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Auteurs

Kene Boun My, Benoît Chalvignac

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Faculté des sciences économiques et de gestion
Pôle européen de gestion et d'économie (PEGE)
61 avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Secétariat du BETA
Géraldine Manderscheidt
Tél. : (33) 03 90 24 20 69
Fax : (33) 03 90 24 20 70
manderscheidt@cournot.u–strasbg.fr
http://cournot2.u–strasbg.fr/beta

cnrs
Nancy-Université
Université Nancy 2
UNIVERSITÉ DE STRASBOURG

Voluntary participation and cooperation in a collective-good game

Kene Boun My and Benoît Chalvignac*

BETA, Louis Pasteur University, Strasbourg (France)

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Abstract

We study the effect of voluntary participation in the context of a collective-good experiment. We investigate whether the freedom to participate in the game or not increases contribution levels and enhances their evolution. The analysis of two voluntary participation treatments supports a positive effect of an attractive exit option on both contribution levels and their sustainability. We conclude that the voluntary contribution mechanism can provide sustainable cooperation levels and that the usually observed decay of average contribution levels can be counteracted by voluntary participation in the game.

KEYWORDS: Collective Goods; Cooperation; Voluntary participation ; Laboratory experiments.

JEL CLASSIFICATION CODES: H41; C92.

*Corresponding author. Email: chalvignac@cournot.u-strasbg.fr

1 Introduction

Many tools to foster cooperation and solve the social dilemma in an efficient way have been designed and tested. However, the implementation of these tools is costly, whereas many real life examples, as well as the study of human societies, show that cooperation can be thought of as an emergent phenomenon. Thus, if free-riding behaviour may lead to inefficient social outcomes, the systematic use of costly coercive mechanisms such as taxes or incentives may hinder the emergence of cooperation and reduce the associated benefits where those benefits could be non negligible(Ostrom (2005)).

We specifically address the case of collective production processes, where a sizable group of agents is generating a single outcome which benefits equally all the declared members of the group. Our case can be directly documented by the rich literature on public goods.

Three decades of public-good experiments find that almost all possible outcomes could be observed in voluntary-contribution mechanism settings, either at the individual or at the group levels. Behaviors range from pure free-riding to full contribution, depending on variations of the design and parameter setting. This high heterogeneity of choices and outcomes, combined with the subtle interaction between individual and group levels, may explain why behavioral models have failed up to now to provide robust frames to the analysis of the evolution cooperation once it happens. Results have mainly arisen from treatment comparisons, testing among other things the effect of group size (Isaac and Walker (1988a), Isaac, Walker, and Williams (1994)), multiplier value(Isaac, Walker, and Thomas (1984)), communication(Isaac and Walker (1988b)), or punishment(see, e.g., Fehr and Gächter (1999), Masclet, Noussair, Tucker, and Villeval (2003)). Positive levels of contribution have always been observed in the standard settings of public good games, using the sole voluntary contribution mechanism. At the aggregate level (inter-group average) an average of 50% of the social optimum is the usual level reported for one-shot settings or first period outcomes in repeated settings, followed in the latter case by a progressive decrease (see e.g. Ledyard (1995) for a review). We have thus some evidence that the voluntary contribution mechanism can provide a substantial provision of collective good without resorting to costly additional mechanisms such as monitoring or punishment, which may furthermore not be available.

Since in many real settings where voluntary cooperation can be observed agents have some freedom to choose to interact with partners, or to leave if they are not satisfied, we have used, in addition to the standard public good game setting, a voluntary-participation treatment in which players can exit the game. This gives us the opportunity to test the potential bias created by the standard condition in public good experiments that participation to the game is compulsory. Our results suggest a positive effect of voluntary participation on the evolution of cooperation levels.

Section 2 reviews results from seminal and recent papers related to voluntary participation and endogenous group formation in the presence of social dilemmas. Since we focus on standard linear collective good games outcomes, we refer to Ledyard (1995) comprehensive survey for this part of the related literature. Section 3 presents the experimental settings, theoretical predictions and hypothesis. We present and discuss our results in section 4 and conclude in section 5 with a summary of our results and possible directions for further exploration.

