Communication and Free Riding Behavior: The Voluntary Contribution Mechanism.

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I. Introduction

One of the most commonly discussed problems in resource allocation literature is the so called "free rider" hypothesis for the production of public goods. Briefly, the economic premise is that agents, acting in their own self interest, will under-reveal demand, thus leading to an under allocation of resources to the public good, As reported in Isaac, Walker and Thomas (1984) , hereafter IWT, there is a growing body of experimental literature aimed at examining the degree to which "free-riding" behavior can be observed in true public good environments (e.g., Chamberlain,1978; Marwell and Ames,1979; Ferejohn, Forsythe, Noll and Palfrey, 1980; Isaac, McCue and Plott,1980; Kim, Walker and Dawes, 1981; and Schneider and Pornmerehne,1981) .

More specific to the problem investigated here is that segment of this work which focuses on identifying those environmental characteristics which influence the level of free riding behavior in the particular context of the voluntary contribution mechanism. From this previous work and after further experimental investigation (see Isaac and Walker (1984) , hereafter IW), we find considerable support for the premises that:

a) free riding behavior increases with repetition of the decision process.

b) free riding increases as the marginal per capita return from the public good decreases.

Further, the results of IW suggest that in environments (1) characterized as true end periods and (2) in which individuals perceive the marginal contribution as having little impact on the level of the public good, there is considerable support for the standard single period dominant strategy model. (In true end periods with "low" marginal per capita return from the group good, IW find, on average, contributions equal to 3.67% of optimum.)

In light of these findings, an important research question focuses on what environmental changes can be used to eliminate or significantly reduce such sub-optimal allocation of resources. Specifically, this paper investigates the impact of communication as a means for altering *free* riding behavior in the context of the voluntary contribution mechanism, As an initial approach, we investigate the effect of communication in an environment with market parameters which generally induce a significant degree of sub-optimal contributions to the public good (low *per* capita return and multiple periods).

The role of communication in influencing cooperative behavior has been examined previously in the context of 2-person prisoner dilema games (e.g.,. Loomis, 1959; Deutsch, 1960; Radlow and Weidner,1966; Swenson,1967; and Wichman,1972) and to limited extent in n-person PD games (e.g., Jerdee and Rosen,1974; Caldwell,1976; and Dawes, McTavish and Shaklee, 1977) . Each of these studies involved experiments where subjects made binary type decisions of whether to cooperate or defect. In general, these studies

support the premise that communicaton significantly improves cooperation. (Caldwell found significant effects using communication with sanctions but insignificant effects without sanctions.)

However, the behavioral properties of the voluntary contribution mechanism are potentially quite different from those of the PD type games. Unlike the binary decisions of the PD games, the voluntary contribution mechanism allows economic agents to make a "continuous" choice in terms of the level of contributions to the group good, and thus choose the degree of cooperation at a continuous level. Supporting a premise of potential differences in behavioral properties between the voluntary contribution mechanism and PD type games is the standard result in many PD environments that cooperation decays in initial periods but increases in subsequent periods (see Radlow and Weidner, p504) . This pattern is in sharp contrast to the general decay in cooperation observed by IWT, IW and Isaac, McCue and Plott in experiments employing the voluntary contribution mechanism.

Thus, given our particular experimental design which genera11y induces significant sub-optimal group behavior, a significant communication effect (combined with the results from the PD experimnents) would point to the strong role of communication as a tool for reducing sub-optimal resource allocation in public goods production. On the other hand, if communication is found to have little impact this would point to further differences in the behavioral properties of PD type decisions compared to the voluntary contribution mechanism.

Given the consistency of the empirical results from the PD studies, we form the following research hypothesis:

H_0: Non-binding communication between decision makers in the context of the multiple period voluntary contribution mechanism will lead to a decrease in free riding behavior and thus an increase in efficiency in the provision of the group good.

As stated above the hypothesis leaves unspecified the avenue by which communication could foster less free riding. One possibility is that communication simply increases the speed and awareness of optimal group behavior. If this is the case then the ameliorative effects of communication should continue even if the opportunity for communication is later removed. A second possibility is that the effect of communication is attributed to an impact on subject's beliefs about other decision makers responses. If this is the case, communication may have to be a continuing process in order to be continually effective. In light of these questions, we investigate the role of communication through an experimental design which allows for intra-group comparisons as well as inter-group comparisons with changes in sequencing of opportunities for communication.

II. Experimental Design and Parameters

A. *Subjects and Experimental Setting*

The *20* experiments reported in this study were conducted using subjects drawn from a population of undergraduate students at the University of Arizona. The students were currently enrolled in lower level economics courses. Subjects were volunteers who had received a brief explanation of what it meant to be in an economics experiment. Emphasis was placed on the fact that no special background in economics was needed to participate. ALL subjects were experienced. That is, all subjects had previously participated in an experiment employing the same decision institution. However, there was no opportunity for discussions in "trainer experiments". Further, all experiments reported here are of size 4 while all trainers were of size 10. Finally, no 4 member group from any experiment came from the same trainer.

The experiments were conducted using the PLATO computer system. This system allows for minimal experimenter— subject interaction during experimental sessions and also insures that all subjects see identical instructions and examples for a given experimental design. The use of the computer also facilitates the accounting process that occurs in each decision period and minimises subject's transactions costs in making decisions and recalling information from previous decisions.

B. *The Decision Mechanism*

At the beginning of each experimental session participants were told they would be participating in an economic market in which they would make investment decisions. It was explained to the participants that the computer system was used only to instruct them in the specifics of the decision problem they would face and act as the means for transacting their decisions. It was emphasized to participants that their individual investment decisions would not be known by other participants in the market. The subjects faced individual computer terminals with side-board "blinders" used to gain as much anonymity as possible.

The programmed instructions described to the participants the following decision problem: given a specific endowment of tokens (resources) participants faced the decision of allocating them between an individual exchange (private good) and a group exchange (public good). The individual exchange was described as an investment which paid to the investor $.01 for each token invested. This was true across all experiments. The group exchange was explained to the participants as an investment which yielded a specific return per token to the individual as well as the same return to all other participants. Thus, the payoff a

participant received from the group exchange was explained to be dependent upon his own investment in the group exchange as well as upon the investment in the group exchange by all other participants. The payoff from the group exchange was reported to each participant in the form of a table which gave group and individual returns from the group exchange for various investment levels (from zero up to the total tokens owned by the group).

