Comment

Towards unified characterization of cooperation mechanisms: comment on "Universal scaling for the dilemma strength in evolutionary games" by Wang et al.

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"I will jump into the river to save two brothers or eight cousins": This famous quote by J. B. S. Haldane accurately anticipates the conditions under which cooperation is the favorable choice in an interaction between genetic relatives. The general condition can later be formulated as a surprisingly simple mathematical expression, known as the Hamilton's rule, stating that natural selection favors cooperation if the genetic relatedness (r) between the donor and the recipient of a cooperative act is greater than its cost (c) to benefit (b) ratio [1]: $r > c/b$. Motivated by Hamilton's elegant early studies, researchers have attempted to find simple and concise rules that characterize the conditions for cooperation to be selected under various social viscosity [2, 3]. For example, the seminal work by M. Nowak [3] in 2006 shows that similarly simple rules can be derived that govern each of the other four popular mechanisms of cooperation—direct reciprocity, indirect reciprocity, group selection and network reciprocity—, which can be expressed via the cost-to-benefit ratio being smaller than some critical value associated with the mechanism at work (as seen, for kin interactions, the critical value is relatedness). However, these rules are restricted to the donor and recipient (D&R) paradigm. The question is thus whether it is possible to obtain simple rules even for the general case? The answer is not trivial as a general two-player game is described by four independent parameters, not just two as in the D&R game.

The excellent review by Wang et al. [2] precisely addresses this question, capturing recent approaches and their pitfalls, and furthermore, proposing a novel approach tackling the pitfalls. The authors show that, using a new set of two scaling parameters (see precise definitions of D_g' and D_r' in Equation (6) of the review), one can consistently characterize the conditions for the emergence and stability of cooperation in the general pairwise game when social viscosity is introduced through any of the five aforementioned mechanisms. Using theoretical analysis and simulations, the validity of the approach is demonstrated for both finite and infinite, well-mixed populations, as well as for various updating rules in structured populations. As such, the authors have proved that the new approach is better than all existing ones as the latter fail to produce consistent results when either social viscosity or population structure is considered. It is noteworthy that all existing approaches reduce the four parameter set that defines the general game to a reduced set of two scaling parameters. As an application of the newly introduced approach, the authors demonstrate that the paradox of cooperation

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benefits, suggested by Németh and Takács [4], can be convincingly resolved by simply applying their parameters scaling.

The advantages of having a unified characterization that promises consistent results across different modeling scenarios, are numerous. Typically, a theoretical model of evolution of cooperation focuses on resolving a single cooperation dilemma, and very often, a simplified parameterization of the payoff matrix is adopted (mostly for the sake of convenient analysis). It is therefore difficult to judge the validity of such a model in the general context, and more importantly, to compare results across models and even across analytical tools and methods. Adopting a unified characterization framework, such as the one proposed by Wang et al., would clearly facilitate such a problem. Secondly, the characterization may also benefit more theoretical analysis, for instance, where properties of equilibrium points in a general evolutionary game with random payoff matrices are studied [5-7], since in this case, all possible social dilemmas can occur. Finally, as a unified conceptual framework, it would enable a convenient and cross-domain analysis of various practical applications, ranging from traffic flows, swarm robotics, resource allocation, to behavioral epidemiology (see references in [2]), in which solutions for population cooperation have proven useful.

The important steps made to date are nicely captured in the review by Wang et al. [2], which provides much inspiration and references for those who wish to dwell into this fascinating line of research. Yet, much space for improvements and future advancements can be envisaged (next to the co-evolution and multi-player games issues already pointed out in the review). First, it would be interesting to study the validity of Wang et al. approach for other mechanisms of cooperation, such as punishment and reward [8]. The former is particularly interesting as human decision making seems to differ between cooperation dilemmas with and without punishment (see for instance the recent behavioral experiment in [9]). Second, while much attention has been given to different social viscosity in the literature, very few efforts have been made to study how individual cognition may impact the outcome of evolution dynamics and population cooperation levels [10-13]. Hence, it would be important to look at unified characterizations from an individual cognition perspective, as well as across cognitive skills.

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