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The individual behavior in a public goods game

THE INDIVIDUAL BEHAVIOR IN A PUBLIC GOODS GAME

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Abstract: *Generally, with a standard linear public goods game, one observes at the aggregate level that contributions lay between the Nash equilibrium and the social optimum and decrease over time with an end-effect.Our purpose is to see whether these general aggregate results remain available at the group and at the individual levels. To do so, we formed six groups of four persons and made them play a public goods game. At the aggregate level, we find that our results correspond almost to the standard experimental findings in literature.Using the classification of Isaac et al. (1984), we find that at the group level, only two groups adopt the standard behavior and only two groups present a behavior similar to what we obtain at the aggregate level. At the individual level, we compare contributions over time of each subject to the group and the aggregate results and classify them into types. Only in one of the 6 groups individuals adopt an homogeneous behavior. In the five other groups, individuals have different behaviors.*

Résumé: *Dans un jeu linéaire de bien public, les expériences mettent en évidence quelques faits stylisés. Ces expériences montrent, en effet qu'au niveau aggrégé les contributions se situent entre l'équilibre de Nash correspondant à une contribution nulle et l'optimum social. Ces contributions baissent dans le temps avec un "end-effect" caractérisant les dernières périodes. Notre objectif est de savoir si ces résultats reflètent le comportement des groupes ainsi que celui des individus. Malgré la correspondance de nos résultats au niveau aggrégé à ceux de la littérature, suelement deux groupes ont le même comportement que celui observé au niveau aggrégé. Quant au niveau individuel, la similarité de comportement des sujets est évidente dans un seul des six groupes. Le critère de comparaison utilisé est celui de la classificationdes sujets en types, telle qu'elle est définie par Isaac et al (1984).*

Key-words: *Public Goods; Free-Riding; Aggregate level; Individual Behavior; Experiments.*

Mots-Clés: *Biens Publics; Passager clandestin; Niveau Agrégé, Comportement individuel, Expériences.*

JEL Classification: *C91; H41*

1 Introduction

In public goods games, some stylized facts and general results emerged from experiments dealing with this field. Generally, with a standard linear public goods game giving full contribution as social optimum and zero as Nash equilibrium, one observes at the aggregate level that contributions do not correspond to the Nash equilibrium, but also that full cooperation is not achieved. Instead, average contribution is about 60% of the initial endowment (see Davis and Holt (1993), Ledyard (1995) and Keser (2002) for a survey). This suggests that subjects are not totally free-riders and that some incentives like Warm Glow (Andreoni (1990)), kindness (Andreoni (1995)), altruism (Anderson et al. (1998)), conditional cooperation (Fischbacher et al. (2001)) or reciprocity, lead subjects to contribute a certain amount to the public good. On the other hand, while playing the game, contributions are generally decreasing over time with an "end effect" observed during the last periods and corresponding to a clear decrease of contributions. This second remark let us think that subjects become more and more "free-riders" while playing the game or that incentives for contribution change over time. A question then arises: do all subjects behave in the same way than what we obtain at the aggregate level, or does the general finding corresponds to different behaviors of different types of subjects? Answering this question will help us to understand better individual interactions and to explain why there is overcontribution, which is one of the main purposes of experiments on public goods. Instead of proposing only one explanation for overcontribution, it may be possible that several parameters act at the same time on the individual behavior. It is then not surprising that altruism (Anderson et al. (1998)) and Free-Riding, strategic behavior (Keser and Gardner (1999)) and equity (Chan et al. (1997)), or conditional cooperation and invariable strategy over time exist in the same group of subjects and in the same period.

Many previous studies have focused on the individual behavior. This is the case in learning models (reinforcement learning, experience weighted attraction learning, evolutionary dynamics...) based on the idea that subjects learn and actualise their strategies and choices while playing a game, which leads to an observed change in behavior owing to experience. Roth and Erev (1998) who use simulations to study the descriptive and the predictive power of learning models, try to find a way to predict behavior at every level of aggregation or disagregation, for every game and for any leght of play. They compare all the models' predictions on the aggregate

data and on individual data. They justify the analysis of the individual data by the fact that the "analysis of individual learning curves can reveal information that is lost in the analysis of the aggregate curves" (Roth and Erev (1998), p.p. 857). As in Roth and Erev (1998), Camerer (1959) focuses on using experimental data to test models of learning and to find what type of models fit the path of learning. Obviously, these tests of two players games' results deal with the individual data.

