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Social Dilemmas: Behavior With and Without Communication

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I. Introduction

In the context of individual and group decision making, the presence of social dilemmas imply a divergence between expected outcomes and outcomes that would be optimal from the perspective of the group. The presence of social dilemmas and the degree of predicted suboptimality depends on three components of the decision situation: (1) the existence of a physical domain in which there are externalities in production or consumption, (2) modes of behavior in which individuals make decisions based on calculations that do not fully incorporate the utilities of others, and (3) environments or institutional settings that do or do not create incentives for internalizing such externalities into individuals' decision calculus.

Externalities occur when the actions of one individual create a positive (negative) impact on other individuals. Such externalities create a divergence in the private costs or benefits from an action and the social costs or benefits from that action. When individuals make choices that do not fully account for all social costs or benefits, their choices lead to outcomes that are suboptimal from the perspective of the group. The empirical significance of social dilemmas thus depends on the physical characteristics of the externalities created in a given situation, the paradigmatic mode of behavior of individuals in that situation, and the incentives created by the institutions governing the situation.

Drawing on results from several previously conducted laboratory studies, this paper focuses on the components of a dilemma situation.[1] Individual and group decision making is examined in the context of two stylized decision situations; public goods and common pool resources. Public goods are man-made facilities (or services) where the production of the public good by one individual (or contribution to provision) creates an external benefit that is shared by other individuals.[2] Common-pool resources are natural or man-made resources in which appropriation by one individual creates an external cost on other users. Exclusion from obtaining external benefits in the case of public goods or exclusion from the resource in the case of common-pool resources is considered to be infeasible or nontrivial from either a technological, constitutional, or economic perspective.

Public goods and common-pool settings offer several contrasting characteristics that shed light on the process of group and individual decision making and on the empirical significance of social dilemma problems. Both settings are generally assumed to create social dilemmas due to the externalities created by individuals in their provision or appropriation decisions. This prediction is based on a paradigm of self interested behavior and an institutional structure that creates individual incentives that are not congruent with group optimality. Under production is predicted in the case of public goods and over appropriation is predicted in the case of common pool resources.

This paper focuses on how behavior differs across two distinct institutional settings within the public goods and common-pool resource settings. The first, what might be referred to as a "stark" setting from an institutional perspective, creates conditions that have been shown to produce behavior that is broadly consistent with predictions from noncooperative game theory — suboptimality. The second setting allows for face-to-face communication, where subjects have the opportunity to propose decision strategies and to build commitments to those strategies.

The effect of communication in collective-action situations is open to considerable debate. Words alone are viewed by many as minimal constraints when individuals choose between private short term profit-maximizing strategies and strategies negotiated by a verbal agreement.[3] The inability to make enforceable agreements is at the core of the distinction between cooperative and noncooperative theories:

> the decisive question is whether the players can make enforceable agreements, and it makes little difference whether they are allowed to talk to each other. Even if they are free to talk and to negotiate an agreement, this fact will be of no real help if the agreement has little chance of being kept. An ability to negotiate agreements is useful only if the rules of the game make such

agreements binding and enforceable. (Harsanyi and Selten, 1988, p.3)[4]

Thus, much of contemporary, noncooperative game theory treats the ability to communicate as inessential and unlikely to change results unless the individuals involved can call on external agents to enforce agreements.

Studies of repetitive collective-action situations in field settings, however, show that individuals in many settings adopt cooperative strategies that enhance their joint payoffs without the presence of external enforcers. Many situational factors appear to affect the capacity to arrive at and maintain agreed-upon play. The ability to communicate appears to be a necessary but not a sufficient condition.

Previous experimental research on face-to-face communication has shown this mechanism to be a powerful tool for enhancing efficiency. As Dawes states, The salutary effects of communication on cooperation are ubiquitous' (1980, p. 185).[5] Hypotheses forwarded to explain why communication increases the selection of cooperative strategies identify a process that communication is posited to facilitate: (1) offering and extracting promises, (2) changing the expectations of others' behavior, (3) changing the payoff structure, (4) the re-enforcement of prior normative orientations, and (5) the development of a group identity. Experimental examination of communication has demonstrated the independent effect of all five of these processes, but they also appear to re-enforce one another in an interactive manner.[6] Prior research that relied on signals exchanged via computer terminals rather than face-to-face communication has not had the same impact on behavior. Sell and Wilson (1991, 1992), whose experimental design allowed participants in a public-good experiment to signal a promise to cooperate via their terminals, found much less sustained cooperation than reported for face-to-face communication.

The paper is organized around two principal sections. In the next section the laboratory decision situation and theoretical benchmarks are presented for the public goods and common-pool resource settings, respectively. Following this section, summary observations are provided that: (a) illustrate the important differences in behavior that are found between public goods and common-pool resource settings, and (b) the behavior observed when face-to-face communication is allowed.

II. The Decision Settings

The Decision Environment - VCM

Consider the operationalization of a public goods situation utilizing the following decision framework, commonly referred to as the voluntary contributions mechanism (VCM).[7] N subjects participate in a series of decision rounds. Each participant is endowed with z tokens that are to be divided between a 'private account' and a 'group account.' Tokens cannot be carried across rounds. The subject is informed that for each token he/she places in the private account he/she earns $.01 with certainty. The subject is also informed that earnings from the group account are dependent upon the decisions of all group members. For a given round, let X represent the sum of tokens placed in the group account by all individuals in the group. Earnings from the group account are dependent upon the preassigned earnings function G(X). Each individual receives earnings from the group account regardless of whether he/she allocates tokens to that account—thus the publicness (nonexcludability) of the group account. For simplicity, each individual is symmetric with respect to his/her earnings from the group account. That is, each earns an equal amount from the group account equal to [G(X)]/N cents. Figure 1 illustrates the type of information subjects receive for a given parameterization of the game with a group size of N=10.

Prior to the start of each decision round, each individual knows the number of remaining rounds, the groups' aggregate token endowment, and the groups' aggregate token allocation to the group account in previous rounds. It is explained that the decisions for each round are binding and rewards are based on the sum of earnings from all rounds. During each round, subjects can view their personal token allocations, earnings, and total tokens from the group placed in the group account for all previous rounds.[8]

Each participant's decision to allocate a marginal token to the group account costs that individual \$.01. For appropriate initializations, however, allocations to the group account yield a positive gain in group surplus of $[G'(\bullet) - .01]$. Given that the return from the private account is parameterized to be \$.01, the strategic nature of the game depends on the parameterizations utilized for G(X). In particular, for the individual, the strategic nature of the game depends critically on the marginal per capita return from the group account (MPCR), defined as the ratio of '\$' benefits to costs for moving a single token from the individual to the group account, or $[G'(\bullet)/N]/\$.01$. The behavioral results summarized below focus on two alternative parameterizations that have been investigated by the author and coauthors in previous work.

In the first parameterization, G(X) is linear as in Figure 1, with G' a constant greater than \$.01 and $[G'(\bullet)/N] < \$.01$. Given these specifications, the Pareto Optimum (defined simply as the outcome that maximizes group earnings) is for each individual to place all tokens in the group account. Further, from the perspective of the group, for any level of group good provision, group earnings increase with increases in MPCR and, holding MPCR constant, group earnings increase with increases in N. On the other hand, the single-period dominant strategy is for each individual to place zero tokens in the group account. The 'social dilemma' follows strategically because the return from the private account and G(•) are chosen so that the MPCR < 1. For finitely repeated play, the outcome of zero allocations to the group account is also the unique, backward induction, complete information Nash equilibrium. In summary, for all parameterizations in which MPCR < 1, complete information noncooperative game theory yields the same prediction -- zero allocations to the group account.

For the second parameterization, consider the case where G(X) is quadratic. In particular, consider parameterizations of the form $G(X) = BX\text{-}CX^2$ and $[G'(\bullet)/N] > .01$ for initial allocations to the group account, but declining so that $[G'(\bullet)/N]$ becomes equal to .01 at some allocation level X_{NASH}.

With this parameterization, the Nash equilibrium for a single play of the game is for group allocations to the group account to equal X_{NASH}. However, the Pareto Optimal allocation of tokens to the group account is an allocation level where $G'() = .01$, an allocation level greater than that predicted by the Nash equilibrium.

For clarification, a diagrammatic exposition of the two types of parameterizations are shown in Figure 2. Both panels display characterizations of marginal private benefits (MPB) from provision of the public good, marginal social benefits (MSB) from provision of the public good, and marginal cost (MC) of provision of the public good. The upper panel displays a characterization of a setting where the Nash equilibrium implies a zero allocation to the group account. The lower panel displays a characterization in which the Nash equilibrium is an "interior" prediction of X_{NASH} tokens allocated to the group account.

