More Realism in the Prisoner's Dilemma

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One important assumption made in the standard Prisoner's Dilemma game, and one for which Robert Axelrod's (1984) work has been criticized, is the assumption that an individual has only two extreme choices when interacting with another individual. Robert Trivers (1985) also stated an interest in seeing if the same results could be achieved in a more complex model. In response to these ideas, a computer simulation was run with an expanded payoff (5 × 5) matrix that was created by interpolating values from the original payoff matrix used by Axelrod. The new payoff matrix is presented below.

			B				
			Total Cooperation ◄——► Total Defection				
			1	2	3	4	5
A	TC ↕ TD	1	(3.00,3.00)	(2.25,3.50)	(1.50,4.00)	(0.75,4.50)	(0.00,5.00)
		2	(3.50,2,25)	(2.69,2.69)	(1.88,3.13)	(1.06,3.56)	(0.25,4.00)
		3	(4.00,1.50)	(3.13,1.88)	(2.25,2.25)	(1.38,2.63)	(0.50,3.00)
		4	(4.50,0.75)	(3.56,1.06)	(2.63,1.38)	(1.69,1.69)	(0.75,2.00)
		5	(5.00,0.00)	(4.00,0.25)	(3.00,0.50)	(2.00,0.75)	(1.00,1.00)

There was some question whether to use a 3 × 3 matrix instead of the 5 × 5 matrix that was used. Axelrod used a 2 × 2 matrix; the next logical step in realism would be the use of a 3 × 3 matrix. First, a 3 × 3 matrix does not greatly increase the number of choices available to the participants. There are still only three choices for each individual, while a 5 × 5 matrix gives the impression of having significantly more choices. And although a 3 × 3 matrix would seem to be the next logical step, a 5 × 5 matrix will yield the same results, and the steps involved when each rule either does or does not converge to an equilibrium are more clearly visible.

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With a larger payoff matrix, the variety of strategies available to the players is greatly expanded. One such strategy is called SUBTLE CHEATER (Trivers, 1985). SUBTLE CHEATER is a strategy that begins by cooperating at one degree less than total cooperation. In all subsequent turns it cooperates at one degree less than its opponent did in the previous turn. Two other possibilities are strategies called tit-FOR-TAT and TIT-FOR-tat, in which the degree of retaliation is one degree less and more, respectively, than the other's defection. With the larger payoff matrix, a greater degree of reality is incorporated within the Prisoner's Dilemma simulation.

THE SIMULATION

The simulation consisted of a round-robin tournament in which each rule plays a game with each of the other rules, including itself. Each game lasts for a fixed 200 turns since none of the strategies included has any special endgame objectives. The decision on which rules to include in the simulation was based on several factors. First, the rules that received some attention in Axelrod's book were included and in some cases had to be adapted to the new system. Next, the strategies that are variations of TIT-FOR-TAT were included to test how varying degrees of retaliation affect the overall outcome. Also included were all of the suspicious rules from the TIT-FOR-TAT family because of the interesting implications of strategies beginning in an unfriendly relationship. Finally, the strategy SUBTLE CHEATER, as described by Trivers (1985), was included because it is of interest to see how a strategy that always tries to get a little more than its partner will do in the long run.

THE WINNER

The strategy that achieved the greatest average score in the simulation was tit-FOR-TAT. Out of the 12 strategies examined, TIT-FOR-TAT came in second behind tit-FOR-TAT. TIT-FOR-TAT's average score was 37 points below that of tit-FOR-TAT. Although the environment was designed to challenge TIT-FOR-TAT, the large margin by which it was beaten by tit-FOR-TAT is indicative of some of TIT-FOR-TAT's shortcomings.

	1	2	3	4	5	6	7	8	9	10	11	12	ave earned
1	600	600	600	600	598	600	371	596	585	450	450	149	517
2	600	600	600	600	598	600	462	500	292	500	206	199	480
3	600	600	600	600	574	600	480	500	240	500	205	199	475
4	600	600	600	600	597	600	422	448	514	203	206	199	466
5	600	598	451	597	596	154	382	589	583	150	357	150	434
6	600	600	600	600	401	600	592	203	259	203	205	199	422
7	588	456	328	491	579	110	443	439	451	333	308	103	386
8	601	500	500	451	595	203	440	200	253	200	205	200	362
9	610	290	238	552	607	260	458	253	262	253	206	199	349
10	575	500	500	209	399	203	493	200	256	200	204	200	328
11	700	211	205	216	605	211	511	205	210	201	204	199	307
12	403	204	204	204	399	204	587	200	204	200	203	200	268
ave given	590	480	452	477	546	362	470	361	342	283	247	183	

1. tit FOR TAT
2. TIT FOR TAT
3. TIT FOR tat
4. TIT FOR TWO TATS
5. SUSPICIOUS tit FOR TAT
6. FRIEDMAN
7. RANDOM
8. SUSPICIOUS TIT FOR TAT
9. JOSS
10. SUSPICIOUS TIT FOR tat
11. SUBTLE CHEATER
12. ALL D

There are several reasons for tit-FOR-TAT's success in the simulation. First, tit-FOR-TAT was able to prevent a breakdown of relations between itself and the opposing strategies that tried to get away with a little more. Instead of escalating the mutual punishment, as TIT-FOR-TAT does with JOSS (Axelrod, 1984) and SUBTLE CHEATER, tit-FOR-TAT is able to maintain peace between itself and such quarrelsome rules. For example, as illustrated in the following table (1 = total cooperation, 5 = total defection), when TIT-FOR-TAT plays SUBTLE CHEATER, TIT-FOR-TAT will begin with total cooperation and SUBTLE CHEATER will begin with "not quite total" cooperation. On the next turn both strategies will "not quite" cooperate. On the following turn, SUBTLE CHEATER will cooperate at an even lower level while TIT-FOR-TAT continues with its previous level of cooperation. This

Turn	TFT	Subtle	Cheater	tFT	Subtle	Cheater
1	1		2	1		2
2	2		2	1		2
3	2		3	1		2
4	3		3	1		2
5	3		4	1		2
6	4		4	1		2
7	4		5	1		2
8	5		5	1		2
9	5		5	1		2
.	.		.	.		.
.	.		.	.		.
.	.		.	.		.

slowly escalates to the point where both strategies are defecting completely.