Our aim is to see whether these general results remain available at the individual level, or whether subjects behave differently and adopt several strategies. To do so, we formed six groups of four persons and made them play the public goods game. After comparing our aggregate result to the general findings in literature, we compare it to the contributions of each group to see whether we have the same behavior. To take into account individuals, we compare contributions over time of each one of the 24 subjects who have participated to the experiment to the group and the aggregate results and classify them into types using the classification of Isaac et al. (1984). This classification considers as "Complete Free-Riders" those who contribute zero, as "Incomplete Free-Riders" those who contribute an amount between zero and 35% of their initial endowment, and as "Weak Free-Riders" individuals who's contributions lay between 35% and 70% of the initial endowment. Those who's contributions are between 70% and 99% are called "Incomplete Cooperators" and if there is full contribution (100%), the player is a "Complete Cooperator."

After explaining the experimental design in Section 2, we present in section 3 the main results of our experiment. We find that the aggregate behavior corresponds to the standard experimental findings concerning the linear public goods game in the literature. At the group level, only two groups (Groups 4 and 5) have the same behavior than in the standard result and only two groups (Groups 2 and 6) have a behavior that is similar to what we obtain at the aggregate level. At the individual level, there is only one of the 6 groups where individuals adopt the same behavior. In the five other groups, individuals behave differently.

2 Experimental design and procedures

In a public goods game, each subject $i = \{1, .., N\}$ has to decide about the amount y_i she has to take from her endowment E (the same for all subjects and for all periods) to allocate to

the public good. The standard public goods game uses a linear payoff function for both, the private and the public good. This kind of design predicts complete free-riding by all subjects. As in Hichri (2003), we used a payoff function that was linear for the private good and concave for the public one. Such a function has the advantage of giving an interior Nash equilibrium (see Keser (1996), Sefton and Steinberg (1996) and Isaac and Walker (1998)), which eliminates the error hypothesis[1] in case of over-contribution. But this equilibrium takes a low value that is not far from zero such that we could then assimilate our design to the linear case. For all subjects $i = \{1, .., N\}$, the payoff function was the following:

$$Z_i = E - y_i + \theta(\sum_{i=1}^{N} y_i)^{1/2} \tag{1}$$

To make the social optimum coincide with the sum of the endowments of the group (corner social optimum), we attribute to θ the value of 8.944272. For the experiment, a total number of 24 subjects have played the public goods game. We randomly made six groups of four people and we ran two sessions with three groups at each time. Seeing that the groups were totally independent and do not interact or communicate with each other, we obtained six independent statistical observations.

To compare the individual level to the aggregate result, we will compare for each group the group contribution to the average groups contributions. This first comparison allows us to see whether the group behavior is similar to the aggregate result or whether on the contrary the general finding is the result of groups that behave in different ways. Than, to test the heterogeneity of individuals, we will compare the individual behavior of the 24 subjects and define the proportion of free-riders, cooperators, etc.. We will compare also these results to the aggregate level to see whether the latter is the result of an homogeneous behavior or whether different agents were at the origin of the standard general result.

The experiment took place in November 2001 at the *LeeX* (Laboratori d'Economia Experimental) at "*Universitat Pompeu Fabra*" in Barcelona. It was computerized and we used as software *z-Tree* developed by Fischbacher (1999). During the experiment, there was no communication either between groups or between members of a same group. Interaction was only

[1] The error hypothesis was tested by Keser (1996) who introduced a design with an interior Nash equilibrium. With such a design, contributions could be below or above the equilibrium, which was not possible with the linear design where the Nash equinibrium was at zero and negative contributions were not allowed.

between the members of a same group via physically isolated computers.

Instructions (see Appendix) were distributed in a written form to subjects and were read out loud before the beginning of each session. We made sure that these instructions were well understood. Subjects were asked to rase their hands if they have any questions and answers were given privately by the experimenter.

Each group played 25 times the one-shot game and was composed by the same members during all the experiment[2] (partners design). The total gain is the sum of the payoffs of the 25 periods. Subjects were informed in every period that they were endowed with 70 *ECU*[3] and were asked to allocate them to part A (the private good) and/or to part B (the public good). Parts allocated by all the members to the public good allowed the group to have a certain amount that was presented to subjects in a tabular form (see Appendix). After the end of the experiment, a questionnaire was distributed to subjects. The gain of each subject was converted at the end of the session from *ECU* into *Pesetas* and people were paid privately in cash. Each session lasted on average one hour.

