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Abstract

This paper presents experimental evidence concerned with behavior in one-shot, finite repetition, and infinite repetition, two-person Reciprocity Games. Both symmetric and asymmetric games as well as games with explicit punishment actions are studied and compared. Along with classifying the group outcomes to the games, individual strategies are classified. The importance of alternation or turn-taking, group welfare, and equality as focal solutions is examined. Also considered is whether or not outcomes are unique, Pareto Optimal, or individually rational, and whether or not finite repetition treatments are subject to end-game effects.

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An Experimental Analysis of Two–Person Reciprocity Games*

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1 Reciprocity Games

As described in Ostrom (1990), the farmers near the city of Valencia, Spain take turns directing water from canals onto their fields. When one farmer has taken all the water he needs, the next farmer, who has been waiting, gets to take all the water he needs. There is obvious temptation for the waiting farmers to try to take water out of turn; Valencia is hot and dry and the crops are in constant danger, especially in drought years. Remarkably enough, these turn-taking schemes have survived for centuries.

The purpose of the turn-taking scheme is to insure an efficient, or at least near efficient, use of the water supply. Without the agreement to rotate, the farmers would waste valuable resources fighting amongst themselves over the scarce water. It is possible that farmers closer to the canals, or further upstream, would have an advantage in an unfettered contest for the water. The advantaged farmers might even be better off with free competition than with the turn-taking scheme. However, the disadvantaged farmers might be forced out of business, the total amount of crops produced might go down. By following the turn-taking scheme, the farmers avoid these potential problems.

There are other situations in which turn-taking schemes can enable groups of people to exploit a resource to their collective advantage. Two firms, for example, can alternatively offer monopoly price bids in a series of contract auctions. Without the turn-taking scheme, the firms would be forced to offer competitive price bids; the earnings of the auction's winner would be drastically reduced. Similarly, two opposed politicians can

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alternatively vote against their immediate best interests so that a string of bills, some of which please their constituents, will be assured of passage. If the politicians did not agree on a turn-taking scheme, their votes would cancel out and perhaps no bills would pass.

All these situations can be classified under the rubric of Reciprocity Games. A Reciprocity Game, then, is any non-cooperative situation in which some efficient outcomes can only be realized by utilizing non-trivial correlated strategies, or turn-taking. Repeated versions of classical games like the Battle of the Sexes and Chicken fall into this category, pure coordination games like The Repeated Prisoner's Dilemma do not.

As an example of a Reciprocity Game, consider the repeated, finite action, two player game implied by the stage-game payoff matrix G_1, where

$$G_1 = \begin{bmatrix} (3,3) & (3,7) \\ (7,3) & (4,4) \end{bmatrix}$$

Label the actions A and B. Let the top row represent the payoffs to the row player for choosing action A. Let the lefthand column represent the payoffs to the column player for choosing action A.

Assuming that both players are rational, or expected utility maximizers, and that they have complete information about the payoffs and the rationality of the other player, non-cooperative game theory offers certain predictions about the player's behavior. The clarity of these predictions depends upon the number of times that the stage-game is repeated.

If the stage-game is not repeated, each player has a dominate strategy, which is to choose action B. Play of this action at every stage is also the unique subgame perfect equilibrium of any finite repetition game. In equilibrium, each player receives a payoff of four in each stage. The equilibrium is efficient only in the non-repeated or one-shot game; in the repeated game, all the efficient outcomes involve alternating between the stage-game payoffs of $(3,7)$ and $(7,3)$. To gain these payoffs, both players must choose their dominated action, and furthermore, the players must coordinate so that they do not choose the dominated action at the same time. Given an even number of stages, the simple alternation scheme of having the players take turns choosing action A leads to an outcome in which each player gets an average stage payoff of five.

If the stage game is repeated an infinite number of times, the folk theorem implies that there are an infinite number of subgame perfect equilibria. In fact, there are an infinite number of efficient, subgame perfect equilibria. The multiplicity of equilibria is in itself a problem for the players – which equilibrium should they coordinate on? Axiomatical concepts like symmetry, group welfare, or equality can be used to determine focal points, yet, even with these concepts there need not be a unique equilibrium. The efficient payoffs do share a common trait, however. In the efficient outcomes, the players must resort to a pattern of alternation between the stage-game payoffs of $(3,7)$ and $(7,3)$.

The purpose of this paper, then, is to examine the ability of people to enter into alternation schemes and achieve efficient outcomes to reciprocity games. The games will be studied under three different repetition conditions: one-shot, finite repetition, and infinite repetition. Comparisons will be made between a game that has symmetric payoffs and a game that has asymmetric payoffs. The effects of adding a third action, one intended to be a clear punishment, will also be considered.

2 Related Research

As previously mentioned, Ostrom (1990) is concerned with examining the ability of people to efficiently exploit common pool resources. She reviews several case histories in which groups of people are able to introduce rotation schemes and successfully exploit the resource. Some of her examples have been in place for centuries.

Ostrom *et al.* (1991) have abstracted from these real life examples in an experimental study of the use of a common pool resource. In their study, rotation schemes offer an efficient way to exploit the resource, and, in fact, some of the eight-person groups try to institute these schemes. Ostrom *et al.* find that these schemes fail do to mistrust, mistakes or cheating. The authors find that the efficiency of the use of the resource increases if individuals are allowed to impose fines on one another; however, resource use never reaches optimal levels.

Palfrey and Rosenthal (1991a; 1991b) and Cooper *et al.* (1990; 1989; 1987) have studied various public goods and coordination games that with repetition become Reciprocity Games. Cooper *et al.* (1990; 1987) also examined the addition of an action deemed to be a punishment. They found that the availability of the extra action did effect the players choice of strategies.

Selten and Stoecker (1986), in their work on finitely repeated Prisoner's Dilemmas, developed a system of outcome classification that is similar to the strategy classification system used here. In their paper, either a Cooperative outcome or End-Effect Play occurs if the cooperative alternative in the one-shot game is chosen consecutively for $m > 4$ periods during the supergame. Unlike Selten and Stoecker, this paper examines the sequence of play at the individual level and makes inferences about the types of strategies that each individual plays, either Alternating, or Nash (or Other).

3 The Experimental Design

Each of four different payoff treatments will be examined under three different repetition conditions: one-shot, finite repetition, and infinite repetition. The four different payoff treatments are: symmetric (G_1), asymmetric (G_2), symmetric with punishment (G_3), and asymmetric with punishment (G_4), and are represented by the payoff matricies in Table 1.

3.1 Equilibria

In the one-shot condition, G_1 and G_2 have either dominate strategy or dominate solvable Nash equilibria. In G_1 the equilibrium is for both players to choose action B and then to receive a payoff of four. Name the outcome $\{B, B\}$ so that each players move is reflected. In G_2 the equilibrium, $\{A, B\}$, is for the row player to choose action A and receive a payoff of three, and for the column player to choose action B and receive a payoff of seven.

G_3 and G_4 both have two additional equilibria, one in mixed strategies. In G_3 the additional equilibria are: $\{(\frac{1}{4}B, \frac{3}{4}C), (\frac{1}{4}B, \frac{3}{4}C)\}$ and $\{C, C\}$. In G_4 the additional equilibria are: $\{(\frac{1}{3}A, \frac{2}{3}C), (\frac{1}{7}A, \frac{6}{7}C)\}$ and $\{C, C\}$. These additional equilibria are dominated, in respect to both players, by the $\{B, B\}$ equilibrium in G_3 and the $\{A, B\}$ equilibrium in G_4.

Unlike the finite repetition versions of G_1 and G_2, in which equilibrium play implies play of the unique one-shot equilibrium in each stage, in finite repetition versions of G_3 and G_4 there are many subgame perfect equilibria. In fact, any minimax-dominating outcome can be approximated by a subgame perfect equilibrium if the number of stages is large enough.[1]

The set of equilibria in any of the four infinite repetition games is infinite. In fact, if the discount rate is low enough, any outcome to a game which results in average stage payoffs which are greater than the minimax payoffs is supportable as a subgame perfect equilibrium. [2]

The minimax payoffs for G_1 through G_4 are, respectively: $(4, 4), (3, 7), (1\frac{3}{4}, 1\frac{3}{4})$, and $(1\frac{2}{3}, 1\frac{3}{4})$.

