Interior Collective Optimum in a Voluntary Contribution to a Public Good Game : an Experimental Approach.

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Abstract

We run a public good experiment with four different treatments. The payment function is chosen such that the Nash equilibrium and the collective optimum are interior solutions. We try to test the effect of varying the level of the collective optimum on the decision of contributing to the public good. These levels are experimentally tested in two different conditions : with and without communication. Our results show that contribution increases with the level of the interior collective optimum and that communication has as effect an increase in contributions. There is over contribution in comparison to the Nash equilibrium and under contribution in comparison to the collective optimum. To study the **strategic interactions between subjects**, we compare the aggregate comportment (average contribution of six groups) with the behavior of each one of the six groups and with the individual comportment (192 subjects) to see whether the aggregate level reflects or not faithfully the individual one. We find that the **interaction of heterogeneous agents** (free-riders, altruists,...) having different comportments leads to an homogeneous and standard comportment at the aggregate level.

Key-words: Public goods, interior solutions, cooperation, interaction, heterogeneity.

Classification JEL: C72, C92, H41

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1 Introduction.

The problem of voluntary contribution to public goods has been treated in the literature in different manners. Several parameters influencing the decision of contributing have been experimentally tested. This problem is a good mean of studying the comportment of free-riding and the variation of cooperation in a group of subjects who interact with each other and who are motivated both by individual and collective interests. In the basic game, each subject has to share an initial endowment into two parts : one part represents his contribution to the private good, and the other part represents his contribution to the public one. The payoff of each good depends on and vary with the experiment, but is generally linear. This linear case permits to have corner solutions. In fact, such a function gives a Nash equilibrium at zero and full contribution as collective optimum.

The fact that the Nash equilibrium is at zero and that contribution to public goods is a stylized fact let unexplained the difference between the theoretical and the experimental case. This difference of results is the main subject of the literature on private contribution to public goods. In fact, answering why do we have such a difference and giving an explanation to that represents the main solution for the problem. To do so, different parameters have been tested in different contexts to try to see the effect of their variation on contributions of subjects[2]. Among the explanations given to overcontribution, there is altruism, kindness, error, etc...

One of the studies that have been done to answer the former question is the one of Keser (1996) who tried to test the hypothesis that subjects make mistakes while taking their decisions of contributing. In the linear case[3], seeing that the Nash equilibrium is at zero, and seeing that the experimental design makes negative contribution not possible, error can only be an overcontribution. There is no possibility of undercontribution seeing that subjects could not give negative amounts. To see whether error is an explanation of the stylized fact of overcontribution in comparison to the null Nash equilibrium, Keser (1996) proposed the case of interior equilibrium (see also Sefton and Steinberg (1996) and van Dijk, Sonnemans and van Winden (1997) who used an interior equilibrium using a quadratic form for the payoff of the private good). In fact, if we have an interior Nash equilibrium, error could be an overcontribution or an undercontribution and the mean of error could than be expected to be null. This case permits to see whether overcontribution is or not due to error.

Willinger and Ziegelmeyer (2001) use the same function than Keser (1996) and compare it to three other functions that give different levels of interior Nash equilibria. This is possible by varying the marginal payoff of the public good. The collective optimum (C.O.), however, in both keser's and Willinger's work is obtained by contributing all the endowments to the public good. That let unexplained the effect of varying the collective optimum level on contributions. Answering such a question is interesting according to us for two reasons: the first one is to see whether the optimum level is a parameter that

[2]see Ledyard (1995) and Keser (2000) for a survey
[3]See Andreoni (1995)

affects contributions' decisions. In fact, if while varying this level contributions vary, one should take in account this parameter while studying the collective comportment behavior in a problem of financing a public good. Moreover, if the influence of this parameter is confirmed by the experimental data, one have to answer why and how the level of the collective optimum intervene in the decision process. We try in this paper to answer these questions by comparing for treatments representing a low (L), medium (M), high (H) and a very high (VH) level of the C.O. Our results show that contributions levels vary with the C.O. level and that overcontribution in comparison to the Nash equilibrium increases with the C.O. Average of contributions is as far from the C.O. as the level of this latter is high. We find also that communication has as effect an increase of contributions.

A more precise analysis of the group and the individual comportment in both treatments with and without communication shows that at the group level there is an asymmetry between the variation in time of contributions in the (H) and (VH) treatments. At the individual level, this asymmetry is absent in the case without communication and very present in the case with communication.

The paper is organized as follows: section two summarizes the different studies that introduce the interior solutions. After presenting in section three the theoretical design of our experiment, we introduce the practical procedures in section four. Section five analyses the experimental results and section six concludes the paper.

2 Public goods experiments with Interior solutions:

There are two ways to obtain an interior solution[4] in a public good contribution game. We can either choose a concave function for the private payoff, which gives us a unique dominant strategy equilibrium, or use a concave function for the public payoff. In this case, the are several possible Nash equilibria, seeing that the dominant strategy of a given player i depends on the contributions of the other players. One of these equilibria is particularly interesting. It's the symmetric one where all players contribute the same amount to the public good. In our experiment, we will compare the experimental results with this symmetric Nash equilibrium.

Sefton and Steinberg (1996) compare experimentally these two reward structures with interior solutions. The setting that produces an interior Nash equilibrium is presented by the following function:

$$Z_i = \alpha(E - y_i) + w(\sum y_i)$$

where

$$w' > 0, w'' < 0$$

[4] For a theoretical analysis of the interior solution, see S. P. Anderson et al. (1998)

To have an interior dominant strategy, the authors use the function:

$$Z_i = v(E - y_i) + \beta \sum (x_j)$$

where

$$v' > 0, v'' < 0$$

The results show that "average donations significantly exceed the predicted equilibrium under both treatments, falling roughly midway between the theoretical equilibrium and optimum...Donations are less variable under the dominant strategy equilibrium treatment than under the Nash equilibrium treatment". The authors also find that, although average donations are lower in the Dominant strategy equilibrium treatment, this difference is not significant.

Andreoni (1993) uses a reward structure where both, the private and the public payoff are concave. He designs an experiment to test the public-goods crowding-out hypothesis and find that crownding-out is incomplete and that subjects who are taxed are significantly more cooperative.

Keser presents a 25 periods' experiment on voluntary contribution to a public good where the game has an interior dominant strategy solution. That means that each player has to contribute only a part of his endowments to the public good. She obtains an interior Nash equilibrium by introducing a concave payoff for the private good and keeping a linear payoff for the public one. The payoff function of a given subject i is:

$$Z_i = 41x_i - (x_i)^2 + 15 \sum y_j$$

where x_i represents the contribution of subject i to the private good X and y_i represents his contribution to the public good Y.

The experiment contains three sessions, with 16 subjects each and 12 groups of 4 players (48 subjects in total). Two third of the participants are students in Economics. In each period four players have to share their personal endowments (e_i = 20 tokens) between two activities X and Y. The rule of sharing is freely chosen by each player who decide how to allocate his tokens between the two activities. Once this allocation is done, players know at the end of each period the sum of tokens allocated by the group to activity Y, all as their individual payoffs from the two activities. The sum of these payoffs during the 25 periods gives the total payoff of each player. The number of periods constituting the game is common knowledge. The experiment is computerised and no communication is allowed between subjects.

The theoretical results one obtains from such a function show that it is a dominant strategy to allocate 13 tokens to X and 7 tokens to Y. This is the unique subgame-perfect equilibrium of the 25 period game. The social optimum is attained if each member contributes all of his tokens to activity Y. This is due to the fact that the sum of the marginal payoffs of one token allocated to activity Y is superior to what a player can get if he invests this token in activity X.

The corner solution experiments where it is a dominant strategy to contribute nothing to the public good, show that there is generally overcontribution (30 to 70% of the initial endowments) (for a survey, see Davis and Holt (1993) and Ledyard (1995)). The results of keser's experiment confirmed this observation and show concerning the average contribution to the public activity that "we observe first a minimal increase and than slight but continuing decrease of the average contributions". In each period, contributions are above the dominant solution. There is in the first periods an overcontribution rate of about 33%. This rate is at 15% in the last period. The average rate of over-contribution is 25%. The average contribution per group is also above the value 7 for each group. The existence of over-contribution means the rejection of the hypothesis of error as an explanation to this stylized fact. A χ^2 test for the null-hypothesis that there is no difference between contributions above and under 7 is found to be significant at the level of 1%. The results show also that there is an end effect behavior and that 13% of the decisions are below 7 against 60% above.