The information position of each participant can be described as follows. First, each participant knew his own endowment of tokens for each decision trial and the total tokens of the group. In what we will later describe as complete (incomplete) information experiments subjects did (did not) know the allocation of tokens to other participants. Second, participants knew the exact size of the group and that each participants return from the group exchange was identical. Each participant knew with certainty his own return from the private exchange. Third, each participant knew that there would be 10 decision trials and that his endowment for each trial would be equal. Finally, it was explained that the monetary gains from each trial were binding and that total payments to the participant equaled the sum of his return from the group and individual exchanges totaled over all ten trials. At the end of each trial the participant received information on his return from the individual and group exchange, as well as the total number of tokens contributed by the group to the group exchange. Before making an investment decision in any one trial, a participant could obtain this same information for all previous trials.

The decision process itself operates as follows. In each period, the experimenters endow each of four participants with Z_i tokens. Each token may be invested in an "individual exchange" (where it pays the individual \$.01 with certainty), or the individual could invest tokens in a "group exchange". Let m_i represent individual i's contribution of tokens to the group exchange in a given period. The group exchange was the "public good" in that each individual received a payment of:

$$(1/4) \times G(m_i + \sum_{j \neq i} m_j)¢$$

where $G(\cdot)$ was an appropriately specified function. In fact, the $G(\cdot)$ function was chosen so that the Pareto-Lindahl optimum was for every individual always to invest all tokens in the group exchange (i.e. to set $m_i = Z_i$).

Since contributing tokens to either of the exchanges results in a well defined monetary payoff, we can write a representative individual's utility function in any one period as:

$$U_i(Z_i - m_i + (1/4) \times G(m_i + \sum_{j \neq i} m_j)).$$

If the individual views each trial as a single period decision problem, this would be represented as:

$$\max_{0 \le m_i \le Z_i} U_i(Z_i - m_i + (1/4) \times G(m_i + \sum_{j \neq i} m_j))$$

Consider as maintained restrictions two facts which were true about all of our parameterizations: i) the return from a token invested in the individual exchange was \$.01; and ii) $(1/4) \times G(\cdot)$, the MPCR, was set equal to \$.003. This representation of the decision environment allows for predictions from several familiar game theoretic models. Interpreted as a single period process, the dominant strategy for every individual is to contribute zero tokens to the public good. In the finite repeated game framework (Friedman[1977]), zero contribution by each individual in every period is the unique multi-period Nash equilibrium strategy. Further, with the maintained payoff conditions, zero contribution by each individual in the final period is the prediction of any model which assumes: i) that the $U_i(\cdot)$ are selfish; ii) that no individual believes that his period T decision affects the period T decision of others; and iii) all individuals maximize $U_i(\cdot)$, knowing the form of $G(\cdot)$. This decision environment replicates the four-person, "low" marginal per capita return design of IWT and IW, which fostered significant free riding behavior.

In the experiments reported in this paper, the participants faced two consecutive series of ten decision trials. This allowed us to vary the communication within an experiment providing inter-group, intra-group, and sequencing comparisons on the effects of communication.

In the non-cornmunication condition, participants were told that they were not to communicate with any other participant. In the communication condition, the experimental setting was modified as follows. The subjects were brought together at four chairs adjacent to the computer terminals. The following announcement was read to the group.

> Sometimes, in previous experiments, participants have found it useful, when the opportunity arose, to communicate with one another. We are going to allow you this opportunity between periods. There will still be some restrictions.
>
> 1) You may not discuss any quantitative aspects of the private information on your screen.
>
> 2) You are not allowed to discuss side payments or physical threats.
>
> Since there are still some restrictions on communication with one another, one of us will monitor your discussions between periods. To make this easier, we will have all discussions at this site.
>
> Remember, after you have returned to your terminals and the next period has begun, there will be no more communication until the next period. We allow a maximum of 4 minutes in any one discussion session, but you

> may unanimously agree to return to your terminals earlier than that.

Subjects were then briefed as to what aspects of the experiment constituted "private information" and as to what was the distinction between qualitative and quantitative discussions. Before each discussion session, the individuals were allowed to review privately their prior personal profits and prior total group contributions to the "group exchange."

IV. Experimental Results

The presentation of our results will be divided into two parts. Series I presents results from 10 experiments designed to: (a) investigate the role of communication in a symmetric environment we found from previous research to be conducive to strong free riding, when no opportunity for communication existed and (b) investigate any sequencing effects of Communication/No Communication versus No Communication/Communication experiments. Series II experiments were designed to investigate the robustness of any communication effects we found in Series I.

ft. Series I

The experimental design for the *18* experiments of Series I is presented in Table I. In all Series I experiments the allocation of total group tokens was divided equally among the members of a group. More specifically, total group tokens equaled 248 with 62 allocated to each group member. Given a marginal return of $.0.03 per member for each token invested in the group good (hereafter the MPCR), the Pareto optimal solution of full investment of all tokens into the group good would yield a return of $.75 per subject for each of the 2.0 decision periods. This compares to a $.62 *per* period return if all subjects contribute zero to the group good (returns from the private good equaled $.01 per token). Participants were not told explicitly that the allocation of group tokens was symmetric.

1) *Data from the three design conditions*

We begin the discussion of results with a sequence by sequence presentation of the data from 9 of the 10 experiments of Series I. Figure 1 contains data from the baseline (No communication / No comunication) experiments. This figure displays the percentage of contributions to the group good for each period and each experiment (along with the means of these observations). Clearly, we have chosen a research design which, absent of the opportunity for

communication, fosters robust free riding behavior. Figure 2 displays the same information for the (NC/C) treatment; figure 3 for the (C/NC) treatment. The results of a tenth experiment, the only (C/NC) experiment in which there was cheating on the group agreement, will be discussed later.

2) *Inter-group comparisons*

The data from the first sequence of 10 periods in each experiment allows for an inter-group comparison on the initial effects of communication. That is, looking only at the first group of 10 periods, we have six experiments where there was not and had not been communication, and we have three experiments in which communication was possible. In all ten periods, the three observations from the communication condition dominate the six observations from the NC condition, making a non-parametric rank order test an arithmetic exercise. The faiIure of communicating groups to obtain full efficiency in early periods was not due to cheating on group agreements in these experiments, but rather represents search for optimal strategies.

3) *Intra-group and sequencing comparisons*

The preceding results demonstrate the power of communication in a "pure" context (i.e. the C-NC comparison was made across the first ten periods only). By sequencing the treatment (switching from communication to non-communication and vice versa) we are able to examine more closely issues regarding the effects of communication. Specifically, based upon intra-group and sequencing comparisons, we offer the following observations.

