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Evolution of fairness in the dictator game by multilevel selection

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HIGHLIGHTS

- We model the evolution of fairness in the dictator game.
- We show that fairness is favored at the level of the group.
- An agent-based is used in evolutionary simulations of the dictator game.
- Evolved levels of fairness can explain empirical results from dictator games.

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ABSTRACT

The most perplexing experimental results on fairness come from the dictator game where one of two players, the dictator, decides how to divide a resource with an anonymous player. The dictator, acting self-interestedly, should offer nothing to the anonymous second player, but in experimental studies, dictators offer much more than nothing. We developed a multilevel selection model to explain why people offer more than nothing in the dictator game. We show that fairness can evolve when population structure emerges from the aggregation and limited dispersal of offspring. We begin with an analytical model that shows how fair behavior can benefit groups by minimizing within-group variance in resources and thereby increasing group fitness. To investigate the generality of this result, we developed an agent-based model with agents that have no information about other agents. We allowed agents to aggregate into groups and evolve different levels of fairness by playing the dictator game for resources to reproduce. This allowed multilevel selection to emerge from the spatiotemporal properties of individual agents. We found that the population structure that emerged under low population densities was most conducive to the evolution of fairness, which is consistent with group selection as a major evolutionary force. We also found that fairness only evolves if resources are not too scarce relative to the lifespan of agents. We conclude that the evolution of fairness could evolve under multilevel selection. Thus, our model provides a novel explanation for the results of dictator game experiments, in which participants often fairly split a resource rather than keeping it all for themselves.

1. Introduction

People often behave fairly even when it is not in their self-interest (e.g., Forsythe et al., 1994; Oosterbeek et al., 2004; Henrich Q4 et al., 2006, 2010; Engel, 2011; Yamagishi et al., 2012). Perhaps the most perplexing cases of this apparently irrational behavior are found in experiments using the dictator game (DG). A DG consists of two players and a resource to divide. One player, the dictator, decides how to divide the resource and can offer a portion of the resource to the other player, the recipient. The recipient can only accept what is offered. Unlike other fairness games such as the ultimatum and public goods games, the recipient has no leverage on the dictator. In experimental contexts in which both players are anonymous, punishment, reputation, and reciprocity can play no direct role. It is therefore always in the self-interest of the dictator to offer nothing to an anonymous recipient. Nevertheless, experimental studies have consistently found that dictators offer much more than nothing to anonymous recipients (e.g., Forsythe et al., 1994; Henrich et al., 2006, 2010; Engel, 2011). A meta-analysis of DG experiments found a mean offer of 28% (Engel, 2011), while the largest cross-cultural study to date found a mean offer of 37% across societies (Henrich et al., 2010).

Why people offer fair divisions of a resource in the DG is difficult to explain from an evolutionary perspective, but headway has been made. André and Baumard (2011) showed that if recipients (i) are less common than dictators in a market, (ii) have

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information about how dictators played in the past, and (iii) can choose a dictator based on information they have, then fairness can evolve. That is, when recipients are rare in a market, dictators who make unfair offers are not selected as partners and thus suffer the cost of not participating in a game.

These theoretical results run into difficulty when applied to fair behavior in DG experiments. In André and Baumard (2011)'s analysis, individuals have access to information about other individuals' past behavior and reputation plays the key role in explaining the evolution of fairness. In typical DG experiments, dictators and recipients are anonymous with no access to information about the past behavior of others. Anonymous players are randomly paired in these experiments, eliminating market conditions. It is therefore not in the self-interest of a dictator to offer anything at all to an anonymous recipient. Thus, the theoretical assumptions of André and Baumard (2011)'s analysis do not match the very specific conditions of DG experiments.

The ultimatum game (UG) is similar to the DG except that the recipient explicitly has leverage over the proposer through the ability to reject offers. If the recipient accepts the offer, it is divided as proposed otherwise both players receive nothing (Guth et al., 1982). There is no advantage to the proposer in offering more than the least amount the responder will accept and so the self-interested solution to the UG is for the proposer to offer the least amount possible and for the responder to accept any positive offer (Guth et al., 1982). Because of similarities between the UG and DG, theoretical insights into the UG may provide theoretical insights into the DG.