Marc Willinger and Anthony Ziegelmeyer (2001) run the same experiment with the equilibrium level of contribution as a treatment variable. They use the same quadratic payoff function and make the marginal payoff of the public good (θ) varying such that the Nash equilibrium takes different interior levels. This function is

$$Z_i(x_i, \sum y_j) = 41x_i - (x_i)^2 + \theta \sum y_j$$

where $y_i = 20 - x_i$ and θ is the marginal revenue from investing one token in the public good.

They choose different values for θ such that they have a low (L), middle (M), high (H) and very high (VH) level for the interior Nash equilibrium. The following table summarizes the theoretical predictions for the four treatments :

Value of θ	Equilibrium condition	Nash equilibrium (contribution to the public good)
15	L	7
21	M	10
27	H	13
35	VH	17

One should notice that an increase in the value of the marginal payoff of the public good has as effect an increase of the value of the Nash equilibrium. That means that an increase in the marginal payoff of the public good makes this latter more interesting and leads subjects to increase strategically their contributions to this good. The equilibrium of the repeated game is just the sum of the equilibria of each of the 25 periods.

The social optimum for such a function is to contribute all the endowments to the public activity. In fact, the maximum marginal payoff (which is decreasing) of one token allocated to the private activity is the one of the first token that has a payoff of 40, which is inferior to the sum of the marginal payoffs of any token allocated to the public good. This latter payoff is equal to 15 and is the same for all the tokens. For any value of θ inferior to 10, the social optimum is a corner solution, that is to contribute all the endowments to the public activity. The social optimum becomes an interior solution when the sum of the marginal payoffs from the public activity becomes inferior to the maximum marginal payoff of the private activity.

The experiment contains for sessions, each with four groups. Each group contains four subjects (64 subjects in total) and each subject has 20 tokens as an endowment at the beginning of each of the 25 periods constituting the game.

The experimental results show that subjects' contributions increase with the Nash equilibrium level and that over-contribution decreases with this level, except for the very high level. The results show also that "moving the equilibrium level of contribution closer to the Pareto optimum, leads to a decrease in average overcontribution".

A χ^2 test rejects the null hypothesis of no difference between the average level of contribution and the equilibrium predictions at the 5% level for the Low equilibrium. For the three other treatments, there is no significant difference between the average level of contribution and the equilibrium predictions at the same level of 5%, which is different from the other experimental studies where there is always significant overcontribution.

By moving from L to M and from M to H, there is a decreasing in the rate of overcontribution, which is in contradiction with the standard theoretical predictions. This result is different from the case of the VH treatment, where the average overcontribution rate is more variable than the other three cases.

The results of Willinger confirmed the stylized fact of overcontribution in comparison to the theoretical equilibria, but reject some behavioral rules, such as altruism, kindness or reciprocity, seeing that the average rate of overcontribution is not very different from zero. The authors present a theoretical model combining forward-looking behavior and backward looking behavior to explain the observed pattern. The main idea is that this pattern is due to the interplay of different types of behaviors (strategic, reciprocal...).

An other experiment done by Keser and Gardner (1999) uses a concave function that gives an interior solution by introducing a linear payoff for the private good and a concave one for the public good:

$$\prod(x_i; y_i; \sum_{j=1} y_j) = 5x_i + \frac{y_i}{\sum_{j=1} y_j} * F(\sum_{j=1} y_j)$$

where

$$F(\sum_{j=1} y_j) = 23\sum_{j=1} y_j - 0.125(\sum_{j=1} y_j)^2$$

is the total payment of the group.

It's question of a non-cooperative 20 times repeated game with 2 groups. Each group contains 8 persons and each player have an endowment of 25. The authors consider five solutions : the "sure payment" ($x_i = 0$), the Nash equilibrium, the collectively optimal solution, the "rent dissipation" solution which is based on the fact that the difference between the production of common resources and the opportunity cost of the investment in common resources is null, and the "Naive optimum" which maximizes the total payoff of the group without taking in account the opportunity cost. The results of the game show that players don't play the equilibrium of the game of common resources. They don't try to cooperate for two reasons : the first is that these players don't see clearly at which level cooperation should take place. The second reason is that they don't see any possibility of influencing the comportment of the others by their own comportment. The authors explain the lack of cooperative strategies by the difficulty of identification by subjects of a cooperative aim.

Willinger and Ziegelmeyer (1999) use an interior solution to study the difference of contributions in the case of positive externalities and negative externalities. This was done yet by Andreoni (1995), but in the context of a game with " strangers " and with a corner solution. Willinger and Ziegelmeyer (1999) replace "strangers" by "partners" and corner solutions by interior Nash equilibrium. They "show that subjects contribute more to the public good if they perceive the actions of others as a positive externality rather than a negative externality".

All these studies, except in Keser (1999) and Andreoni (1993), use functions with a concave payoff for the private good and linear payoff for the public one. This kind of function gives an interior Nash equilibrium and a corner solution for the collective optimum. Our experiment defers from all the experiments exposed above by the fact that we present an experimental design that gives an interior collective optimum. We are interested in the study of the effect of the variation of the collective optimum on the contribution's decision process. This could be possible if we use a function that is linear on the private payoff and concave on the public one. There is nevertheless one disadvantage from using such a function, seeing there are several possible Nash equilibria. But in a game where there are many subjects interacting between each other, we can focus our analysis on one of these Nash equilibria that is particularly interesting; this Nash equilibrium is the symmetric one, where all subjects of the same group give the same amount to the public good.

3 theoretical design:

In this paper, we will keep the notion of interior solutions. In fact, we will try to study the effect of varying the level of the collective optimum on the decision of contributing to the public good. To do so, we choose to use a function that is different from the one used by Keser (1996) and Willinger and Ziegelmeyer (2001). While their function is quadratic on the private payment and linear on the public one, to have an interior collective optimum, we choose to use a function that is linear for the private payment and quadratic for the public one. This function is :

$$Z_i = x_i + \theta(\sum y_i)^{1/2}$$

The marginal payoff of the private good is equal to one and θ represents the individual marginal payoff of one token allocated to the public good.

The choice of a different function is motivated by the fact that this kind of function has the public part as concave. This means that the total gain depends on the comportment of all players. The collective comportment and cooperation are more strong in our case than in the case where the concave part is the private payoff. In that case, only the individual comportment can influence in a concave way the individual comportment. Our function is more adapted to study cooperation and represents an incentive for subjects to take into account cooperation and the comportment of the other players in the group.

The comparison between the collective optimum $\bar{y}$ and the Nash equilibrium y^* shows that the Collective optimum is superior to the Nash equilibrium. In fact, we have:

$$\bar{y} = \frac{1}{N}(\frac{bN}{2a})^2 \succ y^* = \frac{1}{N}(\frac{b}{2a})^2$$

This kind of function gives an interior collective optimum, but also an interior Nash equilibrium, even if this equilibrium is almost near of zero and very low in comparison to the level of the collective optimum.

We have four treatments in our experiment. Each treatment have a specific value for the marginal payoff of the public good. By varying this value, we vary the collective optimum and the Nash equilibrium levels. In Willinger (2001), the variation of the marginal payoff of the public good has as effect the variation of only the Nash equilibrium and has no effect on the collective optimum which stays at the maximum possible level of contribution.

The following table summarizes for each treatment the different levels of interior solutions for each group:

Value of θ	Treatment	Endowment	Symmetric Nash equilibrium	Collective optimum
16	L	280	4	64
22	M	280	8	128
27	H	280	12	192
35	VH	280	20	280

These values are recalculated for one subject and presented in the following table:

Value of θ	Treatment	Endowment	Symmetric Nash equilibrium	Collective optimum
16	L	70	1	16
22	M	70	2	32
27	H	70	3	48
35	VH	70	5	70

As we can see, the values of the Nash equilibrium level are very low in comparison to those of the collective optimum and to the initial endowment. That's why we will have interest only on the variation of contributions in comparison to the collective optimum level.

4 Practical procedures.

We run the experiment in November 2001 at the LeeX (Laboratori d'Economia Experimental) at the department of economics at Universitat Pompeu Fabra in Barcelona. 192 subjects participated to these experiments. We use the software z-Tree developed by Fischbacher (1999). We run 16 sessions, each one contains three randomly formed groups of four persons playing the same treatment. Each group plays a session of 25 periods. The total game is a repetition of the one-shot game. A total of six independent observations per treatment is collected. In each period, subjects are endowed with 70 ECU,[5] to be shared into two parts : one for the private good and one for the public one. Parts allocated to the public good allow the group to have a certain amount that is presented for subjects in a table. The gain of each subject is converted at the end of the session from ECU into Pesetas.

We test four treatments with four different payment tables, each with and without communication. Each treatment has his own marginal payoff value for the public good.

