

EPL 40th anniversary highlight: Reward and cooperation in the spatial public goods game by A. Szolnoki and M. Perc

Statistical physicists aim to understand the patterns and structures that emerge from the interactions between components of a many-body system. Although originally developed in the context of condensed matter physics, concepts and methods from statistical physics underpin studies of complex systems, where the interactions need not derive from an energy function, but may have a biological, social or economic character.

Statistical physics thinking has been very fruitfully applied in the context of evolutionary game theory, a paradigm that aims to understand how social behaviours evolve from individual self interests. A classic problem is the public goods dilemma. Suppose a group of you get together, and agree that you can contribute (or not) to an investment, the returns shared equally between you, whether or not you choose to contribute. To get the best overall return requires everyone to cooperate and make a contribution—but if you choose not to contribute when everyone else does, you will do better in the end, through gaining a return without having paid in to begin with. A mean-field treatment of such a system shows that cooperation is unstable when everyone acts in self-interest to maximise their personal gain relative to others. This breakdown of cooperation was named by Garrett Hardin as the tragedy of the commons.

Many resolutions of the public goods dilemma have been proposed, for example, punishing those who defect. In their letter, *Reward and cooperation in the spatial public goods game* (EPL, **92** (2010) 38003), Atilla Szolnoki at the Institute of Technical Physics and Materials Science in Budapest and Matjaž Perc at the University of Maribor in Slovenia, explored a different mechanism. They introduced a new “super-cooperator” strategy, individuals who pay a cost to reward group members who cooperate. This means that regular cooperation is now an intermediate strategy, more cooperative than not contributing, but less cooperative than distributing rewards. This creates a possibility that cooperation may now thrive.

The authors explain that two ingredients combine to promote cooperation: “We demonstrated that spatially restricted interactions can make rewarding an effective mechanism for promoting cooperation—but not in the intuitively expected way. In particular, moderate rewards can be more effective than generous ones”. The origin of this effect is the emergence of cyclic dominance among the three strategies, sometimes referred to as a “rock-paper-scissors” effect, whereby each strategy outcompetes the next in a cycle (see fig. 1). “As recognised in statistical physics, such cyclic interactions can sustain stable coexistence in spatial systems”.

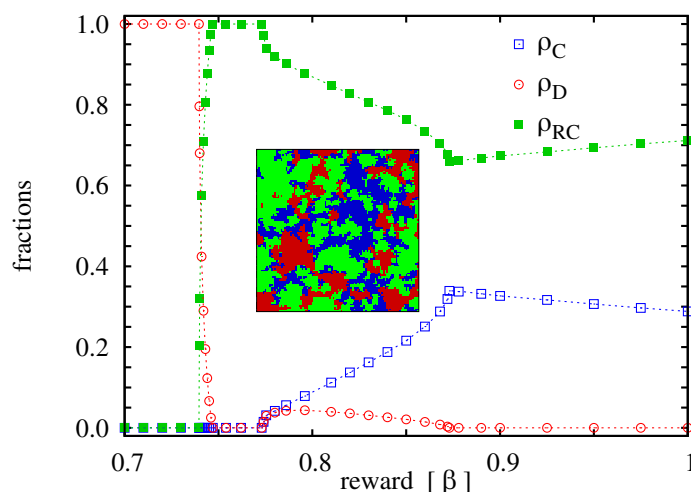


Fig. 1: Fractions of cooperators (C, blue), defectors (D, red) and rewarding cooperators (RC, green) as a function of the reward for cooperation. Intermediate rewards promote the RC strategy, which allows the cooperators to outcompete defectors. Inset: a typical spatial distribution in the coexistence phase where all three strategies are present. Credit: Atilla Szolnoki.

Xiaojie Chen, a former *EPL* Deputy Editor based at the University of Electronic Science and Technology of China, described this as insightful work that revealed “a previously hidden relationship between emerging evolutionary outcomes and the spatial structure of interacting agents”. The importance of going beyond mean-field analyses remains important, with Chen noting that the consequences of more complex interaction structures are not yet fully understood. Szolnoki and Perc concur, and further point out such research can also influence policy design, for example, by identifying which incentives are effective and how they should be distributed.

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