Alternatively, when tit-FOR-TAT plays SUBTLE CHEATER, the first turn will be the same as when TIT-FOR-TAT plays SUBTLE CHEATER. However, on the next turn, tit-FOR-TAT will continue to cooperate and SUBTLE CHEATER will continue to not quite cooperate. Although tit-FOR-TAT is taken advantage of by rules like SUBTLE CHEATER, the scores it manages to earn are much greater than the scores that TIT-FOR-TAT earns against these rules. In fact, the greatest number of points given up was 700 by tit-FOR-TAT to SUBTLE CHEATER. Although tit-FOR-TAT gave up 700 points to SUBTLE CHEATER, the score it achieved against SUBTLE CHEATER was more than double the score earned against SUBTLE CHEATER by all of the other rules, except for SUSPICIOUS tit-FOR-TAT, which is just a variation of tit-FOR-TAT.

Another strength of tit-FOR-TAT is its ability to restore mutual cooperation when the series of interactions began with mutual punishments. For example, SUSPICIOUS tit-FOR-TAT was able to deescalate the "cold war" situation between itself and all of the other "suspicious" variants of the TIT-FOR-TAT family to a situation of cooperation or near cooperation. Notice the following example with SUSPICIOUS tit-FOR-TAT playing SUSPICIOUS TIT-FOR-TAT, both strategies begin with total defection. On the next turn, SUSPICIOUS tit-FOR-TAT will reduce its degree of defection by one, while SUSPICIOUS TIT-FOR-TAT continues to defect. Then on turn three, both strategies will be at the same reduced level of defection. This continues until both strategies are in a situation of total cooperation. The payoffs when mutual cooperation is achieved are much better than the payoffs at the beginning of the situation.

Turn	STFT	StFT
1	5	5
2	5	4
3	4	4
4	4	3
5	3	3
6	3	2
7	2	2
8	2	1
9	1	1
10	1	1
.	.	.
.	.	.
.	.	.

Although tit-FOR-TAT does well against many of the more challenging rules, it does much more poorly then the other rules when dealing with unresponsive strategies. It received its lowest score against ALL D and its second lowest score against RANDOM (chooses action randomly). To illustrate this weakness, look at a game with tit-FOR-TAT against ALL D; tit-FOR-TAT will begin by cooperating and ALL D will defect. On the next turn, tit-FOR-TAT will also defect, but not quite as strongly as ALL D's defection. This goes on for the rest of the game so that tit-FOR-TAT does extremely poorly against ALL D. Even with its weakness against unresponsive opponents it still managed to achieve an average score that was greater than each of the other rules.

Turn	tFT	ALL D
1	1	5
2	4	5
3	4	5
.	.	.
.	.	.
.	.	.

CONCLUSION

Several of the policy implications Axelrod included in his book can be expanded upon with the expanded matrix. First, do not be envious of the other players (Axelrod, 1984)—the main lesson taught by tit-FOR-TAT. Although tit-FOR-TAT received the highest average score, it also gave away the greatest average score of 590 points. Also, in a regression analysis of the correlation between the average points given and the average points earned, there was a high positive correlation of 0.91. This

EARNED = 192.2 + 0.413 (GIVEN) + 67.94 (NICE) + 16.9 (RESPONSIVE)
STD. ERR. (7.028) (0.0172) (4.281) (5.032)

EARNED – average number of points earned by a strategy in the round robin tournament.

GIVEN – average number of points a strategy allows its partner to earn in the round robin tournament.

NICE – dummy variable

0 if the strategy is not nice (it will defect before being defected on first)

1 if the strategy is nice (it will not defect first)

RESPONSIVE – dummy variable

0 if a strategy does not react to its partner's previous moves

1 if a strategy reacts to its partner's previous moves

$R^2 = .99$

Correlation coefficients:

EARNED, GIVEN = .9C
EARNED, NICE = .81
EARNED, RESPONSIVE = .43

indicates that, in general, a strategy that allows its opponent to earn more points will in return earn a greater score.

A second implication is "never be the first to defect." Axelrod has shown that there is some correlation between whether a rule is nice and its round-two tournament score. In the regression analysis of the extended model, it was found that when a rule is nice it earns an average of 68 points more than rules that are not "nice." It is also important to look at the suspicious half of the TIT-FOR-TAT family. Although the only variation from their cousins is that instead of cooperating on the first move, the suspicious TIT-FOR-TATs defect on the first move, the suspicious variety of TIT-FOR-TAT achieves an average score of 100 points less than the scores earned by the nonsuspicious variety. This leads to the conclusion that a rule that is nice actually does better in the long run.

A third implication listed by Axelrod is to "reciprocate both cooperation and defection." He found that reciprocating induces cooperation from the opponent. It was also found in the regression analysis that when a rule is responsive to its opponents previous actions it earns an additional 17 points. The success of the strategy tit-FOR-

TAT also supports Axelrod's recommendation to reciprocate "only nine tenths of a tit for a tat" in real life situations.

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