The Effect of Repeated Play in the IPG and IPD Team Games

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Repeated interaction in intergroup conflict was studied in the context of two team games: the intergroup public goods (IPG) game and the intergroup prisoner's dilemma (IPD) game. The results reveal (a) a main effect for game type; subjects were twice as likely to contribute toward their group effort in the IPG game than in the IPD game, and (b) a Game-Type × Time interaction; subjects contributed less over time in the IPD game while continuing to contribute at about the same rate in the IPG game. The second finding supports the hypothesis that subjects learn the structure of the game and adapt their behavior accordingly and is compatible with a simple learning model, which assumes that choices that have led to good outcomes in the past are more likely to be repeated in the future. A reciprocal cooperation hypothesis, which assumes that players make their choices contingent on the earlier choices of the other players, received little support.

A fundamental distinction in the theoretical and empirical study of strategic interaction is the distinction between iterated games, in which the players interact repeatedly, and one-shot games, in which the players interact only once. An iterated game is different from a one-shot game in two critical aspects: First, in an iterated game, behavior can be dependent on the earlier choices of other players, whereas in a one-shot game this is not possible. Second, in an iterated game, players have an opportunity to learn the structure of the game and adapt their behavior accordingly—an opportunity that they do not have in a one-shot game.

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Much research has been done on repeated interaction in experimental games. The most detailed and thorough study of this kind is that of Rapoport and Chammah (1965). However, this research has centered chiefly on two-person mixed-motive games, especially the prisoner's dilemma (PD) game (Colman 1982). The focus of the present study is on the dynamics of repeated play in the context of team games—a new research paradigm designed specifically for the study of intergroup conflict. The following section introduces the notion of team games and describes the team games used in the present study.

INTERGROUP CONFLICTS AS TEAM GAMES

Intergroup conflicts are often characterized by conflicts of interests within each of the competing groups as well. The intragroup conflict stems from the fact that the benefits associated with the outcome of the intergroup conflict (national security, group pride) are public goods; that is, goods from which any member of the group can benefit, whether or not he or she contributed in any way to their provision. If an individual cannot be excluded from sharing the benefits, it is possible for him or her to be a free rider on the effort of others. But if everyone else in the group tries to free ride as well, the group will lose the intergroup competition and there will be no benefits to share.

To incorporate this intragroup dilemma, Bornstein (1992) suggested modeling intergroup conflicts as team games. The notion of team games, which was originated by Palfrey and Rosenthal (1983) in the context of voting behavior, can be applied to a wide variety of intergroup conflicts involving economic, political, and social issues (Bornstein and Hurwitz 1993). A team game involves two groups, or teams of players. Each player chooses whether or not to contribute toward his or her group's effort. Contribution is assumed to be costly in terms of time, money, or risk taking. Payoff to a player is an increasing (or at least nondecreasing) function of the total number of contributions made by members of her own team, and a decreasing (or at least nonincreasing) function of the total number of contributions made by members of the opposing team. All players on the same team receive the same payoff.

The present study contrasted two such team games: the intergroup public goods (IPG) game (Rapoport and Bornstein 1987; Bornstein 1992) and the intergroup prisoner's dilemma (IPD) game (Bornstein 1992). The IPG game models intergroup conflicts over step-level goods. Common examples of such conflicts are elections and sports competitions, in which a margin of even one vote (or one point) is sufficient to provide the public good in its entirety. The IPD game models intergroup conflicts over continuous public goods. Wars and labor-management disputes in which the rewards are divided between the parties on the basis of the margin (rather than merely the direction) of victory exemplify this type of conflict. The IPG and IPD team games are illustrated below with the parameters used in the present study (a general definition appears in Bornstein 1992).

Both games involve a competition between two teams each with three members. Each of the six players receives an endowment of 2 points (which is later converted into money) and has to decide between keeping the endowment and contributing it toward his or her group's benefit. In the IPG game, a bonus of 6 points is given to each member of a group if the number of ingroup contributors exceeds the number of contributors in the outgroup. Members of the losing team receive nothing. In the case of an equal number of contributors in both teams, each player receives a reduced bonus of 3 points. In addition to the bonus, each player keeps his or her endowment if he or she does not contribute it.

In the IPD game, a bonus of 6 points is given to each member of a group if all three members of that group contribute and none of the outgroup members contribute. Members of the losing group receive nothing. If there are two more contributors in one group than in the other group, each member of the winning group receives 5 points, and each member of the losing group receives 1 point. If one group has only one more contributor than the other group, each member of the winning group receives 4 points, whereas each member of the losing group receives 2 points. Finally, in case of a tie (an equal number of contributors in both groups), each player receives a bonus of 3 points. As in the IPG game, players get to keep their 2-point endowment if they decide not to contribute.

The payoff to player i (where i denotes a member of group A) in the IPD and IPG team games, as a function of player i's decision to contribute (C) or not contribute (D) and the difference between the number of ingroup contributors (m_A) and outgroup contributors (m_B), is shown in Table 1.