Observation 1: Communication reduces free riding even when the opportunity of communication follows substantial free riding in a non-communication environment.

In 29 of 30 per-period paired intra-group comparisons in the (NC/C) sequence, total per-period contributions were greater in the communication condition. If paired per-period orderings were treated as independent random binomial events with probability of .5, one would expect to observe 29 successes or more with probability less than .00000.0029.

Observation 2: Observation 1 is not due to a sequencing effect. That is, without communication second series observations do not lead to higher contribution levels.

Indeed, in the baseline experiments (NC/NC), in 26 of 30 cases the second of the paired observations yielded lower total group contributions than the first.

Observation 3: The ameliorative effects of communication when it follows non-communication are hampered relative

to the case in which communication is present from the beginning.

Compare figure 2 with figure 3. Participants in the (NC/C) sequence achieve 99% efficiency in only one of ten communication-periods, compared with seven of ten with communication in the (C/NC) sequence. Further, in the three (C/NC) experiments the non-communication sequence yields 10 of 10 periods with mean contributions at the 99% plus level. This strong continuation of contributions after communication in the (C/NC) sequence leads to our next somewhat surprising observation.

Observation 4: All three groups which used communication successfully (i.e. achieved full contribution efficiency with no cheating) continued with 98% plus efficiency in 30 of 30 periods, even after the opportunity for communication was removed.

This phenomena is particularly surprising in light of the fact that participants were told that period 10 of the second sequence was the terminal point.

Because we were quite surprised by this result, the robustness of continued cooperation in other environments is obviously a question of interest. In many ways, this addresses the issues of the "evolutionary success" of cooperative strategies (see Milgrom [1984] for a review).

We did obtain a. partial clue as to whether the efficiency improving effects of communication may break down if communication ceases. In a fourth (C/NC) experiment (see Table 2) there was some cheating by participant 4 in periods 4 and 6. Nevertheless, the cheating ceased and the group obtained 100% efficiency in 8 of 10 periods. In the same *expirime*nent, fu11 efficiency is continued for 5 periods under the NC condition. Then, in period 6, the same individual who had cheated in the communications period began a *very* slight reduction in contributions. In period 8 participants 1 and 4 free rode significantly and by period 10 all four participants had reduced contributions considerably. Thus, it appears that while active communication was able to "weed out" free riding tendencies in the group, the effect of prior communication did not stop the decay of contributions in the NC phase.

B. Series II

Given the above results, it seems logical that our next research question should involve the robustness of communication effects to changes in the economic environment. Our initial design was symmetric in that each individual's endowments and payoffs were identical. Subjects were not informed explicitly that endowments were identical but from discussions during communication periods (and from conjectures from previous audiences) there is

strong support for the view that subjects acted "as if" endowments were equal. For this reason we chose to investigate in Series II an experimental design which allowed for assymetries" in endowments and incomplete information concerning endowments. Table 3 shows the design for the experiments of Series II.

All experiments of Series II were run as Communication/ NO Commucication sequences of 18 periods. We maintained the parameters of 1) $.01 return per token invested in the private good, 2) $.003 return for *every* group member for each token invested in the group good and 3) total group endowments of 248 tokens per period.

Given our conjecture that subjects treated Series I experiments as equal endowment experiments we classify the C/NC experiments of Series I as the Complete Information/ Symmetric design experiments of Series II. Our Incomplete Information/Symmetric design was chosen to maintain endowments as equal as possible and yet make clear to subjects that their endowments were <u>not</u> one fourth of the group total (i.e. not 62 of 248). The possible endowments for the assymetric design experiments were constrained by the fact that any endowment over 75 tokens would result with free riding as a dominant (income maximizing) strategy even in a multi-period environment. That is, at the group optimum of no free riding each subject received $.75 per period. Thus, any endowment over 75 tokens would leave investment in the private good as a dominant strategy. We chose the 70/54 split to compromise between maintaining an incentive to cooperate and maximizing differences in endowments.

1. *The data for Series II*

The C/NC design of the 14 experiments of Series II was constructed to focus on two primary points of interest.

a) To what extent is the effect of communication altered by variations in symmetry of endowments and/or level of group information concerning distribution of endowments?

b) To what extent is the level of contribution in periods of no communication (preceded by communication) affected by symmetry of endowments and level of information concerning distribution of endowments?

We begin this investigation with a series-by-series presentation of the data for the 14 experiments of Series II. Figure 4 presents the percentage of contributions to the group good for each period and each experiment (along with the means of those observations) for the 4 experiments of the Symmetric/ Complete Information condition. Recall for each experiment in the first 10 periods communication is allowed and for the second 10 no communication is allowed.

Figures 5,6 and 7 display the same information for the Assymetric/Complete Information, Symmetric/ Incomplete Information and the Assymetric/Incomplete Information conditions respectively.

2. *Sequence 1- Results from periods in which communication was allotted*

The results from the communication experiments of Series I demonstrated the strength of communication in the "pure" environment of the Symmetric/ Incomplete information condition. Combining those results with the new experiments of Series II we offer the following observations.

Observation 5: Levels of contributions to the group good were significantly increased in the variety of conditions in which communication was allowed when compared to the base condition of no communication with symmetric endowments.

Calculating the mean contribution for each period with communication and comparing this with the mean contribution in each period with no communication (using the sequence 1 data from the NC/NC experiments of Series I), we find in 10 of 10 periods a significantly higher mean contribution for the communication experiments (a =.10, one tail test).

Observation 6: Levels of contributions in experiments with symmetric endowments tend to dominate those under conditions of assymetric endowments.

Comparing the 7 experiments of Series II with symmetric endowments to the 7 with assymetric endowments we find in 10 of 10 periods a higher level of contributions under conditions of symmetric endowments. However, this difference is statistically significant in only 5 of the 10 periods (α =.10, two tail test).

Observation 7: Levels of contributions in experiments with complete information tend to dominate those under conditions of incomplete information. But the effect is weaker than that related to distribution of endowments.

Comparing the 7 experiments of Series II with complete information to the 7 experiments with incomplete information we find in 9 of 10 periods a higher mean level of contributions under conditions of complete information. This difference is statistically signficant, however, in none of the 10 periods (α =.10, two tail test).

B. Sequence 2: hysteresis effects of communication

The results of Series I suggested a very strong lagged effect of communication in significantly increasing the

levels of contributions to the group good in periods of no communication which followed periods of communication. In this section we examine the robustness of that result.

Observation 8: Levels of contributions in periods preceded by communication periods tend to dominate those observed when no prior communication existed.