Communication is controlled in our experiment. In the sessions with communication, subjects are asked in every period, before they give their effective contribution, to give the amount they intend to contribute. Before giving their effective contributions, the sum of the intentions of the group is than revealed to subjects.

Instructions are distributed in a written form to subjects. The marginal payoff of the public good, all as the accumulated payoff are presented and given to subjects in tabular form.

The experiment's instructions (see appendix) are read loudly before the beginning of each session. We made sure that these instructions are well inderstood. Subjects are asked to rase their hands if they have any questions and answers are given privately by the experimenter.

After the computerized experiment, a questionnaire is distributed to subjects. People are paid privately in cash at the end of the session. The total gain is the sum of the payoff of the 25 periods. Each session lasts on average one hour.

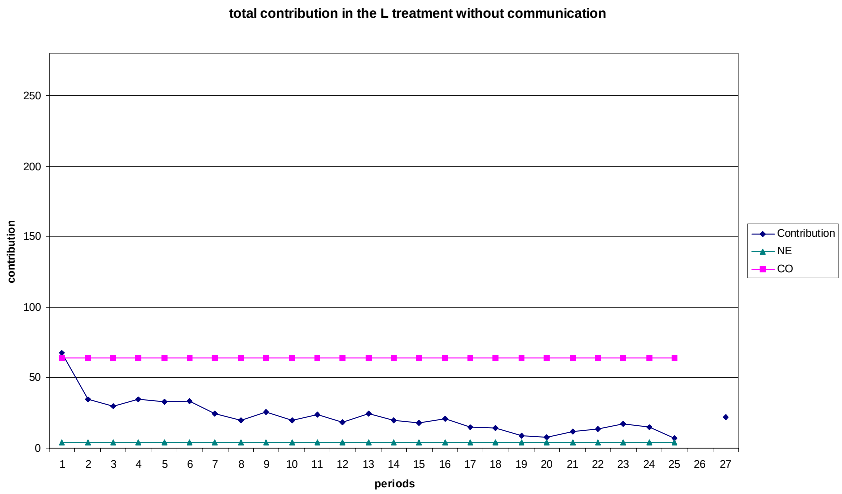
[5] Experimental Currency Unit

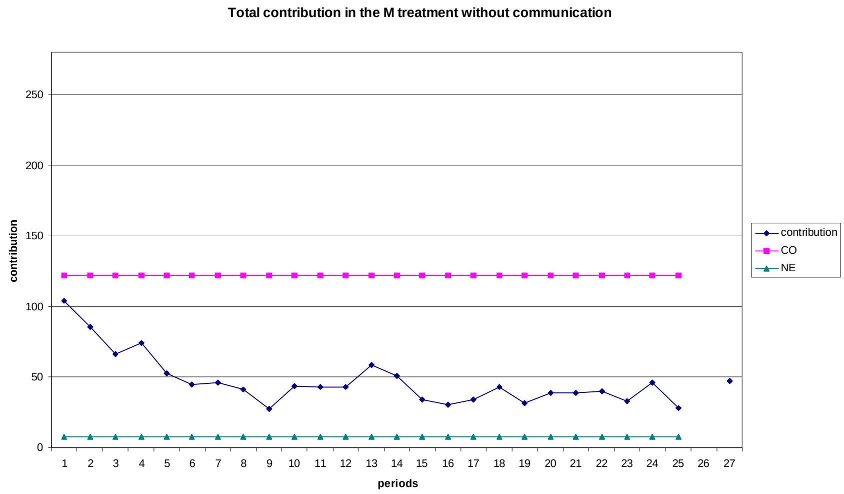
5 Experimental results.

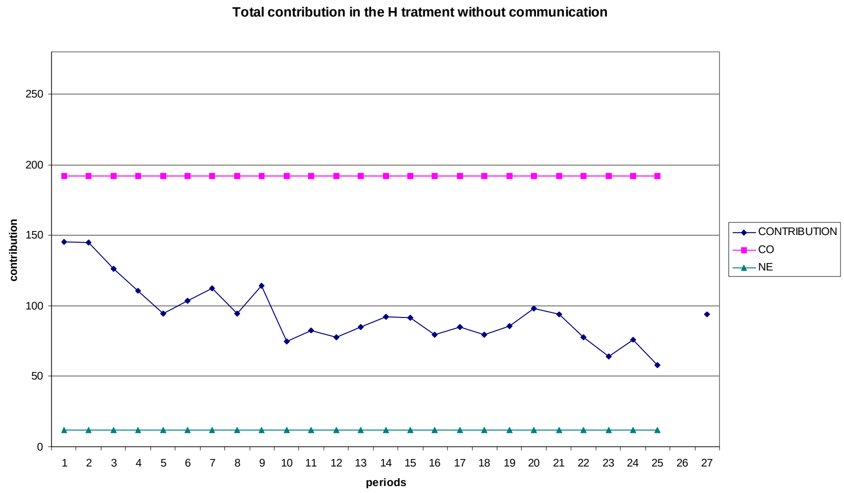
Using the results we obtained from our experiment, we will successively present an analysis of the aggregate comportment and an other of the individual comportment. We'll focus after that on the relation between both.

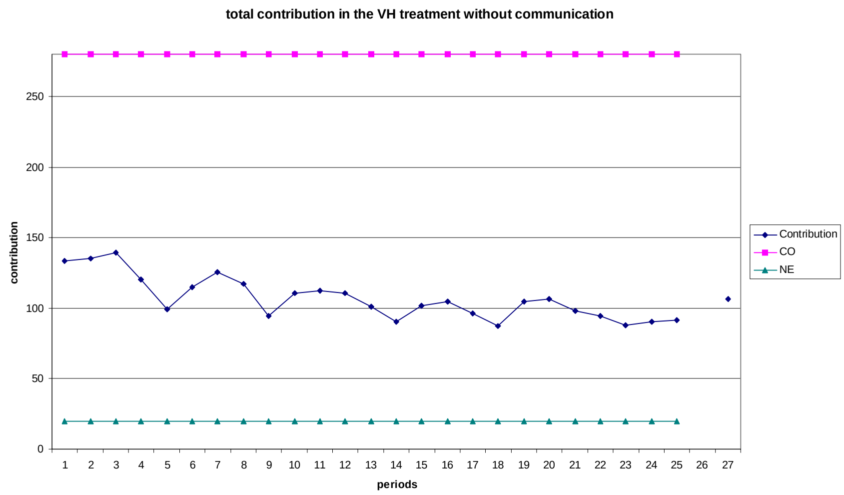
We have three levels of study : the first one (**global aggregate level**) is the average of the comportment of the six groups in each treatments. The second one, the **local aggregate level**, corresponds to the comportment of these six groups for each treatment. The last level, which is the **individual level**, is the comparison of the comportment of the four persons of each group. We are interested in the comparison of the results of these levels to see whether the aggregate comportment is representative of the subjects' one and whether it is the result of the comportment of homogenous or heterogenous subjects.

The first thing we can observe while analyzing the results is the fact that average contribution decreases over time. In fact, in the Low level treatment ($\theta = 16$), contribution starts at the average of 67.67 and decreases harmoniously during all the periods of the game until finishing at the average value of 7.16 (figure 1). This is available too for the three other treatments. The last treatment VH has 133.33 and 91.5 as values









of the first and the last periods (figure 4). In the case of the M and the H treatments, Contributions decrease during the 10 first periods and stay at a steady level during the rest of the periods of the game (figures 2 and 3). The decrease of contributions in however less evident in the VH treatment.

The following table summarizes these results:

Treatment	first period	Average on 25 periods	Last period	Max	Min	Overcontribution
L	67.67	22.41	7.16	67.67	8	18.41
M	103.83	47.23	28.16	103.83	27.5	39.23
H	145.33	93.87	58	145.33	58	81.87
VH	133.33	106.77	91.5	139.67	87.33	86.77

The results confirm our intuition that the level of the collective optimum has an effect on subjects contributions. By varying the level of this optimum, contributions vary in the same direction. The following table gives average contributions for each treatment :

θ	16	22	27	35
Average contribution for the 25 periods	22.41	47.23	93.87	106.77
Rate of average contribution for the 25 periods	8%	16.87%	33.53%	38.13%

We remark that average contribution to the public good increases with the level of the collective optimum. As the marginal payoff θ of the public good increases, average contribution increases too. The average contribution rate[6] is equal to 8% of the initial endowment for the L treatment. This value is equal to 16.9% (respectively 33.5% and 38.1%) for the M (respectively H and VH) treatment. This lets us think that the collective optimum level is one of the several parameters that could intervene in the decision of contributing. As different precedent studies show that parameters like the Nash equilibrium level, the number of players constituting the group or the context of the experiment can intervene in the choice process of the contribution decision, our experiment shows that the collective optimum should also be taken in account and could have the same effect than these parameters.