From the point of view of the competing teams, the IPD and IPG games are practically identical. The optimal team strategy in both games is for all three team members to contribute. Contribution by all team members maximizes the team's security level by guaranteeing at least a tie and a payoff of 3 points per player. It is also an equilibrium strategy vis-à-vis the other team. That is, no team can benefit from having less than three contributors when the three members of the other team all contribute. (In the IPD game, contribution by all team members is also the dominant team strategy.) But, as can be seen in Table 1, if all six players contribute, each ends up with 3

TABLE 1
Individual Payoff in the IPG and IPD Team Games[a]

	IPG		*IPD*	
$m_A - m_B$	C	D	C	D
3	6	—	6	—
2	6	8	5	7
1	6	8	4	6
0	3	5	3	5
–1	0	2	2	4
–2	0	2	1	3
–3	—	2	—	2

NOTE: C = contribution, D = noncontribution or defection, $m_A - m_B$ = the difference between the number of C choices in team A (player i's team) and the number of C choices in the team B (the competing team).
a. As a function of the difference between the number of ingroup and outgroup contributors.

points, whereas if none contributes each gets 5 points. The structure of the *intergroup* conflict in the IPG and IPD team games is thus that of the two-person PD game: If both sides choose their optimal strategies, the outcome is collectively deficient (Dawes 1980).

However, from the point of view of the participating individuals, the IPD and IPG team games are quite different. In the IPD game, withholding contribution is the dominant strategy for each player. This is because, independent of the strategies of the remaining ingroup and outgroup players, by contributing, each player increases his or her bonus by 1 point but pays 2 points, hence reducing the final payoff by 1 point. Obviously, the equilibrium solution for the IPD game played noncooperatively is for all players to choose their dominant strategies and defect ($m_A = m_B = 0$).[1]

In the IPG game, on the other hand, there is no dominant strategy. A player should contribute when his or her contribution is critical for tying or winning the game, but not otherwise. Moreover, when the two groups are of equal size, as in the present case, the pure-strategy equilibrium solution of the noncooperative IPG game is for all players to contribute ($m_A = m_B = 3$). In addition, the IPG game with the parameters presented in Table 1 has two symmetric mixed-strategy equilibria—one in which each player contributes with a probability of .3 and another in which each player contributes with a probability of .7.

1. A (Nash) equilibrium is defined as a strategy vector such that no player can obtain a larger payoff by using a different strategy while the other players' strategies remain the same.

REPEATED INTERACTION IN THE IPG AND IPD TEAM GAMES

In a recent study, Bornstein (1992) compared subjects' choice behavior in the IPG and IPD team games played once. The results clearly demonstrate the importance of the game's payoff structure in determining individual choice. Subjects were much more likely to contribute toward their group effort in the step-level IPG game, where contribution is also individually rational, than in the continuous IPD game, where contribution is clearly the irrational individual choice. When no communication among subjects was allowed, the rate of contribution in the IPG game was 60.0%, as compared to only 26.7% in the IPD game. When subjects were allowed to communicate with the other ingroup members before making their (private) decision, contribution rates increased to 93.3% and 65.0% in the IPG and IPD games, respectively.

The 1992 Bornstein study employed one-shot games, treating intergroup conflict in an entirely static way. However, most conflicts outside the laboratory are more likely repeated games, where the decision of whether (or how much) to contribute toward the group's effort is a recurring one. The purpose of the present study was to examine the dynamics of repeated interaction in the IPG and IPD team games. In particular, we were interested in studying the two processes that become possible in repeated-play situations: The first involves the possibility of conditional cooperation, whereas the second involves the possibility of learning. The following sections discuss these two possibilities in the context of the IPD and IPG team games.

CONDITIONAL COOPERATION

In a one-shot game the players make their decisions simultaneously (that is, in ignorance of the other players' choices) and only once. Therefore, behavior cannot be made conditional on the behavior of the other players. In a repeated game, on the other hand, subjects play a sequence of iterations of the same game. Although the choices for each single game are made simultaneously, the dynamic setting enables players to make their choices dependent on the earlier choices of other players. The opportunity for tacit coordination is particularly important in the context of mixed-motive games, because a mutually beneficial outcome may be achieved by making cooperation conditional on the cooperation of the other players. Indeed, many game theorists agree that although rational players should always defect in the one-shot PD game, they should nevertheless cooperate when the game is played repeatedly. This argument was formalized by Axelrod (1984) for the two-person PD "supergame" and was later extended by Taylor (1987) to the context of the iterated n-person PD game.