The axiomatic refinements of Equality, Symmetry, and Welfare Maximization, combined with Pareto Optimality, pare the set of equilibrium outcomes down to a manageable level. The Equality refinement requires each player to receive the same payoff; the Symmetry refinement requires each player to choose their dominated action the same number of times; the Welfare Maximization refinement requires the sum of the player's payoffs to be maximized.

In G_1 and G_3, the *one to one* alternation scheme leads to average stage payoffs of $(5, 5)$ and satisfies all of these refinements. In G_2 and G_4, the Equality refinement requires a *one to two* alternation scheme. In this scheme the row player chooses action A half as often as the column player chooses action B and players end up with average stage payoffs of $(4\frac{1}{3}, 4\frac{1}{3})$. The Symmetric refinement requires a *one to one* alternation scheme and leads to average stage payoffs of $(4, 5)$. The Welfare Maximizing refinement leads to play of the $\{A, B\}$ stage game equilibrium and average stage payoffs of $(3, 7)$.

3.2 Hypotheses

In describing the outcomes to the experiments, reference will be made to the following qualitative hypotheses, presented in order of least likely to most likely:

Hypothesis 1 (Uniqueness) *The outcome to the game is unique.*

Hypothesis 2 (Pareto Optimal) *The outcome to the game is Pareto Optimal.*

Hypothesis 3 (Individually Rational) *The payoffs associated with the outcome of the game are greater than or equal to the minimum payoff that a player can guarantee himself using a pure strategy.*

All three of these hypotheses are concerned with the rationality of the players, or at least with their perceived theoretic understanding of the game. As a definition of rationality, Hypothesis 3 is very weak. In fact, every outcome to G_3 or G_4, under any repetition condition, satisfies it. Hypothesis 2 is more strict, it requires all players to coordinate on some efficient outcome. Hypothesis 1 is the most strict, it requires all players to coordinate on the same efficient outcome. The outcomes to a game will be called more *predictable* if the most observed outcome is seen a higher percentage of the time than the most observed outcome in another game.

The behavior in the one-shot games should be considered as a calibrating device. The outcomes achieved are worst case outcomes in the sense that there is no chance for the players to use an efficient rotation scheme. Theory predicts that behavior will conform to the Nash Solution, which will be defined as Hypothesis 4.

Although not equilibria in all cases, the following hypotheses will be considered for both the finite and infinite repetition treatments (notice that they do not specify behavior in the earliest stages of the game; they allow a period of time for the players to coordinate):

Hypothesis 4 (Nash Solution) *After a certain period, each player chooses the action which leads to the highest Pareto-Ranked, subgame perfect equilibrium.*

Hypothesis 5 (Alternating Solution) *After a certain period, the outcome to the game will have players alternating between action A and action B such that the realized play will be* $\{\ldots, \{A, B\}, \{B, A\}, \{A, B\}, \ldots\}$.

Hypothesis 6 (Welfare Solution) *After a certain period, the outcome to the game will be such that the sum of the players payoffs is maximized.*

Hypothesis 7 (Equality Solution) *After a certain period, the outcome to the game will maximize the sum of the players payoffs subject to having each player receive the same payoff.*

Hypothesis 4 embodies the predicted outcome in the finite repetition games. The Nash solution is also an equilibrium in any of the infinite repetition games, although it is not an efficient equilibria in the symmetric cases. Hypothesis 5 embodies the axiomatic refinement of Symmetry, it requires the players to adopt a one to one rotation scheme; Hypothesis 6 embodies the axiomatic refinement of Welfare Maximization; and Hypothesis 7 embodies the axiomatic refinement of Equality. Although not always equilibria, these three solutions are efficient outcomes to the finite repetition games.

In the symmetric cases, G_1 and G_3, one outcome satisfies each of the Alternating, Welfare, and Equality Solutions, hence there is competition between only the Alternating and Nash Solutions. The asymmetric games, G_2 and G_4, were designed so that each of the three refinements identified a different outcome. In the Asymmetric games, the Nash Solution and the Welfare Solution are identical, hence there is competition between only the Alternating, Welfare and Equality Solutions.

4 The Experiments

All the experiments were performed in a laboratory at the California Institute of Technology. The experiments were run on a set of computers linked together in a network. The subject pool consisted of students, most of whom were recruited from introductory economics and political science courses. There were nine experimental sessions: one session for each finite and infinite repetition treatment of G_1, G_2, G_3, and G_4; and one session for all the one-shot treatments. The number of subjects in each session varied from ten to fourteen due to the fact that some of the recruited subjects did not show up for some of the experiments.

The following outline describes the order of events that took place in a typical experimental session:

1. Each subject entered the laboratory and sat at the terminal of their choice.
2. The subjects were read a set of directions detailing the rules of the session. The subjects were not shown a payoff matrix, instead each action and payoff was explained to them independently. The subjects were led through two practice periods and then quizzed.[3]
3. In a period, each subject chose either A or B (or C) and was then informed of their payoff and partner's choice. This was repeated under the following conditions:

(a) In the one-shot treatments, each subject was randomly matched with another at the beginning of each period. The game ended after 15 periods.

(b) In the finite repetition treatments, each subject played the same person each period. The game ended after 15 periods.

(c) In the infinite repetition treatments, each subject played the same person every period. After the 15th period, a ten-sided die was rolled so that the subjects could see the result. If a 9 was rolled then the game ended, otherwise the game continued another period after which there was another die roll. The game did not end until a 9 was rolled.

4. At the end of the game, the subjects were randomly matched with a person whom they had not played and another game was started.

5. Each subject in a session played 4 games and was then paid cash for each *point* they earned in the experiment. In the one shot treatments, the order of games was: G_1, G_3, G_2, and G_4. In the finite and infinite repetition treatments, the subjects played the same game four times.

6. The experimental session ended.

In the symmetric treatments, every player faces the same payoffs and therefore there is no difference between a row and a column player. In the symmetric treatments, all subjects were treated identically.

On the other hand, in the asymmetric treatments, the labels row and column have meaning – the row player is at a disadvantage. In order to prevent row players from gambling that they would become column players, at the beginning of each asymmetric treatment, half of the subjects were informed that they would be row players for all four games in the session. In the one-shot session, this division took place after the second game.

Table 2 reports the number of subjects and the number of observations, respectively, in each treatment.[4] An observation consists of the outcome of one complete game and two sequences of actions, one for each player involved. The table also shows the dates of each session, the length, the exchange rate, and the order of the one-shot treatments.

5 The Results

The results of the experimental sessions will be presented in four part data: the one-shot treatments' data, the finite and infinite repetition treatments' payoff data, a comparison of average payoffs, and, finally, the finite and infinite repetition treatments' strategy data.

5.1 The One-Shot Treatment

The first step is to examine the player's behavior in the one-shot treatments. The Table 3 describes the number of times each possible outcome pair was observed.[5]

In order to determine whether or not an individual's actions changed as s/he gained experience with the game, the data was split into the first eight periods and the last seven periods and then compared using a standard χ^2 test.[6] The results are shown in Table 4. Notice that in no case is there a significant difference between the distribution of actions at the beginning and the distribution of actions at the end.

Hypothesis 3, Individual Rationality, is applicable only to the games without the punishment action, games G_1 and G_3; it is satisfied trivially in the other games. In G_1, fourteen of the 150 observations, approximately 10 percent, assigned payoffs below the minimax to at least one of the players. In G_2, sixteen of the seventy-five row player observations and six of the seventy-five column player observations, 21 percent and 8 percent respectively, assigned payoffs below minimax payoffs. Even assuming that the true frequency of below individually rational payoffs is the upper end of a 95 percent confidence interval around these observed frequencies, there is a surprising amount of irrational play, especially in the case of the row player in G_3.