Finally, in the stark institutional setting in which subjects are not allowed to discuss the decision problem, each subject makes decisions for each round in complete privacy. When face-to-face communication is allowed, subjects are brought together in a common area in the laboratory environment. They are told they can discuss anything they choose, except that: (1) no private information can be exchanged (such as individual decisions in past rounds), (2) no physical threats can be made and no side-payments can be discussed, and (3) there discussions will be monitored for compliance to the first two conditions.

Common Pool Resources

The Decision Environment - CPR

Contrast the common-pool resource (CPR) appropriation game with the VCM game.[9] In the CPR game, subjects are endowed each decision round with a specified number of tokens that are to be divided between two markets. Market 1 is described as an investment opportunity in which each token yields a fixed (constant) rate of output and each unit of output yields a fixed (constant) return. Market

2 (the CPR) is described as a market that yields a rate of output per token dependent upon the total number of tokens invested by the entire group. Investments in Market 2 can be though of as appropriating units from the CPR.[10] Subjects are informed that they receive a level of output from Market 2 that is equivalent to the percentage of total group tokens they invest. Further, subjects know that each unit of output from Market 2 yields a fixed (constant) rate of return. Prior to each decision round, subjects know the total number of decision makers in the group, that individual endowments are equal, and total investments in Market 2 for all prior decision rounds.

In the experiments reported here, the CPR is operationalized with eight appropriators (N = 8) and a quadratic production function $F(\Sigma x_i)$ for Market 2, where:

$$F(\Sigma x_i) = 23\Sigma x_i - .25(\Sigma x_i)^2$$

MPCR = [illegible] / N

with a return from Market 2 of $.01 per unit of output. Subjects are endowed each round with either 10 tokens or 25 tokens and receive a return from Market 1 of $.05 per token invested. With these payoff parameters, a group investment of 36 tokens yields the optimal level of investment. The complete information symmetric noncooperative Nash equilibrium is for each subject to invest 8 tokens in Market 2 (regardless of the endowment condition) - for a total group investment in Market 2 of 64 tokens.[11]

Figure 3 illustrates the type of information subjects see in a given parameterization of the game. The negative externality imbedded in this game is a result of the production function used for Market 2. More specifically, as an individual invests tokens in Market 2 the marginal and average return to that individual and all other individuals is reduced for Market 2. A self interested decision maker is assumed to make investment decisions that take into account the impact on his/her own investments, but disregard the negative return imposed on others.

The experimental results for the CPR game have generally focused on what is termed 'Maximum Net Yield' from the CPR, as opposed to overall efficiency.[12] This measure captures the degree of optimal yield earned from the CPR only, Market 2. Specifically, net yield is the return from Market 2 minus the opportunity costs of tokens invested in Market 2 divided by the optimal return from Market 2 minus the opportunity costs of tokens invested in Market 2 at the optimum. For the CPR investment, opportunity costs equal the potential return that could have been earned by investing the tokens in Market 1. Dissipation of yield from the CPR is known in the resource literature as 'rent' dissipation. Note, as with the symmetric Nash equilibrium, optimal net yield is invariant to the level of subjects' endowments, as long as individual endowments are sufficient to meet the Nash prediction. Thus, even though the range for subject investment decisions is increased with an increase in subjects' endowments, the equilibrium and optimal levels of investment are not altered. At the Nash equilibrium, subjects earn 39 percent of maximum net yield from the CPR. These relationships and their relationship to rents, the social optimum, and the Nash equilibrium are displayed in Figure 4.

As in the VCM experiments, in the institutional setting in which subjects are not allowed to discuss the decision problem, each subject makes decisions for each round in complete privacy. When face-to-face communication is allowed subjects are given the same notification as in the VCM face-to-face condition.[13]

HI. Behavior

The VCM Environment

Summary Results - No Communication - VCM. Consider behavior from the parameterization where zero tokens allocated to the group account is the Nash equilibrium prediction. Behavior from experiments involving groups of size 4, 10, 40, and 100 yield the following summary conclusions.

1. Depending upon specific parameterizations, replicable behavior is observed where allocations are very near the predicted outcome of zero allocations to the group account or are significantly above zero allocations to the group account.

2. There is considerable heterogeneity in decisions across subjects and across decision rounds.

3. Allocations to the group account are either unaffected by MPCR or are inversely related to MPCR.

4. Holding MPCR constant, allocations to the group account are either unaffected by group size or are **positively** related to group size.

5. Increasing group size in conjunction with a **sufficient** decrease in MPCR leads to lower allocations to the group account.

6. There tends to be some decay (but generally incomplete) to the predicted outcome of zero allocations to the group account.

7. Even with a richer information set regarding the implications of alternative allocation decisions, highly experienced subject groups continue to follow a pattern of behavior generally inconsistent with the predictions of the complete information Nash model.

8. Inconsistent with models of learning, the rate of decay of allocations to the group account is inversely related to the number of decision rounds.

Figure 5 illustrates the pattern of observations observed across parametric conditions. Reported are mean levels of allocations as a percentage of optimum across decision rounds. The top left hand panel displays results from parametric conditions where N=10 and MPCR=.3 or MPCR=.75. Note the general increase in allocations to the group account for the MPCR=.75 condition. The top right hand panel displays results from conditions where MPCR=.3 and N=10 or N=100. Contrary to many of the broad generalizations that are found in textbook discussions of public goods, holding MPCR constant, one observes an increase in allocations to the group account (less free riding) with the larger group size. But in some textbook discussions of the free rider phenomena, authors explicitly illustrate group size effects with specific arguments related to decreases in the marginal value of the public good in conjunction with increases in group size (crowding effects) and/or illustrations of large group public goods settings with inherently small marginal valuations. The bottom panel displays results from the conditions where N=10, MPCR=.3 and N=40, MPCR=.O3. That is, with an increase in group size, the value of the public good at the margin decreases to group members. In this case, we observe a validation of the proposition that an increase in group size leads to a decrease in the level of public goods provision.

Now turn to experiments in which the Nash prediction is interior — a positive allocation to the group account. In this environment previous findings can be summarized as follows:

9. In experiments in which the Nash prediction of tokens allocated to the group account is a relatively small percentage of total token endowments (less than 50%), allocations to the group account tend to follow a pattern of being greater than the Nash prediction, but with some decay in the direction of the Nash prediction over decision rounds.

10. In parameterizations in which the Nash prediction of tokens allocated to the group account is a relatively large proportion of total endowments, allocations to the group account tend to fall below that predicted by the Nash equilibrium.

Figure 6 illustrates these summary observations. Designs are illustrated in which the Nash equilibrium equals 0, 48, 124, and 200 tokens, denoted as designs NashO, Nash48, Nashl24, and Nash200. Given token investments of 62 tokens per subject (248 aggregate), these designs purposely partition the aggregate token space into three distinct cases. Given a total group endowment of 248, Nash48 and Nash200 require Nash group investments that are mirror images. That is, in the Nash48 and Nash200 designs, the area for deviations relative to the Nash prediction is symmetric with respect to the boundary of the choice space and with respect to the midpoint of the choice space. On the other hand, Nashl24 has an area for deviations that is symmetric around the Nash equilibrium. As one can see from Figure 5, mean investments in designs Nash0 and Nash48 are systematically biased above the Nash prediction. Mean investments in Nash124 begin very close to the Nash prediction, but show a downward trend (below Nash) in later decision rounds. In Nash200, there is a downward bias in group investments relative to the Nash prediction of 200.

In summary, results from this VCM setting (with minimal institutional structure in regard to coordinating decision making by group members) reveals a pattern of behavior in which provision of the public good is frequently above that predicted by complete information noncooperative game theory. This result is contingent, however, on the particular parameterizations investigated. In experiments with a sufficiently low MPCR or with an interior Nash equilibrium that requires a high percentage of tokens being allocated to the public good, the patterns of behavior are more supportive of game theoretical predictions (at least at the level of aggregate group behavior).

Summary Results - Face-to-Face Communication - VCM. **To date, all of the data collected on** communication in the VCM environment is in the context of the first parameterization — where the Nash strategy is zero tokens allocated to the group account. Figure 7 summarizes the results from the first study that was completed (Isaac and Walker, 1988), in which all groups were of size N=4. In this figure, means are reported across three treatment conditions: (1) NC/NC, where no communication was allowed, (2) NC/C, where 10 initial rounds of no communication were followed by 10 rounds in which communication was allowed between every decision round, and (3) C/NC where 10 initial rounds with communication was followed by 10 rounds with no communication.

Summarizing the results from these experiments:

1. In the NC/C treatment, communication has an immediate positive effect on allocations to the group account and that effect increases with repetition.

2. In the C/NC treatment, communication has a significant positive effect on communication and there is a strong hysteresis effect in the rounds which follow where no communication is allowed. In fact, in the four experiments that are included in this condition, in only one was there significant decay in group allocations. In 3 of the 4 experiments, the groups reached efficiencies of 98% or higher in 30 or 30 rounds.