2 Related literature on voluntary participation

To our knowledge, the first experimental setting implementing voluntary participation in a social dilemma game is to be found in Orbell, Schwartz-Shea, and Simmons (1984). They report experimental data from one-shot n-player prisoner's dilemma games. This appears to be a hybrid form of game since it involves several players as in the standard public good game, but the choice offered to the players is binary (cooperate or defect) as in the standard prisoner's dilemma (or more precisely ternary since they added an exit option). Their main investigation was to test whether cooperators would "exit more readily than defectors", so they did not run a baseline treatment. Instead they reversed the usual order of choice and asked first the defect/cooperate choice before the enter/exit choice. Their intuition that cooperators would exit more readily than defectors was strongly contradicted by their results, since proportionally, cooperators were no more likely, and often significantly less likely, to exit than defectors. Their results further confirm the strong effect of communication in increasing cooperation levels. Their design has however some important features that reduce the significance of the results. First they do not provide benchmark results, which would have required testing the exit option against a standard game where players do not have the opportunity to exit. Second, if they actually tested two levels of the exit option named "low" and "high" exit incentives, they chose relatively high values for both parameter levels. The low exit option yields an average return equal to the expected pay-off of the game. Further, the binary cooperate/defect choice does not allow the subjects to fine tune their contribution levels. Finally, they ran one-shot games. We address all these issues: we run a baseline treatment without the exit option; we set our high exit option to the average expected pay-off of the game; we use a ten-level contribution scale; and we run a twenty-period repeated game.

Subsequently, Orbell and Dawes (1993) present results from a one-shot two-player prisoner's dilemma game, with and without the option to play the game. They observed a positive effect of the option not to play the game on the proportion of cooperative interactions.

Hauk (2003) reports results of a repeated multiple prisoner's dilemma game experiment. In the "attractive outside option" setting (i.e. when the pay-off yielded by exiting the game is higher than the mutual defection pay-off) choosing whether to play the game or not with each of the potential partner led to more cooperative relationships relative to active relationships than in the baseline treatment (without outside option) and to higher cooperation levels conditional on entry over the 10 periods. However, a closer examination of the results mitigates this observation in the sense that the average cooperation level per period reported for the exit option treatment is conditional on entry, meaning that the overall cooperation level (percentage of cooperative relationships relative to all possible relationships) may not be higher than in the baseline treatment. In another two-player public good game, Coricelli, Fehr, and Fellner (2004) found that unidirectional partner selection has some positive effect on cooperation, though it does not prevent the decay of contributions over time.

Voluntary teaming has also been observed to increase cooperation levels in the related context of effort games and team incentives by Keser and Montmarquette (2004). Their setting involves a two-player game where each player first chooses between private and team remuneration, then chooses his effort level according to an individual cost function. They compare the outcome of this game to a baseline treatment where teaming is enforced: players cannot choose the private remuneration. They found that effort was significantly higher under the voluntary teaming treatment than under the enforced teaming treatment, in the case of symmetric effort cost functions.

However, contribution levels in social dilemmas have sometimes been observed to be sensitive to group size per se (see e.g. Isaac, Walker, and Thomas (1984) or Ledyard (1995)) and results from two-player games may not be linearly generalized to n-player games.

In n-person public-good games, closer to our setting, Ehrhart and Keser (1999) report a permanent cycle where free-riders chase high contributors, the latter continually escaping by joining smaller groups. Their results support the hypothesis of persistence of both free-riding and cooperative behaviour, but the design neither controlled the net effect of endogenous group size variations, nor provided players the opportunity not to play the game.

Page, Putterman, and Unel (2005) explored the effects of punishment and endogenous group formation. They used a standard repeated public good game setting and a 2×2 design crossing both parameters. Endogenous group formation was implemented by a "regrouping" treatment where players had the opportunity to give their preferences among the other 15 subjects, ranking them as prospective partners. Their results show a 70% average contribution for the regrouping treatment, as compared to 38% in the baseline treatment. Thus, introducing some freedom in the constitution of groups already increased the contribution level. However, this did not appear to be enough to trigger sustained contribution, the results showing a clear decay through the 10 periods. In addition, the experimental design relies on the possibility of an immediate regrouping (groups are rebuilt from one period to the next), which is seldom the case in real settings. Finally, as in Ehrhart and Keser (1999), players cannot exit and stop playing the game.

All these results begin to shed some light on the positive effect of voluntary participation on cooperation levels. However, this stream of work has several limitations. First it is mainly concerned with two-person settings. Second, it does not provide clear clues on the effect of an effective exit option at the aggregate group level. Last, it does not established whether voluntary participation is an efficient feature for sustaining contribution levels when players can really choose not to play the game.