The performance of the subjects gets progressively worse when considering Hypothesis 2, Pareto Optimal play, and then Hypothesis 1, Unique play. The exceptions are the outcomes to G_1, where three of the four possible outcomes are Pareto Optimal, and its counterpart G_3. Between these two treatments, only 4 of 150 outcomes were not Pareto Optimal. In the other two treatments, 39 of 150 outcomes were not Pareto Optimal.

In no case does the addition of the punishment action significantly change the support for these hypotheses. These findings are summarized in Table 5.

Although a large percentage of the subjects play the equilibrium strategy in every once-repeated treatment, there is a substantial minority that play non-equilibrium strategies. In an ideal environment, Hypothesis 4, that each player chooses the subgame perfect equilibrium strategy, would be rejected on the basis of even one non-equilibrium play. However, the criteria adopted for this experimental environment allows their rejection only if the upper bound of the 95 percent confidence interval around the observed proportion of plays is less than 0.95. These bounds are displayed in the Table 6. Hypothesis 4 must be rejected for G_1, and for the row players in both asymmetric treatments. The fact that not all people always play the unique, subgame perfect equilibrium strategy in one-shot games has been observed many times.[7]

Notice the significant change in the behavior of the column players when comparing G_2 and G_4. In G_2, 8 percent of the actions chosen by the column players violate the Nash Solution, in G_4 no actions chosen violate the Nash Solution. This is anomalous in that behavior does not change for the row player or in fact between G_1 and G_3. One explanation for the data is that, because G_2 and G_4 were played in succession by the same players, the column players learned how to play according to Hypothesis 4. Oddly enough, the row players did not share in the revelation.

5.2 The Finite and Infinite Repetition Treatments: Average Payoffs

The outcomes to the finite and infinite repetition treatments are represented by the average payoffs of both players. In order to allow a period of time for the players to coordinate on a specific outcome, the first four periods are ignored. Also, so that the infinite repetition treatments remain comparable to the finite repetition treatments, the averaging ends with the fifteenth period (the finite repetition treatments are fifteen periods long).

Referring to Figure 1, the set of possible outcomes to G_1 if it were infinitely repeated is represented by the triangular figure in both the top and bottom diagrams. The solid dots in the diagrams represent the payoffs to the one-shot game. Given that a ten period average is used, the possible outcomes are a subset of the triangular set. Actual outcomes to the games are shown by a letter representing one or more observations. The letter is located at the coordinates determined by the average payoffs of the players.

For an outcome to be Pareto Optimal, it must be located on the hypotenuse of the triangular set. The 45° line highlights the outcomes in which the players receive equal payoffs. Every outcome located northeast of the dotted lines payoff dominates the minimax. These minimax dominating outcomes, given a small enough discount rate, are subgame perfect equilibria if the game is infinitely repeated.

In Figure 1, the top diagram represents the outcomes of the finite repetition treatment of G_1. The bottom diagram represents the outcomes of the infinite repetition treatment of G_1. Similar figures are constructed for the two treatments of G_2, G_3, and G_4.

In G_1 and G_3, there is no difference between a row and a column player. In order to avoid drawing conclusions from arbitrarily scattered outcomes, all the outcomes are located on or below the 45° line. In G_2 and G_4, there is a difference between a row and a column player.

Again referring to Figure 1, specifically to the top diagram which shows the outcomes of the finite repetition treatment, notice that the outcomes seem to occur in two clusters. One cluster is located around the unique one-shot equilibrium or Nash Solution, point $(4,4)$. The other is located around the focal solution, the outcome that embodies the three other focal points, the Alternating Solution, Equality Solution and Welfare Maximizing Solution, point $(5,5)$. The observations are divided roughly between the two clusters. Although the Nash Solution was the most observed with five, fourteen groups were able to improve upon it using some pattern of reciprocation, three actually implemented the focal solution. One player out of the twenty pairs received below minimax payoffs.

The bottom diagram, which shows the outcomes of the infinitely repeated treatment, is in sharp contrast to the top one. Here, twenty-one of twenty-four observations are located at the focal solution. Of the three remaining outcomes, two are located near the Nash Solution, and the last is located at an outcome better than the Nash Solution but not as good as the focal solution. The extension of the time-horizon from finite to infinite draws many outcomes away from the Nash Solution and to the focal solution. People appear to have few problems implementing a rotation scheme and achieving efficient payoffs, approximately 90 percent succeed, if G_1 is infinitely repeated.

Figure 2 shows the outcomes to the finite and infinite repetition treatments of G_3. Recall that G_3 is identical to G_1 except that an additional action, a punishment, was added to the action space. Despite the additional strategy, Figure 2 closely resembles Figure 1. In the top diagram, the finite repetition treatment, roughly half of the outcomes are close to the focal solution. In the bottom diagram, the infinite repetition treatment. roughly 80 percent of the outcomes are at the focal solution.

The top diagram in Figure 3 shows the outcomes to the finite repetition treatments of G_2, the first of the asymmetric games. Seven outcomes were at the Nash Solution, point $(7,3)$. This point is also the Welfare Maximizing Solution; other outcomes were nearby. One outcome was at the Alternating Solution, point $(5,4)$. No outcomes were at or even near the Equality Solution, point $(4\frac{1}{3},4\frac{1}{3})$.[8] More than half of the outcomes, eleven of twenty, have the row player receiving less than minimax payoffs.

The bottom diagram shows the outcomes to the infinite repetition treatment of G_2. Unlike in the symmetric games, there is no improvement in the efficiency of the outcomes as the time horizon gets longer. Roughly the same proportion of outcomes are at the Nash Solution, the Alternating Solution, and the Equality Solution (eight, two, and zero observations out of twenty-four, respectively) as in the finite repetition treatment. Again, half of the outcomes have the row player receiving less than minimax payoffs. If anything, the payoffs in the infinite repetition treatment seem worse than the payoffs in the finite repetition treatment.

Figure 4 shows the outcomes to G_4. Recall that G_4 is identical to G_2 except that a punishment action is added. Unlike in the symmetric case, here the punishment action makes a difference. In the top diagram, the most observed outcome is the Alternating Solution, point $(5,4)$. This is in contrast to the most observed outcome in the finite repetition treatment of G_2 which was the Nash or Welfare Solution, point $(7,3)$. However, a substantial number of outcomes are still inefficient outcomes. The bottom diagram has these same features: the most observed point is the Alternating Solution, and many observations are at inefficient outcomes. Again, drawing on the similarity between the top and bottom diagram, infinite repetition did not greatly improve the chances of coordinating on an efficient outcome.

Table 7 shows the distribution of outcomes and the support for Hypotheses 1, 2, and 3 in the finite repetition treatments. Clearly, the expectation that the outcomes are unique or even Pareto Optimal is unfounded. In fact, in the asymmetric game G_2, even the expectation that the outcome is individually rational is unfounded. The addition of the punishment action made no difference in the support of these hypotheses.

Table 8 shows the distribution of outcomes and the support for Hypotheses 1, 2, and 3 in the infinite repetition treatments. Surprisingly, the symmetric treatments. G_1 and G_3, exhibit strong support for a unique and Pareto Optimal solution. Unfortunately, the asymmetric treatments, G_2 and G_4, do not follow suit and support remains minimal. In the asymmetric game G_2, there is still little in the way of individual rationality on the part of the row player. The addition of the punishment action again made no difference in the support of these hypotheses.

By examination of Table 9, it is clear that infinite repetition makes a difference in the symmetric games. The infinite repetition, symmetric games are much more *predictable.* In other words, in these games, the most popular outcome is chosen by a significantly higher percentage of the players. Also higher is the probability of obtaining Pareto Optimal payoffs. However, infinite repetitions does not seem to have any effect on the asymmetric games.