In addition to the results reported above, Isaac and Walker (1988) also draw the following two conclusions.

3. In experiments in which subjects receive asymmetric endowments of tokens and communication is allowed, the levels of allocations of to the group account in experiments with symmetric endowments tend to dominate those under conditions of asymmetric endowments.

4. In a more complex environment in which group size was increased to N=8 and subjects faced a declining MPCR for allocations to the group account, communication significantly increased allocations to the group account. However, in this more complex setting: (a) agreements were less explicit, (b) allocations were not sustained at high levels (the mean decreased from almost 100% down to near 40% by the last period, (c) post experiment interviews suggested that non-compliance subjects rationalized that the optimum could be reached without their cooperation.

Finally, Isaac and Walker (1991) investigate a setting where communication is available to the subjects, but at a cost. Before the start of the experiment, it was explained that the subjects would have the opportunity to meet before each decision round, if they "purchased" the opportunity to do so. The opportunity to communicate was funded as a provision point public good. Groups were all of size N=6. If at least 4 individuals chose to contribute $.10, the groups was allowed to meet. In effect, this setting created a second order dilemma game where individuals must expend resources to provide a mechanism that may alter the strategic nature of a first order dilemma game.[14] The results from these set of experiments can be summarized as follows:

1. Of 6 groups, only 2 succeeded in funding the communication opportunity in the first round. By the forth round, however, all groups were successful.

2. The groups used the opportunity to communicate to make allocation commitments to the group good and to solve the second order efficiency problem — not having to fund the opportunity to meet every round. That is, the subjects explicitly discussed this problem and made multi-period commitments.

3. In the decisions which followed the first opportunity to communicate for each group, average efficiency in providing the public good was 91 %. There was, however, an end period effect in which efficiencies dropped significantly in 4 of 6 experiments.

The CPR Environment

Summary Results - No Communication - CPR. Figure 8 presents data from a series of CPR experiments in which individual token endowments were either 10 or 25. Displayed is average net yield from the CPR as a percentage of optimum across decision rounds. The data in these panels are typical of the 'baseline' experiments reported by Ostrom, Gardner, and Walker (1994), leading to the following summary observations:

1. Subjects make investments in Market 2 (appropriate from the CPR) well above optimum, leading to significant inefficiencies.

2. Investments in Market 2 are characterized by a 'pulsing' pattern in which investments are increased leading to a reduction in yield, at which time investors tend to reduce their investments in Market 2 and yields increase. This pattern reoccurs across decision rounds within an experiment, with a tendency for the variation across rounds to diminish as the

experiment continues.

3. Investment behavior is affected by token endowments. Yields as a percentage of optimum are less in 25-token experiments than in 10-token experiments.

4. The Nash equilibrium is the best predictor of aggregate outcomes for low-endowment experiments. In the high-endowment setting, aggregate behavior is far from Nash in early rounds but approaches Nash in later rounds. However, at the individual decision level, there is virtually no evidence that behavior converges to the Nash equilibrium.

Summary Results - Face-to-Face Communication - CPR, **The top panel of Figure 9 presents** period by period observations on rents accrued in the four (Design I) communication experiments conducted by Ostrom and Walker (1991). Parallel to a subset of the experiments conducted by Isaac and Walker (1988), communication followed a series of no-communication decision rounds, and was allowed immediately before decisions were made in periods 11-20 of these experiments. All four experiments show a strong shift toward maximum rents beginning with period 11. In the first 10 periods of the communication experiments the mean level of rents is nearly identical to that observed in baseline no-communication experiments (30 percent compared to 29.9 percent). In periods 11-20, rent shifts dramatically to an average of 97.8 percent. This compares to 35.3 percent in periods 11-20 of the baseline experiments. Clearly the ability to communicate has translated into a shift in efficiency to near optimality.

In further experimentation, Ostrom, Gardner, Walker (1994) extend this analysis. In particular, they examine the degree to which these results are sensitive to the environmental setting in which communication takes place. Summarizing, they find that:

1. Subjects in repeated, high-endowment, CPR games, with one and only one opportunity to communicate, obtain an average percentage of net yield above that obtained in baseline experiments in the same decision rounds without communication (55 percent compared to 21 percent).

2. Subjects in repeated, high-endowment, CPR games, with repeated opportunities to communicate before every decision period, obtain an average percentage of net yield that is substantially above that obtained in baseline experiments without communication (73 percent compared to 21 percent). In low-endowment games, the average net yield is 99 percent as compared to 34 percent.

3. Repeated communication opportunities in high-endowment games lead to higher joint outcomes (73 percent) than one-shot communication (55 percent), as well as lower defection rates (13 percent compared to 25 percent).

4. In no experiment where one or more subjects deviated from an agreed-upon joint strategy did the other subjects then follow a grim trigger strategy of substantially increasing their investments in the CPR.

The bottom panel of Figure 9 displays the results from yet another set of experiments conducted by Ostrom and Walker (1991). These experiments parallel the nested public goods problem discussed above in the study by Isaac and Walker (1991). In these experiments the opportunity to communicate was a costly public good that subjects had to first provide through voluntary (anonymous) contributions. As Ostrom and Walker (1991) note, the provision problem players faced in the costly communication experiments was not trivial and did in fact create a barrier. Summarizing these findings:

1. In all experiments with costly communication, the problem of providing the institution for communication diminished the success of either: (a) having the ability to develop a coordinated strategy and/or (b) dealing with players who cheated on a previous agreement.

2. On the other hand, all groups succeeded to some degree in providing the communication mechanism and in dealing with the CPR dilemma. On average, efficiency in these groups increased from approximately 42 percent to 80 percent.

Hackett, Schlager, and Walker (1994), hereafter HSW, further extend the above analyses. In previous CPR experiments individuals were homogeneous in decision attributes. It is possible that the strong efficiency enhancing properties of face-to-face communication significantly depend upon homogeneities in decision attributes. In fact, the literature provides several arguments that point to heterogeneity as a serious deterrent to cooperation (R. Hardin, 1982; Johnson and Libecap, 1982; Libecap and Wiggins, 1984; Isaac and Walker, 1988a; Wiggins and Libecap, 1985, 1987; E. Ostrom, 1990; Kanbur, 1992; Hackett, 1992). The task of agreeing to and sustaining agreements is more difficult for heterogeneous individuals because of the distributional conflict associated with alternative sharing rules. In heterogeneous settings, different sharing rules generally produce different distributions of earnings across individuals. While all individuals may be made better off by cooperating, some benefit more than others, depending upon the sharing rule chosen. Consequently, individuals may fail to cooperate on the adoption of a sharing rule because they cannot agree upon what would constitute a fair distribution of benefits produced by cooperating.

HSW examine the CPR decision setting with heterogeneous players. Heterogeneity is introduced by varying the input endowments of the subjects. Heterogeneities in endowments imply that alternative rules adopted to reduce over appropriation from the CPR will have differential effects on earnings across subjects. HSW find that, even with heterogeneity, face-to-face communication remains a very effective institution for increasing efficiency. Investigating two designs, one where heterogeneities in endowments were assigned randomly and one through an auction mechanism, both treatment conditions led to significant increases in net yield over baseline (no-communication) conditions. With noncommunication, HSW report a level of net yield relatively close to that predicted by the Nash equilibrium for their designs (48.9 percent). With communication, overall yield increases to over 94 percent on average across treatment conditions.

III. Concluding Comments

Collective-action problems offer a unique and challenging setting for social scientists interested in the linkages between theory, institutions, and behavior. Evidence from field and experimental studies provides support for three fundamental propositions:

PI Without some form of coordination or organization to enable individuals to agree upon, monitor, and sanction contributions to the provision of a public good, the good is *under provided.*

P2 Without some form of coordination or organization to enable individuals to agree upon, monitor, and sanction the patterns of appropriation from a CPR, the resource is *overused.*

P3 Face-to-face communication in small groups settings has an immediate efficiency enhancing effect on behavior. Subjects openly use communication to find a joint strategy, to build agreement to using that strategy, and to verbally sanction noncompliance (even when there insufficient information to identify actual defectors).