In order to test the robustness of the previous findings in a context of repeated interactions within groups of agents, we extend the settings to an n-player repeated game where the individual pay-off depends on the level of cooperation within the participating group.

3 Experimental settings and treatments

The experiment was carried out at the Laboratoire d'Economie Exprimentale de Strasbourg (LEES) using using our in-house designed data-processing software. 135 voluntary subjects took part in the experiment after being randomly selected through ORSEE[1] among 1200 students from various programs.

None of them had previously confronted public good experiments (inexperienced subjects). Written instructions were distributed and read aloud to the subjects[2] before they performed a pre-experimental test to check proper understanding. The session began as soon as they all had correctly answered every question. No communication was allowed between subjects as long as the

[1]A web-based Online Recruitment System for Economic Experiments developed by Ben Greiner.

[2]See the *Appendix B* for a translated version of the original instructions written in French.

experiment was running. We applied three treatments, namely *B*, *VP-11* and *VP-16* (*B* for baseline treatment, *VP-11* for voluntary participation treatment with a fixed exit payoff of eleven and *VP-16* for voluntary participation treatment with a fixed exit payoff of sixteen). For each treatment we formed randomly nine independent groups of five subjects who played twenty periods with the same partners. Each subject participated in one treatment only and in only one group, so that group data are independent from any group to any other. Table 1 summarizes the experimental treatments.

Table 1: Experimental design.

Treatment	No of sessions	No of independent groups	No of subjects
B	3	9	45
VP-11	3	9	45
VP-16	3	9	45
		Total	135 subjects

3.1 The baseline (B) treatment

In order to link our experiment as closely as possible to existing work either using a voluntary participation mechanism or examining other determinants of cooperation in a traditional public good game setting, we used the most standard form of linear public good game as baseline treatment. This furthermore gave us some clues on what values to choose for the parameters since some combined effects of group size and multiplier value in public good games have already been investigated. Though the net effect of group size variations is not always precisely predictable, it has been shown that for reasonably high values of the multiplier (private return of the collective investment) contribution levels are not correlated with group size (see Isaac, Walker, and Thomas (1984) and Isaac, Walker, and Williams (1994)).

We formed random groups of five subjects and kept the same groups for a repeated game of twenty periods (since we focus on cases where the identity of the agents determines the potential interactions we only used partner treatments). At the beginning of each period, each player i is endowed with $Y_i = 10$ tokens, and chooses how to distribute them between a private account and a public account, named "project". Each player has thus to split her endowment between the two investment possibilities so that all her tokens are invested. The profit Π_i of a player is determined by her contributed amount C_i and by the sum of the contributed amounts of the j other players, and is defined as:

$$\Pi_i = Y_i - C_i + \alpha \sum C_i, C_j \tag{1}$$

with $\alpha = A/N$, $0 < \alpha < 1$, $A > 1$ and where Π_i is player i's pay-off, Y_i is the individual endowment. C_i is player i's contributed amount to the collective account and C_j is the individual contribution of the other participating players. We set α at 0.75, $Y_i = 10$ and used nine groups of five players for each treatment.

Setting the parameter values for the baseline treatment is a crucial choice since the number of players involved in the public good game varies in the second treatment. In order to set an acceptable basis for comparison it was thus necessary to discuss various possible ways of declining expression (1). Varying the number of players in a public good game is not trivial, and to date no clear answer has been given to the effect of group size *per se* on cooperation levels. In the voluntary participation (*VP*) setting, the potential total contribution increases with the number of participating players if α is kept constant. Hamburger, Guyer, and Fox (1975) and Bonacich, Shure, Kahan, and Meeker (1976) give some clues on what can be considered as equivalent public good games when group size varies, which led us to keep α constant so that the marginal substitution rate from the private to the public account is unchanged whatever the number of players participating in the game (N). This also means that the potential individual payoff increases with group size, which can be interpreted as the effect of increasing marginal returns of the collective production function within the scale of the group size (from two to five).

The total contribution of the group is common knowledge at the end of each period and players can display the history of their own contributions and of all past total contributions of the other players. The composition of the group is the same all along the game, and players do not know the identity of their counterparts.