Table 10 shows the distribution of outcomes over the focal point solutions and reconfirms the evidence in Table 9. Infinite repetition makes a difference in the symmetric treatments – it results in a dramatically higher percentage of efficient Alternating Solution outcomes. In the asymmetric case, infinite repetition does not seem to make a difference, the distribution over the focal solutions remains similar. However, the addition of a punishment action causes a shift from the Welfare Maximizing Solution to the Alternating Solution. In every asymmetric treatment, a substantial number of outcomes are not efficient.

5.3 Comparing Average Payoffs

Table 11 shows the average payoffs in the one-shot treatments and in rounds 5 – 15 of the finite and infinite repetition treatments. In the symmetric treatments, the average payoffs rise as the time horizon lengthens. In the one-shot treatment, the average is near the payoff associated with the Nash Solution, which assigns each player four. In the infinite repetition treatments, the average is near the payoff associated with the Alternating Solution, which assigns each player five. There seems to be little lost or gained from the addition of the punishment action.

The asymmetric treatments are much different than the symmetric ones, the longer horizons do not imply more efficient group payoffs. In fact, from the point of view of the column player, the longer time horizon is disastrous – especially when the punishment action is present. The average column player's payoff drops more than 20 percent when moving from the one-shot treatment to either the finite or infinite repetition treatment of G_4. From the group's perspective, this drop in the column player's payoff is not made up for by fact that the average row player gets around 10 percent more when moving from the one-shot to either repeated treatment of G_4. The finite repetition treatment of G_2 is the only one where the players improve upon the payoffs of the one-shot treatment.

5.4 The Finite and Infinite Repetition Treatments: The Strategy Space

The following definitions divide the strategy sets associated with each repetition treatment into three disjoint parts:

Definition 1 (Alternating Strategy) *An individual's sequence of play is an Alternating Strategy if, for every period in the sequence, the group's play in the previous period was* $\{A, B\}$ *or* $\{B, A\}$*, then individual's play in this period is* B *if last period it was* A *and* A *if last period it was* B*.*

Definition 2 (Nash Strategy) *An individual's sequence of play is a Nash Strategy if for every period in the sequence, the individual's play corresponds to the action taken in the highest Pareto ranked, one-shot, subgame perfect equilibrium.*

Definition 3 (Other Strategy) *An individual's sequence of play is an Other Strategy if it is not an Alternating Strategy or a Nash Strategy.*

It is possible to sort every individual's complete sequence of actions into one of the three previous categories. The Alternating Strategy category includes all strategies that try to alternate - dire punishment strategies as well as completely forgiving strategies. The Nash Strategy category includes only the one strategy.[9] The Other Strategy category is a catchall and could contain many things, completely random behavior being one example.

Table 12 shows the distribution of strategies for each game's finite repetition treatment. Notice that in the symmetric games G_1 and G_2, the Alternation Strategy is picked most often. Also there is not a significant difference between the distributions, so the punishment action makes little difference.

In the asymmetric games G_2 and G_4, there is a significant difference between the distribution of strategies with and without the presence of the punishment action. The difference exists for both the row and the column players. The presence of Other Strategies on the part of the row players in G_2 shows that there were attempts at alternation – they do not just play the Nash Strategy. Most of the column players, however, play the Nash Strategy. So, the row players tend to either give up and play the Nash Strategy themselves or they punish their partners with the minimax. Most of them start playing the Nash Strategy.

The proportion of players that play an Alternating Strategy in G_4 is much higher for both types when the the punishment action is present. Note that the players never have to use this action, its presence is enough to cause the shift. A substantial number of players, both row and column, still pick an Other Strategy.

In fact, in each of the finite repetition games, a large number of Other Strategies are chosen. One explanation for this is that there is conflict between the players, or they miscoordinate in the early rounds. In any case, there is uncertainty during the game about which equilibrium strategy, the Alternating Strategy or the Nash Strategy, each player is supposed to use.

Another explanation is that there are end-game effects present. With end-game effects, players who had been choosing their action according to the Alternating Strategy would change to the Nash Strategy before the last period. Unlike in G_1 and G_2, in G_3 and G_4 end-game effects would be consistent with many subgame perfect equilibria.

Table 13 reproduces each strategy distribution when the last two periods of play are ignored [10] There is, in fact, a dramatic end-game effect in both symmetric games; 17.5 percent of the subjects switched from Alternating Strategy to Other Strategy in the last two periods of G_1, 20 percent switched in G_3. The data from the asymmetric games, on the other hand, show positively no evidence of an end-game effect. One must conclude, then, that the Other Strategies present in G_2 and G_4 are due to conflict or miscoordination.

Table 14 shows the distribution of strategies for each game's infinite repetition treatment. Notice that in the symmetric games G_1 and G_2, the Alternation Strategy is again picked most often. Also there is not a significant difference between the distributions, so the punishment action makes little difference.

The presence of the punishment action also makes little difference in the asymmetric games, although there is some shift away from the Nash Strategy for the column players. The high number of Other Strategies shows that the conflict and miscoordination present in the finite repetition treatments is still there in the infinite repetition treatments.

Finally, Table 15 shows the results of a comparison between the finite and infinite repetition treatments. The null hypothesis in these tests is that the distribution of strategies is the same under both repetition conditions.

The strong difference between the symmetric finite and infinite repetition treatments is not surprising considering the presence of the end-game effects. What is surprising is the strong support claiming a difference between the finite and infinite repetition treatments of G_2. There was no end-game effect present in the finite treatment of G_2.

6 Conclusions

After considering the evidence presented here, it is not unreasonable to predict that some groups of people, like the aforementioned Valencian farmers, will be able to enter into stable alternation schemes if they are faced with situations similar to Reciprocity Games. The farmers are in a symmetric situation, 80 percent of the farms are less than 1 hectacre.

The farmers are involved in an infinite repetition conflict; the farms have been there for centuries. Like most of the participants in infinite repetition treatments of G_1 and G_3, the farmers have been able to institute an efficient rotation scheme.

In these experiments, it has been shown that people faced with symmetric Reciprocity Games enact solutions which are progressively more efficient as the time horizon increases from one-shot to finite repetition to infinite repetition. End-game effects have been found in the finite repetition treatments. In symmetric situations, punishment options play very little role.

The ability of groups of people to obtain efficient outcomes if there are large asymmetries between them is much more doubtful. As has been seen, there can be a conflict or miscoordination if the turn-taking and welfare maximizing solutions are different. Although some succeed in instituting one of these two efficient focal outcomes, of those who fail, many get non-individually rational payoffs. Not a single group successfully instituted a *one to two*, or equal payoff, rotation scheme.

Unlike the symmetric games, efficiency in the asymmetric games does not tend to increase as the time horizon lengthens. In fact, due to prolonged conflict or miscoordination, average payoffs in the infinite repetition treatments are below the average payoffs in the one-shot treatments. With finite repetitions, the presence of the punishment action causes an increase in the number of alternation schemes that are successfully implemented or tried, although the number of efficient outcomes does not increase significantly.

Notes

1 For example, for G_1 repeated $T >= 3$ times,

$$[\{B,A\}_1, \{A,B\}_2, \{B,A\}_3, \ldots, \{A,B\}_{T-1}, \{B,B\}_T]$$

with the threat of playing $\{C,C\}$ for each subsequent stage if there is a defection is subgame perfect. To be more specific, in repeated versions of one-shot games that have multiple Nash equilibria, for any individually rational and feasible outcome u there exists a length T and a subgame perfect equilibrium such that if U is the average stage payoff in the equilibrium,

$$\|U - u\| < \varepsilon$$

for any $\varepsilon > 0$. The result holds for two-person games and for n-person games if the dimensionality of the payoff space is equal to the number of players. For details see Benoit and Krishna (1985); p. 919; refer to Theorem 3.7.

2 The equilibrium payoffs must be such that the following equation holds:

$$\frac{1}{1-\delta} v_i \geq \bar{v}_i + \frac{\delta}{1-\delta} v_i^*$$

$$\frac{1}{1-\delta} v_i^* = \frac{1}{1-\delta}((1-\delta^t) v_{i,min} + \delta^t v_i)$$

where v_i is the average payoff of the equilibrium strategy given no defection, $\bar{v}_i$ is the maximum payoff a player can get by deviating, vi^* is the average payoff of the chosen punishment strategy, and δ is the discount rate. Equation 1 says that the total payoff for playing the equilibrium must be greater than the total payoff for deviating once and then getting the punishment payoff for the rest of the game. For details see Fudenberg and Maskin (1986); pp. 533 - 554; refer to Theorem 1. In the infinite repetition treatments, the discount rate was ten percent.