In intergroup conflicts, as modeled by the IPG and IPD team games, the notion of conditional cooperation is considerably more complex. Contribution, which constitutes an act of cooperation toward one's own group, is at the same time a competitive act toward the outgroup. Cooperation may therefore develop either within or between groups and may depend on the behavior of both ingroup and outgroup players. If reciprocal cooperation evolves within the groups, one should expect contribution rates to increase over time in both the IPG and IPD games. As we have already seen, the optimal *team* strategy in both games is for all three members to contribute. If, on the other hand, cooperation evolves between the groups, contribution in the IPG and IPD games is expected to decrease over time. As demonstrated above, the Pareto optimal strategy in both games—the one that maximizes the collective outcome of all participants—is for all of them to withhold contribution. Thus, although the reciprocal cooperation hypothesis cannot predict whether contribution in the IPG and IPD team will increase or decrease over time, it does suggest that the difference in contribution rates between the two games should diminish as the games progress.

LEARNING

There is, however, another possibility—namely, that subjects, as they gain more experience, will become more likely to choose the equilibrium strategy of the constituent (one-shot) game.

The game-theoretic equilibrium solution is based on the strong assumption of mutually expected rationality (Colman 1982). According to this assumption, individual players take the actions of others into account when deciding on a course of action and can adjust their expectations to arrive at an equilibrium solution. Although logically compelling, this formal solution is usually not considered a good predictor of actual behavior, mainly because "human beings have bounded rationality and cannot be expected to analyze the payoff matrices of any but the simplest games" (Hardin 1982, 254; Simon 1955). In the dynamic context of a repeated game, one can provide a different, and perhaps more realistic, justification for the theory of equilibrium that does not assume strategic rationality (e.g., Maynard-Smith 1984; Harley 1982; Selten 1991). Instead, it is assumed that equilibrium is a result of learning (Boyd and Richerson 1985). Learning does not require any insight into the situation. Rather, simple trial-and-error adaptation to success and failure can steer players in the direction of the game-theoretic equilibrium.

The learning model we considered in the present study is a simple model that assumes that choices that have led to good outcomes in the past are more likely to be repeated in the future. This model, which was recently proposed by Roth and Erev (1993), will be dealt with in detail in the results section. At this point, it is sufficient to say that if learning takes place in both the IPG and IPD team games contribution rates should gradually converge on the games' respective equilibria. Thus the learning hypothesis predicts that as the game progresses and subjects gain more experience with the task, the difference in contribution rates between the IPG and IPD games will increase.

METHOD

SUBJECTS AND DESIGN

The subjects were 96 male undergraduate students at The Hebrew University of Jerusalem. Subjects were recruited by campus advertisements promising monetary reward for participation in a group decision-making task. Subjects participated in the experiment in sets of six; eight such sets participated in the IPD condition and eight sets in the IPG condition.

PROCEDURE

On their arrival at the laboratory, subjects were seated in a single room and were randomly assigned to two three-person groups. Subjects were given verbal instructions concerning the rules and payoffs of the game (see Table 1). The game instructions were neutral and were phrased in terms of individual i's payoffs as a function of his or her own decision to invest or not and the decisions made by the other players in his or her set. Subjects were not instructed to maximize their earnings, and no reference to cooperation or defection was made. Subjects were given a quiz to test their understanding, and explanations were repeated until the experimenter was convinced that all subjects understood the payoff matrix. Subjects were told in advance that to ensure the confidentiality of their decisions they would receive their payment in sealed envelopes and leave the laboratory one at a time with no opportunity to meet the other participants. Subjects were also assured that the experiment involved no deception.

Each set of 6 subjects played 20 rounds (iterations) of the same game. The number of rounds to be played was not made known to subjects.[2] Each subject had an electric switch that controlled a green or a red light bulb (according to group membership) on an electric board at the front of the room. At the beginning of each round, all the switches were off. Subjects had 30 seconds to decide between contributing and not contributing. If a subject decided to contribute, he or she was to turn on his or her electric switch. The decision was not indicated on the board until the 30 seconds were up, at which time the lights were turned on automatically according to the decisions made by each subject (e.g., if there were two contributors in the red group and one in the green group, two red lights and one green one came on). This procedure ensured that each round (constituent game) was played simultaneously. Following the completion of a round, subjects were given 30 seconds to record the outcome and calculate their payoff in that round. The lights on the board were turned off and the sequence was repeated.

Following the last round, the points were added up and cashed in at the rate of IS 1 for 5 points (1 Israeli Shekel was equal to approximately 40 U.S. cents at the time the experiment took place). Subjects were then debriefed on the rationale and purpose of the study, and were paid and dismissed individually.

RESULTS AND DISCUSSION

Figure 1 presents the proportion of contribution in each round of the IPD and IPG games. The mean contribution proportion over the 20 rounds was .52 in the IPG game and .26 in the IPD game. This difference in contribution rates is highly significant, $t(14) = 5.66$, $p < .0001$.

