Three is a crowd in iterated prisoner's dilemmas: experimental evidence on reciprocal behavior"

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Cooperation constitutes a key ingredient to understand the origins of animal societies and, in particular, of human ones. The reasons why this general prevalence of cooperation is not disrupted by cheaters or free-riders more often are not well understood yet. In spite of the fact that a number of mechanisms leading to the emergence and stability of cooperative behavior in social dilemmas have been proposed, experimental studies have shown that without additional enforcement mechanisms, human groups often fail to sustain a public resource, which every group member is free to overuse.

One of the most plausible explanations for the decay of cooperation in public goods settings is the fact that many individuals are willing to contribute only by reciprocating what their partners do. This behavior, called conditional cooperation, has been observed in many public goods experiments, often along with a large percentage of free-riders.

The most recent development on this issue arises from in the experiments by Grujić *et al.*[1]. Although in these experiments the players play Multiplayers Prisoner's dilemma on a network, which is not exactly equivalent to a public goods game, conditional cooperation is observed again. Interestingly, it was found that conditional cooperation may also depend on the individual's own past action, i.e., on the 'mood' in which the subject currently is. In this case, individuals behave as conditional cooperators if they cooperated in the past while they ignore the context and free-ride with high probability if they did not cooperate. These moody conditional cooperators are a majority of the population in the aforementioned experiments, but a large group of defectors is also seen. This is in contrast with theoretical results based on a replicator dynamics approach[2], that showed that in groups with five or more people the coexistence of moody conditional cooperators with free-riders (and possibly a few unconditional cooperators) is not possible.

Inspired by the predictions of this work, in this paper we advance the knowledge on this issue by reporting on a series of experiments with human subjects playing an iterated multiplayer Prisoner's dilemma in groups of different sizes. Our starting research question is whether individuals actually behave in a moody conditionally cooperative manner or not, and whether the behavior of real subjects changes with the group size. We have addressed this question by looking at very long IMPDs on groups of 2, 3, 4 and 5 subjects. In our experimental setup, human subjects played a Prisoner's Dilemma (PD) with each member of their group, taking only one action, either to cooperate (C) or to defect (D), the action being the same against all the opponents. After every round the players were shown how many of their partners cooperated and defected in their group and the payoffs of cooperators and defectors. The number of rounds was 100, which was unknown to the players.

The analysis of our results allowed us to confirm very clearly the existence of moody conditional cooperation in all group sizes, this being in fact the behavior of almost all subjects. There is a very clear difference between the probability of cooperating after having cooperated or having defected, highlighting the importance of relating the current action with the one in the previous round. As for the linear behavior of each one of those probabilities, they appear to have larger intercepts for groups of size 2, while those of larger groups are comparable, while slopes are similar in all cases. The groups of size two (i.e., pairwise interactions or usual 2 Prisoners Dilemma) are very different for the observations on the rest of groups (sizes three and higher). Pairwise interactions show very high cooperation levels with an increasing trend, whereas for the rest of groups we find that cooperation decays from initially large values (around 60% or larger) much in the same way as in most Public Goods or networked PD experiments. In addition, for the case of pairwise prisoner's dilemma the cooperation level decreases in the first rounds, just like in the previous experiments[4–6]. However, here we conducted the experiment much longer than that, and, although the cooperation level does decrease at the beginning, after that it starts increasing reaching 80% after 100 rounds.

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