Comparing the sequence 2 results of the 14 experiments of Series II with the second sequence of our base NC/NC experiments, we find higher levels of contributions to the group good in 10 of 10 periods in the 14 C/NC experiments of Series II. Note however, this difference in means is statistically significant in only the first two periods (α =.10, one tail test).

Observation 9: The documented hysteresis effects of communication show a consistent decay in 10 of the 14 experiments of Series II.

Examining the observations found in the second sequence of figures 4 through 7 shows a consistent decay in contributions for all experiments except for: a) the 3 Symmetric/Complete Information experiments examined in Series I in which no cheating occured and b) in one experiment from the Assymetric/Incomplete Information design (again where no cheating occured).

It appears that cheating on group agreements not only has ah important role in affecting direct cooperation attempts but also diminishes the degree of any hysteresis effects of communication. In the 4 experiments where we do not find a decay in contributions in sequence 2, there was no cheating. In the 10 experiments where we find decay there was cheating in 9 of 10 experiments. The one exception to this last result was the third experiment in our Symmetrtic/Incomplete Information design. In this experiment the group had contributed the Pareto optimum in 10 of *10* communication periods. However, in the first period of sequence 2, subject number 1 contributed zero to the group good. Following period 1, there was a continual decay in contributions to the group good.

V. *Conclusions*

Out results document the significant impact of group communication in the reduction of free riding behavior. These results were generated in a public goods environment where the marginal benefit (for every individual) from contributions to the public good was less than the marginal cost at all levels of public goods provision. When viewed as a single period decision, standard economic theory would imply the income maximizing strategy of each individual is to contribute zero to the public good. Indeed, earlier studies and baseline data for this study show significant

levels of free riding occur in this environment when no group communication is allowed. What the results in this paper have shown is that even in this environment (strongly conducive to free riding), inter-period non-binding communication between decision makers fosters significant reductions in free riding behavior. However, the magnitude of this effect is shown to be reduced significantly by assymetries in endowments of group members and to a more limited extent by decreased information regarding the distributions of endowments. Our results also indicate that when non-communication decisions follow periods in which communication had been allowed, the effect of communication persists with significant cooperation between subjects. However, the magnitude of this hysteresis effect is clearly dependent upon the strength of cooperation in prior communication periods.

Discussions by participants during allowed communication, along with observed actions, suggest that the role of communication is (at 1east partially) a combination of: a) learning by groups of those decisions which yield maximum return from the group good and b) awareness and credibility given to the expected decisions of others. Initial periods with communication began many time with a search by members for that allocation which would yield maximum group profit. However, much discussion focused on each person "agreeing" verbally to the group decision and following through in their private decisions.

Table I

Parameters and Design of Communication Experiments: Series I

Experiment Parameters:

1) Group Endowment Per Period: 248 Tokens
2) Individual Endowment Per Period: 64 Tokens
3) Private Return: $.01/ token
4) Marginal Per Capita Return from Group Good: $.003

Experiment Sequencing:

Experiment Type	Number of Experiments	Communication Condition Sequence 1	Communication Condition Sequence 2
NC,NC	3	No Communication	No Communication
NC,C	3	No Communication	Communication
C,NC	3*	Communication	No Communication

*A 4th C,NC experiment is reported separately

Table 2

Fourth (C/NC) Experiment

Per-Period Contributions of Tokens

	Participant Period	1	2	3	4	Total
C	1	62	62	62	62	248
	2	62	62	62	62	248
	3	62	62	62	62	248
	4	62	62	62	2*	188
	5	62	62	62	62	248
	6	0	62	62	58*	182
	7	62	62	62	62	248
	8	62	62	62	62	248
	9	62	62	62	62	248
	10	62	62	62	62	248
NC	1	62	62	62	62	248
	2	62	62	62	62	248
	3	62	62	62	62	248
	4	62	62	62	62	248
	5	62	62	62	62	248
	6	62	62	62	60	246
	7	62	62	61	60	245
	8	2	62	60	22	146
	9	0	40	60	0	100
	10	31	62	20	4	117

*represents a contribution less than group agreement

Note: The zero contribution by subject 1 in period 6 was not cheating. The group had aggreed to attempt a rotation scheme. This attempt was eliminated after the group observed the period 6 results.

Table 3

Parameters and Design of Communication Experiments: Series II

	Symmetric Endowments	Assymetric Endowments
Complete Information	Tokens Per Subject 64, 64, 64, 64 Number of Experiments (4)	Tokens Per Subject 70, 54, 70, 54 Number of Subjects (3)
Incomplete Information	Tokens Per Subject 63, 61, 63, 61 Number of Experiments (3)	Tokens Per Subject 70, 54, 70, 54 Number of Experiments (4)

