CLASSICAL *VERSUS* EVOLUTIONARY GAME THEORY

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Classical and evolutionary game theory attempt to explain different phenomena. Classical game theory describes socially and temporally isolated encounters while evolutionary game theory describes macro-social behavioural regularities. The actors in classical game theory are payoff maximizers whose identity remains fixed during the course of play. By contrast, in evolutionary game theory, the players are constantly changing, and the central actor is a replicator — an entity having some means of making approximately accurate copies of itself. However successful in its own realm, evolutionary game theory is ill-constructed to model the phenomena addressed by classical game theory. We must look to as yet undeveloped principles to achieve classical game theory's unfulfilled promise. I indicate a possibly fruitful step in this direction.

Brian Skyrms has given us a rich set of examples illustrating important differences between classical ('rational choice') game theory and evolutionary game theory. 'As an explanatory theory of human behaviour', he concludes, evolutionary models 'hold more promise of success than models based on rational choice'. I agree with this assessment. I want to stress, however, that the two approaches *attempt to explain different phenomena.* However successful in its own realm, evolutionary game theory is ill constructed to model the phenomena addressed by classical game theory. We must look to as yet undeveloped principles to achieve classical game theory's unfulfilled promise. I shall indicate a possibly fruitful step in this direction.

Classical game theory describes *socially and temporally isolated encounters,* while evolutionary game theory describes *macro-social behavioural regularities.* The actors in classical game theory are payoff maximizers whose identity remains fixed during the course of play. By contrast, in evolutionary game theory, the players are constantly changing, and the central actor is a *replicator* — an entity having some means of making approximately accurate copies of itself. The replicator can be a gene, a species, a strategy, a belief, a technique, a convention, or a more general institutional or cultural form. In classical game theory, behaviour is unaffected by historical or social context (though players may have 'beliefs' that presumably come from somewhere). In evolutionary game theory, the isolated encounter of classical game theory (often called the *stage game*), is embedded in a *behavioural context* that describes (a) the characteristics of the population of game players; (b) the relationship between game players and replicators; (c) how players are chosen to play the stage game in each time period; and (d) how the success and failure of players is reflected in the frequency distribution of replicators in the next period.

Classical game theory analyses the *Nash equilibria* of the isolated encounter. Evolutionary game theory analyses the *evolutionary equilibria* of the dynamic system implied by the stage game in its behavioural context. This dynamic can generally be represented by a set of differential equations or a stochastic process. An evolutionary equilibrium is accordingly represented as an asymptotically stable fixed point of the set of differential equations, or stationary distribution of the stochastic process. As Skyrms notes, in simple cases (for example, where agents are randomly paired in each period, and the replicator dynamic is operative), evolutionary equilibria are Nash equilibria of the stage game.

For the sake of concreteness, consider a prisoner's dilemma repeated n times (n is known to the players). On each round the two players receive \$2 each if both play C, \$1 if both play D, and C against D gives the C-player \$4 and the D-player zero. The game terminates the first time either player chooses D, or after n rounds if players have not played D to that point. A simple induction argument shows that if it is common knowledge that both players are 'rational' (i.e., that they play best responses), then both players will play D on the first round. To see this, note that on round n, both players will play D, since the game is now a one-shot prisoner's dilemma. Thus nothing the players do on round $n - 1$ can affect the outcome on round n. Thus both players will defect on round $n - 1$. And so on, back to round 1. When people actually play games of this sort with $n > 25$ (the payoffs and details of the game take many differing forms), they generally cooperate for many rounds (McKelvey and Palfrey, 1992; Andreoni and Miller, 1993; Kahn and Murnigham, 1993). Clearly, classical game theory gives an incorrect prediction here. But what prediction does evolutionary game theory give?