3 Results

With a total endowment in each group equal to 280, our design gives 280 as social optimum and theory predicts that the total amount corresponding to the Nash equilibrium that should be contributed by all the members of the group is 20.

At the aggregate level, average contribution over the 25 periods of the game is 106.77, which corresponds to 38.13% of the social optimum, with a standard deviation of 15.18. According to the classification of Isaac et al. (1984), this reflects a "Weak Free-Riding" behavior. When computing the overcontribution rate[4] as defined in Willinger and Ziegelmeyer (2001), we obtain 33.37%. Contribution is decreasing over time, starting at 133.33 and ending at 91.5, which means that contributions are closer to the Nash equilibrium and farther from the social optimum. But if we do not consider the first five periods which can be considered as "*learning periods,*" contributions are almost constant. There is no "*end effect*" and contributions in all periods are

[2]Seee Andreoni (1988) and Croson (1996) for a comparison between partners and strangers designs.

[3]Experimental Currency Unit

[4]Willinger and Ziegelmeyer (2001) define the rate of overcontribution as the difference between the effective and the equilibrium contribution relative to the range of possible over contribution.

between the Nash equilibrium level and the social optimum (see *figure 1*).

With a design where the Nash equilibrium is different from zero, this result eliminates error as an explanation of overcontribution (Keser (1996)). Except the absence of an "*end effect,*" and of a clear decreasing of contributions over time, these results correspond to the standard experimental findings concerning the linear public goods game in literature (see Andreoni (1995)) as we still have the typical contradiction between the theoretical predictions of "no contribution" and the experimental results.

Our purpose is to see whether this global result corresponds to homogeneous or different groups behaviors and whether at the individual level, we have several strategies used by players.

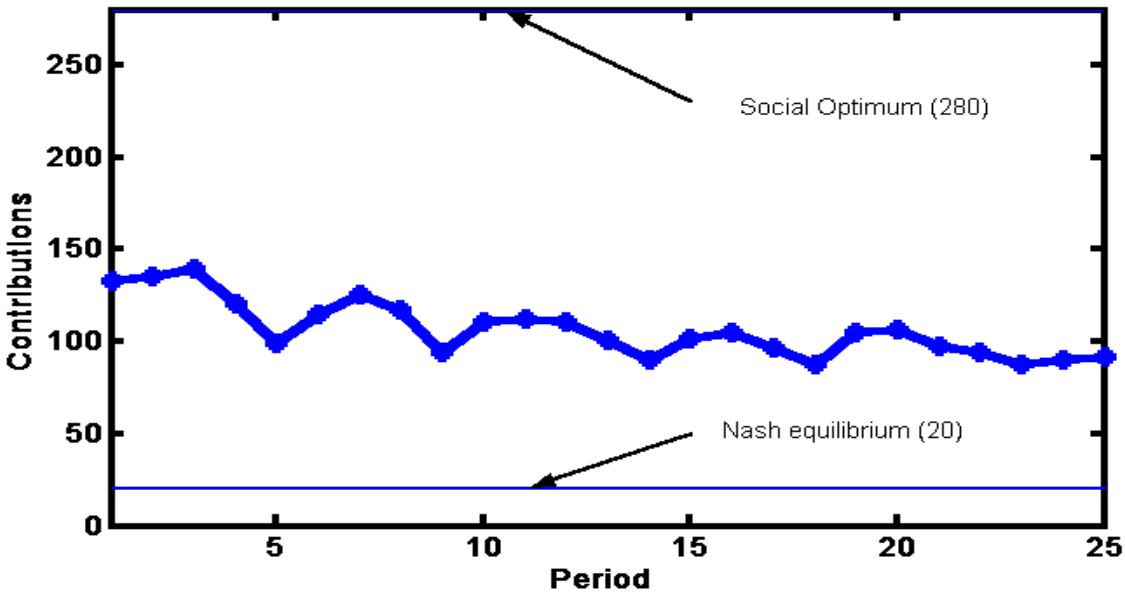

Figure 1: Time path of average contributions at the aggregate level

At the group level (see *figure 2*), there is no evident "end effect" in none of the six groups. Among the six independent groups playing the public goods game, only two of them (groups 2 and 5) have almost the same rate of overcontribution over the 25 periods of the game than what we obtain at the aggregate level (respectively 33.11% and 32.94%).

Two other groups have a lower rate of overcontribution close to 15% (Groups 3 and 4), and the remaining two groups choose a higher rate of overcontribution that exceeds 45% (respectively 57.65% for group 1 and 46.38% for group 6). According to the classification of Isaac et al. (1984), there are two categories of groups: four of the six groups (Groups 1, 2, 5 and 6) are "Weak Free-

Riders" and Two groups (Groups 2 and 4) are "Incomplete Free-Riders." This observation implies that different behaviors are at the origin of our aggregate result.