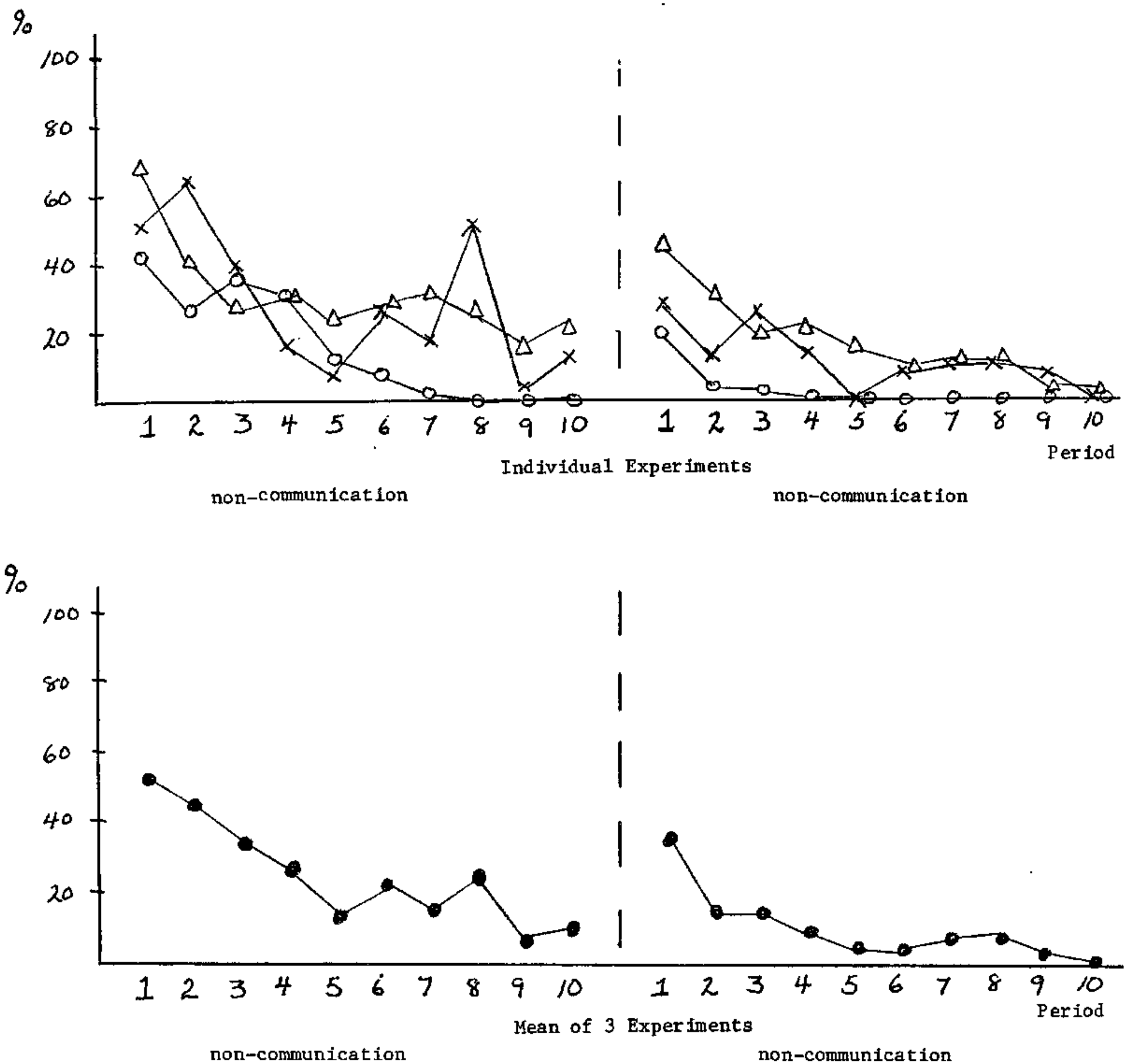


Figure 1

Percentage of Contributions to Group Good: NC/NC Experiments

Figure 2

Percentage of Contributions to Group Good: NC/C Experiments