To test the effect of experience on subjects' choices we calculated a linear contrast for each group using the number of the round as the measure of experience.[3] A t test performed on these contrasts revealed a significant

2. If the players knew ahead of time the exact number of iterations in the supergame, the strategic properties of the situation would have remained those of the constituent one-shot game. At the start of the supergame, each player knows that in the final game he/she should use the individually optimal strategy and expects all other players to do the same. The outcomes of the final game are therefore predetermined and the game before last becomes the final game with the same argument applying to it, and so on back to the first game. Although experimental evidence shows that subjects do not always use the above logic, it does show that subjects tend to change their behavior toward the end of the game.

3. The contrast is C = 19(I1) + 17(I2) + 15(I3) +13(I4) + 11(I5) + 9(I6) + 7(I7) + 5(I8) + 3(I9) + 1(I10) – 1(I11) – 3(I12) – 5(I13) – 7(I4) – 9(I15) – 11(I16) – 13(I17) – 15(I18) – 17(I19) – 19(I20), where I1 – I20 indicate the observed investment rate in each of the 20 rounds.

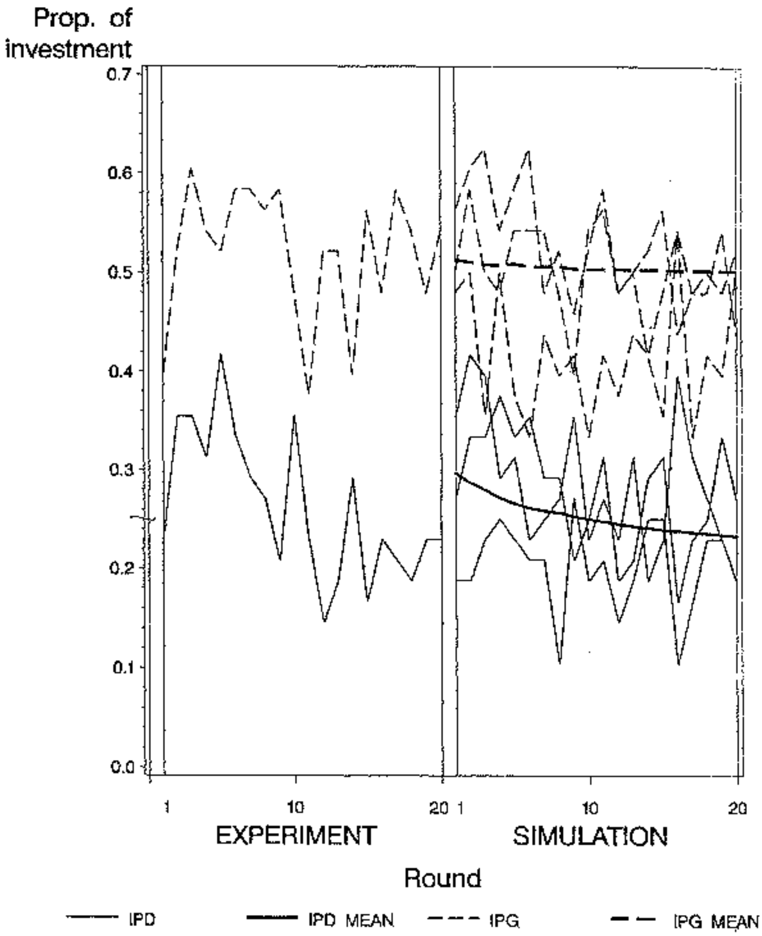

Figure 1: Experimental and Simulated Contribution Rates as a Function of Game Type and Round Number

interaction between game type and number of round, $t(14) = 2.63$, $p < .02$. This interaction was due to the fact that contribution rates in the IPD game decreased as the game progressed, $t(14) = 3.55$, $p < .01$, whereas in the IPG game there was no significant trend in either direction. Little variation between groups was observed in the IPG game. In the last 10 rounds of the game, six of the eight groups contributed at a rate of .47 to .53. The remaining two groups had investment rates of .4 and .65.

This pattern of results seems to support the learning hypothesis, which predicts that the difference between the games will increase over time, rather than the reciprocal cooperation hypothesis, which predicts that the difference in contribution rates between the two games will diminish over time. We therefore discuss the learning hypothesis first.

A REINFORCEMENT-BASED LEARNING MODEL

The learning model considered here was suggested recently by Roth and Erev (1993). Similar models were proposed by Bush and Mosteller (1955) and by Harley (1982). The basic principle underlying the Roth and Erev model is that choices that have led to good outcomes in the past are more likely to be repeated in the future. This principle, known as the "Law of Effect" (Thorndike 1898), has been confirmed in a wide variety of environments and seems to be a robust property of both human and animal learning. Roth and Erev (1993) demonstrated that their simple model does a surprisingly good job of reproducing the major features of choice behavior observed in experimental games.

