in social conflicts can be more distinctive than others.

Second, costly signaling with altruistic punishment might contain information concerning how much social capital the signalers own. Here we use the definition of “social capital” in an individualistic approach, in which social capital means the investment in social relations with expected returns [52]. Anthropological studies provide an example of how costly signaling can convey information about the social capital of individuals. In many Melanesian societies, planting a type of yam with little material value is deemed the symbol of attractiveness for allying and mating. The reason for this is not only that growing the yam is a time-consuming process that can display the capacity to make a living but also that the well-grown yam signals the high social capital that one owns. The key to producing a long yam is to obtain pieces of a very long yam as the propagule; as a result, only those who possess a wide social network and high social capital can become producers of bigyams [23]. Here, we propose that altruistic punishment as costly signaling also contains information about social capital which is hardly conveyed by signals with nonpunishing contributions. First, ostracism has been one of the main ways of punishing free riders for a long time in human society [53]. Altruistic punishers, as the sponsors of ostracism, need enough social capital to let others take their side. Second, altruistic punishers always face the risk of retaliation [54]; thus, punishers who have strong social support have a greater chance to deter potential retaliation. Thus, altruistic punishment is a good opportunity for displaying the social capital that one owns.

The simulation result might shed light on some pieces of experimental evidence. One experimental study shows that women specifically regard men who are war heroes as more attractive. Meanwhile, researchers have found that heroism is a gender-specific signal because this effect is absent when male participants judge female war heroes [55]. This experimental evidence can be related to a folk psychological phenomenon that women generally find men in uniform, such as police officers and soldiers, attractive. From the perspective of this study, the uniform is essentially the symbol of third-party punishment. After the state emerged in human history, altruistic punishment was replaced, to a large extent, by the punishment enforced by the state. The men in uniform, who are the performer of thisenforcement, would be regarded as the individuals who have made a commitment to take risks or become involved in social conflicts for others, thus inheriting social attractiveness. Further experimental studies are needed to investigate whether women would regard men who are altruistic punishers as being more attractive than men who only contribute nonpunishing public goods.

Another experiment has shown that dominant male participants are no more attractive than the dominated male participants if they are nonprosocial. At the same time, study found that if all men are prosocial, then the dominant males would be deemedmore attractive [56]. If we relate these experimental results with the simulation in this study, we can find another reason why altruistic punishment, as a costly signaling, receives more positive social attention than nonpunishing contributions. That is, if female attraction is an interactive function of male dominance and altruism, then altruistic punishment signals both of these aspects at the same time, considering that punishments are usually performed by the dominant on the dominated.

To explain altruistic punishment as a costly signaling for mating can also help us to put together some experimental evidence. For example, on the one hand, men perform fewer instances of altruistic punishment on the condition of anonymity than do women[57]. On the other hand, men punish more than female participants in a public goods game with explicit rank-based incentives [58] or reputational benefits [59]. However, this “it’s a man’s world” explanation for altruistic punishment runs into the obvious difficulty as to why women punish altruistically. The important point to note is that once altruistic punishment has gained a foothold under the mechanism of costly signaling, it can be maintained by other mechanisms such as conformism. One possibility might be that women punish altruistically as a result of conforming to the norm, whereas men retain a psychological mechanism that requires incentives, such as social attention, to punish [57,60].

Finally, we would like to regard this study as another version of “via freedom to enforcement” [16], which suggests that free choice of some kind becomes the key for the emergence of cooperation. Although choosing freely about whether to join a public endeavor might be hardly achieved [17], free choices regardingpaying social attention to mating and allying might work. Because the hunter-gatherer society, in which the human species spent most of its history, had a relatively equal social structure without absolute coercion [53], competitions for mating and social ranks evolved into competitions for social attention. In this case, the generous receive much attention, and the righteous possess even more, fortunately. A recent study has shown that the selection pressure regarding how men can attract a mate is considerably changed in current society. This is because mate choice has become less forced as a result of social transition during the past few centuries [61]. If the mechanism depicted in the present study works, then the change might have a far-reaching influence on human society.

5. Conclusion

The question of how altruistic punishment can evolve is the key question for explaining the evolution of cooperation. On the one hand, previous studies that have solved the second-order social dilemma by recouping punishers have faced the n-order social dilemma. On the other hand, studies based on costly signaling theory, which is not subject to the n-order social dilemma, have rarely explained the emergence of altruistic punishment, because they do not distinguish punishing costly signals and nonpunishing costly signals. This study addresses these issues by exploring the rules of transforming payoffs into fitness via costly signaling with simulation. The simulation results in this study show under what conditions the mechanism of costly signaling can explain the emergence of altruistic punishment as follows. First, if the efficacy of costly signaling is high, the social dilemma can be solved at the first-order. Second, in the situation where the efficacy of costly signaling is low, the cooperation can hardly be established even if the punishment is introduced and if there is no distinction between punishing costly signals and nonpunishing costly signals; Third, altruistic punishment can emerge, under the conditions in which the efficacy of costly signaling is low, if individuals regard altruistic punishment as a more distinctive costly signal than nonpunishing contribution.

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