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Comment

Theory must be informed by experiments (and back) — Comment on "Universal scaling for the dilemma strength in evolutionary games", by Z. Wang *et al.*

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The emergence and stability of cooperation has received a great deal of attention in the last two decades, and in fact the number of papers about this issue has increased in the last few years: compare the 155 references in [1] with the 314 in [2]. In spite of all this effort, the conditions allowing cooperation to be sustained are still unclear, in particular among humans, a key issue to understand our complex societies. One of the main reasons for this is that the models proposed to study cooperativeness from a theoretical viewpoint have ingredients, such as evolutionary dynamics or population structure, whose choice changes dramatically the corresponding predictions. Furthermore, apparently minor details, e.g., the presence of small mutations or different time scales in the dynamics, strongly modify the model outcomes, as discussed in detail in [1]. In this context, the review [2] deals with one of this difficulties, namely the effect of the payoff values on cooperation in a set of social dilemmas, and proposes a reparametrization that might lead to a more unified view.

While the ideas presented by Wang *et al.* [2] may be useful, it is of the utmost importance that the community of researchers working in the field starts taking into account the experimental results that have appeared in the last years. Otherwise, we will continue seeing more and more results obtained from a theoretical viewpoint that have nothing to do with the problem under consideration. A paradigmatic example is the so-called network reciprocity, i.e., the hypothesis that the existence of a structure (in the form of a network of connections) in a

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population supports cooperation. To date, this hypothesis is the main object of study of many theoretical papers in spite of the fact that experiments show that it is either wrong or, at best, has limited validity, only when the temptation to defect is small. The conclusion relies on already a few experimental papers that did not observe any cooperation at all [3, 4, 5, 6, 7] or found that some cooperation might be observed for low cooperation cost [8]. This negative result has been connected to other experiments showing that cooperation is very difficult beyond dyadic interactions [9]. There is also experimental evidence that the existence of a network structure does not affect the observed behavior in coordination [10]. Of all these papers, only [6] is quoted by Wang *et al.* [2] and, quite surprisingly, to support the claim that heterogeneous networks lead to cooperation, opposite to what the paper reports.

It may be argued that these experiments are done with human subjects and that theoretical models that are nullified by them may be of relevance to other species or situations. This may well be true, but in that case the proponents of those models should really try to focus on a specific context to avoid defining them in an *ad hoc* manner that produces confusing results. On the other hand, model proponents explicitly say that they are interested in human cooperation. In this case, ignoring the experimental results hampers the advancement of the field. Only a proper feedback between theory and experiments will help us understand how cooperation is achieved. Thus, the finding that people are moody conditional cooperators [4, 6] and do not pay attention to others's payoffs [7] is the basis for a theoretical approach [11] that is in agreement with the experimental observations. Consequently, models with a dynamics based on the payoffs of opponents should be disregarded as candidates to explain human behavior. Of course, larger payoff changes might affect this conclusion (in a similar manner to the results of [8] for low temptations to defect) and perhaps the approach proposed by Wang *et al.* [2] might pave the way to a comprehensive picture, but much more experimental work is needed to inform future models.

Finally, an important insight in [2] is the realization that the so-called five mechanisms supporting cooperation are in fact one: as shown in [12], all these mechanisms are nothing but different expressions of assortment, i.e., of the process by which cooperators try to outcompete defectors by restricting their interactions to inviduals whom they know will cooperate as well. This is an important step that has received strong support from experiments [13, 14, 15, 16, 17]: when people can choose their connections cooperation is significantly increased, and the key to that increment turns out to be reputation. It would be very interesting to develop an approach similar to the scaling in [2] for a population structured in a dynamic network and incorporating realistic dynamics, whose predictions could be tested in further experiments.

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