The basic version of the model assumes that player i, when deciding how to act in the IPG or the IPD team game, considers the two pure strategies: contribution or cooperation (C) and noncontribution or defection (D). At time t = 1 (before any experience with the task has been acquired), player i has some initial propensity to play each of these two strategies. His or her propensity to select a particular strategy, say strategy C at time t = 1, is denoted by $q_{iC}(1)$. If player i plays strategy C at time t and receives a payoff of x, then the propensity to play C is updated by setting $q_{iC}(t + 1) = q_{iC}(t) + x$, while for the other strategy, D, $q_{iD}(t + 1) = q_{iD}(t)$. The probability $p_{iC}(t)$ that player i will play strategy C at time t is $p_{iC}(t) = q_{iC}(t)/q_{iC}(t) + q_{iD}(t)$, the ratio of the propensity to play C divided by the sum of the propensities to play each of the two strategies. Thus the probability of playing strategy C increases the more successful that strategy has been on previous rounds.

To test this learning model, we computed the correlation between the decision to play C on round t and the relative success of this strategy on the previous t – 1 rounds. Relative success was calculated on the basis of the monetary payoffs—that is, we divided the payoff of cooperation in rounds t – 1 by the total payoff in these rounds. In each condition, there were 48 subjects each making 19 choices (in rounds 2-20), for a total of 912 decisions. The correlation between the decision to cooperate on round t and the relative success of the cooperating strategy on round t – 1 over the 912 decisions was

$r = .259$ in the IPG game and $r = .279$ in the IPD game. Both correlations are significant at the $p < .0001$ level.[4]

These positive correlations indicate that the subjects' decisions to contribute in the IPD and the IPG games depended at least to some extent on the relative success of this strategy in earlier stages of the game. In other words, subjects in both games seem to be learning, as our model predicted. Why then do we observe a convergence on the equilibrium in the IPD game but not in the IPG game? Is this phenomenon predicted by the learning model? The computer simulations reported below attempted to answer this question.

COMPUTER SIMULATIONS OF THE IPG AND IPD TEAM GAMES

In performing the computer simulations, we assumed that at $t = 1$ all players in the same game condition have the same initial propensity to cooperate. In setting these initial propensities, we considered two factors: The ratio $q_{iC}(1)/q_{iD}(1)$ of the propensities to play strategy C and D, which determines the probability that C will be played at time $t = 1$; and the sum of the initial propensities over the two strategies C and D, $S(1) = q_{iC}(1) + q_{iD}(1)$. This second factor can be thought of as the *Strength* of the initial propensities. When the value of S(1) is large, the initial propensities are strong and learning is relatively slow. When the value of S(1) is small, the initial propensities are weak and adaptation occurs more quickly. Following Roth and Erev, we set $S(1) = 10$ and calculated the ratio $q_{iC}(1)/q_{iD}(1)$ for the IPD and the IPG games from the observed choices in the first three rounds in each game. Thus the initial propensities for the computer simulations were set at 5.1 and 4.9 for C and D, respectively in the IPG game, and at 3.1 and 6.9 for C and D in the IPD game.

The wide curves on the right-hand side of Figure 1 represent the mean contribution rate in 400 simulated groups, each playing 20 rounds of the IPD or the IPG game. As can be seen in this figure, the simulated data reproduce the actual data quite nicely. The simulated subjects, like the real ones, contributed less over time in the IPD game while continuing to contribute at about the same rate in the IPG game. Statistical analysis of the simulated data reveals a significant interaction between game type and number of round, $t(798) = 4.01$, $p < .0001$. A decrease in contribution rate over time was observed in 64% of the simulated groups in the IPD game, as compared with only 49% of the simulated groups in the IPG game.

4. The fact that the correlations are relatively small is not an indication of a failure of the model. Indeed, low correlations can be expected due to the probabilistic nature of the model. At the extreme, when the model predicts contribution with a probability of .5, the expected correlation is zero!

To facilitate comparison with the actual data, the narrower curves on the right-hand side of Figure 1 were drawn to represent the contribution rate in the IPD and the IPG games in three smaller sets of simulations containing eight groups each—the number of groups actually participating in each experimental condition. Examination of these curves shows that the variability of the simulated groups' contribution behavior over time is quite similar to that of the experimental groups.

INTERMEDIATE VERSUS LONG-TERM RESULTS

Roth and Erev (1993) distinguish between the long-term and the intermediate-term predictions of their learning model. They argue that the two can be quite different from each other for certain games. For example, when the reinforcement-based learning model (with the parameters studied here) is applied to the Ultimatum game (Guth, Schmittberger, and Schwarz 1982), it predicts that in the very long run the game will converge on the game-theoretic equilibrium solution. But in the intermediate term (up to 10,000 rounds in the simulations of Roth and Erev), no such convergence is to be expected.

To study the effect of long-term interaction in the IPG and IPD team games, we ran our simulations (with the same parameters described in the previous section) for 1 million rounds. Figure 2 presents the results of 100 such simulations—50 for each game type. It shows that in the IPD game contribution decreases steadily over time until it converges on the game's equilibrium solution, where none of the players contributes. In the IPG game, on the other hand, contribution remains virtually constant (around .50) for the first 10,000 rounds. Only at this late stage is there a change in behavior, such that most groups move toward the mixed-strategy equilibrium of .3. (Two of the 50 simulated groups appear to move toward the pure-strategy equilibrium of full contribution.)