The experimental studies reported here are not the first to observe high levels of cooperation in experimental social dilemmas with communication. They add to the growing literature on the strength of this relatively simple mechanism. As discussed by Ostrom, Gardner, and Walker (1994), one approach for explaining observed patterns of cooperation relies on notions of incomplete information and interprets the game as if it were infinitely repeated (Friedman, 1990).[15] This approach relies on incomplete information surrounding the termination point for the experiment. For example, suppose the subjects approach the game as if it were repeated, but with only a vague notion of the number of repetitions.[16] Further suppose that the subjects think the termination of the experiment is due to randomness, and that the probability of termination in any round is small. In these circumstances, subjects may recognize more than one sensible way of playing the game, some of which increase group gains. That is, not knowing exactly when it ends, the subjects act as though the game might last forever. If this were the case, there are many other equilibria available to them. All of these equilibria have efficiencies at least as great as that of the subgame perfect equilibrium of the finitely repeated game. The data are not inconsistent with such an interpretation. Given the plethora of equilibria available to the subjects (if they were to perceive the game as infinite), they face a difficult coordination problem. Communication allows the subjects to focus on a particular strategy and build assurance that others will play this strategy.

One, however, should be skeptical of this interpretation as being the sole explanation for these findings. For instance, as documented above, in public-goods experiments, even when the termination point is made explicit to the subjects, communication continues to have a significant impact in improving efficiencies. Also, in the CPR experiments of Hackett, Schlager, and Walker (1993) reported above the termination point was made very clear in advance. Ostrom, Gardner, and Walker (1994) offer a second approach relying on incomplete information concerning other subjects' types. For example, face-to-face communication (and resulting verbal commitments), may change subject's expectations of other players' responses. In particular, if a subject believes that other subjects are of a cooperative type (that is, will cooperate in response to cooperative play), that subject may play cooperatively to induce cooperation from others. In this case, cooperating can be sustained as rational play in the framework of incomplete information regarding player types. The cost of this approach is the incredible calculation processes involved in determining an equilibrium under incomplete information.

Ostrom, Gardner, and Walker (194) offer a final interpretation based on bounded rationality. They propose two principles based on the evidence gathered. The first principle is that agents use communication to reach an agreement.[17] The second principle is that agents will find and adopt a simple agreement. In a communication sessions, subjects tend to do two things: (1) focus on an agreement approximating the group maximum and (2) formulate a simple symmetric plan of play for the repeated game. The principle of simplicity in the one-shot case carries over to the repeated case. Interestingly enough, these two principles are consistent with arguments of bounded rationality.[18] Game theory based on complete rationality requires that players have a strategy— a complete plan of play for every contingency. Selten, Mitzkewitz, and Uhlich (1988) argue that players are basically reactive in nature. Suppose that players in a communication phase have reached agreement on how play should proceed. As long as play proceeds according to the agreement, there is no need to react. Reaction is only called for when something unexpected happens, in particular, a defection from the agreement. The first principle that subjects use when communicating about equilibrium selection—find a simple symmetric solution—gives the subjects a reference point, their agreement, for reactions. The second principle—simplicity—reinforces the agreement as a reference point and suggests the form that reactions may take to deviations from the agreement. One possible type of "simple" reaction is a *measured reaction.*[19]

In a measured reaction, a player reacts mildly (if at all) to a small deviation from an agreement. The larger the deviation from an agreement, the larger the reaction. Thus, a measured reaction is already different from a grim trigger strategy. The intuition behind measured reactions is that, by keeping play near the agreement, it is easier to restore the agreement. Further, the risk of a complete unraveling toward the one-shot game equilibrium is reduced when players do not overreact to deviations. Since the payoff achieved from an agreement (or, play close to the agreement) dominates the one-shot game equilibrium, measured reactions represent a useful response to the problem of equilibrium selection. When most individuals use a measured reaction, even in challenging situations, they are able to gain joint returns close to the level agreed upon. Their closeness to optimality depends both on the yield potential of their agreement and on their rate of compliance. Individuals who exhibit measured reactions are able to sustain cooperation for an extended period and reap the benefits of doing so. On the other hand, when one or a few individuals do *not* respond consistently with measured reactions and are able to deviate in an extreme manner from an agreement (have available sufficient resources to be very disruptive to attempts by others to form near optimal agreements), measured reactions are not very effective. This is especially problematic when players communicate only once. The ability to chastise offenders verbally on a repeated basis is essential to preventing agreements from unraveling.

Even if measured reactions work, this still leaves unanswered why some groups exhibit them and others do not. Where is the behavioral foundation for such reactions? One answer to this question starts with Selten's dictum that complete rationality is the limiting case of bounded or incomplete rationality (see Selten 1975, 35). From this perspective, a behavioral response like measured reactions are heuristics used by individuals as problem-solving tools when complete analysis is difficult and short-term self-interest dictates unsatisfactory long-term outcomes, such as the case where the cognitive task is beyond the immediate scope of the individual, or game equilibria lead to suboptimal outcomes. Individuals learn to use a repertoire of heuristics depending upon their experience and their perception of the situation in which they find themselves, including the likely behavior of others.

REFERENCES

Bomstein, Gary and Rapoport, Amnon. 1988: Intergroup competition for the provision of step-level public goods: Effects of preplay communication. *European Journal of Social Psychology,* 18, 125-42.

Bomstein, Gary, Rapoport, Amnon, Kerpel, Lucia, and Katz, Tani. 1989: Within- and between-group communication in intergroup competition for public goods. *Journal of Experimental Social Psychology,* 25, 422-36.

Braver, Sanford L. and Wilson, L. A. 1984: A laboratory study of social contracts as a solution to public goods problems: Surviving on the lifeboat. Presented at the Western Social Science Association meeting, San Diego, California.

Braver, Sanford L. and Wilson, L. A. 1986: Choices in social dilemmas: Effects of communication within subgroups. *Journal of Conflict Resolution,* 30(1) (March), 51-62.

Bagnoli, Mark and McKee, Michael. 1991: Voluntary contribution games: Efficient private provision of public goods. *Economic Inquiry,* 29(2) (April), 351-66.

Caldwell, Michael D. 1976: Communication and sex effects in a five-person prisoners' dilemma game. *Journal of Personality and Social Psychology,* 33(3), 273-80.

Dawes, Robyn M. 1980: Social Dilemmas. *Annual Review of Psychology,* 31, 169-93.

Dawes, Robyn M., McTavish, Jeanne, and Shaklee, Harriet. 1977: Behavior, communication, and assumptions about other people's behavior in a commons dilemma situation. *Journal of Personality and Social Psychology,* 35(1) (Jan.), 1-11.

Dawes, Robyn M., Orbell, John M., and van de Kragt, Alphons. 1984: Normative constraint and incentive compatible design. University of Oregon, Department of Psychology. Typescript.

Dorsey, Robert E. 1992: The voluntary contributions mechanism with real time revisions. *Public Choice,* 73(3) (April), 261-82.

Edney, Julian J. and Harper, Christopher S. 1978: The commons dilemma: A review of contributions from psychology. *Environmental Management,* 2(6), 491-507.

Friedman, James W. 1990. *Game Theory with Applications to Economics.* 2d ed. New York: Oxford University Press.

Hackett, Steven. 1992: Heterogeneity and the provision of governance for common-pool resources. *Journal of Theoretical Politics,* 4(3), 325-42.

Hackett, Steven, Schlager, Edella, and Walker, James M. 1994: The role of communication in resolving commons dilemmas: Experimental evidence with heterogeneous appropriators. *Journal of Environmental Economics and Management,* 27, 99-126.

Hardin, Russel "Collective Action", The Johns Hopkins University Press, Baltimore MD (1982).

Harsanyi, John C. and Selten, Reinhard. 1988: *A General Theory of Equilibrium Selection in Games.* Cambridge, Mass.: MIT Press.

Isaac, R. Mark, McCue, Kenneth, and Plott, Charles R. 1985: Public goods provision in an experimental environment. *Journal of Public Economics,* 26, 51-74.

Isaac, R. Mark, Schmidtz, David, and Walker, James M. 1989: The assurance problem in a laboratory market. *Public Choice,* 62(3), 217-36.

Isaac, R. Mark and Walker, James M. 1988a: Communication and free-riding behavior: The voluntary contribution mechanism. *Economic Inquiry,* 26(4) (Oct.), 585-008.

Isaac, R. Mark and Walker, James M. 1988b: Group size effects in public goods provision: The voluntary contributions mechanism. *Quarterly Journal of Economics,* 103 (Feb.), 179-99.

Isaac, R. Mark and Walker, James M. 1991: Costly communication: An experiment in a nested public goods problem. In Thomas R. Palfrey (ed.), *Laboratory Research in Political Economy.* Ann Arbor: University of Michigan Press, 269-86.

Isaac, R. Mark and Walker, James M. 1993: Nash as an organizing principle in the voluntary provision of public goods: Experimental evidence, working paper. Bloomington: Indiana University.

Isaac, R. Mark, Walker, James M., and Thomas, Susan. 1984: Divergent evidence on free riding: An experimental examination of some possible explanations. *Public Choice,* 43(2), 113-49.

Isaac, R. Mark, Walker, James M., and Williams, Arlington. 1994: Group size and the voluntary provision of public goods: Experimental evidence utilizing large groups. *Journal of Public Economics,* 54(1) (May), 1-36.