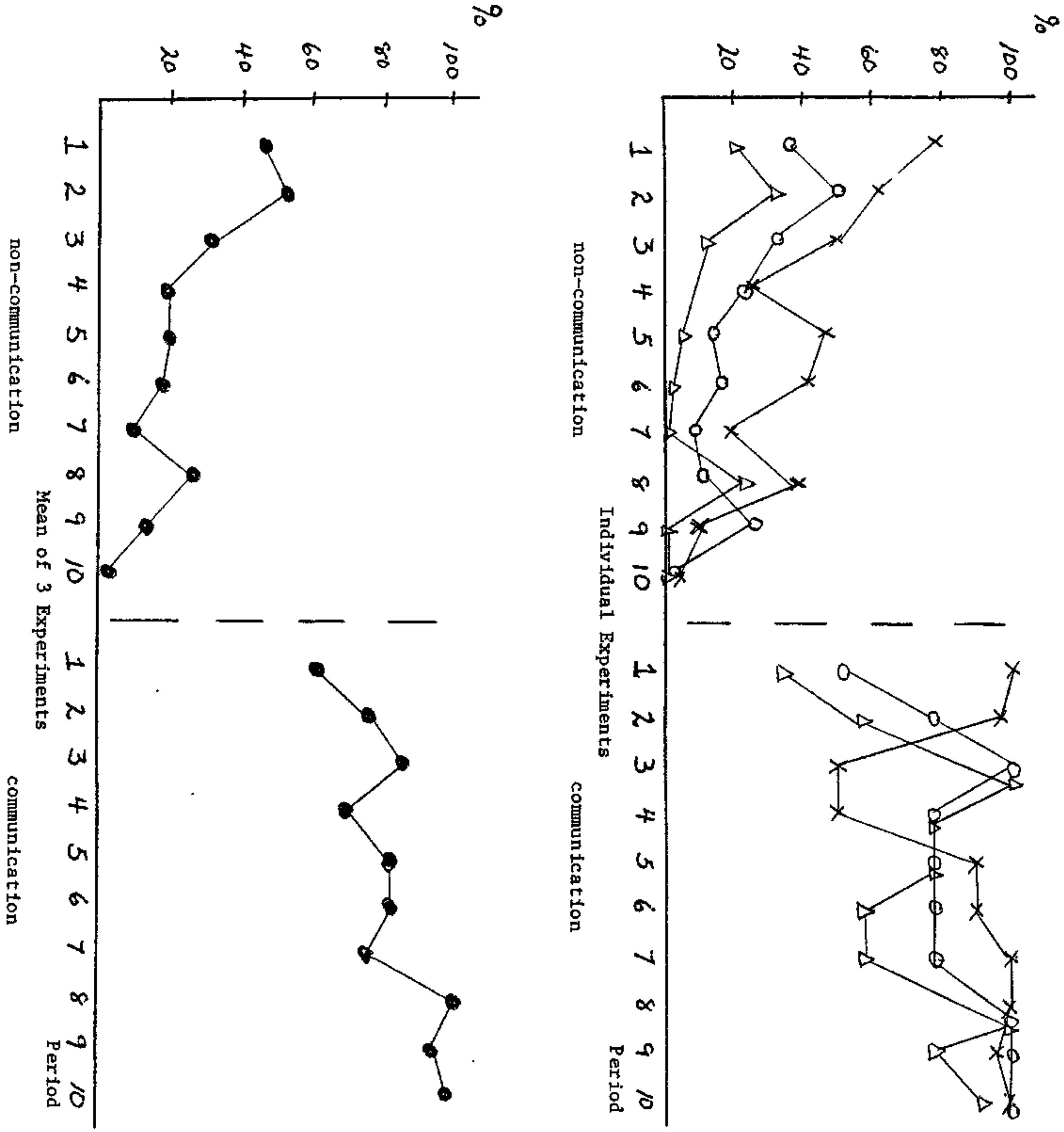


Figure 3

Percentage of Contributions to Group Good: C/NC Experiments

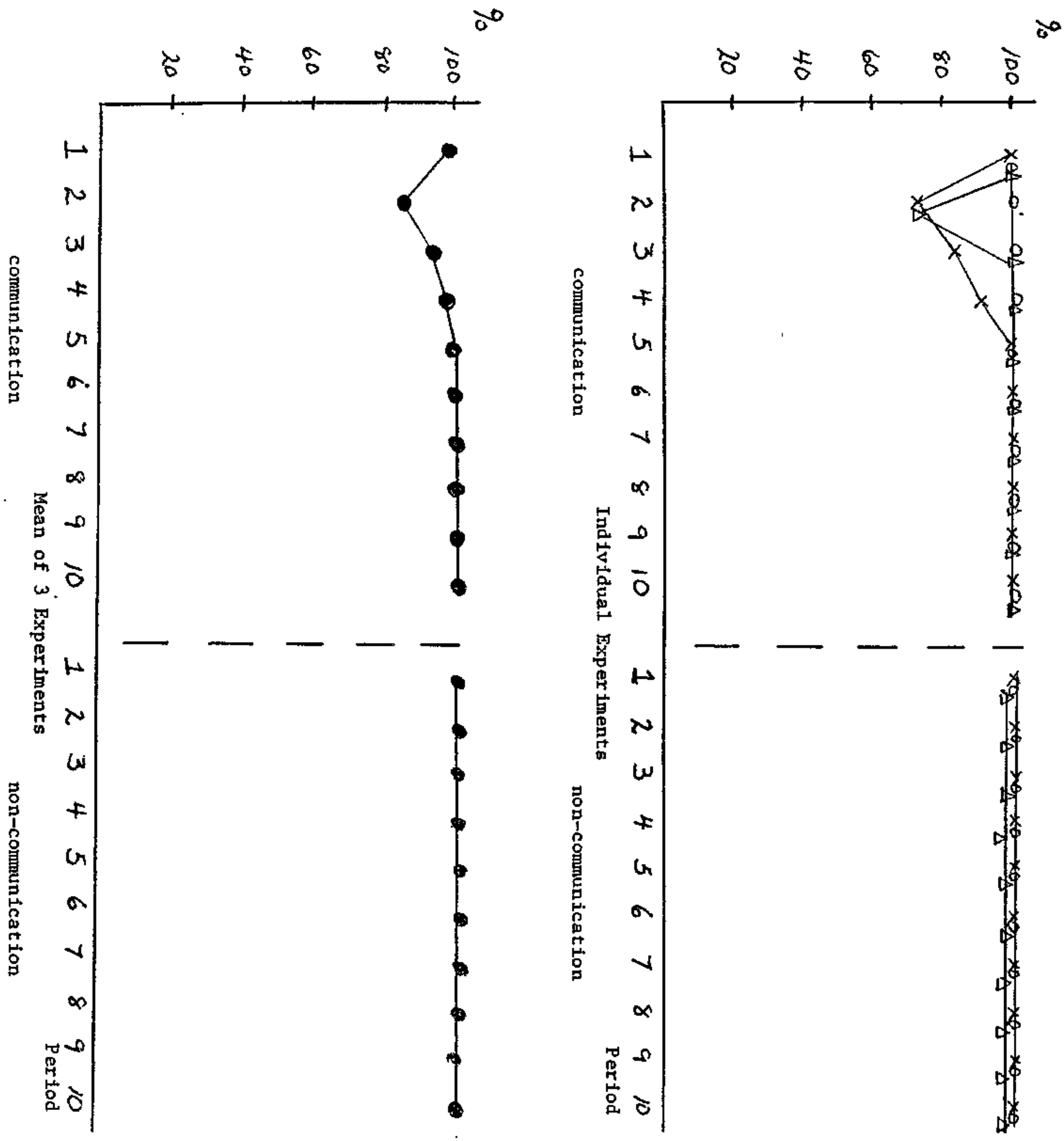
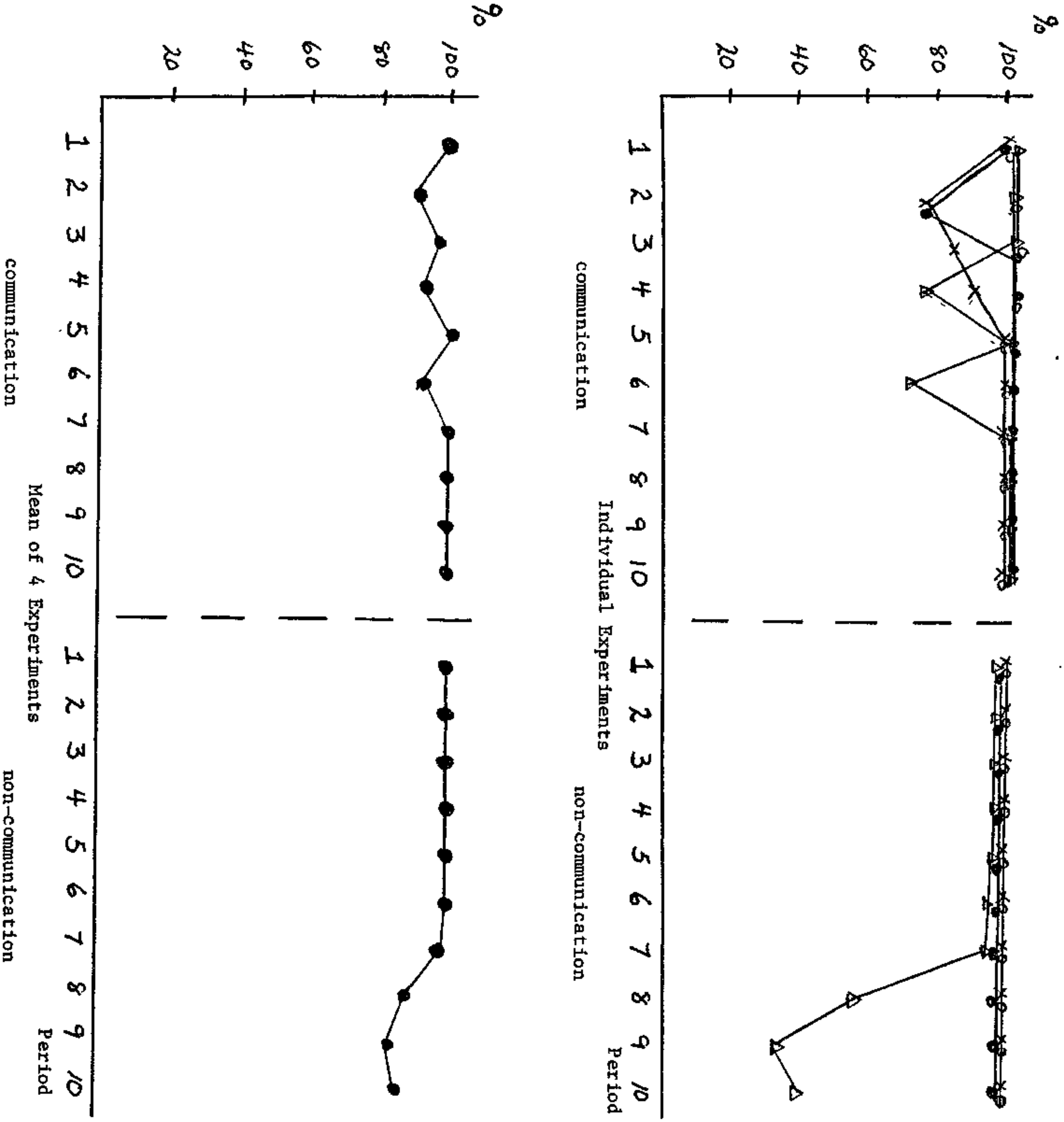