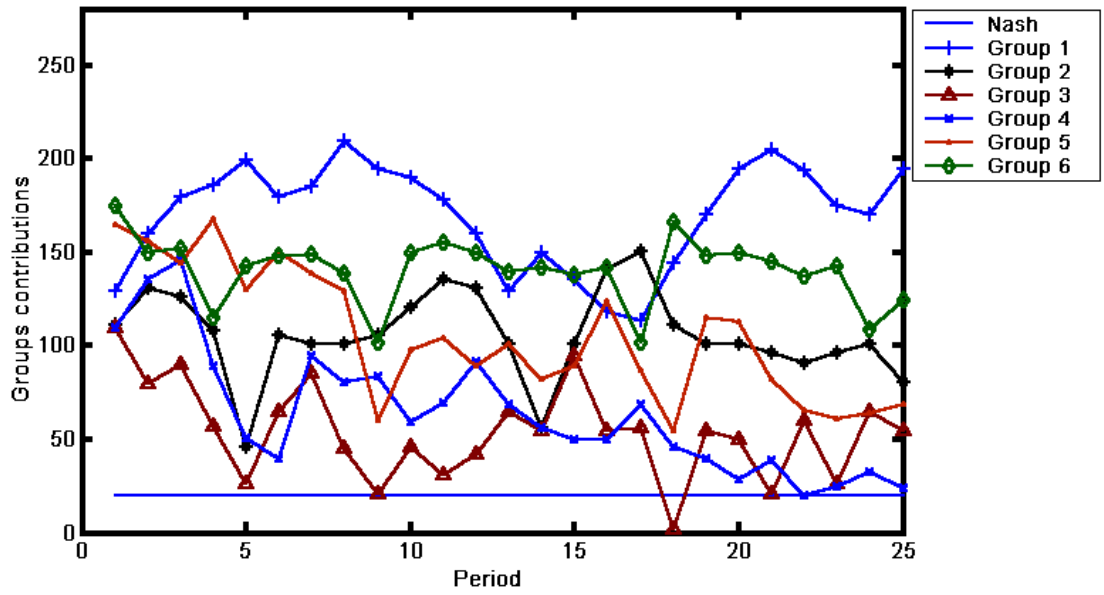

Figure 2 : Time path of average contributions for the six groups

Over time, Group 5 is the group that presents the most similar results in comparison to the aggregate level. Only two groups (4 and 5) have a "standard behavior," that is a decreasing contribution over time that is tending towards the Nash equilibrium, as in the general standard result. The four remaining groups present a "non decreasing" behavior. Two of these four groups have "steady contributions" over time (Groups 2 and 6). Groups 1 and 3 present an "oscillating behavior." In Group 1, average contributions vary in big oscillations: they increase during the eight first periods, than decrease until period 17 to increase again and tend toward the social optimum in the rest of the periods. These oscillations are present in group 3, but they are small. Contribution in Group 3 is low and very close to the Nash equilibrium. It even falls below this equilibrium in period 18. Consequently, only two groups (Groups 4 and 5) have the same behavior than the standard result and only two groups (Groups 2 and 6) present a behavior similar to what we obtain at the aggregate result. The study of the individual behavior could give us an idea about the different ways of interaction between individuals into groups. *Figure 3* gives for each group the contributions of its four subjects over the 25 periods of the

game.

All individuals in Group 1 have the same Behavior and are "Weak Free-Riders". Three of them start with high contributions and all of them increase their contributions during the first periods.

The steady behavior in Group 2 is the result of a combination of different behaviors: Subject 1 is a complete free-rider. She contributes 1 during all the experiment. Subject 2 have also a steady behavior, but with a constant contribution at almost 50% of the initial endowment. Subject 3 represents an oscillating behavior between zero and 40, all as subject 4 who's contributions oscillate between full contribution and 50% of the initial endowment with a social optimum played 9 times. Two subject are "Incomplete Free-Riders" (S1 and S3) and Two subjects are "Weak Free-Riders" (S2 and S4).

The low contributions in Group 3 are the result of low individual contributions: two players have a steady behavior during all the game, and two others have an oscillating behavior between zero and 50% of the initial endowment. All subjects in this group are "Incomplete Free-Riders."