Jerdee, Thomas H. and Rosen, Benson. 1974: Effects of opportunity to communicate and visibility of individual decisions on behavior in the common interest. *Journal of Applied Psychology,* 59(6), 712-16.

Johnson, Ronald and Libecap, Gary D. 1982: Contracting problems and regulation: The case of the fishery. *American Economic Review,* 72(5) (Dec), 1,005-23.

Kanbur, S. M. Ravi. 1992: Heterogeneity, distribution, and cooperation in common property resource management. Background Paper for the World Development Report. Washington, D.C.: World Bank.

Kanbur, Ravi. Heterogeneity, Distribution and Cooperation in Common Property Resource Management, Background Paper for the World Development Report, 1992.

Kramer, R. M. and Brewer, Marilyn M. 1986: Social group identity and the emergence of cooperation in resource conservation dilemmas. In Henk A. Wilke, David M. Messick, and Christel G. Rutte (eds.), *Experimental Social Dilemmas.* Frankfurt am Main: Lang, 205-34.

Libecap, Gary and Steve Wiggins, Contractual Responses to the Common Pool: Prorationing of Crude Oil Production, The American Economic Review 74, 87-98 (1984).

Laury, Susan, Walker, James M., and Williams, Arlington. 1995. Anonymity and the voluntary **provision of public goods.** ***Journal of Economic Behavior and Organization,*** **27, 365-380.**

Ledyard, John. 1994: Is there a problem with public goods provision? In John Kagel and Alvin Roth (eds.), *The Handbook of Experimental Economics.* Princeton, N.J.: Princeton University Press.

Mitzkewitz, Michael, and Rosemarie Nagel. 1991. "Envy, Greed, and Anticipation in Ultimatum Games with Incomplete Information: An Experimental Study." Bonn: University of Bonn, Sonderforschungsbereich 303, Discussion Paper B-181, March.

Orbell, John M., Dawes, Robyn M., and van de Kragt, Alphons. 1990: The limits of multilateral promising. *Ethics,* 100(4) (April), 616-27.

Orbell, John M., van de Kragt, Alphons, and Dawes, Robyn M. 1988: Explaining discussion-induced **cooperation.** ***Journal of Personality and Social Psychology,*** **54(5), 811-19.**

Orbell, John M., van de Kragt, Alphons, and Dawes, Robyn M. 1991: Covenants without the sword: The role of promises in social dilemma circumstances. In Kenneth J. Kofford and Jeffrey B. Miller (eds.), *Social Norms and Economic Institutions.* Ann Arbor: University of Michigan Press, 117-34.

Ostrom, Elinor and James Walker. 1997. Neither markets nor states: Linking transformation processes in collective action arenas. *Perspectives on Public Choice,* 35-72, Cambridge University Press..

Ostrom, Elinor, Walker, James M., and Gardner, Roy. 1992. Covenants with and without a sword: Self-governance is possible. *American Political Science Review,* 86(2) (June), 404-17.

Ostrom, Elinor, Gardner, Roy, and Walker, James M. 1994: *Rules, Games, and Common-Pool Resources.* Ann Arbor: University of Michigan Press.

Rockenbach, Bettin, and Gerald R. Uhlich. 1989. "The Negotiation Agreement Area: An Experimental Analysis of Two-Person Characteristic Function Games." Bonn: University of Bonn, Sonderforschungsbereich 303, Discussion Paper B-126, October

Sell, Jane and Wilson, Rick. 1991: Levels of information and contributions to public goods. *Social Forces,* 70(1) (Sept.), 107-24.

Sell, Jane and Wilson, Rick. 1992: Liar, liar, pants on fire: Cheap talk and signaling in repeated public goods settings. Working paper. Rice University, Department of Political Science.

Selten, Reinhard, Michael Mitzkewitz, and Gerald R. Uhlich. 1988. "Duopoly Strategies Programmed by Experienced Players." University of Bonn Special Research Project 303, Discussion Paper B-172.

Selten, Reinhard. 1975. "Reexamination of the Perfectness Concept for Equilibrium Points in Extensive **Games."** ***International Journal of Game Theory*** **4:25-55.**

van de Kragt, Alphons, et al. 1986. "Doing Well and Doing Good as Ways of Resolving Social Dilemmas." In *Experimental Social Dilemmas,* ed. Henk A.M. Wilke, Dave Messick, and Christel Rutte, 177-204. Frankfurt am Main, Germany: Verlag Peter Lang.

Wiggins, Steve and Gary Libecap, Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information, American Economic Review 75, 368-84 (1985).

_________, and _________ , Firm Heterogeneities and Cartelization Efforts in Domestic Crude Oil, Journal of Law, Economics, and Organization 3, 1»25 (1987).

Yamagishi, Toshio. 1986: The provision of a sanctioning system as a public good. ***Journal of Personality and Social Psychology,*** **51(1), 110-16.**

Yamagishi, Toshio. 1988: Seriousness of social dilemmas and the provision of a sanctioning system. ***Social Psychology Quarterly,*** **51(1), 32-42.**

ENDNOTES

1. This work relies significantly on previous work by the author and co-authors. In particular, see Ostrom, Gardner, and Walker (1994), Ostrom and Walker (1997), and Isaac, Walker, and Williams (1994).

2. Public good situations can be defined over situations where the shared outcome is either positive, zero, or negative to recipients. Here the focus is on the case where values are positive.

3. See E. Ostrom, Walker, and Gardner (1992) for further discussion of this topic.

4. Harsanyi and Selten (1988, p. 3) add that in real life, 'agreements may be enforced externally by courts of law, government agencies, or pressure from public opinion; they may be enforced internally by the fact that the players are simply unwilling to violate agreements on moral grounds and know that this is the case.' To model self-commitment using noncooperative game theory, the ability to break the commitment is removed by trimming the branches that emanate from a self-commitment move to remove any alternative contrary to that which has been committed. In a lab setting, this would mean changing the structure of the alternatives made available to subjects after an agreement, which was not done.

5. Among the studies showing a positive effect of the capacity to communicate are: Bornstein and Rapoport (1988); Bornstein et al. (1989); Braver and Wilson (1984, 1986); Caldwell (1976); Dawes, McTavish, and Shaklee (1977); Dawes, Orbell, and van de Kragt (1984); Edney and Harper (1978); Hackett, Schlager, and Walker (1994); Jerdee and Rosen (1974); Kramer and Brewer (1986); van de Kragt et al. (1986); Isaac and Walker (1988a, 1991); Orbell, Dawes, and van de Kragt (1990); Orbell, van de Kragt, and Dawes (1991); and E. Ostrom and Walker (1991).

6. Orbell, van de Kragt, and Dawes (1988) summarize the findings from ten years of research on one-shot public-good experiments by stressing both the independent and interdependent nature of the posited explanatory factors for why communication has such a powerful effect on rates of cooperation.

7. The discussion and results presented in this section draws heavily on Isaac, Walker, and Williams (1994) and Isaac and Walker (1994).

8. There are numerous other studies of public goods provision games using institutional settings similar to the VCM game described here. For a summary of these papers see Ledyard (1994).

9. The discussion in this section relies significantly on Ostrom, Gardner, and Walker (1994).

10. In both the VCM environment and the CPR environment, the language of the experiment is kept neutral. That is, such terms as public goods, common pool resources, contributions, etc. are not used.

11. See E. Ostrom, Gardner, and Walker (1994) for details of the derivation of this game equilibrium.

12. If rents from the CPR are maximized then overall efficiency is 100%.

13. One difference in procedures is that in the CPR experiments subjects conversations were audio taped.

14. Yamagishi (1986, 1988) examines the imposition of sanctioning to change the structure of a simple public-good dilemma situation.

15. If a game were to be repeated infinitely, there would be no last period and the logic of backward induction no longer applies.

16. As mentioned in chapter 5, subjects are told that the experiment will last up to two hours and have already experienced training experiments that lasted no more than 20 rounds.

17. This point is made forcefully by Banks and Calvert 1992a, 1992b.

18. Colleagues working with Reinhard Selten in the Department of Economics at the University of Bonn have developed and tested a series of behavioral strategies related to various types of games. See Rockenbach and Uhlich 1989 on two-person characteristic function games; Mitzkewitz and Nagel 1991 on ultimatum games with incomplete information.

19. The use of this term was inspired by the concept of "measure-for-measure" introduced by Selten, Mitzkewitz, and Uhlich 1988. However, there are important differences in this application relative to theirs. Namely, their subjects do not have a communication phase, and they model their subjects using Selten's three-stage theory of bounded rationality. This application makes use of only one of these three stages and substitutes communication for another stage.