Figure 4

Percentage of Contributions to Group Good:
Symmetric/ Complete Information Experiments



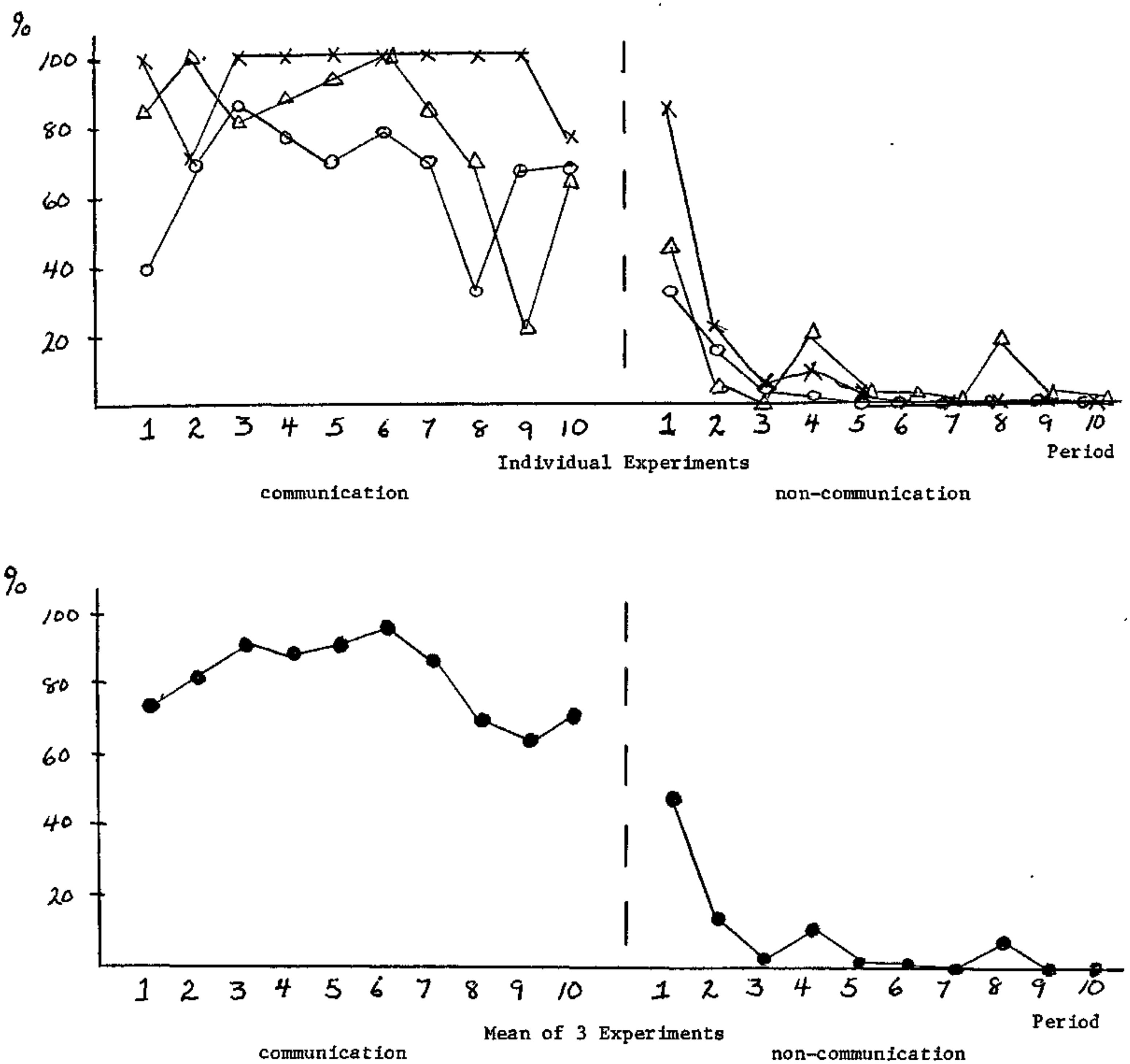


Figure 5

Percentage of Contributions to Group Good:
Assymetric/ Complete Information Experiments

Figure 6

Percentage of Contributions to Group Good:
Symmetric/ Incomplete Information Experiments