Consider a behavioural setting consisting of a large population of players randomly paired at times $t = 1, 2, \ldots$, such that for each t, each pair plays the repeated prisoner's dilemma with $n = 100$. Suppose also that the payoffs are player fitnesses, so after each period, players reproduce proportionally to their success in the game. Then, if we start with a population including all possible strategies, the unique evolutionary equilibrium is *also* to play D on every round! This is because the 'defect on round 1' strategy is the only one to survive the iterated elimination of strictly dominated strategies, and an evolutionary equilibrium under the replicator dynamic includes only strategies of this type (Gintis, 2000, chapter 10). This is illustrated in Figure 1, which is an artificial life simulation of this game.
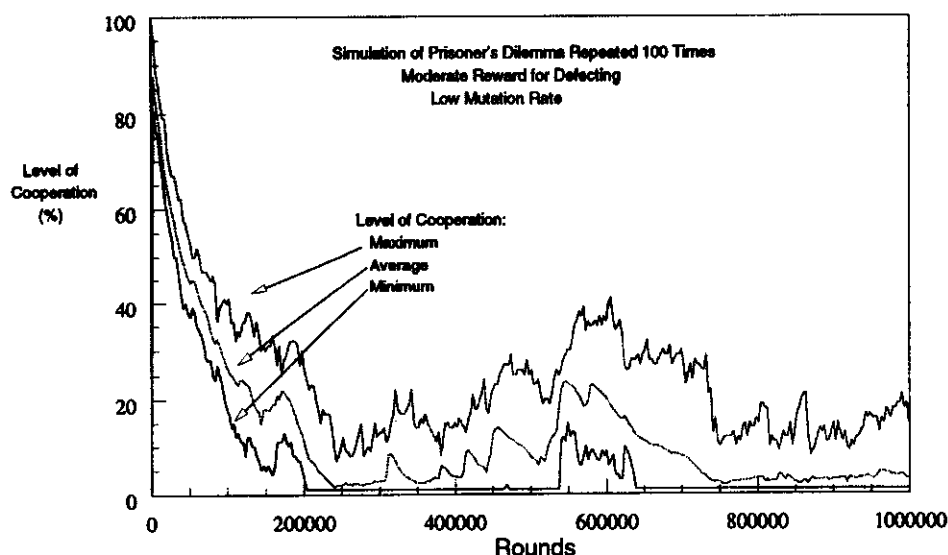

Figure 1

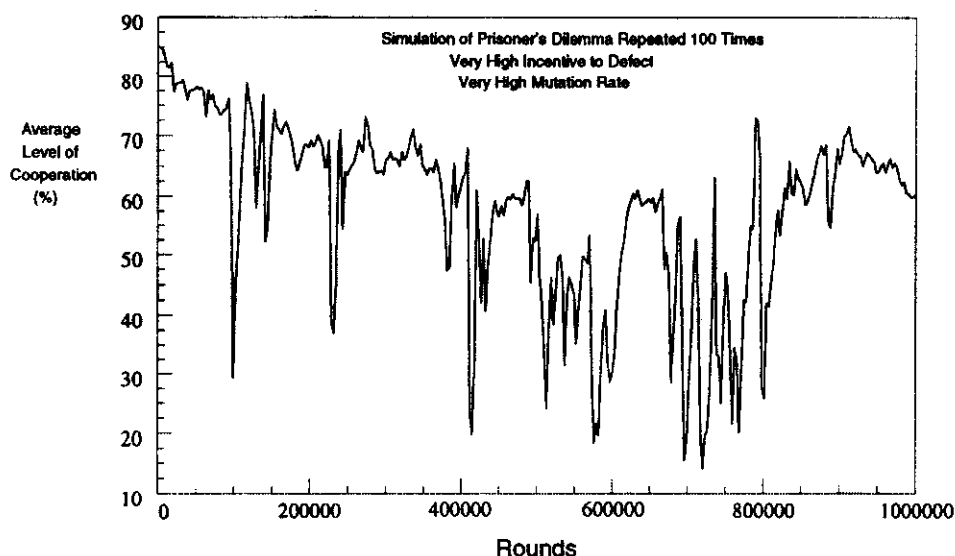Simulation of the finitely repeated Prisoner's Dilemma with a low mutation rate (0.1 %)

Figure 2

Simulation of the finitely repeated Prisoner's Dilemma with a high mutation rate

In this simulation, there is a population of 2,000 agents who are hard-wired with a 'gene' to cooperate for a certain number of rounds before defecting. Each agent is initially randomly assigned a gene with a value between 1 (defect immediately) and 101 (never defect). The agents are then randomly paired on each round, and paired agents play the above game. After each round, the lowest 0.50 per cent of scorers die, an equal number of the highest scorers reproduce, with a mutation rate (where an agent's defection point is randomly altered) of 0.001. Notice that cooperation at first increased rapidly to the 95 level, and then declines to very low levels. There are surges of cooperation up to 20 rounds, but the average generally hovers below 5. The evolutionary equilibrium value of 1 is not attained only because there is a positive mutation rate.

Evolutionary game theory suggests two reasons why this result might *not* be observed in practice. First, if there is enough mutation, a moderately high level of cooperation can be supported. This is illustrated in Figure 2, where cooperation varies between 15 per cent and 60 per cent. The second is that since *Homo sapiens* has *not* been subjected to an evolutionary process whereby people who do poorly in the finitely repeated prisoner's dilemma receive fitness penalties! Humans have simply never faced the relentless 'weeding out' of cooperators in daily life that is depicted in our simulation.