Contributions in Group 4 are the result of low and oscillating behaviors and the four players are "Incomplete Free-Riders." The decrease of contributions over time is less evident at the individual level.

Concerning Group 5, two subjects (Subjects 1 and 4) have almost the same group behavior. Contributions of subject 2 start with full contribution, than decrease until the Nash equilibrium (period 9) to increase again to the social optimum (period 19) and decrease again to finish at the Nash equilibrium (Last period). These three subjects are "Weak Free-Riders." Subject 3 ("Incomplete Free-rider") have an oscillating behavior until period 17 where he contributes zero till the end of the game.

The steady behavior of Group 6 is also the result of a steady, but different individual behaviors: Subjects 1 ("Incomplete Cooperator") have almost full contribution as a behavior, while subjects 2 and 4 (Weak Free-Riders") contribute almost 50% of the initial endowment. Subject 3 ("Incomplete Free-Rider") free ride and contribute 5 during the 25 periods of the game. This group is a good representation of subjects having a steady but heterogeneous behavior in the same group.

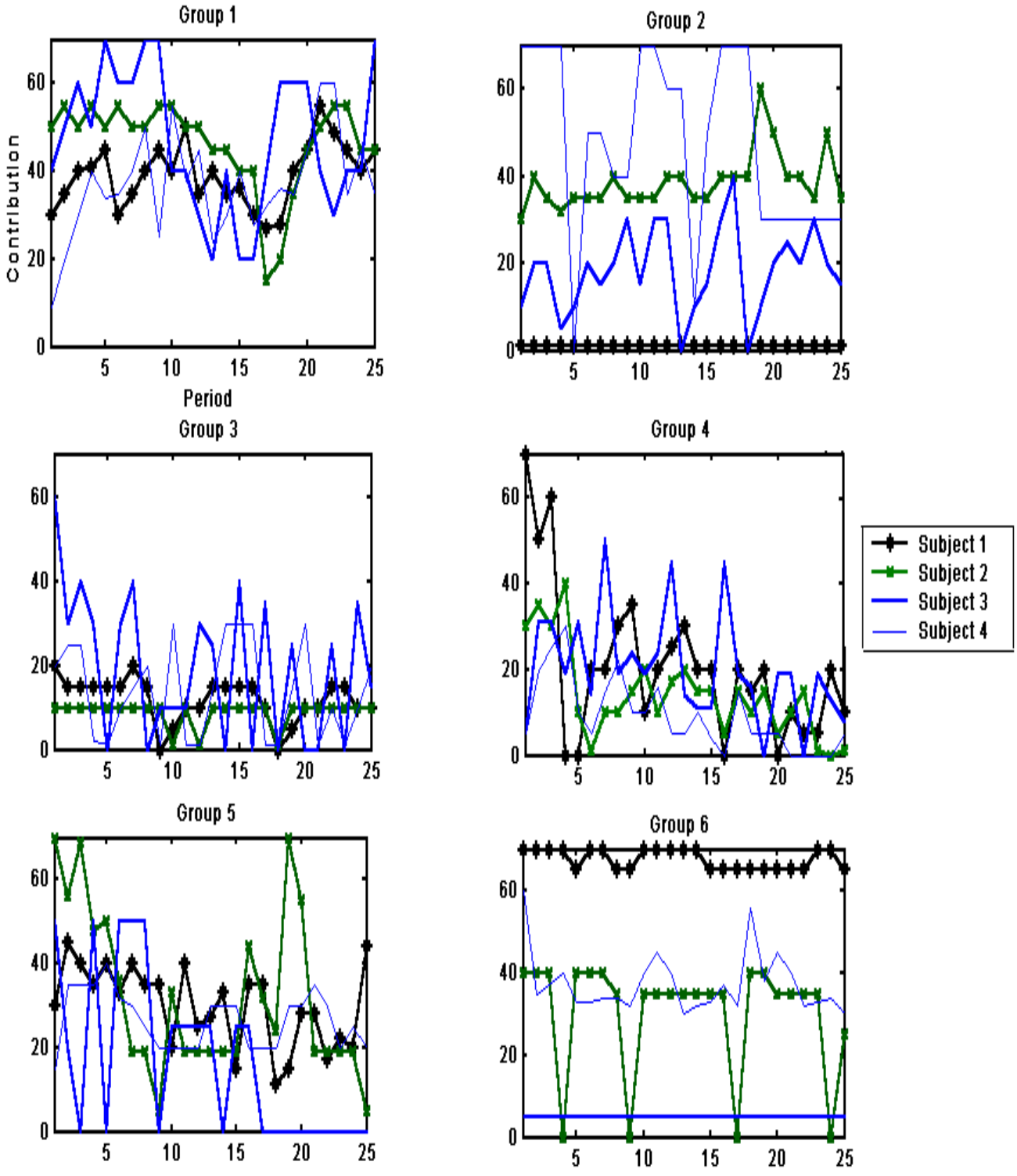

Figure 3: Time path of individual contributions in the six groups

Consequently, there is only one of the 6 groups where individuals adopt the same behavior. In the five other groups, individuals have different behaviors. The latter are either oscillating, or steady and individual contributions have either high, or low levels.