The collective optimum is never reached and in all periods of all treatments there is overcontribution. This result is not in contradiction with those of other experiments on public goods. The stylized fact of undercontribution in comparison to the collective optimum and of overcontribution in comparison to the Nash equilibrium is confirmed by our experiment and the difference between the experimental and the theoretical result is maintained. This suggests that the level of the collective optimum could not be the only parameter that is token in account by subjects while taking the decision of contributing.

Contrarily to the results in the literature, overcontribution is however very high in comparison to the level of the Nash equilibrium. This is due to the fact that the equilibrium values are very low in the four treatments in comparison to the initial endowment.

The difference between contributions and the collective optimum increases with the level of this optimum. that means that players are more likely to play the collective optimum when its level is low

[6] The average contribution rate is equal to the ratio 'contribution / Endowment'.

than when it is high. Contributions are nearer to this optimum as the level of the collective optimum goes down.

Contributions are always between the Nash equilibrium level and the collective optimum one. In fact, except the first period of the Low treatment, where average contribution (67.67) is bigger than the collective optimum value (64), for all the other periods of the four treatments contributions are between the Nash equilibrium level and the Collective optimum one.

Let's define the under-optimum value as the difference between the collective optimum and average contribution and the overNash value as the difference between average contribution and the Nash equilibrium. The results above show that the overNash value is decreasing over time and that the under-optimum value is increasing over time in all the treatments. This means that while playing the game, subjects' contributions are closer to the Nash equilibrium and farther from the collective optimum. These values are also increasing with the collective optimum level. That means that an increase of this level has as effect both, an increase of contributions but also an increase of the under-optimum value.

The rate of average undercontribution, defined as the ratio of average undercontribution (in comparison to the collective optimum) and the initial endowment (280), is equal to 14.85% in the L treatment. This rate increases while changing treatments from the low treatment to the VH one. It takes the values of 28.85% for the M treatment, of 35.05% for the High treatment and of 61.87% for the Very High one.

The following table summarizes the mean of undercontribution for the four treatments:

θ	16	22	27	35
Average of undercontribution for the 25 periods	41.59	80.77	98.13	173.23
Rate of average undercontribution for the 25 periods	14.85%	28.85%	35.05%	61.87%

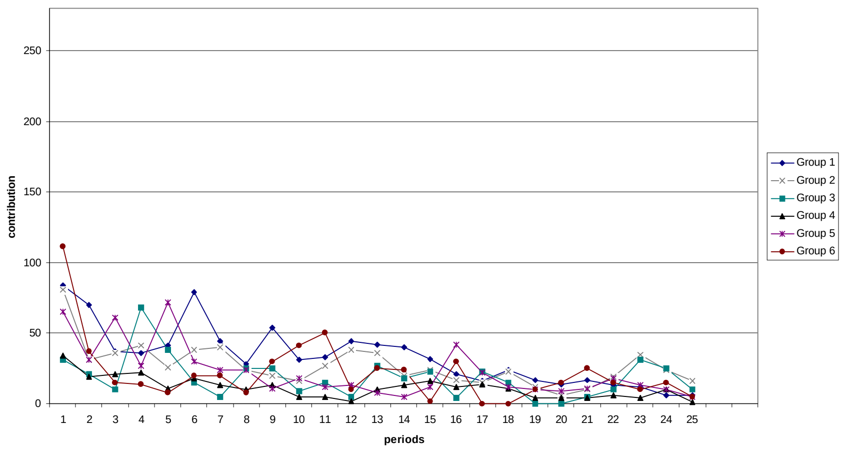
The results show also that players don't play the Nash equilibrium. Except in the L treatment where contributions seem to converge harmoniously to the Nash equilibrium value, players don't play the symmetric Nash equilibrium. This result joins those found in previous experiments in the literature.

Except in the H treatment, there is no an "end effect" in the three other treatments. This effect characterizes a decrease in contributions at the end of the game, during the last periods. This comportment is due to the backward induction and to the fact that the end time of the game is common knowledge. Subjects know that their final decision does not take in account the reaction of the others to this decision.

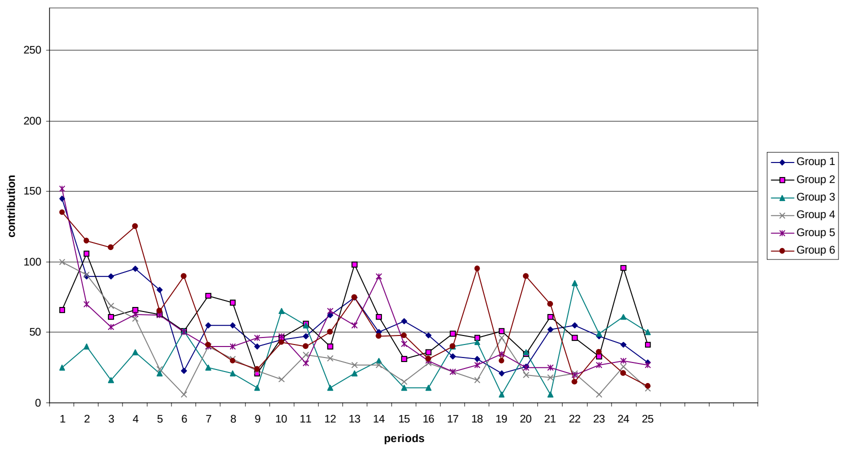
5.1 The group comportment:

The analysis of the average contributions of the several groups participating to our experiment shows that heterogeneity of these groups increases with the marginal payoff θ of the public good seeing that they adopt a more asymmetric comportment (see Figures 5, 6, 7 and 8).

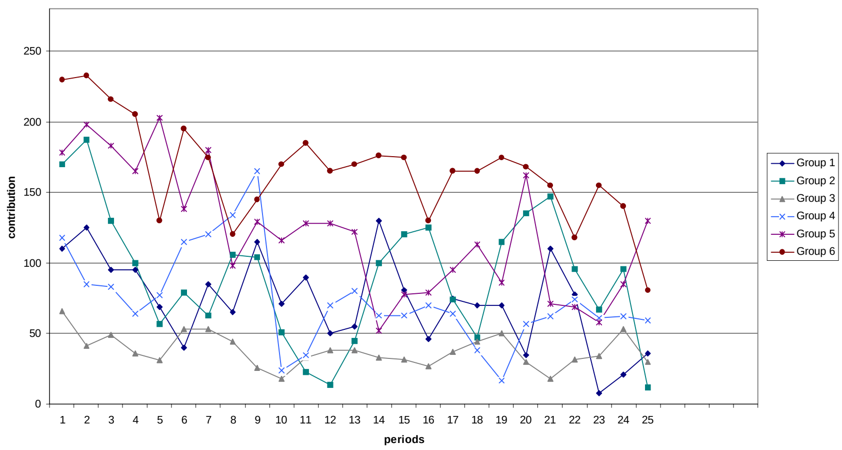
Contribution per group in the L treatment without communication

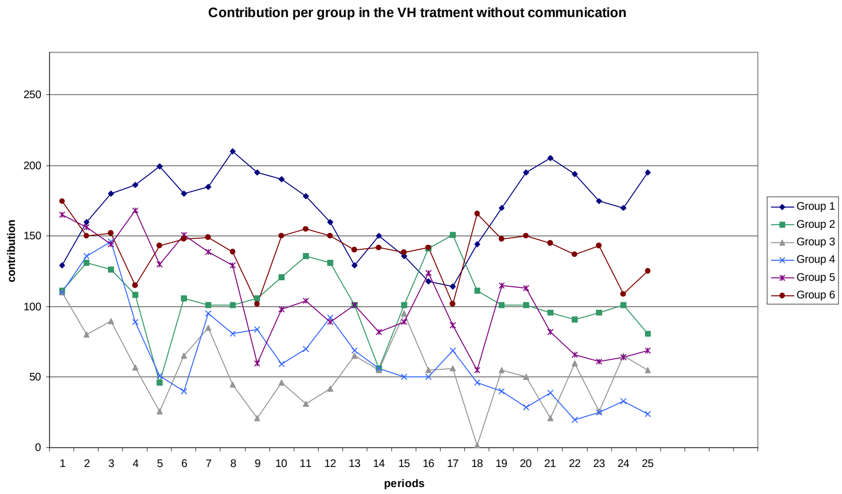


Contribution per group in the M treatment without communication



Contribution per group in the H treatment without communication





In the L treatment, average contributions of the six groups vary between 11.28 (Group 4) and 33.64 (Group 1), that is under the collective optimum (64) and above the Nash equilibrium (4):

L treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	33.64	6	84	445.57	21.11
G2	25	27	6	81	225.5	15.02
G3	25	18.32	0	68	215.56	14.68
G4	25	11.28	1	34	57.71	7.6
G5	25	22.6	5	72	350.25	18.71
G6	25	21.6	0	111	507.75	22.53

This variation in the M treatment is limited between the minimal value 33.04 and the maximal value 59.12. As in the L treatment, all of the six groups have an average contribution over the 25 periods of the game that is superior to the Nash equilibrium (8) and inferior to the collective optimum (128):

M treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	55, 72	21	145	779.54	27, 92
G2	25	56, 28	21	106	454, 63	21, 32
G3	25	33, 04	6	85	430, 54	20, 749
G4	25	32, 36	6	100	580, 57	24, 1
G5	25	46, 88	20	152	794, 11	28, 18
G6	25	59, 12	12	135	1289, 86	35, 91

The same remark applied to the H treatment show a wider variation of the average contribution of the six groups (from 37.84 to 165.68):

H treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	73	8	130	1019, 33	31, 93
G2	25	90, 52	12	187	2109, 1	45, 92
G3	25	37, 84	18	66	132, 89	11, 53
G4	25	74, 4	17	165	1161, 17	34, 08
G5	25	121, 76	52	203	2030, 19	45, 06
G6	25	165, 68	81	233	1240, 98	35, 23

Concerning the VH treatment, the increase of the difference between the several average contributions is confirmed:

VH treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	169, 88	114	210	788, 36	28, 078
G2	25	106, 08	46	151	558, 49	23, 63
G3	25	54, 32	2	110	643, 64	25, 37
G4	25	64, 12	20	146	1131, 78	33, 64
G5	25	105, 64	55	168	1233, 24	35, 12
G6	25	140, 60	102	175	318, 08	17, 83

We can say than that groups are as more homogeneous and are as more likely to adopt a similar comportment as the collective optimum is low. The Standard error of the average contributions increases in fact when we change the treatment from L to VH. There is a similarity between the aggregate comportment and the group comportment in the L and M treatments, while in the H and VH treatments the fact that groups adopt different comportments do not allow such a similarity.

5.2 The individual comportment:

An analysis of the individual comportment of all the subjects that have participated to each treatment can give us an idea about the strategic comportment that is at the origin of the results obtained and announced above at the aggregate and the group levels. In such an analysis, we have in each treatment 24 persons playing 25 periods. This means that we have a data of 600 observations per treatment (see figures 9, 10, 11 and 12).

In all the treatments, the limit values observed are the null value and the amount of the initial endowment (70), except in the L treatment, where contributions never exceed 60. The standard error increases with the collective optimum level, as subjects adopt more heterogeneous comportments when the collective optimum is higher, although it is the same in the H and the VH treatment:

Treatment	N data	Mean	Min	Max	Variance	St. error
L	600	5.60	0	60	63.11	$7,94$
M	600	11.81	0	70	160.47	$12,67$
H	600	23.47	0	70	395.32	$19,88$
VH	600	26.69	0	70	394.69	$19,87$

In the L treatment, more than 25% of the 600 contribution decisions taken are equal to the null contribution and more than 86% of these decisions are inferior to 10. We may notice that these decisions could vary between 0 and 70, the initial endowment of a subject. In this treatment, 97% of the contribution decisions are inferior to 20. There is an informal consensus between subjects to not contribute:

L treatment	effect.	Cumul.Effect.	Freq. (%)	Cumul.Freq. (%)
$x = 0$	152	152	25.33	25.33
$0 < x \leq 10$	369	521	61.5	86.83
$10 < x \leq 20$	61	582	10.17	97
$20 < x \leq 30$	7	589	1.17	98.17
$30 < x \leq 40$	4	593	0.17	98.83
$40 < x \leq 50$	5	598	0.83	99.67
$50 < x \leq 60$	2	600	0.33	100

The number of nul contributions decreases when the marginal payoff of the public good increases. In the M treatment, the percentage of null contributions is 16.67%:

M treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.
$x = 0$	100	100	16.67	16.67
$0 < x \leq 10$	278	378	46.33	63
$10 < x \leq 20$	136	514	22.67	85.67
$20 < x \leq 30$	43	557	7.17	92.33
$30 < x \leq 40$	27	584	4.5	97.33
$40 < x \leq 50$	7	591	1.17	98.5
$50 < x \leq 60$	1	592	0.17	98.67
$60 < x \leq 70$	8	600	1.33	100

The percentage of the decisions of contributing a high amount is nevertheless still insignificant in the M treatment, where 92.33% of the decisions taken are inferior to 30. This is not the case in the H and VH treatments where almost 11% (respectively 12%) of the decisions lay between 50 and 70:

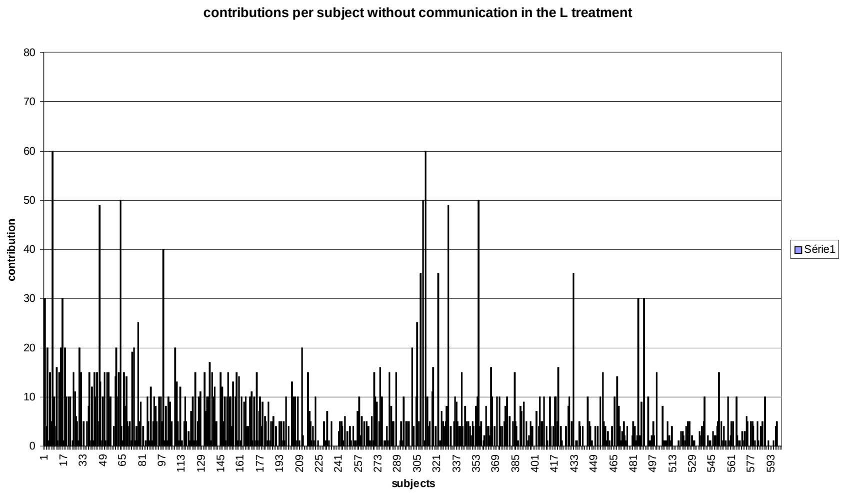
H treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.
$x = 0$	36	36	6	6
$0 < x \leq 10$	182	218	30.33	36.33
$10 < x \leq 20$	133	351	22.17	58.5
$20 < x \leq 30$	77	428	12.83	71.33
$30 < x \leq 40$	62	490	10.33	81.67
$40 < x \leq 50$	46	536	7.67	89.33
$50 < x \leq 60$	25	561	4.17	93.5
$60 < x \leq 70$	39	600	6.55	100

Although the difference between the Low, the Medium and the High treatments is clear, the Very High treatment is not significantly different from The H treatment ay the individual level, all as what we noticed above at the group level:

VH treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.
$x = 0$	42	42	7	7
$0 < x \leq 10$	139	181	$23,17$	$30,17$
$10 < x \leq 20$	101	282	$16,83$	47
$20 < x \leq 30$	75	357	$12,5$	$59,5$
$30 < x \leq 40$	127	484	$21,17$	$80,67$
$40 < x \leq 50$	48	532	8	$88,67$
$50 < x \leq 60$	26	558	$4,33$	93
$60 < x \leq 70$	42	600	7	100

There is nevertheless one similarity between the four treatments: in each treatment, most of subjects contribute an amount between 10 and 20.

