Evolutionary dynamics of collective action

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Abstract

In the natural world, performing a given task which is beneficial to an entire group often requires the cooperation of several individuals of that group who often share the workload required to perform the task. The modeling toolkit to address problems related with the dynamics of collective action and other conflict of interests is game theory, often combined with its dynamical counterpart, Evolutionary Game Theory [1]. In this context, the last decades have witnessed the discovery of key insights into the emergence and sustainability of cooperation at different levels of organization. Special attention has been paid to two-person dilemmas such as the Prisoner's Dilemma (PD), the Snowdrift Game (SG) and the Stag-Hunt game (SH), which constitute powerful metaphors to describe conflicting situations often encountered in the natural and social sciences.

Yet, unlike two-person games, current models of collective action have typically overlooked the necessity of some form of coordination among individuals, pervasive in biological and social collective dilemmas [2]. From social organization to the salvation of the planet against environmental hazards [3, 4], examples abound where a minimum number of individuals, which does not necessarily equal the entire group, must simultaneously cooperate before any outcome (or public good) is produced. With this abstract we intend to discuss the predictions of evolutionary game theory for the emergence of collective action, whenever a minimum threshold of individuals must cooperate simultaneously in a group before any viable public good is achieved. These conclusions were previously reported in Refs [2, 3, 5, 6].

We have concentrated on two of the most important collective dilemmas: the N-person snowdrift game (NSG) [5] and N-person prisoner's dilemma (NPD) [2]. In doing so, we uncover a new framework in which the advantage or not of cooperators depends sensitively on group and population size, as well as on the threshold for collective action. Such interplay leads to rich evolutionary scenarios of simultaneous co-existence and bi-stability, impossible to anticipate based on the traditional assumption of infinite populations, providing valuable insights into the variety and complexity of many person social dilemmas, inescapable especially among Humans.

In addition, it is noteworthy that irrespective of the distinctive features of the N-person Prisoner's dilemma (a defector's dominance dilemma) and the N-person Snowdrift game (a coexistence game) [5], the existence of a coordination threshold is able to produce a unifying framework associated with a generalized stag-hunt game [2]. Moreover, the necessity of coordination is shown to increase the equilibrium fraction of cooperators, even if this enhancement comes together with a strong dependence on the initial level of cooperation, since coexistence between cooperators and defectors only emerges when a minimum number of cooperators is already present in the population. This result is of particular relevance given that the existence of coordination thresholds constitutes a rule, rather than the exception. In addition, we shall also discuss how the chances of collective cooperation are strongly dependent on the perception that individuals have of the collective risk of failure [3]. In this context, we are able to show how global cooperation is better achieved within *i)* small groups, addressing *ii)* highly risky situations characterized by *iii)* stringent condition to meet goals [3]. This result has strong implications on our current understanding of various collective problems, from collective hunting, voluntary adoption of public health measures and other prospective choices, to the mitigation of the effects of global warming. Overall, our results reinforce the idea that even minor differences in the nature of collective rewards and/or costs can have a profound effect in the final outcome of evolution.

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