To gain a better understanding of these long-term effects in the IPG game, we ran two additional sets of simulations. In the first set we used the same parameters described above (see Figure 2) except for one thing: We systematically varied the initial propensities. These parameters (i.e., the probabilities with which the simulated players contributed in the first round) were set at .25, .35, .65, .75, and .95. Each of these values was selected such that its distance from an equilibrium point of the IPG game is .05, and each was used to initiate 10 simulations. The results of these simulations appear in Figure 3.

As can be seen in this figure, most of our simulated groups converged to the nearest equilibrium point. When the initial propensity was to contribute with a probability of .25 or .35, 17 of the 20 groups converged to the .3 mixed-strategy equilibrium. When the initial propensity was to contribute

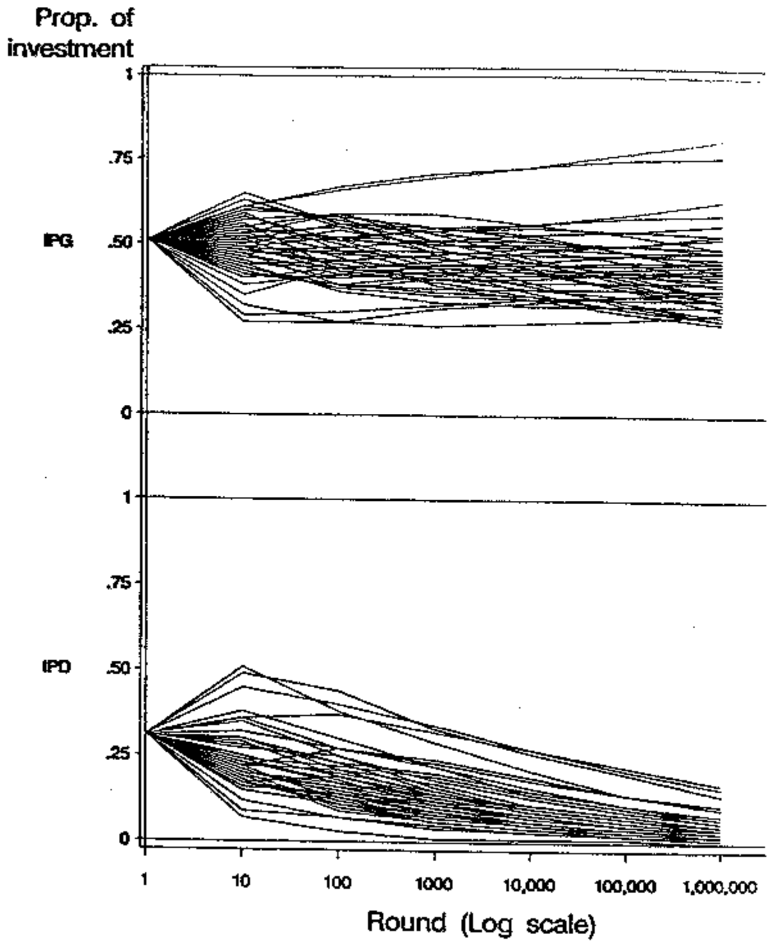

Figure 2: Contribution Rates in Simulations of 1,000,000 Rounds of the IPD and IPG Games (Each Curve Represents One of the 100 Simulated Groups)

with a probability of .95, 9 of the 10 groups converged on the pure-strategy equilibrium of full contribution. A different result, however, was obtained with regard to the groups whose initial propensity was to contribute with a probability of .65 or .75. Rather than converging to the nearest equilibrium point of .7, these groups appeared to be moving toward one of the other two equilibria. It would therefore seem that the mixed-strategy equilibrium of .7 is not an attraction point in the IPG game. The second set of simulations used