In all the treatments, the individual comportments vary generally in the same way in each group, except in the VH treatment where there is an asymmetric comportment of subjects in each group. The graphs representing the individual contributions per group give us a more clear idea about the individual contributions of each of the 24 subjects participating to the treatment during the 25 periods:


contributions per subject without communication in the L treatment
contribution
subjects
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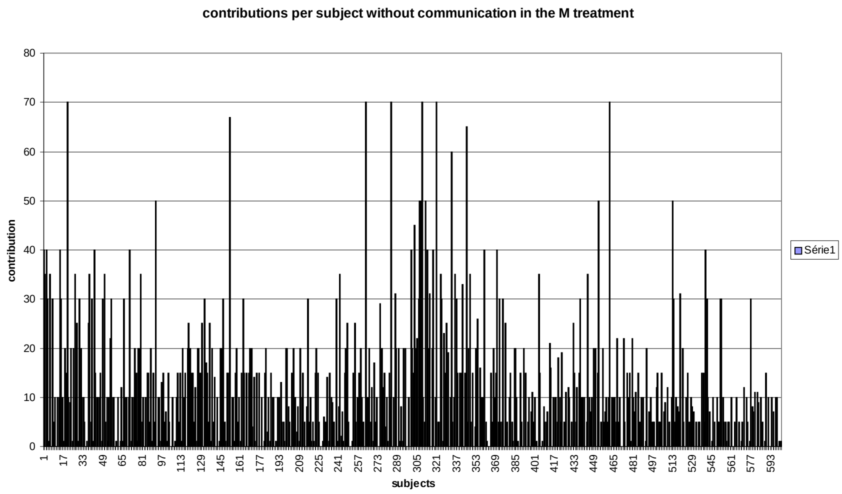
contributions per subject without communication in the M treatment
contribution
subjects
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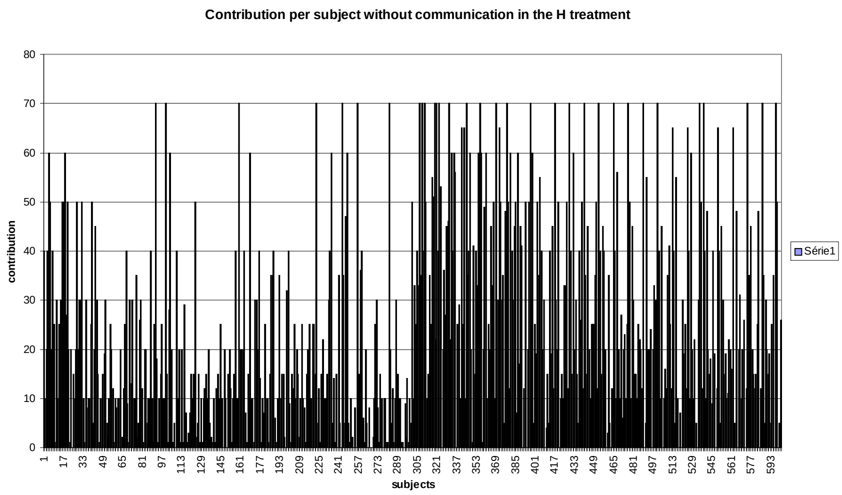
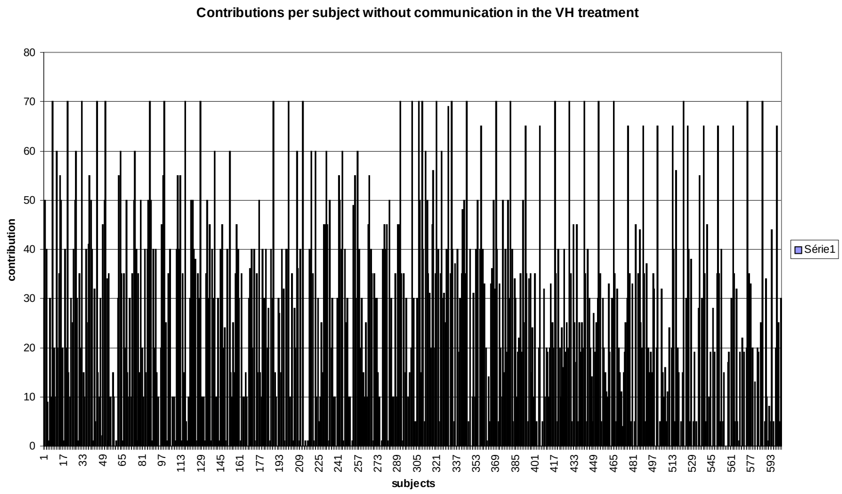

Contribution per subject without communication in the H treatment
contribution
subjects
Série1



5.3 The effect of communication :

5.3.1 Communication as a treatment variable:

While running an experiment, one should make sure that there is no communication between subjects. This absence is necessary to eliminate any bias in the study of the effect of the tested variable treatment. However, in the case where communication is the tested parameter, it must be controlled. The use of computers while running experiments facilitates this task. In fact, communication could influence decisions and comportments and could affect the individual contributions. This parameter is considered as one of the possible solutions that could attenuate the problem of "free-riding " and that could allow cooperation to exist. That's why we will try to introduce this parameter in our experimental study. We present the variation of the level of the collective optimum in two different contexts, with and without communication. Generally, communication increases the level of contribution, as it is shown in several previous experiments.

Our experiment will follow the idea of Cason and Khan (1999) who present games without communication between players and compare them to other games with communication. In this study, the authors add the study of information which is another parameter of interest in a public good game[7]. They focused on the influence of the fact that contributions were not known at the end of each period, but after the development of some periods. They thought that this will decrease contributions, but they found that they do not vary so much consequently to the variation of this parameter.

[7]Rondeau, Schulze and Poe (1999) present a game with complete and, than incomplete information concerning the parameters of the game. In another study, Michael Begg (2000) Develops a model showing the possibility of a socially optimum income resulting from a non cooperative game using incomplete information. Using two types of subjects (cooperators and defectors), he shows that the production function of the public good should have scale increasing incomes to have a cooperative result.

While Yukihiko Funaki and Takehiko Yamato (1999) have introduced the discussion between subjects as a mean allowing the formation of coalitions into the different groups, Luca Anderlini (1999) presents a theory of equilibrium selection for a strategic finite common resources game with two persons and one period. To make possible the coordination of actions between players, he introduces in the game a preliminary stage where the two players can communicate without restriction of time and without any cost to pay. He shows that this introduction facilitates the reach of the unique Pareto-efficient payment in such a game and that only this equilibrium survives to the restrictions imposed.

The use of communication as a treatment variable in our experiment is motivated by the fact that this parameter stimulates the interaction between subjects. The study of communication is a mean of studying the evolution of cooperation between subjects. We are interested in communication as a support for cooperation.

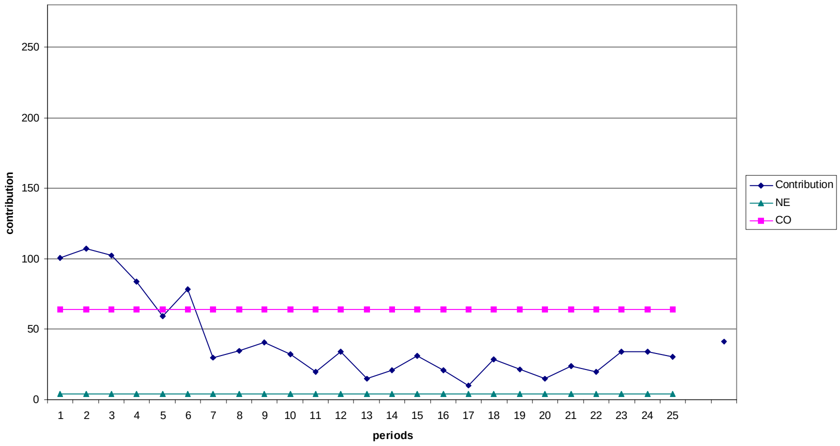
Communication takes in our experiment the form of signals sent by subjects in each period before taking the decision of contribution to the public good. Each subject is asked to say how many he intend to contribute. The sum of the intentions of contribution becomes common knowledge and constitutes the aggregate signal sent by the members of the group. This sum represents an information that will be interpreted by each subject in a way that should reflects the expected comportment of the other members of the group.

5.3.2 Experimental results with communication:

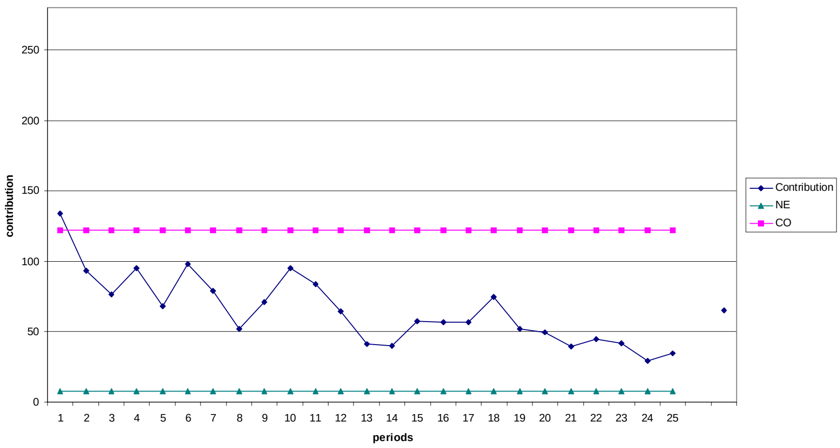
The first evident result we can draw is that, at the **global aggregate level**, contribution starts at a higher level in comparison to the case without communication and decrease over time. This result is available for the four treatments. Except in the VH treatment, and contrarily to the case without communication, subjects contribute more than the Collective optimum in the first periods of the game. We also notice that as it was expected, communication leads to more contribution to the public good and makes than contributions farther from the Nash equilibrium and nearer to the collective optimum in comparison to the case without communication. Subjects do not play neither the Nash equilibria nor the Collective optima. The under-contribution is inferior to what we obtain in the case without communication. The evolution of contribution is also more oscillating in the case with communication.