FIGURE 1
VCM SUMMARY INFORMATION TABLE
ILLUSTRATION FOR N=10 & MPCR=.30

ROUND 1 CURRENTLY IN PROGRESS

YOUR ENDOWMENT of tokens in each round: 50 ; Group size: 10
TOTAL GROUP ENDOWMENT of tokens in each round: 500
Each token retained in your PRIVATE ACCOUNT earns: $ 0.01

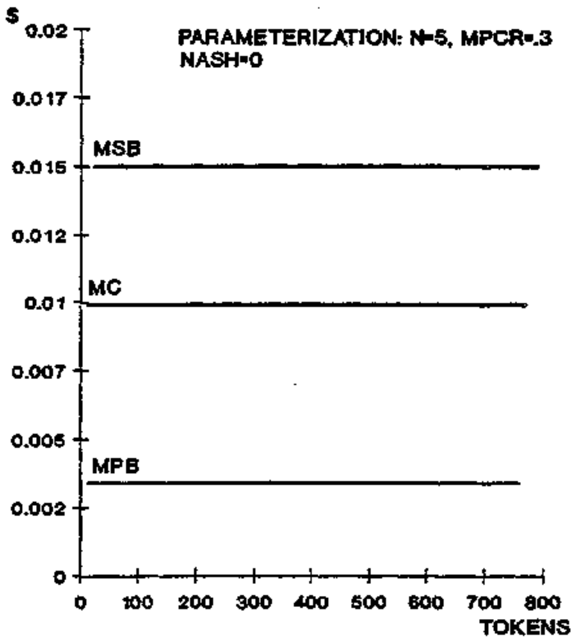
Examples of possible earnings from the GROUP ACCOUNT

Tokens in GROUP ACCOUNT (from the entire group)	Total Group Earnings	Your 10% share of Group Earnings
0	$ 0.000	$ 0.000
31	$ 0.930	$ 0.093
63	$ 1.890	$ 0.189
94	$ 2.820	$ 0.282
125	$ 3.750	$ 0.375
156	$ 4.680	$ 0.468
188	$ 5.640	$ 0.564
219	$ 6.570	$ 0.657
250	$ 7.500	$ 0.750
281	$ 8.430	$ 0.843
313	$ 9.390	$ 0.939
344	$ 10.320	$ 1.032
375	$ 11.250	$ 1.125
406	$ 12.180	$ 1.218
438	$ 13.140	$ 1.314
469	$ 14.070	$ 1.407
500	$ 15.000	$ 1.500

-HELP→ review instructions.
-LAB→ view the earnings from the group account for any possible value of "Tokens in Group Account".

How many tokens do you wish to place in the GROUP ACCOUNT? ≫

FIGURE 2
VCM BOUNDARY AND INTERIOR EQUILIBRIUM



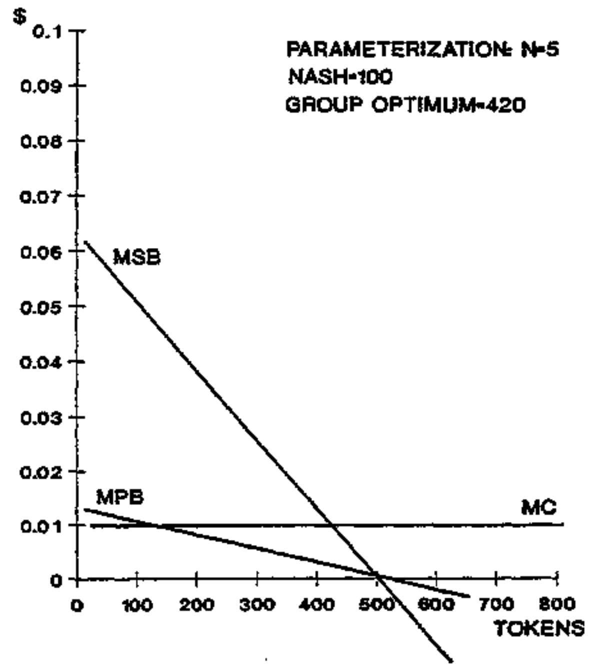


FIGURE 3
CPR SUMMARY INFORMATION TABLE
ILLUSTRATION FOR N=8 & ENDOWMENT=25

UNITS PRODUCED AND CASH RETURN FROM INVESTMENTS IN MARKET 2
commodity 2 value per unit = $ 0.01

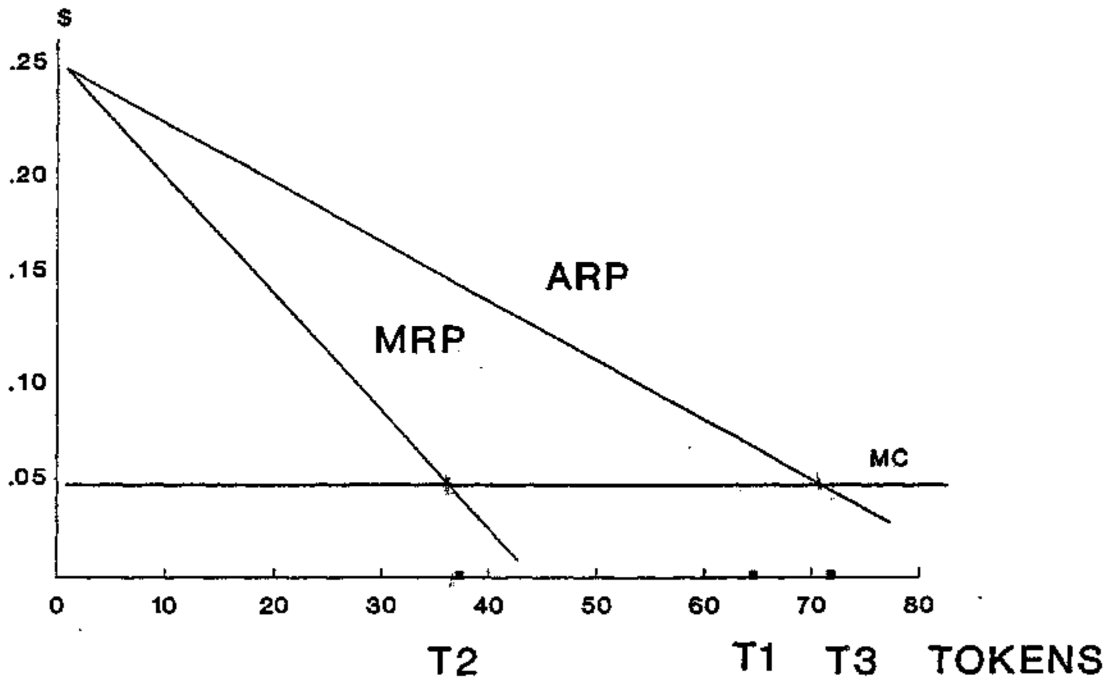
Tokens Invested by Group	Units of Commodity 2 Produced	Total Group Return	Average Return per Token	Additional Return per Token
20	360	$ 3.60	$ 0.18	$ 0.18
40	520	$ 5.20	$ 0.13	$ 0.08
60	480	$ 4.80	$ 0.08	$-0.02
80	240	$ 2.40	$ 0.03	$-0.12
100	-200	$ -2.00	$-0.02	$-0.22
120	-840	$ -8.40	$-0.07	$-0.32
140	-1680	$-16.80	$-0.12	$-0.42
160	-2720	$-27.20	$-0.17	$-0.52
180	-3960	$-39.60	$-0.22	$-0.62
200	-5400	$-54.00	$-0.27	$-0.72

The table shown above displays information on investments in Market 2 at various levels of group investment. Your return from Market 2 depends on what percentage of the total group investment is made by you.

Market 1 returns you one unit of commodity 1 for each token you invest in Market 1. Each unit of commodity 1 pays you $ 0.05.