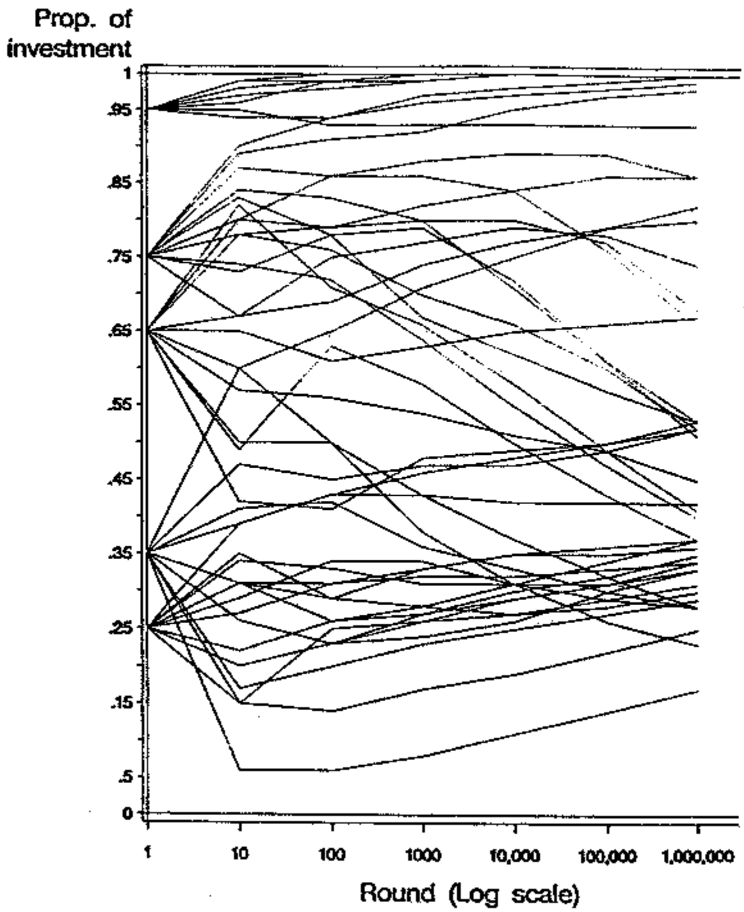

Figure 3: The Effect of Initial Propensities on Contribution Rates in Simulations of the IPG Game

an extension of the learning model. Following Roth and Erev (1993), we introduced two modifications to the basic model. The first modification is a "forgetting" parameter (φ), which speeds convergence by preventing the sum of any player's propensities from growing without bound as t goes to infinity. The second modification is an "exploration" or "error" parameter (ε), which prevents the probability of any strategy from going to zero. Thus, in the extended model, if player i plays strategy C at time t and receives a payoff of x, then the propensity to play C is updated by setting $q_{iC}(t + 1) = \varphi q_{iC}(t) + x(1 - \varepsilon)$, while for the other strategy, D, $q_{iD}(t + 1) = \varphi q_{iD}(t) + x\varepsilon$. Adding the forgetting and exploration parameters allows us to show more clearly how the predictions of the learning model converge in the very long run. The results of this simulation are presented in Figure 4.

The top panel of Figure 4 presents the simulated learning curve in the IPG game given the parameters $\varepsilon = .05$ and $\varphi = .001$. As was demonstrated by Roth and Erev in a different context, the forgetting and exploration parameters had little effect on the learning process in the first 10,000 rounds of the game. The difference between the extended model and the basic model becomes apparent only in the very long term. A clear convergence is observed at round 100,000 and, at round 1,000,000, all 50 groups contributed at a rate of .42 to .47 (with a median of .46). The bottom panel in Figure 4 presents the learning curves with different parameters—$\varepsilon = .01$ and $\varphi = .001$. Except for one group, which converged toward the pure-strategy equilibrium, all the simulated groups converged to a contribution rate of .39 to .44 (with a median of .41). These contribution rates are somewhat higher than those predicted by the mixed-strategy equilibrium of .3. This is due to the fact that when players are close to the mixed-strategy equilibrium cooperation and defection yield similar payoffs, and even a small error parameter can increase the probability that the least likely strategy (namely C in our case) will be chosen. Indeed, as is clear from the figure, the larger the error parameter, the further away are the simulated results from the predicted equilibrium result.

The simulations presented above demonstrate that the intermediate-term results in the IPG game can be quite different from the long-term results. The reproduction in the computer simulations of the slow learning process observed in the experimental context supports the notion that what we observed in the experiment is not merely an artifact of our procedure, but rather a significant property of the IPG payoff structure.

SEQUENTIAL DEPENDENCIES

Although the basic pattern of results, as it appears in Figure 1, does not seem to support the conditional cooperation hypothesis, we examined this hypothesis in more detail by looking at sequential dependencies. According to the conditional cooperation hypothesis, player i's decision to contribute on round t + 1 could depend on the number of contributors in i's team on round t, $m_{in}(t)$, and/or the number of contributors in the competing team on round t, $m_{out}(t)$. We computed the correlations between the individual's decision to contribute and the number of ingroup and outgroup contributors