3 A copy of the directions and quiz used in the one-shot treatment of G_4 is included in the appendix.

4 There were 93 subjects total. An effort was made not to have experienced players, however 7 did participate in two sessions. Two participated in 4/20/90 and 5/17/90, one participated in 5/17/90 and 5/18/90, and four participated in 5/11/90 and 5/18/90. These people were never matched with the same person more than once, even across sessions.

5 In ABS, half of the subjects played A at least once. In ABCA, one subject was responsible for all the plays of action C.

6 χ_i^2, here and elsewhere, is the standard test statistic using Yate's continuity correction. It has a χ^2 distribution with i degrees of freedom. For a complete explanation of this test, see Everitt (1977) pp. 12 - 14.

7 See Dawes (1980) and Cooper *et al.* (1987; 1990).

8 The Equality Solution requires a *one to two* rotation scheme, *i.e.* row plays A once for each two times that column plays A. This rotation scheme has a three move cycle. What is exhibited in the figures is a ten move average payoff. Even if a *one to two* rotation scheme was implemented, the ten move average would not give equal payoffs. However, any *one to two* rotation scheme would result in payoffs located on the Pareto Frontier and the averaging system used would locate the outcome withing 0.2 payoff points of the Equality Solution. No outcomes were within these tolerances.

9 It is possible to have a sequence of plays defined as both an Alternating and a Nash Strategy. In the symmetric treatments, if both players choose action B in every round, each player's strategy will be put into both categories. Fortunately, no pair of players chooses action B in each round, so the problem does not surface.

10 Two was chosen because it is the minimum number of periods that allows both players a chance to defect from the Alternate strategy.

References

[1] Cooper, R. D., D. V. DeJong, R. Forsythe and T. W. Ross. November. 1990. "Cooperation without Reputation." mimeograph.

[2] Cooper, R. D., D. V. DeJong, R. Forsythe and T. W. Ross. 1989. "Communication in the Battle of the Sexes Game." *Rand Journal of Economics* Vol. 20: pp. 568 - 587.

[3] Cooper, R. D., D. V. DeJong, R. Forsythe and T. W. Ross. December 1987. "Selection Criteria in Coordination Games: Some Experimental Results." Hoover Institution Working Papers in Economics No. E-87-54. Stanford: Stanford University.

[4] Benoit, J. P. and V. Krishna. 1985. "Finitely Repeated Games." *Econometrica* Vol. 53, No. 4: pp. 905 - 922.

[5] Devore, J. L. 1982. **Probability and Statistics for Engineering and the Sciences**. Monterey, California: Brooks/Cole Publishing Company.

[6] Dawes, R. M. 1980, "Social Dilemmas." *Annual Review of Psychology* Vol. 31: pp. 169 - 193.

[7] Everitt, B. S. 1977. **The Analysis of Contingency Tables**. London: Chapman and Hall Ltd.

[8] Fudenberg, D. and E. Maskin. 1986. "The Folk Theorem in Repeated Games with Discounting or with Incomplete Information." *Econometrica* Vol. 54, No.3: pp. 533 - 554.

[9] Ostrom, E. 1990. **Governing the Commons: The Evolution of Institutions for Collective Action**. Cambridge: Cambridge University Press.

[10] Ostrom, E., J. Walker, and R. Gardner. 1991. "Covenants with and without a Sword: Self–Enforcement is Possible." Workshop in Political Theory and Policy Analysis working paper, Indiana University.

[11] Palfrey, T. and H. Rosenthal. 1991. "Testing for Effects of Cheap Talk in a Public Goods Game with Private Information." *Games and Economic Behavior* Vol. 3: pp. 183 - 220.

[12] Palfrey, T. and H. Rosenthal. 1991. "Testing Game-Theoretic Models of Free Ridding: New Evidence on Probability Bias and Learning." in **Laboratory Experiments in Political Economy**, T. Palfrey, Ed.. Ann Arbor: University of Michigan Press, in press.

[13] Schelling, T. C. 1960. **The Strategy of Conflict**. Cambridge, Massachusetts: Harvard University Press.

[14] Selten, R. and R. Stoecker. 1986. "End Behavior in Sequences of Finite Prisoner's Dilemma Supergames: A Learning Theory Approach." *Journal of Economic Behavior and Organization* Vol. 7: pp. 47 - 70.

[15] Weissing, F. and E. Ostrom. 1990. "Irrigation Institutions and the Games Irrigators Play: Rule Enforcement without Guards." in **Game Equilibrium Models II: Methods, Morals, and Markets**, R. Selten, Ed.. Berlin: Springer-Verlag, in press.

Appendix A: Instructions

The following is a copy of the instructions given in the one-shot treatments of G_4.

INSTRUCTIONS FOR A DECISION-MAKING EXPERIMENT

This is an experiment in decision making. You will be paid *in cash* at the end of the experiment. The amount of money you earn will depend upon the decisions you make and on the decisions other people make. We request that you do not talk at all or otherwise attempt to communicate with the other subjects except according to the specific rules of the experiment. If you have a question, feel free to raise your hand. One of us will come over to where you are sitting and answer your question in private.

This experiment has 15 separate rounds and then it will end. During each round of the experiment you will be randomly paired with another subject. You will **never** be paired with the same subject for two rounds in a row.

Each round you will be given a token which will be worth either 4 or 2. It will always be worth the same amount. Each round you will be able to use the token in one of three ways: option A, or option B, or option C.

PAYOFFS

The amount of money you earn in a round depends upon which option you pick as well as which option your partner picks. **WHAT HAPPENS IN YOUR GROUP HAS NO EFFECT ON THE PAYOFFS TO MEMBERS OF THE OTHER GROUPS AND VICE VERSA**. In each round, you have nine possible earnings. These are shown in the following table:

EARNINGS TABLE		
Your Choice	His/Her Choice	Your Earnings
A	A	3 points
A	B	3 points
A	C	1 point
B	A	Your Token Value + 3 points
B	B	Your Token Value
B	C	1 point
C	A	1 point
C	B	1 point
C	C	2 points

To summarize the table:

1 **ROWS 1 to 3:** If you choose option A you will get 3 points if your partner picks either option A or option B. If you choose option A and your partner chooses option C, you will get 1 point.

2 **ROWS 4 to 6:** If you choose option B you will get your token value + 3 points if your partner picks option A, you will get your token value if your partner picks option B, or you will get 1 point if your partner picks option C.

3 **ROWS 7 to 9:** If you choose option C you will get 1 point if your partner picks either option A or option B. If you choose option C and your partner chooses option C, you will get 2 points.

SPECIFIC INSTRUCTIONS:

At the end of the experiment you will be paid 5 cents for every point you have accumulated.

Appendix B: Quiz

The following is a copy of the quiz given in the one-shot treatments of G_4.

QUIZ

id #. ______________________________

1. If my token is worth 4 points, the other player in my group will have a token value equal to:

   i. 4 points.

   ii. 2 points.

   iii. Either 4 or 2 points.

   iv. None of the above.

2. If someone was in my group on round 5 of an experiment, it will be **certain, very likely, impossible** that he or she will be in my group on round 6.