The increase of the collective optimum level has the same effect on contributions. By varying this level from L to VH, contributions increase (see figures 13, 14, 15 and 16):

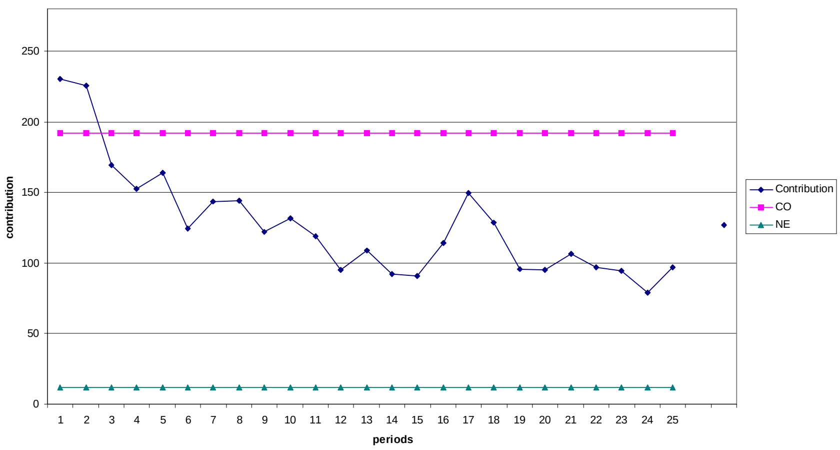
Total contribution in the L treatment with communication

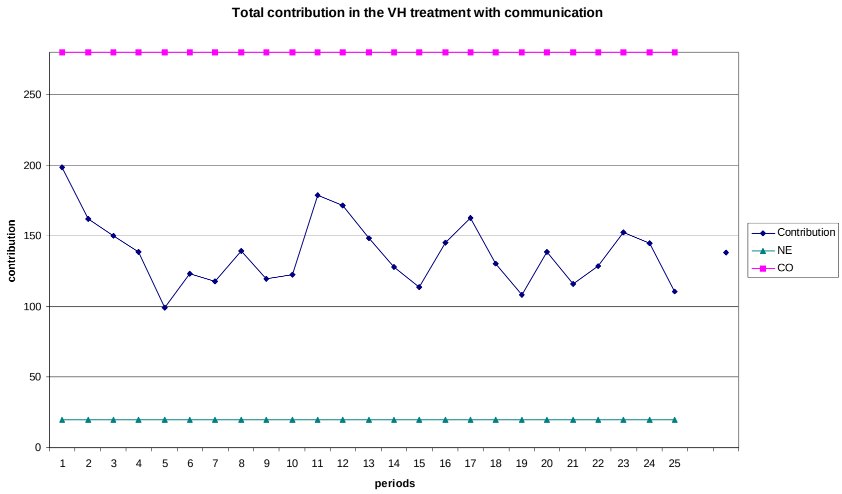


Total contribution in the M treatment with communication



Total contribution in the H tratment with communication





Average contribution for the 25 periods game is equal to 41.12 (14.69% of the initial endowment) in the L treatment, 65.25 (23.30%) in the M treatment, and 126.83 (45.30%) and 138.07 (49.31%) respectively in the H and VH treatments:

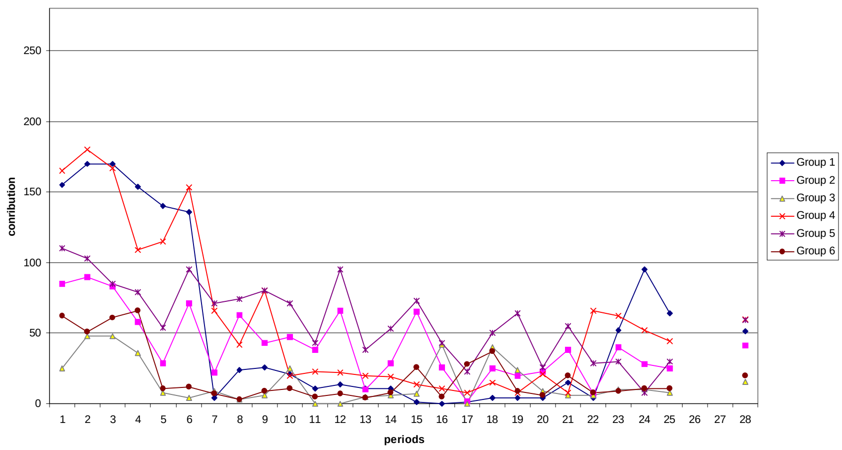
Treatment	First period	Average/25 periods	Last period	Max	Min	AvOvercontribution
L	100.33	41.12	30.33	107	10.33	37.12
M	133.83	65.25	34.67	133.83	29.17	57.25
H	230.17	126.83	97.17	230.17	79	114.83
VH	198.83	138.07	110.67	198.83	99.5	118.07

The following table summarizes the average undercontribution for the four treatments:

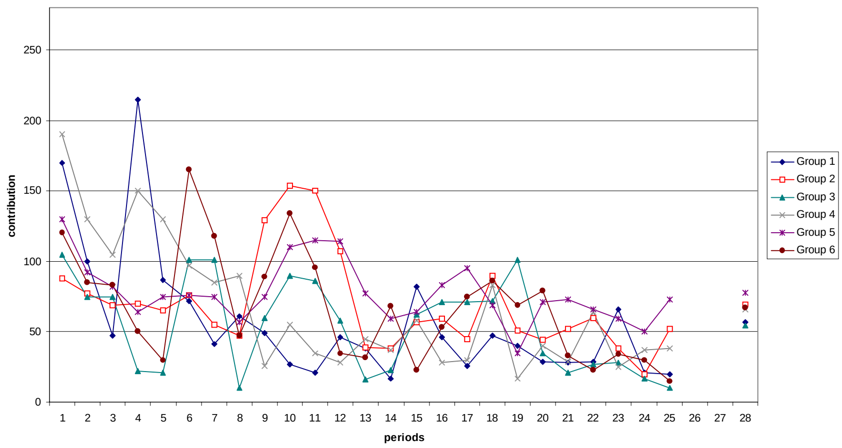
θ	16	22	27	35
Average contribution for the 25 periods	41.12	65.25	126.83	138.07
Rate of average contribution for the 25 periods	14.69%	23.30%	45.30%	49.31%

At the local aggregate level, contributions oscillate more than in the case without communication (see figures 17, 18, 19 and 20), which is reflected by a higher standard error for each group.

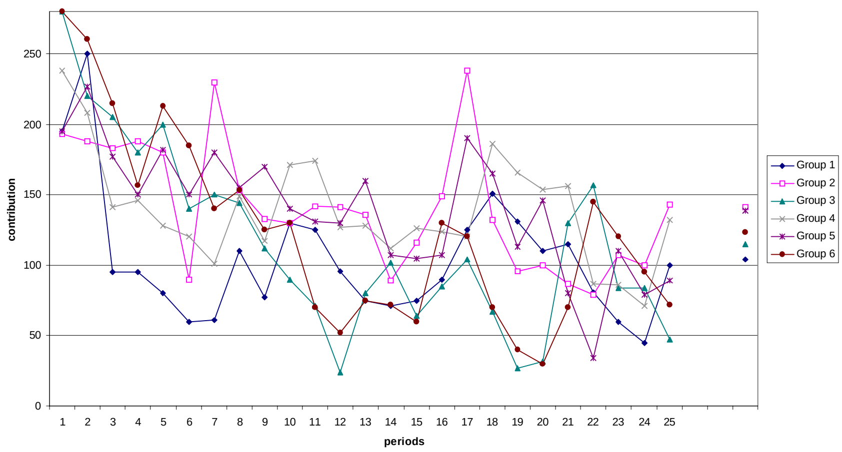
Contribution per group in the L treatment with communication