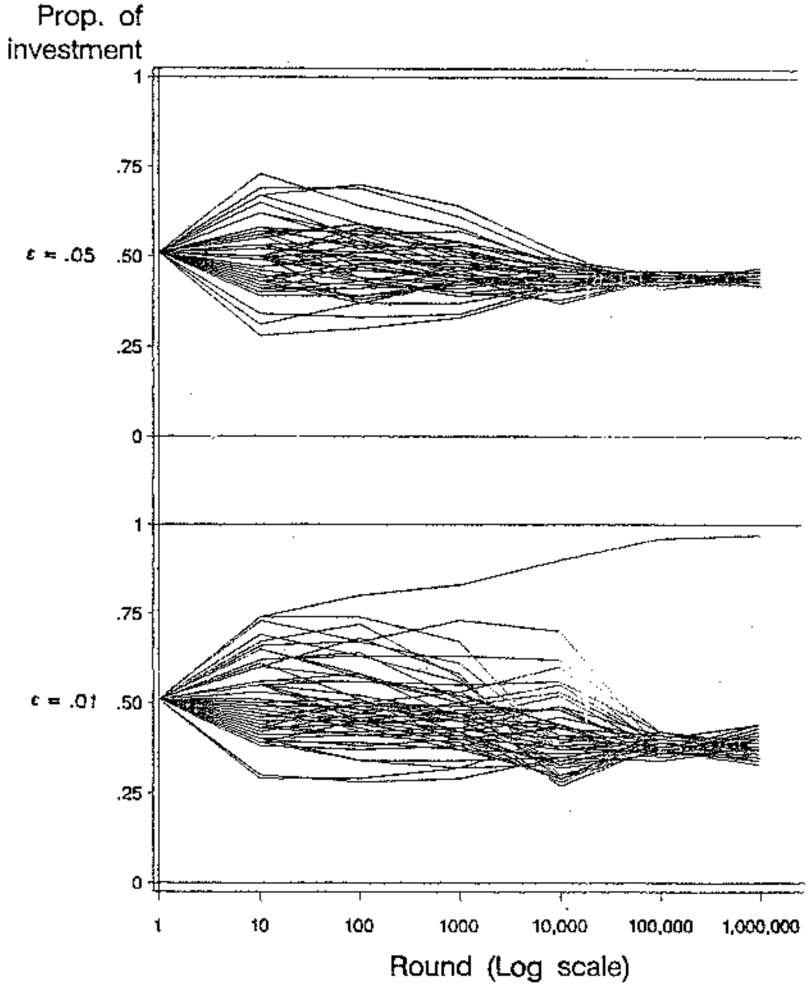

Figure 4: The Effect of Exploration and Forgetting Parameters in Simulations of the IPG Game

separately for each game. Of the four correlations, the only one that came out significant was the correlation involving the number of outgroup contributors, m_{out}, in the IPD game ($r = .17$, $p < .0001$). It seems that, at least in the IPD team game, the decision to contribute was contingent on the level of competition by the outgroup.

Because the decision to contribute in the IPD game was correlated with both the relative success of this strategy and the number of outgroup contributors on the previous round (m_{out}), and because both of these factors affected contribution in the same direction, we performed a regression analysis to see whether each factor has a unique contribution to the observed effect. As it turned out, both factors have a significant predictive value. The final regression model is P(contribution) = .09 + .06(m_{out}) + .5(model), R^2 = .09, $F(909, 2) = 42$, $p < .0003$ for the contribution of m_{out}, and $p < .0001$ for the contribution of the learning model.

CONCLUSIONS

The present study demonstrated that the difference in contribution rates between the IPG and the IPD games observed by Bornstein (1992) in the context of one-shot games is generalizable to the IPG and the IPD supergames. Subjects are much more likely to contribute in the step-level IPG game, in which contribution is individually rational under certain conditions, than in the continuous IPD game, in which contribution is clearly the dominated individual strategy. Because the Pareto optimal strategy (the one that maximizes the outcome of all participants) in both team games is for all players to withhold contribution, the IPG game constitutes a much more competitive model of intergroup conflict.

Another major finding is that the difference in contribution rates between the two games increased as the games progressed. This pattern of results supports the hypothesis that subjects learn the structure of the game and adapt their behavior accordingly. More specifically, the finding that subjects in the IPD game contributed less over time, whereas subjects in the IPG game contributed at about the same rate throughout the game, is consistent with the simple learning model of Roth and Erev (1993). The importance of this model is in showing that the same dynamics do not necessarily converge at the same rate to the equilibria of different games. In other words, the same model can have different predictions for different games. In the present case, the model predicted that the equilibrium point would be approached relatively quickly in the IPD game, whereas in the IPG game learning would be very slow. These predictions, as reflected by the simulated results, were nicely confirmed by the experimental data. It seems that step-level intergroup conflicts are not only more competitive to begin with than continuous conflicts but also remain more competitive for a longer period. It should be emphasized that, although for reasons of presentation we discussed the learning model in the results section, it is by no means a post hoc model tailored to fit the data. In choosing the parameters for assessing the initial propensities, and in all other details, we followed the Roth and Erev procedure to the letter.

The fact that our data provide little support for the reciprocal cooperation hypothesis does not rule out the possibility that had the game lasted longer some form of reciprocation would have evolved. Experiments with repeated games often involve a very large number of repetitions (Colman 1982). In the present study, however, we looked at the short-term or intermediate effects of repetition. We believe that many of the social phenomena we observe in the world are of an intermediate-term nature. In particular, intergroup conflicts, bitter and long lasting as they might be, seldom involve more than a few "rounds."

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