When we compare average contributions over the 25 periods of the game at the individual level, we have 12 (50% of) subjects that are "Incomplete Free-Riders," 11 (45,83% of) subjects that are "Weak Free-Riders" and 1 (4,17% of) subject(s) that is (are) "Incomplete cooperator(s)." *Table 1* gives average individual contributions and average Groups contributions over the 25 periods with their standard deviations.

	Subject 1	Subject 2	Subject 3	Subject 4	Sum
Group 1	39.24	46.4	47.2	37.04	169.88
	(7.21)	(10.26)	(16.21)	(11.88)	(28.08)
Group 2	1	38.68	18.4	48	106.08
	(0)	(6.44)	(9.97)	(21.21)	(23.63)
Group 3	12	8.92	19.6	13.8	54.32
	(5.20)	(2.98)	(17.38)	(11.50)	(25.37)
Group 4	20.6	14.2	20.24	9.08	64.12
	(18.05)	(10.56)	(12.94)	(8.34)	(33.64)
Group 5	29.92	32.24	16.8	26.68	105.64
	(9.68)	(19.88)	(19.99)	(6.78)	(35.12)
Group 6	67.6	30.6	5	37.4	140.6
	(2.55)	(14.02)	(0)	(7.48)	(17.83)

Table 1: Average Individual and Groups Contributions (Standard Deviations) over the 25 periods

If we apply this to the 600 decisions taken during the 25 periods by the 24 persons participating to the game, the corner decisions (null contribution and full contribution) represent

11.83% (7% (42 decisions) that are "Complete Free-Riding" and 4.83% (29 decisions) that are "Complete Cooperations"). Most of decisions correspond to a sharing of the initial endowment between the private and the public good. In fact, 41% (246 decisions) of them correspond to an "Incomplete free-riding" behavior, 36.5% (219 decisions) to a "weak free riding" and 10.67% (64 decisions) to a "Incomplete Cooperation".

4 Conclusion

When studying the individual behavior in a public goods game, we find that subjects can adopt either a steady or an oscillating behavior and are most of the time either "Incomplete Free-Riders" or "Weak Free-Riders" (77.5% of the decisions).Although the aggregate result in our experiment corresponds to the general results in literature dealing with the voluntary contribution game, this result is not representative for all groups and all individuals, seeing that neither groups norindividuals have the same behavior. Consequently, we may not look for only one explanation for overcontribution, but rather for different incitations and different possible ways of interaction that determine simultaneously different individual behaviors. Finally, the use of learning models and the econometric methods to analyse the individual behavior could give us more information about the latter. This will be the object of a future work.

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APPENDIX

Instructions to the Experiment:

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 in cash at the end of the experiment.

You will be randomly assigned in the beginning of the experiment to a group of 4 people (you and 3 others). Each group will consist 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 payoff table[5] (*table 1*).

[5] A summerised version (*table 1)* and a more detailed table are given to subjects.

Your total payoff 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 know the total amount that the group allocates to part B, your personal earnings from the part B and your total profit (from part A and part B).

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.

If the group invests in B	The group wins	Your part from the gain of the group
1	35,77	8,94
10	113,13	28,28
20	159,99	39,99
30	195,95	48,98
40	226,27	56,56
50	252,98	63,24
60	277,12	69,28
70	299,33	74,83
80	319,99	79,99
90	339,41	84,85
100	357,77	89,44
110	375,23	93,8
120	391,91	97,97
140	423,32	105,83
160	452,54	113,13
170	466,47	116,61
180	479,99	119,99
190	493,15	123,28
200	505,96	126,49
210	518,45	129,61
220	530,65	132,66
230	542,58	135,64
240	554,25	138,56
250	565,68	141,42
260	576,88	141,42
270	587,87	146,96
280	598,66	149,66

Table 1: The payoff table for the group and the share of each player

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