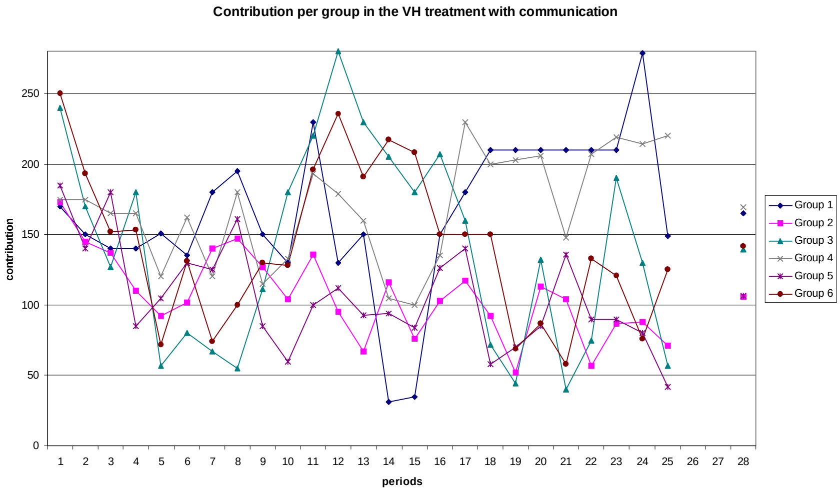


Contribution per group in the M treatment with communication



Contribution per group in the H treatment with communication





The comparison of the six groups shows also that there is more an asymmetric comportment between them in the H and VH treatments than in the L and M treatments. The following tables give a more precise idea about these groups:

L treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	51.64	0	170	3973.07	63.03
G 2	25	41.32	2	90	624.56	24.99
G3	25	15.4	0	48	245.75	15.68
G4	25	59.6	8	180	3163.92	56.25
G5	25	59.28	8	110	752.38	27.43
G6	25	19.48	3	66	394.68	19.87

M treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	57	17	215	2194.67	46.85
G 2	25	69.28	20	154	1170.46	34.22
G3	25	54.32	10	105	1085.81	32.96
G4	25	66.08	17	190	2095.83	45.78
G5	25	77.56	35	130	477.42	21.85
G6	25	66.88	15	165	1528.11	39.09

H treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	104.12	45	250	2022.11	44.97
G 2	25	140.92	79	238	1978.08	44.48
G3	25	115.16	24	280	4242.89	65.14
G4	25	138.72	71	238	1448.29	38.06
G5	25	138.88	34	227	1939.69	44.04
G6	25	123.16	30	280	4501.64	67.09

VH treatment	n data	Mean	min	Max	Var	St. err
Group 1	25	165.4	31	279	2981.25	54.6
G 2	25	106.04	52	173	901.21	30.02
G3	25	139.56	40	280	5024.17	70.88
G4	25	169.16	100	230	1511.47	38.88
G5	25	106.24	42	185	1353.44	36.79
G6	25	142	58	250	2964.08	54.44

The individual level's analysis of the case with communication shows that there are more types of players than in the case without communication. While the majority of subjects in the four treatments contribute an amount between 0 and 10 in the case without communication, subjects are more likely to cooperate and to test several strategies when there is an interaction between them. As a result of this, the individual comportments are more heterogeneous and asymmetric. The majority of subjects contribute an amount between 0 and 10 in the L and the L treatments, between 10 and 20 in the M treatment and between 60 and 70 in the VH treatment. There are much more subjects that give a maximal contribution in the VH treatment than in the other cases and than in the case without communication:

L treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.(%)
$x = 0$	210	210	35	35
$0 < x \leq 10$	228	438	38	73
$10 < x \leq 20$	54	492	9	82
$20 < x \leq 30$	31	523	5.16	87.17
$30 < x \leq 40$	32	555	5.33	92.5
$40 < x \leq 50$	29	584	4.83	97.33
$50 < x \leq 60$	11	595	1.83	99.17
$60 < x \leq 70$	5	600	0.83	100

M treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.(%)
$x = 0$	163	163	27.17	27.17
$0 < x \leq 10$	106	269	17.67	44..83
$10 < x \leq 20$	164	433	27.33	72.17
$20 < x \leq 30$	73	506	12.17	84.33
$30 < x \leq 40$	24	530	4	88.33
$40 < x \leq 50$	47	577	7.83	96.17
$50 < x \leq 60$	11	588	1.83	98
$60 < x \leq 70$	12	600	2	100

H treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.(%)
$x = 0$	45	45	7.5	7.5
$0 < x \leq 10$	106	151	17.67	25.17
$10 < x \leq 20$	91	242	15.17	40.33
$20 < x \leq 30$	86	328	14.33	54.67
$30 < x \leq 40$	74	402	12.33	67
$40 < x \leq 50$	56	458	9.33	76.33
$50 < x \leq 60$	60	518	10	86.33
$60 < x \leq 70$	82	600	13.67	100

VH treatment	effect.	Cumul. Effect.	Freq.(%)	Cumul. Freq.(%)
$x = 0$	90	90	15	15
$0 < x \leq 10$	66	156	11	26
$10 < x \leq 20$	84	240	14	40
$20 < x \leq 30$	72	312	12	52
$30 < x \leq 40$	50	362	8.33	60.33
$40 < x \leq 50$	53	415	8.83	69.17
$50 < x \leq 60$	32	447	5.33	74.5
$60 < x \leq 70$	153	600	25.5	100

Except in the L treatment where subjects adopt a comportment mostly similar, in the three other treatments the individual comportments are totally asymmetric and much more oscillating than in the case without communication. Changing the treatment from L to VH leads to an increase in the standard error of the individual comportment. The H and VH treatments, contrarily to the case without communication, do not present the same individual comportment:

Treatment	N data	Mean	Min	Max	Variance	St. error
L	600	10.28	0	70	236.65	15.38
M	600	16.3	0	70	272.87	16.52
H	600	31.71	0	70	490.81	22.15
VH	600	34.52	0	70	657.47	25.64

6 Conclusion.

Our experiment show that the level of the collective optimum is one of the parameters that should be taken in account in a public good experiment like several other parameters that were been experimentally tested before. Although the collective optimum has not to do with the strategic comportment, we find that the social situation and the group welfare can influence the decisions taken by subjects. This effect is to be found in parameters like altruism, or kindness. These parameters should intervene in the decision process and in the utility function of subjects.

The introduction of communication increases slightly contributions and make them more oscillating. A comparison of this aggregate result with the group and the individual comportment shows an heterogeneity of the results. In fact, while we have an asymmetry between groups in the H and VH treatments in the cases without communication, which is more apparent in the case with communication, the individual comportment is more homogeneous in the case with communication. This latter makes the individual comportments asymmetric and gives different kinds of strategies reflected by several comportments.

7 appendix.

7.1 instructions of the experiment without communication:

Welcome,

This is an experiment that allows you to earn money. The instructions are simple and if you follow them carefully and make good decisions, you may earn a considerable amount of money. This money will be paid to you by cash at the end of the experiment.

You will be randomly assigned in the beginning of the experiment to a group of 4 persons (you and 3 others). Each group will consists of the same persons for the duration of the session. The session will last for 25 periods. In each period you will be required to make a decision and your total income will depend on these decisions. Your total earning for the session will be the sum of your earnings in all the 25 periods. The specific identities of the other people in your group will not be revealed to you.

You are not allowed to communicate with anyone else in the room during all the session. If you have a question at any time, please raise your hand. One of us will come to your seat, and you can privately ask your question. Any communication will lead to your exclusion from the game without any payment.

At the beginning of each period you will receive a constant income in tokens (the same for all the periods). You will be asked to share this income into two parts: part A and part B.

The tokens you allocate to part A are already for you. The rest of the tokens that you will allocate to the part B will allow you to earn an amount that depends on your contribution, but also on the contributions to the part B of the three other persons of your group. The amount you earn from the sum of your contributions to the part B will be shared equally between the four persons of your group. The earning of all the group from the part B will be calculated as shown in the following table.

Your total payment will be equal to the tokens you allocate to part A plus your part from the earnings from the sum of the tokens allocated by all the persons of your group to part B.

At the end of each period, you will have the total amount that the group allocates to part B, your personal earnings from the part B and your total profit.

At the end of the experiment, your total earning from the 25 periods will be given to you privately in cash.

The tokens will be exchanged for money at a rate of :

100 tokens = 17.85714 pesetas.

7.2 Questionnaire.

1. How many in percentage do you estimate the correspondence of your answers during the experiment to your true preferences ?

2. Did you really try to win ?

3. What was your strategy ?

4. What determinates your decisions concerning your
contributions ?

5. If you play again with bigger endowments, will you play differently ?

6. And with a larger group of persons?

7. If yes, what will be different ?

8. Did you play a war strategy (looking for a personnel gain) or a co-operator strategy (looking for a gain shared by everybody) ?

9. Did you lie while answering theses questions ?

7.3 Information about yourself :

Your computer Name :

Your studies :

Level of studies :

Age :

Gender :

Do you participate to any experiments before? :

Are you (cross on cell for each line of the following table) :

	Not at all	A little bit	middle	enough	very
Selfish					
Honest					
Jealous					
Liar					
Rich					

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