Prisoner's Dilemma
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Chapter 2

Effects of Mixing Games and Concealing the Matrix

So FAR we have been mainly concerned with the effects of the payoff parameters on performance. Now let us examine other effects. Our data come from a number of experiments. In all of them Prisoner's Dilemma is played by a pair of University of Michigan students several hundred times in succession. However, as we have seen, certain conditions vary from experiment to experiment. For example, as we pass from the "Pure" to the "Block" to the "Mixed" conditions, the games become progressively more mixed. In the Pure Matrix Condition, each pair plays only one kind of game. In the Block Matrix Condition, each pair plays all seven games, but there are fifty successive plays of each game. In the Mixed Matrix Condition, all seven games are entirely mixed, following each other in random order. A natural question to ask is whether the games "contaminate" each other in the sense that the games, which in the Pure Matrix Condition are characterized by very low *C*, show a higher value when mixed with other games, and games with a high value of *C* in the Pure Matrix Condition show lower values when mixed with other games.

An examination of Table 2 (p. 47) shows that this indeed may be the case. The game with the highest *C* in the Pure Matrix Condition is Game II. The value of *C* in this game is considerably reduced in both the Block and the Mixed Matrix Conditions. Next, Game V, which is the lowest in all conditions, shows a considerably higher *C* in both the Block and in the Mixed Matrix Conditions compared with the

Pure Matrix Condition. In short, the range of *C* is reduced in the Block and in the Mixed Matrix Conditions. We can also examine a somewhat more refined measure of the spread of *C*, namely its variance. This turns out to be .02 in the Pure Matrix Condition, .011 in the Block Matrix Condition, and .01 in the Mixed Matrix Condition.

These results we would expect on commonsense grounds, if we assume that the response propensities are determined by the interaction of the players and tend to spread over all the games played by a pair of players.

Now let us examine the effect upon performance of the displayed matrix. The comparison can be made in the Pure and in the Mixed variants, since both variants appear in our design with matrix displayed and with matrix not displayed. The idea behind this variation was originally inspired by discussions about the relative merits of game theory and learning theory in describing performances on repeated games. Actually the idea is older than game theory. It stems from some early findings in experiments on animals in learning situations in which responses are reinforced probabilistically.

As a simple example consider an animal in a *T*-maze in which right and left turns are differentially reinforced in the sense that food in the same amounts appears at random at the one or the other end with unequal probabilities. It was noted that in many cases the trend is toward a steady state distribution of right and left responses whose probabilities are proportional to the probabilities of finding food at the right or the left end respectively. Observe that this "solution" is not "rational" from our human point of view. Such a situation would be classified in the theory of rational decisions as decision under risk. Ordinarily in such situations the maximization of expected gain is prescribed by normative decision theory. If the relative magnitudes of the two probabilities were correctly estimated by the subject (note that it is not necessary to estimate their numerical values but only their relative magnitudes), then expected gain is maximized if the turn which results in the greater probability of reward is *always* taken. However, the distribution of right and left turns in accordance with the respective probabilities of reinforcement is a consequence of a stochastic theory of learning (Bush and Mosteller, 1955, p. 68 ff.) and so has its "rationale" also, although it is not the rationale prescribed by rational decision theory. Here, then, we have a clear-cut dichotomy between two theories of behavior and an experimental situation in which they can be pitted one against the other.

In recent years other experimental situations have have been designed with the specific purpose of pitting some game-theoretical prescriptions against the predictions derived from stochastic learning theory (Suppes and Atkinson, 1960). In particular, a two-person zero-sum game with probabilistic payoffs lends itself to such a treatment. If such a game has a saddle point, game theory prescribes to each player the choice of strategy containing the saddle point. Thus the solution of such a game is for each player to choose a single strategy and to play it always. Learning theory, on the other hand, may predict an alternation between the strategies. If the two-person zero-sum game does not have a saddle point, game theory prescribes a unique mixed strategy to each player. Here learning theory may also predict a mixed strategy, but possibly a different mixture. In all these cases, therefore, opportunities are offered to compare the prescriptions of game theory with the predictions of learning theory.

In the case of Prisoner's Dilemma, game theory either fails to prescribe a strategy altogether (a point of view taken by those who consider game theory to be entirely a branch of formal mathematics and so not even a normative theory of behavior) or else prescribes a counter-intuitive strategy, namely the strategy $D^{(n)}$ in a Prisoner's Dilemma game played n times.

We did not expect to see $D^{(n)}$ chosen when $n = 300$, and we did not see it. Hence in our case it was not a matter of comparing game-theoretical predictions with learning-theoretical predictions. We hoped at best to see whether two different learning processes were involved, depending on whether the logical structure of the game was immediately apparent to the subjects or had to be learned from the outcomes. Some of us thought, for example, that the effect of the displayed matrix on *C* would be inhibitory. We argued that in a trial and error process, the tacit collusion solution *CC* would be sooner or later hit upon and would persist because of the steady positive payoffs it affords to both players in contrast to the unilateral states *CD* and *DC*, which ought to be unstable (because one of the players loses the largest amount in each of them), and in contrast to the *DD* state, which is punishing. When the matrix is displayed, however, so our argument went, the dominance of the defecting strategy is a constant inhibitor against cooperating. One always is subjected to the temptation of defecting from *CC* to get the bigger payoff *T*, and one is afraid to leave *DD* for fear of getting *S*. It would be better for cooperation, we thought, if these brutal facts were not explicitly before the subjects' eyes.

The results turned out to be exactly the opposite. The amount of cooperation observed in the Pure No Matrix Condition is just about one half the amount observed in the Pure Matrix Condition. The comparisons are shown in Figure 3.

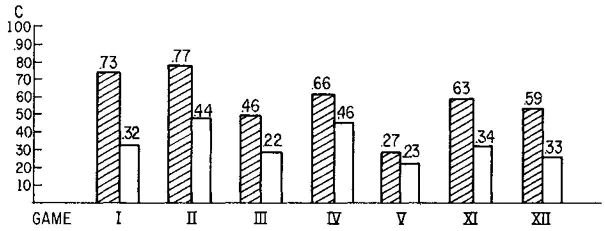

Figure 3. Comparison of frequencies of cooperative choices when game matrix is displayed (left) with when it is not (right).

There is no question of the significance of this result. Even a simple sign test (a very weak test of significance) shows the result to be significant on the $P < .02$ level if only the Pure Matrix Conditions are compared. If both the Pure and the Mixed Matrix Conditions are taken into account, the sign test gives an even greater significance of the difference.

It follows that our original conjectures about the effect of the displayed matrix had to be revised. Instead of serving as a reminder of the prudence of choosing *D*, the matrix seems to serve as a reminder that a tacit collusion is possible quite regardless of what the formal game theoretical prescription (the equilibrium strategy) might be.

In summary, we find that mixing the games makes them less differentiated. In the extreme case where the seven games are presented in random sequence and the matrix is not displayed, the differentiation of the games practically disappears altogether except that the most severe Game V with its very large temptation payoff still stands out as the game that induces the smallest frequency of cooperative responses. The effect of the displayed matrix is a salutary one from the point of achieving tacit cooperation. It manifests itself in all the seven games both in the pure and in the mixed conditions.