3. If my token value is 2 and I choose option B and my partner chooses option A, how many points will I earn?

4. If I choose option A and my partner chooses option C, how many points will I earn?

5. If at the end of a round I have 2 points, how much am I paid for that round?

The Payoff Tables

$$G_1 = \begin{bmatrix} (3,3) & (3,7) \\ (7,3) & (4,4) \end{bmatrix} \qquad G_2 = \begin{bmatrix} (3,3) & (3,7) \\ (5,3) & (2,4) \end{bmatrix}$$

$$G_3 = \begin{bmatrix} (3,3) & (3,7) & (1,1) \\ (7,3) & (4,4) & (1,1) \\ (1,1) & (1,1) & (2,2) \end{bmatrix} \quad G_4 = \begin{bmatrix} (3,3) & (3,7) & (1,1) \\ (5,3) & (2,4) & (1,1) \\ (1,1) & (1,1) & (2,2) \end{bmatrix}$$

Table 1: The payoff tables for the four different payoff treatments: symmetric (G_1), asymmetric (G_2), symmetric with punishment (G_3), and asymmetric with punishment (G_4).

Experiments

game	trtmnt	date	subj.	obs.	length	$\frac{penny}{point}$	order
G_1	O	2/4/91	10	75	1	5	1
	F	1/31/91	10	20	15	4	-
	I	5/18/90	12	24	{61, 37, 17, 29}	4	-
G_3	O	2/4/91	10	75	1	5	2
	F	1/14/91	10	20	15	4	-
	I	5/17/90	12	24	{20, 41, 26, 25}	4	-
G_2	O	2/4/91	10	75	1	5	3
	F	2/1/91	10	20	15	4	-
	I	5/11/90	12	24	{28, 19, 16, 20}	4	-
G_4	O	2/4/91	10	75	1	5	4
	F	2/1/91	14	28	15	4	-
	I	4/20/90	12	24	{16, 29, 21, 24}	4	-

Table 2: The date of each experiment along with the number of subjects, the number of observations, the number of periods, the exchange rate, and, if there were different treatments in one session, the order of treatments. O, F, and I stand for one-shot, finite repetition, ~~and infinite repetition~~, respectively.

The Distribution of Outcomes
One-Shot Treatments

$$G_1 = \begin{bmatrix} 1 & 12 \\ & \underline{62} \end{bmatrix} \qquad G_2 = \begin{bmatrix} 6 & \underline{53} \\ 0 & 16 \end{bmatrix}$$

$$G_3 = \begin{bmatrix} 1 & 9 & 0 \\ & \underline{63} & 2 \\ & & 0 \end{bmatrix} \qquad G_4 = \begin{bmatrix} 0 & \underline{58} & 0 \\ 0 & 13 & 0 \\ 0 & 4 & 0 \end{bmatrix}$$

Table 3: The distribution of outcomes in the one-shot treatments. The entries in each table represent the number of times each outcome was observed in that treatment. The outcomes that satisfy Hypothesis 4, the Nash Solution, have been underlined. Notice that there are no entries below the diagonal in the symmetric games G_1 and G_3; the symmetric outcomes are classified together. In the asymmetric games, all outcomes are classified separately.

One-Shot Treatment
Distribution of Actions,
Periods 1 – 8 and Periods 9 – 15:

	G_1		G_3	
	periods 1 – 8	periods 9 – 15	periods 1 – 8	periods 9 – 15
A	9	5	8	3
B	71	65	72	65
C	-	-	0	2
χ^2	0.3370		1.6290	

Row Players

	G_2		G_4	
	periods 1 – 8	periods 9 – 15	periods 1 – 8	periods 9 – 15
A	30	29	28	30
B	10	6	10	3
C	-	-	2	2
χ^2	0.2983		2.5813	

Column Players

	G_2		G_4	
	periods 1 – 8	periods 9 – 15	periods 1 – 8	periods 9 – 15
A	5	1	0	0
B	35	34	40	35
C	-	-	0	0
χ^2	1.2301		NA	

Table 4: For each One-Shot treatment, the distributions of strategies for the first eight periods and the last seven periods is shown and compared using a χ^2 statistic. In the asymmetric treatments, row players and column players are considered separately.

One-Shot Treatments
Frequencies and Upper Bounds:

	G_1	G_3	G_2	G_4
Hyp. 1 Uniqueness				
successes	62	63	53	58
others	13	12	22	17
freq	0.8267	0.8400	0.7067	0.7733
high	0.8997	0.9107	0.7945	0.8541
χ_1^2	0.0000		0.5544	
Hyp. 2 Pareto Optimality				
successes	74	72	53	58
others	1	3	22	17
freq	0.9867	0.9600	0.7067	0.7733
high	1.0000†	0.9978†	0.7945	0.8541
χ_1^2	0.2568		0.5544	

	G_1	G_2 (ROW)	G_2 (COL)
Hyp. 3 Individual Rationality			
successes	136	59	69
others	14	16	6
freq	0.9067	0.7867	0.9200
high	0.9460	0.8657	0.9723†

† - significant at $\alpha = 0.05$
high is the upper bound of the 95% c. interval around freq.

Table 5: For each **One-Shot** treatment, the breakdown of the outcomes between successes and others for the Uniqueness, Pareto Optimality, and Individual Rationality hypothesis are shown. Also shown is the frequency of success and the upper bound of its 95 percent confidence interval. Finally, the distribution of observations under each hypothesis when there is no punishment strategy is compared to the distribution of observations when there is a punishment strategy; A χ^2 statistic is reported.

One-Shot Contingency Table						
Hyp. 4 Nash Solution						
			Row		Column	
	G_1	G_3	G_2	G_4	G_2	G_4
successes	136	137	59	58	69	75
other	14	13	16	17	6	0
freq.	0.9066	0.9133	0.7866	0.7733	0.9200	1.000
high	0.9460	0.9514†	0.8657	0.8.541	0.9723†	1.000†
χ_1^2	0.0000		0.0000		4.3403*	

† - significant at $\alpha = 0.05$
* - significant by adopted criteria
high is the upper bound of the 95% c. interval around freq.

Table 6: For each **One-Shot** treatment, the breakdown of individual strategy choices between successes and others for the Nash hypothesis is shown. Also shown is the frequency of success and the upper bound of its 9.5 percent confidence interval. Finally, the distribution of observations under the hypothesis when there is no punishment strategy is compared to the distribution of observations when there is a punishment strategy; a χ^2 statistic is reported.

Finite Repetition Treatments Frequencies and Upper Bounds:				
	G_1	G_3	G_2	G_4
Hyp. 1 Uniqueness				
successes	5	8	7	8
others	15	12	13	20
freq	0.2500	0.400	0.3500	0.2857
high	0.4174	0.5894	0.5344	0.4311
χ_1^2	0.4558		0.0249	
Hyp. 2 Pareto Optimality				
successes	3	5	8	11
others	17	15	12	17
freq	0.1500	0.2500	0.4000	0.3929
high	0.2880	0.4174	0.5894	0.5500
χ_1^2	0.1563		0.0622	
	G_1	G_2 (ROW)	G_2 (COL)	
Hyp. 3 Individual Rationality				
successes	49	9	20	
others	1	11	0	
freq	0.9800	0.4500	1.0000	
high	1.0000†	0.6423	1.0000†	

† - significant at $\alpha = 0.05$
high is the upper bound of the 95% c. interval around freq.

Table 7: For each **Finite Repetition** treatment, the breakdown of the outcomes between successes and others for the Uniqueness, Pareto Optimality, and Individual Rationality hypotheses are shown. Also shown is the frequency of success and the upper bound of its 95 percent confidence interval. Finally, the distribution of observations under each hypothesis when there is no punishment strategy is compared to the distribution of observations when there is a punishment strategy; a χ^2 statistic is reported.

Infinite Repetition Treatments
Frequencies and Upper Bounds:

	G_1	G_3	G_2	G_4
Hyp. 1 Uniqueness				
successes	21	19	8	7
others	3	5	16	17
freq	0.8750	0.7917	0.3333	0.2917
high	0.9907†	0.9338	0.4983	0.4507
χ_1^2	0.1500		0.0000	
Hyp. 2 Pareto Optimality				
successes	21	19	10	12
others	3	5	14	12
freq	0.8750	0.7917	0.4167	0.5000
high	0.9907†	0.9338	0.5892	0.6749
χ_1^2	0.1500		0.0839	

	G_1	G_2 (ROW)	G_2 (COL)
Hyp. 3 Individual Rationality			
successes	46	13	23
others	2	11	1
freq	0.9583	0.5417	0.9583
high	1.0000†	0.7160	1.0000†

† - significant at $\alpha = 0.05$
high is the upper bound of the 95% c. interval around freq.

