Social diversity promotes the emergence of cooperative behavior

Francisco C. Santos [a] Marta D. Santos [b] Jorge M. Pacheco [b]

[a] *CoDE-IRIDIA and MLG, Université Libre de Bruxelles, Brussels, Belgium*
[b] *ATP-Group, CFTC & DF, Universidade de Lisboa, Lisbon, Portugal*

Abstract

Throughout their life, humans often engage in public goods games in situations ranging from family related issues to global warming. In all cases, the *tragedy of the commons* threatens the possibility of reaching the optimal solution associated with global cooperation. Up to now, individuals have been treated as equivalent in all respects, in sharp contrast with real life situations, where diversity is overwhelming. In [4] we show how social diversity provides an escape from this paradox. We investigate the impact of social diversity in the evolution of cooperation in populations structured as heterogeneous graphs. We show that the diversity associated with the number and size of the collective endeavors each individual participates and with the individual contribution to each collective investment promotes cooperation. The enhancement of cooperation is particularly strong when both wealth and social ties follow a power-law distribution, providing clues on the self-organization of social communities and their economical implications.

1 Summary

One of the major puzzles faced by theoretical biologists and economists is to understand why individuals voluntarily contribute to public goods — benefits that everyone receives whether or not they contribute to them. From collective hunting to tax paying and green policies, the mechanisms that lead to the emergence of cooperative behavior remain a central challenge for several areas of science. The missing link between paying and benefiting from a public good creates an obvious dilemma between individual and collective goals, leading self-regaring individuals to refuse to contribute (to defect). A similar situation comes into play whenever the same resource is commonly explored by many, in which the so-called *tragedy of the commons* [2] — one of the most evocative metaphors of social sciences — is the ultimate outcome of selfish, non-cooperative behavior. Similarly, numerous engineering applications, in which decentralized control, social learning or population based artificial intelligence are used to achieve, for instance, self-organized task allocation, efficient online adaptive systems or collective robotics applications, require a proper understanding and control of the complex nature of self-organized cooperative behavior.

The problem of contributions to common goals, in all its different flavors, dates back to the classical writings of Rousseau, Hobbes and Hume, discussing the emergence of the *social contract*, a central political and philosophical concept [6]. Similarly, Charles Darwin tried to understand how costly contributions could lead to any kind of evolutionary advantage, given its apparent paradox, also present in most Human collective endeavors. If fact, even if cooperation abounds in Nature and Humans tend cooperate in many public goods dilemmas, current theoretical studies based in (evolutionary) game theory invariably predict, and economic experiments corroborate, that the temptation to forego the public good mostly wins over collective cooperative action.

However, up to now, individuals have been treated as equivalent in most respects, in sharp contrast with real life situations, where diversity is ubiquitous . In [4] we show how diversity provides an escape from the *tragedy of the commons*. We introduce diversity via realistic social networks [1], graphs in which individuals occupy the vertices while the links define the group sizes and social structure of the population. This opens the possibility that some individuals interact and are regarded as social models more often than others. Social diversity becomes associated with the number and size of the public good dilemmas in which

each individual participates, but also with the contribution that each individual, as a cooperator, is able to offer. Behavior becomes dependent on one's social context and ranking, as in real life.

The dilemma of cooperation is modeled as a public good game. Here, each participant is asked to contribute a certain amount to a common pool. The sum of all contributions is multiplied by a factor (given as input) representing how profitable the collective investment is. Afterwards, all members of the group equally share the collective profit. Unlike cooperators, who will pay the cost of contributing to the public good, free riders (defectors) will reap the benefits of the public good without incurring any costs. As usual in most studies of population dynamics that use (as we do) evolutionary game theory [3] as their theoretical tool, the profits accumulated from all public goods games in which each individual participates are associated with fitness values, representing their social (or biological) success. Therefore, behaviors of individuals with higher profits will be imitated more and spread in the population. The network, on the other hand, can be rationalized in terms of the average number of connections that each individual has, and diversity introduced by means of *scale-free* networks [1].

Contrary to homogeneous populations scenarios in which cooperation cannot survive, we show that the heterogeneity associated with the variety of social positions created the social network, is able to increase the overall number of contributions to collective investments, providing new clues concerning the mechanisms that supply Humans with one of the key social features responsible for our evolutionary success: cooperation. Social diversity can turn cooperation into a dominant behavior, even in the absence of complex community enforcement mechanisms, reputations or punishment.

From a moral perspective, this increase in cooperative behavior is shown to be particularly relevant when all contributions are perceived as a cooperative act, i.e., whenever the *act of giving is more important than the amount given*. Given the prevailing variety of economical backgrounds within modern societies, it is encouraging that such feature may work as an inducer of cooperative behavior. It is also shown how the interplay between cooperation and social diversity has important implications in what concerns wealth distribution in a population, whenever one interprets our results in a more economically oriented viewpoint.

Interestingly, our bottom line message of having social diversity as a strong promoter of cooperative behavior has been recently supported by several studies looking at other forms of social diversity. For instance, in [7] the authors show how diversity in learning rates (some individuals tend to learn the best strategies faster than others) can support cooperative behavior. Similarly, in [5] we have shown that diversity in the way one deals with our social contacts — or in the way individuals remain loyal to somebody else —, also promotes cooperation. This is gratifying, as we also hoped from the start to foster more studies on the advantages (or disadvantages) of having diverse and colorful, cooperative societies. A clear-cut answer may be hard to achieve, but we are convinced that useful hints can be grasped by means of mathematical models combined with agent-based simulations.

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