Press -BACK-

FIGURE 4
CPR - BENCHMARKS AND EQUILIBRIUM



PREDICTIONS: T1=64; T2=36; T3=72

FIGURE 5

VCM - NO COMMUNICATION - BOUNDARY DESIGNS
ALLOCATIONS TO GROUP ACCOUNT: % OF OPTIMUM

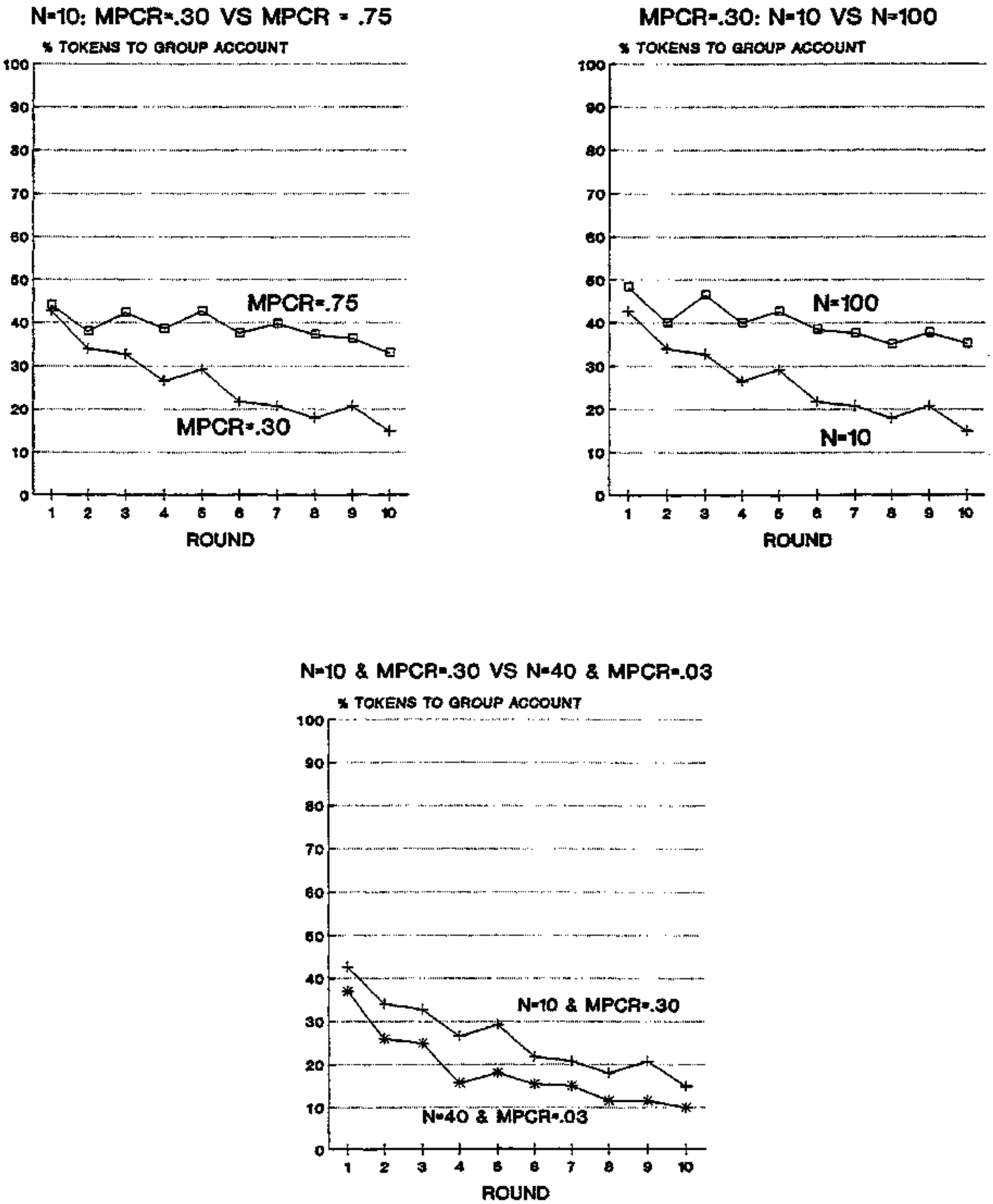


FIGURE 6
VCM - NO COMMUNICATION - INTERIOR NASH DESIGNS

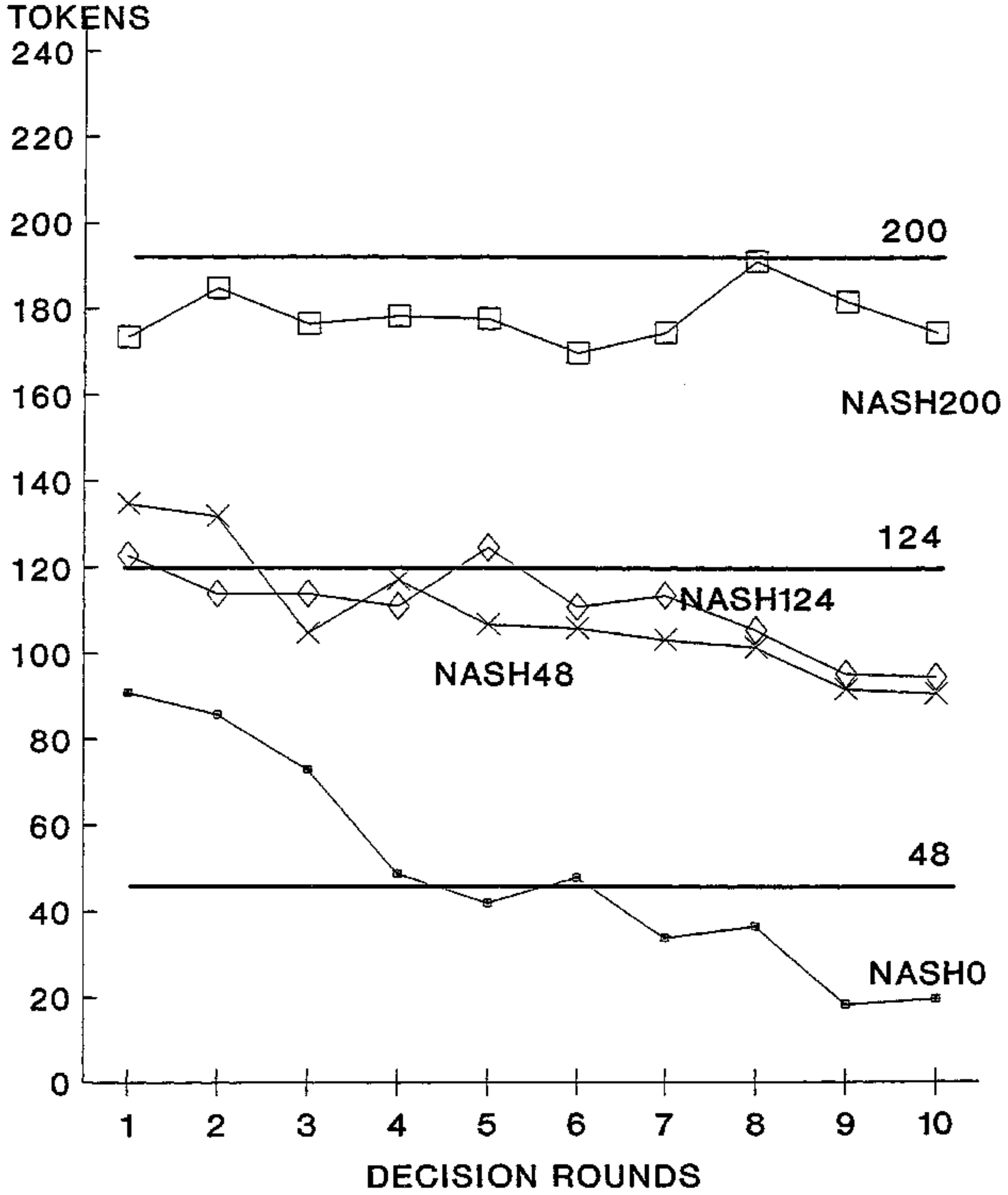


FIGURE 7

VCM - FACE-TO-FACE COMMUNICATION