Table 8: For each **Infinite Repetition** treatment, the breakdown of the outcomes between successes and others for the Uniqueness, Pareto Optimality, and Individual Rationality hypotheses are shown. Also shown is the frequency of success and the upper bound of its 95 percent confidence interval. Finally, the distribution of observations under each hypothesis when there is no punishment strategy is compared to the distribution of observations when there is a punishment strategy; a χ^2 statistic is reported.

Finite vs. Infinite Repetition Treatments: comparisons of levels of support using a χ_1^2 statistic			
	Hyp 1 Unique	Hyp 2 Pareto Opt.	Hyp 3 Ind. Rational
G_1	15.1375*	20.2958*	0.0259
G_3	5.5032*	10.8174*	
G_2	0.0413	0.0384	0.0917 (ROW) 0.0085 (COL)
G_4	0.0675	0.2455	

* - significant at $\alpha = 0.05$

Table 9: The statistics obtained when comparing the distribution of outcomes under the hypotheses in the finite repetition treatments and the distribution in the infinite repetition treatments.

Distribution of Outcomes Over
Focal Point Solution Concepts:

	G_1		G_3		G_2		G_4	
	F	I	F	I	F	I	F	I
Hyp. 5 Alternating	3	21	5	19	1	2	8	7
Hyp. 6 Welfare	*	*	*	*	7	8	3	5
Hyp. 7 Equality	*	*	*	*	0	0	0	0
Hyp. 4 Nash	5	0	1	0	**	**	**	**
Other	12	3	14	5	12	14	17	12

* - Hyp. is the same as Alternating
** - Hyp. is the same as Welfare

Table 10: For each finite (F) and infinite (I) repetition treatment, the distribution of outcomes over each focal point solution is shown.

Average Payoffs						
	One-Shot		Finite		Infinite	
	G_1	G_3	G_1	G_3	G_1	G_3
player	4.147	4.027	4.535	4.585	4.908	4.850
group	8.294	8.054	9.070	9.170	9.816	9.700
	One-Shot		Finite		Infinite	
	G_2	G_4	G_2	G_4	G_2	G_4
row	2.785	2.725	2.955	3.021	2.896	3.029
col	6.040	6.160	6.175	4.757	5.638	4.821
group	8.825	8.885	9.130	7.778	8.534	7.850

Table 11: The average payoffs in the one-shot treatment and in rounds 5 – 15 of the finite and infinite repetition treatments.

Finite Repetition Contingency Table						
			ROW		COL	
	G_1	G_3	G_2	G_4	G_2	G_4
Alt.	21	23	0	11	4	10
Nash	6	4	2	2	15	4
Other	13	13	18	15	1	14
χ^2_2	0.4909		10.2234*		19.4124*	

* - significant at $\alpha = 0.05$

Table 12: In each **Finite Repetition** treatment, the distribution of strategy choices is shown. The distribution of strategies when there is no punishment strategy is compared to the distribution of strategies when there is a punishment strategy; a χ^2 statistic is reported.

Finite Repetition, Strategy Distributions, All Periods and All But the Last 2 Periods:				
	G_1		G_3	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	21	28	23	30
Nash	6	6	4	5
Other	13	6	13	5
		Row Players		
	G_2		G_4	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	0	0	11	11
Nash	2	2	2	2
Other	18	18	15	15
		Column Players		
	G_2		G_4	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	4	4	10	10
Nash	15	15	4	5
Other	1	1	14	13

Table 13: The different strategy distributions over the focal solutions obtained when all periods are taken into account and also when all but the last two periods are taken into account are displayed for each finite repetition treatment.

Infinite Repetition Contingency Table						
			ROW		COL	
	G_1	G_3	G_2	G_4	G_2	G_4
Alt.	42	40	6	6	2	7
Nash	2	1	6	4	12	6
Other	4	7	12	14	10	11
χ^2_2	1.2003		0.5538		4.8254	

* - significant at $\alpha = 0.05$

Table 14: In each **Infinite Repetition** treatment, the distribution of strategy choices is shown. The distribution of strategies when there is no punishment strategy is compared to the distribution of strategies when there is a punishment strategy; a χ^2 statistic is reported.

Finite vs. Infinite Repetition Treatments:
χ^2_2 Statistic
H_o: strategy distributions are identical.

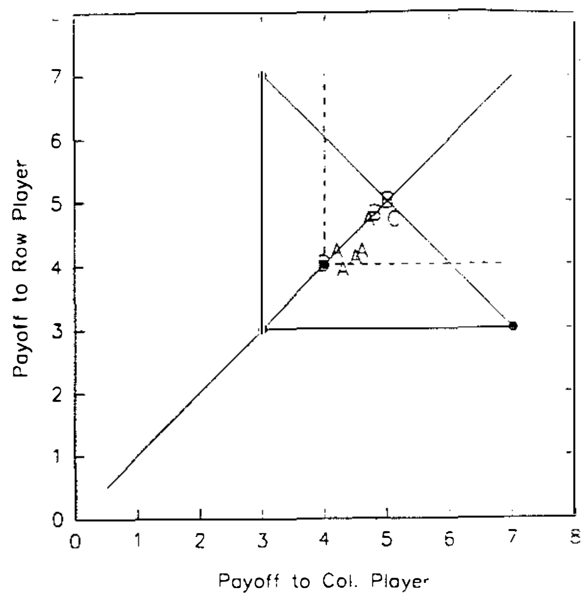
		ROW	COl
G_1	10.4159*		
G_3	5.2478		
G_2		5.9927*	5.6341
G_4		0.7889	0.3435

* - significant at $\alpha = 0.05$

Table 15: The statistics obtained when comparing the distribution of strategy choices in the finite repetition treatments and the distribution in the infinite repetition treatments.

G_1, Finite

A	=	**1**
B	=	**3**
C	=	**4**
D	=	**5**
total	=	**20**



G_1, Infinite

A	=	**1**
B	=	**2**
C	=	**21**
total	=	**24**

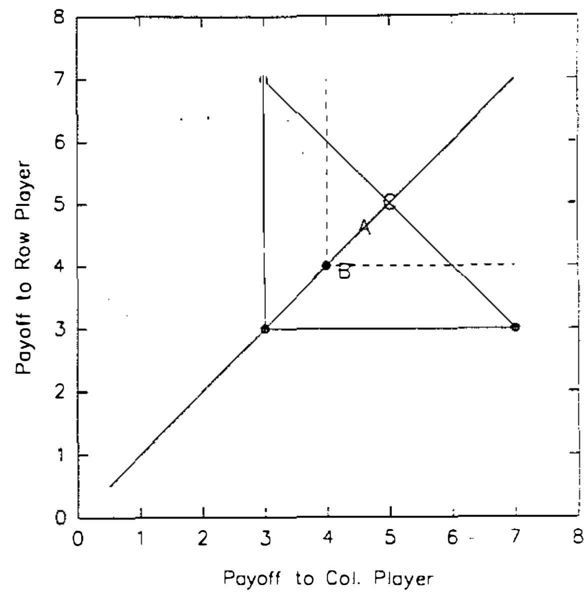
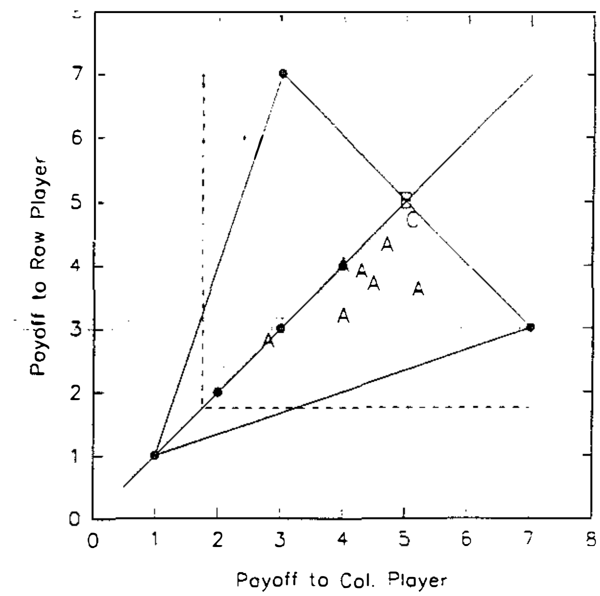