The two explanations of why humans cooperate in the repeated prisoner's dilemma are in fact closely related. Halving the probability that the game will be played in any period is operationally equivalent to doubling the rate of mutation. If there is a constant minimum level of mutation μ_0 per time period, and if convergence to a (suitably defined neighbourhood) of the evolutionary equilibrium requires a maximum mutation-rate μ_{max} per play of game, then if the probability p that an agent plays the game in a given time period falls below $p_{min} = \mu_0/\mu_{max}$, the evolutionary equilibrium will not be observed.

A more suggestive way of expressing this conclusion is that *nature abhors low probability events*. Consider, for instance, an organism with limited information processing capacity. The number of variants in the behavioural repertoire of such an organism will necessarily be small. Upon encountering a set of environmental stimuli, the organism first assigns the situation to one of a limited number of pre-given situational contexts, and then refers to the behavioural repertoire appropriate for that context for the proper choice of action. When the organism comes upon a new and strange situation, it does not create a new context, but rather relates the situation to one of the situational contexts for which it already possesses heretofore effective coping responses. Therefore, *all events encountered by such an organism are high probability events*.

The number of situational contexts an agent recognizes, and the number of behavioural responses appropriate to each, are governed by the principle of evolutionary fitness. It may be thought that more mental capacity and intellectual flexibility are unambiguous fitness enhancers, but this is clearly false. Adding a context, or a response within a context, has two costs that are 'fixed' in the sense that they have minimum levels independent of frequency of use. First, an expanded discriminatory or behavioural repertoire requires additional supporting neurological and physiological mechanisms. These mechanisms must be fuelled and maintained in good repair at all times. Second, such responses can be deployed when they are inappropriate, causing harm to the organism. If there is a minimum probability that an available response will be used, the ratio of inappropriate to appropriate use will then be a decreasing function of the frequency of the context for which it offers an effective response. Therefore, on both counts the lower the probability of occurrence of a context, the less likely will the expanded responsive capacities contribute to the organism's fitness.

Homo sapiens is doubtless no exception to this analysis, although with a larger repertoire of situational contexts than other species. This fact is of central importance, for instance, in interpreting the behaviour of human subjects in experimental game theoretic settings — settings where the predictions of classical game theory are notoriously poor. Neither personal history nor cultural/genetic evolutionary history has prepared subjects for the ultimatum, dictator, trust, common pool resource, bargaining, and other games that they confront in the laboratory. (For a review of some of these experimental settings, see pp. 215–19 above, where I discuss Sober & Wilson's contribution to this volume). Most likely, a subject treats the low probability event (the experiment) as an instance of a high probability event by assigning the event to one of the subject's pre-given situational contexts, and then deploying the behavioural repertoire — payoffs, probabilities, and actions — appropriate to that context. We may call this *choosing a frame* for the experimental situation. It is therefore incorrect to maintain that subjects are 'irrational' or 'confused' when they 'drag their history' into an experimental situation, since such behaviour is an *evolutionarily adaptive behaviour.*

The results of the ultimatum game, for instance, suggest that in a two-person bargaining situation, in the absence of other cues, the situational context applied by most subjects dictates some form of 'sharing'. Suppose we change the rules such that both proposer and respondent are members of different *teams* and they are told that their respective winnings will be paid to the team rather than the individual. Subjects then

often deem a distinct situational context, involving 'competing for one's team,' appropriate. This dictates acting on behalf of one's team and suppressing behaviours that would be otherwise individually satisfying — such as 'sharing'. In this case proposers offer much less, and respondents very rarely reject positive offers (Shogren, 1989). Similarly, if the experimenters introduce notions of property rights into the strategic situation (for example, that the proposer in an ultimatum game has 'earned' or 'won' the right to this position), then motivations concerning 'fairness' are considerably attenuated in the experimental results (Hoffman, *et al.*, 1994;Hoffman, *et al.*, 1996).

It is plausible that some variant of the above schema, involving mapping common situational contexts onto novel, low probability events, may explain behaviour in the sorts of socially and temporally isolated encounters that form the subject of classical game theory. If so, the assumption of 'common knowledge of rationality' must be replaced by some (analytically rigorous) assumption of 'common knowledge of humanity' in the sense that each player in a one-shot game G knows how the other players map their high probability situational contexts onto G. In the finitely repeated prisoner's dilemma, for instance, each player may know that the other will treat the game as a trust game, and will assign a particular probability distribution to defecting on each round — plausibly one that puts zero weight on early stages of the game rising to moderate levels as the players near the final round. Models of this type, which do not involve the choice of best responses by the players, and which are inadequately modelled by either evolutionary or classical game theory, remain to be developed.

Acknowledgements

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