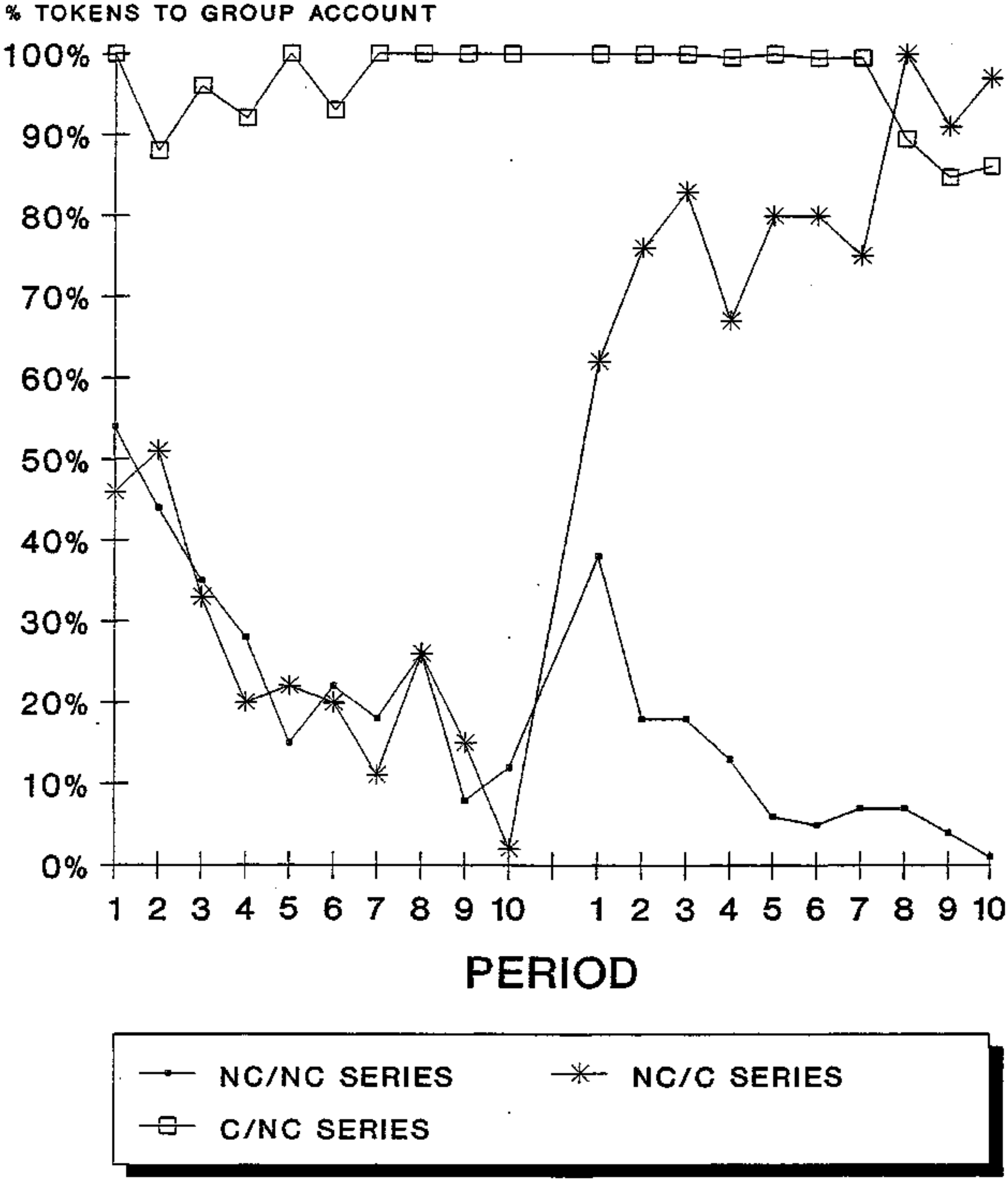
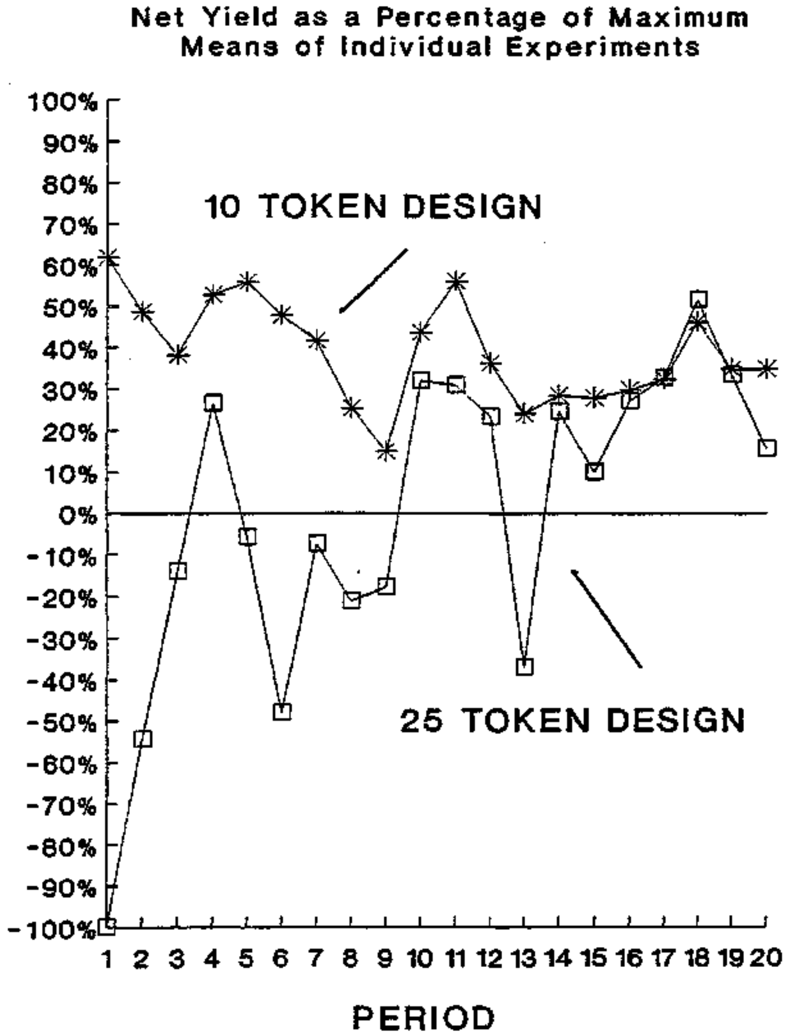
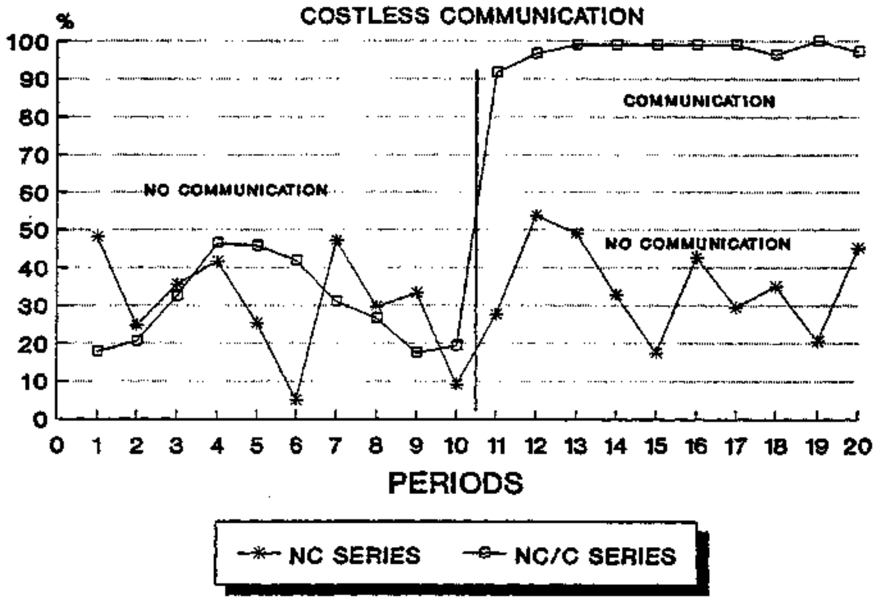


FIGURE 8
CPR - NO COMMUNICATION - NET YIELD

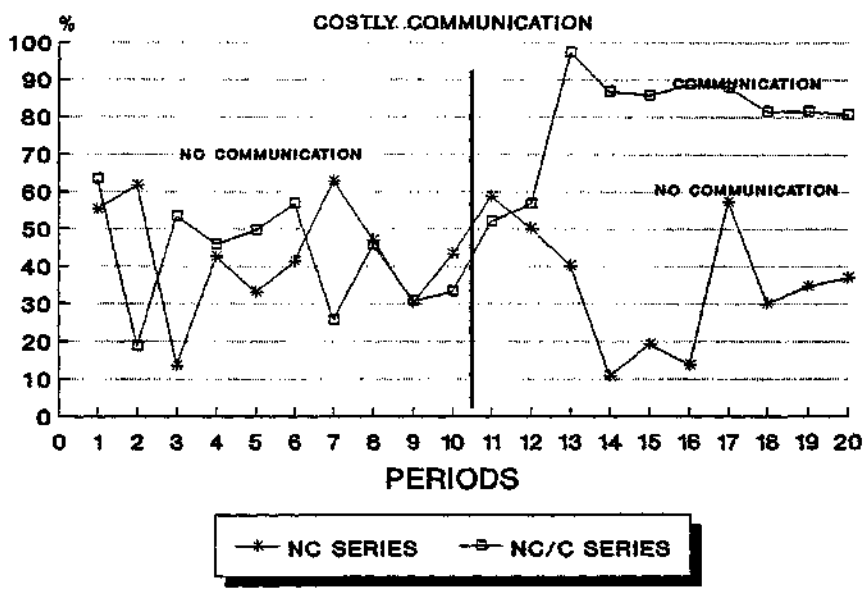


NOTE: PERIOD 1 (25 TOKEN SERIES) = -162%

FIGURE 9
CPR: FACE-TO-FACE COMMUNICATION
RENTS AS A PRECENTAGE OF NET YIELD



• NC/C SERIES: NC (1-10); C (11-20)



• NC/C SERIES: NC (1-10); C(11-20)