Figure 1: The outcomes to the repeated treatments of G_1. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

G_3, **Finite**

A = 1
B = 5
C = 8
total = 20



G_3, **Infinite**

A = 1
B = 19
total = 24

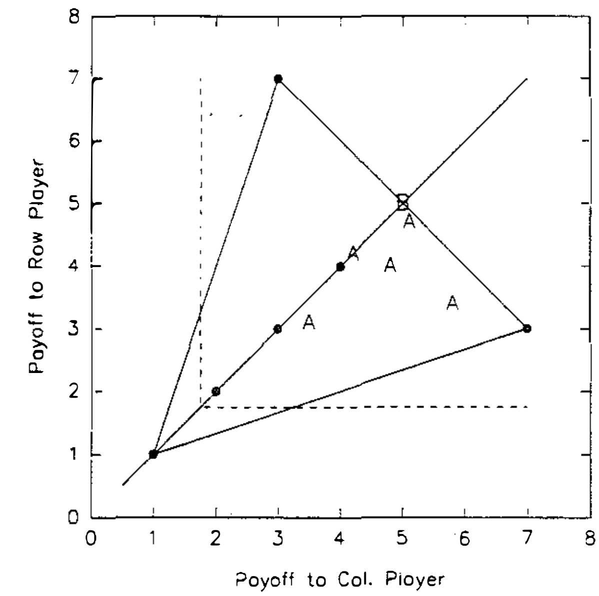


Figure 2: The outcomes to the repeated treatments of G_3. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

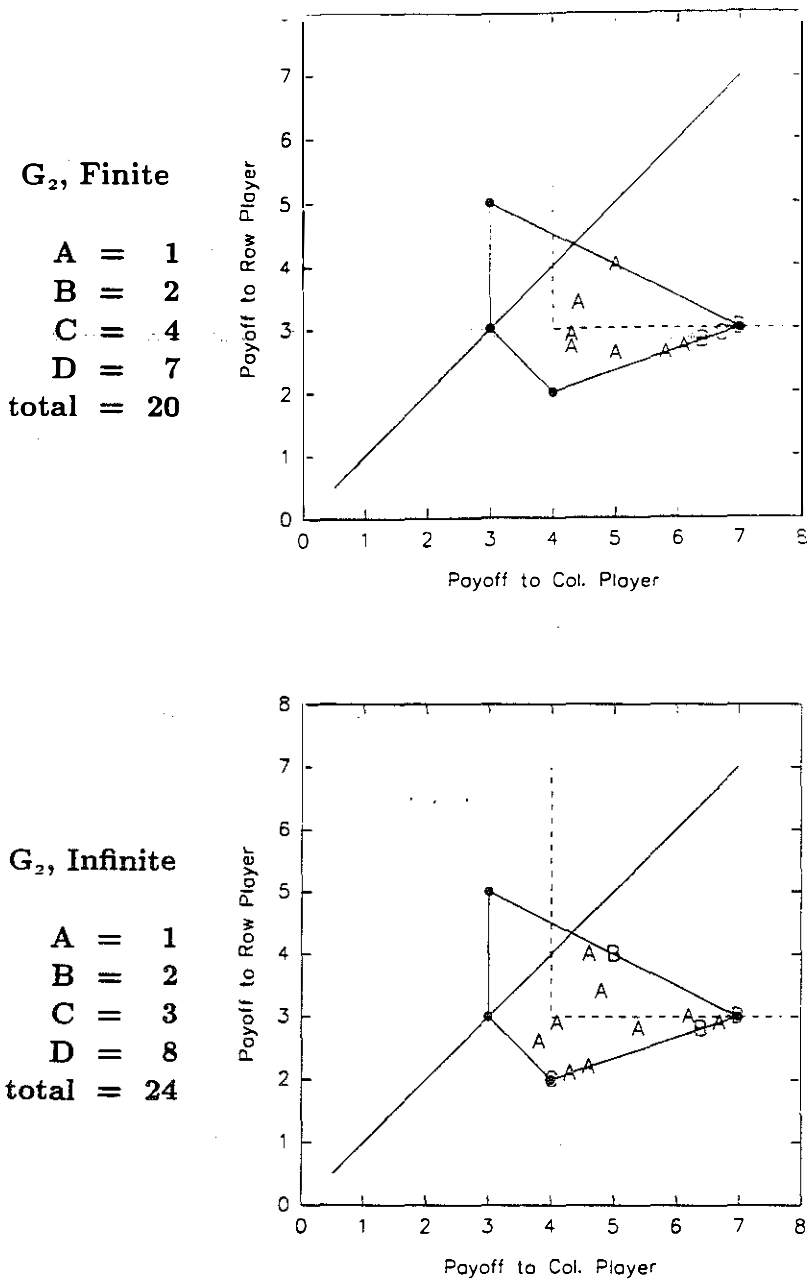
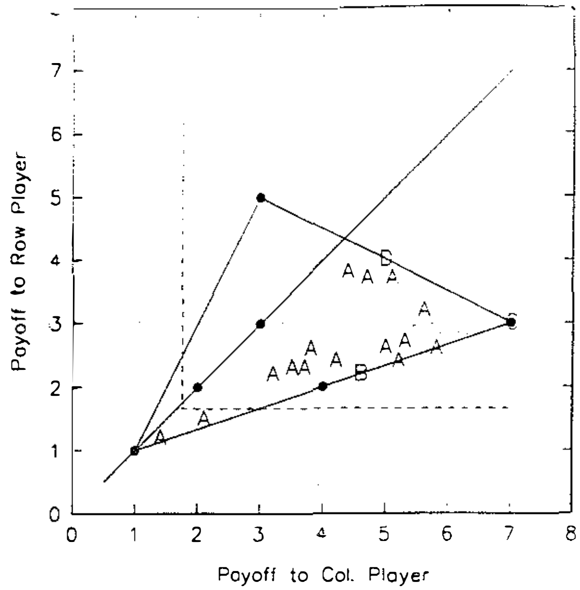


Figure 3: The outcomes to the repeated treatments of G_2. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

G_4, Finite

A	=	**1**
B	=	**2**
C	=	**3**
D	=	**8**
total	=	**28**



G_4, Infinite

A	=	**1**
B	=	**5**
C	=	**7**
total	=	**24**

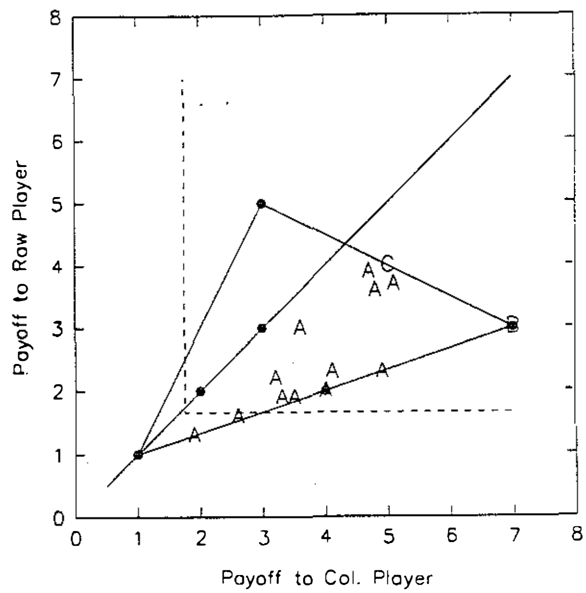


Figure 4: The outcomes to the repeated treatments of G_4. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.