Page et al. (2000) showed that spatial structure matters in evolutionary simulations of the UG. Fairness could evolve if agents aggregate with agents with the same strategy and rejection levels just below offer levels. Although recipients in the DG cannot reject offers, Page et al. (2000)'s results suggest that space may be important for the DG (Page et al., 2000; Iranzo et al., 2011). Kuperman and Risau-Gusman (2008), Sinatra et al. (2009), Eguíluz and Tessone (2009), and Iranzo et al. (2012) reported theoretical results that support the importance of clusters of agents (in networks) in the evolution of fairness. Gao et al. (2011) showed that if network structure is allowed to evolve, clusters of agents evolve fair offers and relatively low rejection levels. This suggests that spatial clustering of similar agents may promote the evolution of fairness, but these theoretical approaches still require the leverage of rejection by the recipient to explain the evolution of fairness.

Researchers have also theorized that positive or negative reciprocity has played a key role in the evolution of fairness (Fischbacher and Gächter, 2002; Henrich et al., 2006; Dawes et al., 2007; Fehr et al., 2002). It could be that some participants in DG experiments do not fully understand the experimental conditions and expect reciprocity from their opponent even when anonymous. However, recent experimental results have found no relationship between behaving fairly in the DG and reciprocity in the ultimatum, prisoner's dilemma, and trust games, which casts doubt on reciprocity explanations of fairness (Yamagishi et al., 2012).

Another explanatory route is to examine the role of positive and negative emotions on fairness. In a recent study on the development of sharing in children playing the DG, researchers found that sharing behavior was positively related to both feelings of sympathy and feelings of guilt (Ongley and Malti, 2013). Another study found that empathy induced higher offers in both young adults and older adults and especially high offers in older adults (Beadle et al., 2013). Although prosocial emotions such as sympathy, empathy, or feelings of guilt towards a recipient may be proximate causes for fairness in the DG, the ultimate question of why fairness is beneficial remains unexplained.

Darwin (1871) recognized that prosocial traits such as sympathy, empathy, or feelings of guilt are difficult to explain by natural selection on individuals: "It is extremely doubtful whether the offspring of the more sympathetic and benevolent parents, or of those who were the most faithful to their comrades, would be reared in greater numbers than the children of selfish and treacherous parents belonging to the same tribe" (Darwin, 1871, p. 163). Darwin's solution to the problem of prosocial or altruistic traits was population structure. When groups can form in a population, selection can favor altruistic traits at the level of the group even if such traits are not favored at the level of the individual: "A tribe including many members who, from possessing in a high degree the spirit of patriotism, fidelity, obedience, courage, and sympathy, were always ready to aid one another, and to sacrifice themselves for the common good, would be victorious over most other tribes; and this would be natural selection." (Darwin, 1871, p. 166).

We theorize that the evolutionary problem of explaining fairness in the DG may require selection at the level of the group. We begin with a simple analytical model, which demonstrates that group selection can favor the evolution of fairness. To assess the generality and robustness of this result, we developed a spatially explicit agent-based model with agents that play the DG for resources to reproduce. The only trait that evolves in our model is the proportion, p, of a resource that is offered by an agent playing the DG. Using evolutionary simulations, we will show that multilevel selection emerges from the spatiotemporal interactions of agents. We will also show that individual and group selection oppose each other, and that the main factor in the evolution of fairness is the population structures that emerge under different population densities. We will find that while mutation and drift have detectable effects on the evolution of fairness, they are generally overwhelmed by individual selection. Finally, we will compare the results of our agent-based evolutionary simulations to a meta-analysis of DG experiments to assess the empirical plausibility of our model as an explanation of participants' fair behavior in DG experiments.

2. A simple model

Consider a population of two isolated groups of agents that play the DG for resources to reproduce. When an agent finds a resource, it divides that resource with another randomly selected agent in its group. For ease of analysis, one group consists entirely of fair agents (who offer half the resource) and the other consists entirely of unfair agents (who offer nothing). On each round of play, half of the agents in each group are randomly selected to obtain a resource and randomly paired with a non-selected member of their group. Each pair then plays the DG. Agents in the fair group split the resource, so if the dictators find 10 units of a resource, all agents in the fair group end up with 5 units of the resource. In the unfair group, the dictator keeps all of the resource and the recipient receives nothing. Thus, half of the agents end up with all of the resource and the other half receive nothing. In the long run, however, each agent is equally likely by chance to be a dictator or recipient in each round, so the expected payoff for both fair and unfair agents is the same: 5 units per round. Because there are no differences in expected payoffs between fair and unfair groups, how can there be fitness differences between groups?

Although the expected payoff for agents is the same in fair and unfair groups, the variance in payoffs within a group differs between groups as a function of fairness. Agents in a fair group split the resource evenly and so the variance in payoffs among agents is zero. Agents in an unfair group do not split the resource evenly and so the variance in payoff among agents is greater than