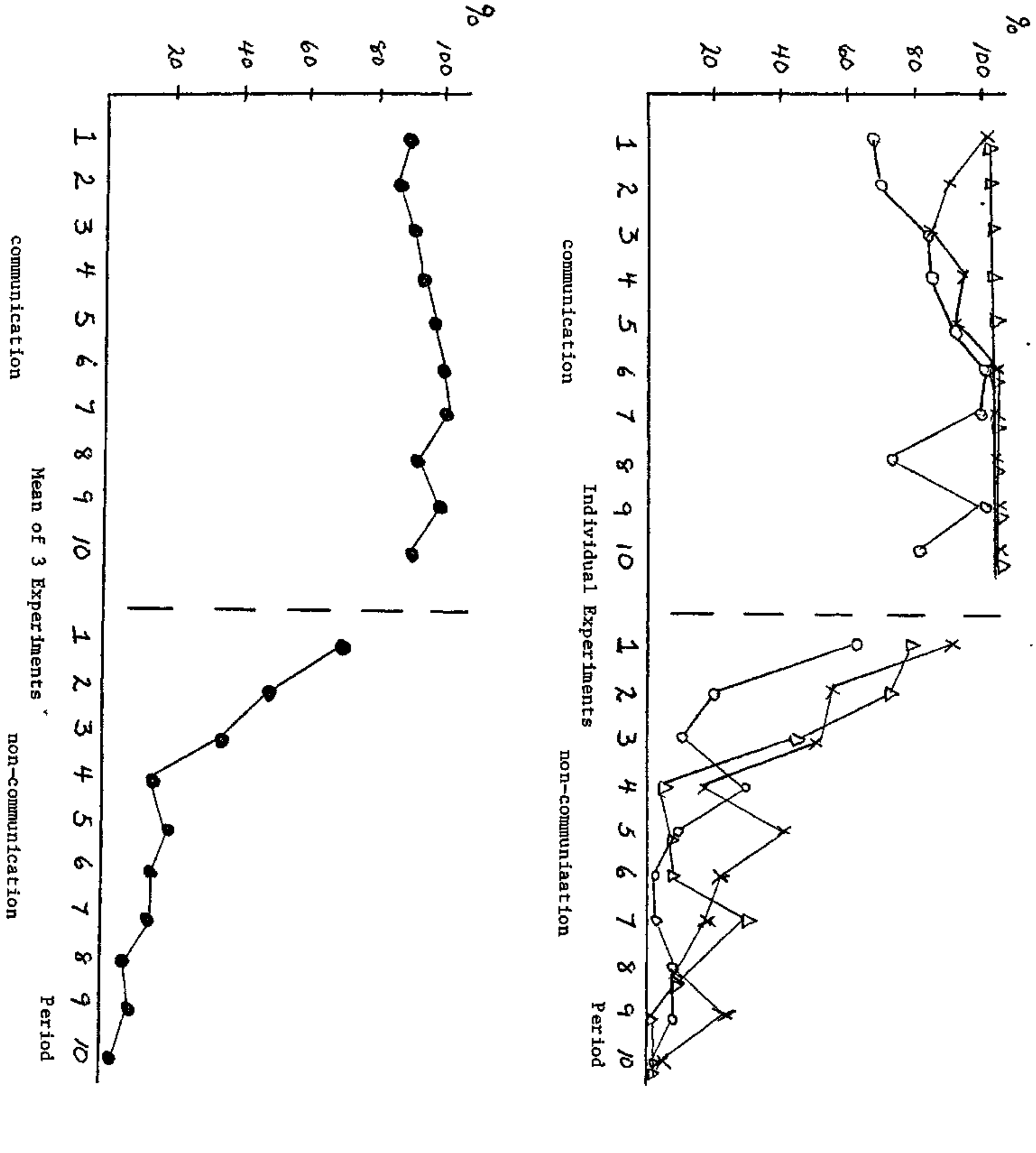
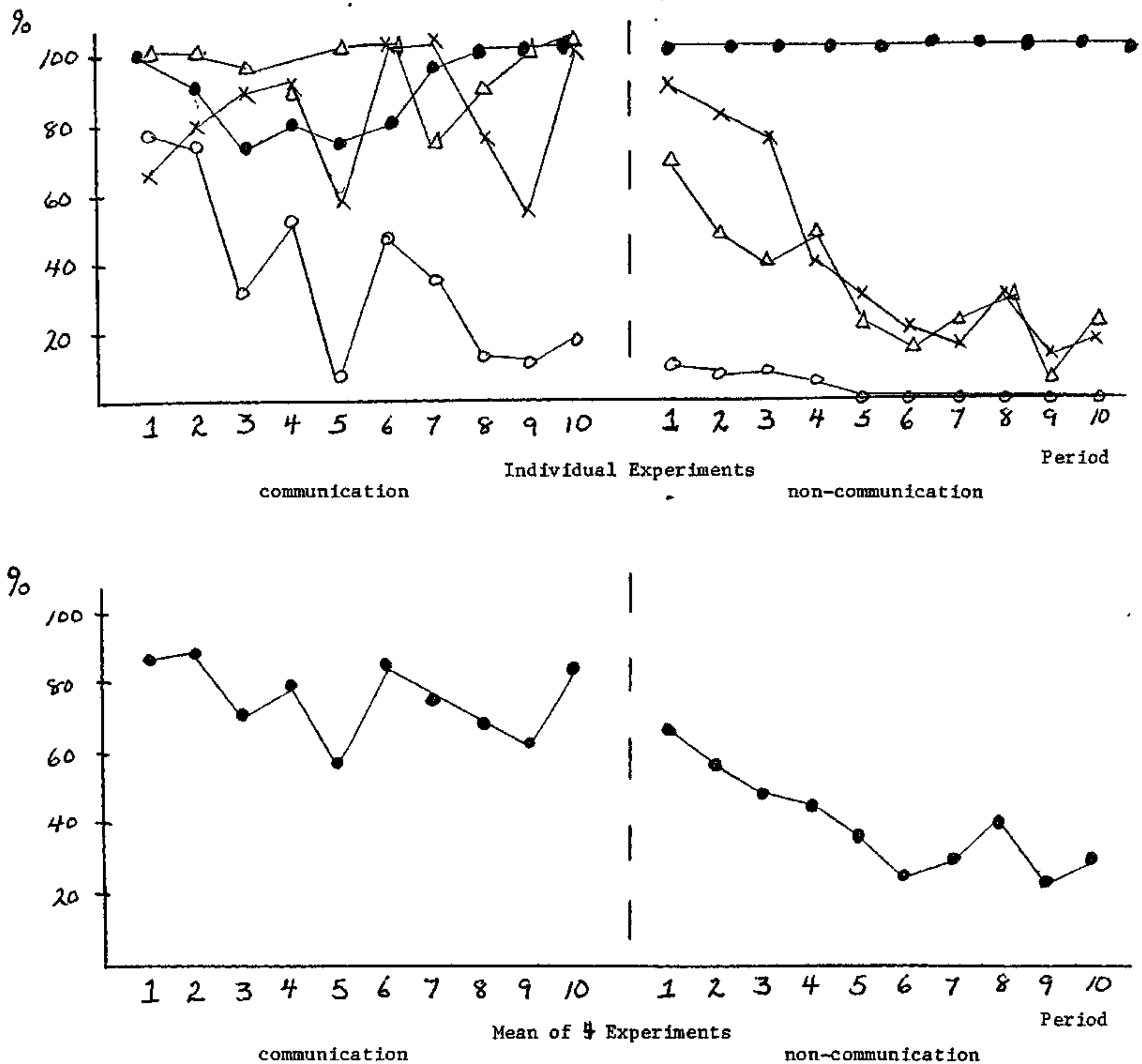


Figure 7

Percentage of Contributions to Group Good:
Assymetric/ Incomplete Information Experiments



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