Theoretical predictions and hypothesis:

The game theoretical outcome of the standard public good game we use here is well known to be that no contribution will be made to the public account, since contributing nothing is the only pure dominant strategy for every player. The only Nash equilibrium is thus that all players free-ride and no one contributes. This result holds in both the one-shot and in the repeated games. Were some players to contribute some positive amount, they would immediately see that the best response to the other players' choice is to contribute nothing and the game would rapidly converge to the Nash equilibrium.

Our first hypothesis is that *null or positive decreasing contribution levels will be observed in the baseline treatment.*

3.2 The voluntary participation (*VP*) treatments

In order to test for the direct effect of voluntary participation on contribution levels, we inserted in the two other treatments a first step before the public good game was played, namely the opportunity for players to choose to participate or not in the public-good game. We thus depart from the principles of pure public good that underlay the voluntary contribution mechanism, in order to integrate at the same time two properties of group projects: only identified participants of the project get some reward from the profits associated therewith, which means nothing other than attributing a perimeter to the non-excludability of the "good" ("good" standing for the value created by the agents). Conversely, subjects have thus the opportunity to isolate themselves from the consequences of others' behaviour by opting out. In that case, they get a fixed income, cannot benefit from the collective project but also cannot incur losses induced by other players' choices. The difference between the two VP treatments is the payoff associated with the exit option. In the first voluntary participation treatment (*VP-11*) the pay-off associated with the exit option is the minimum value higher than the minimum certain payoff procured by the collective-good game, so that exiting is a strictly dominating strategy of the stage game. In the second voluntary participation treatment (*VP-16*), the exit payoff is the closest value to the average expected payoff of the collective-good game. We discuss further these choices in the next subsection. The income per period is thus determined as follows: if a player chooses to opt out, then he gets a fixed income (11 in the *VP-11* treatment or 16 in the *VP-16* treatment); if a player chooses to participate in the collective project, he then plays the public good game with the other participants if there are any, or gets a payoff of 10 if he is the only participant.

Before choosing their contribution players participating in the collective project know how many people in their group have chosen to participate. The number of participating players and the total amount contributed to the collective project is common knowledge after the end of the round. Since the effect of group size on contribution levels is not clearly established, we first planned to apply a 2×2 treatment design to test two different pay-off functions, one where α was hold constant whatever N, and a second one where α was varying against N. However, the second function implies a possibly substantial variation of the marginal private incentive not to contribute if the number of players choosing to opt out varies and implies a strong constraint for the value of the multiplier if all players participate.

Theoretical predictions and hypothesis:

As for the two voluntary participation treatments, there should theoretically be no difference in the outcome: in both cases the payoff associated with the exit option is such that opting out is a strictly dominant strategy, entailing a unique Nash equilibrium where no player enters the game. However, since we would expect substantial contribution levels in the first periods, and since voluntary participation has already been shown to improve cooperation rates, players may choose to enter the game and contribute. Once in the game, the situation can be seen as equivalent to the baseline treatment plus the exit option as a credible threat.

We used two different payoffs for the exit option in order to control for the effect of the possibility to choose between participating in the game or not, and to test if a more attractive exit option could be used as a credible threat. Indeed, in the latter case, free-riders know that contributors have a sure alternative in opting out and getting the exit option payoff.

Our second hypothesis is that *an attractive exit option has a positive effect on the evolution of contribution levels, either in giving free-riders an opportunity to exit the game or in providing players with a signalling tool.*

4 Results and discussion

We collected and analyzed for each treatment the average contribution to the public good, in percentage of the socially efficient outcome ($\sum C_{i,j} = N * Y_i = 100\%$), and the number of participants. For the voluntary participation treatments we computed the average contribution both for the whole group ($N = 5$) and conditional on entry (N =number of players opting in).

4.1 Heterogeneity of individual contribution levels: neither Nash nor the optimal social outcome

Table 2 displays the average contributed amount in percentage of the social optimum outcome for each treatment, averaged on the twenty periods. The evolution of average contribution levels among the nine groups of each treatment are displayed in Fig. 1. Our aggregate data follow the usual pattern observed in public good game experiments (see Isaac, Walker, and Thomas (1984)) with a positive contribution to the collective project in the first period, around half of total players endowment, followed by a significant decay.

Table 2: Averaged contributions.

Treatment	B	VP-11	VP-16	VP-16 (on entry)
Average contribution	43%	33%	35%	39%

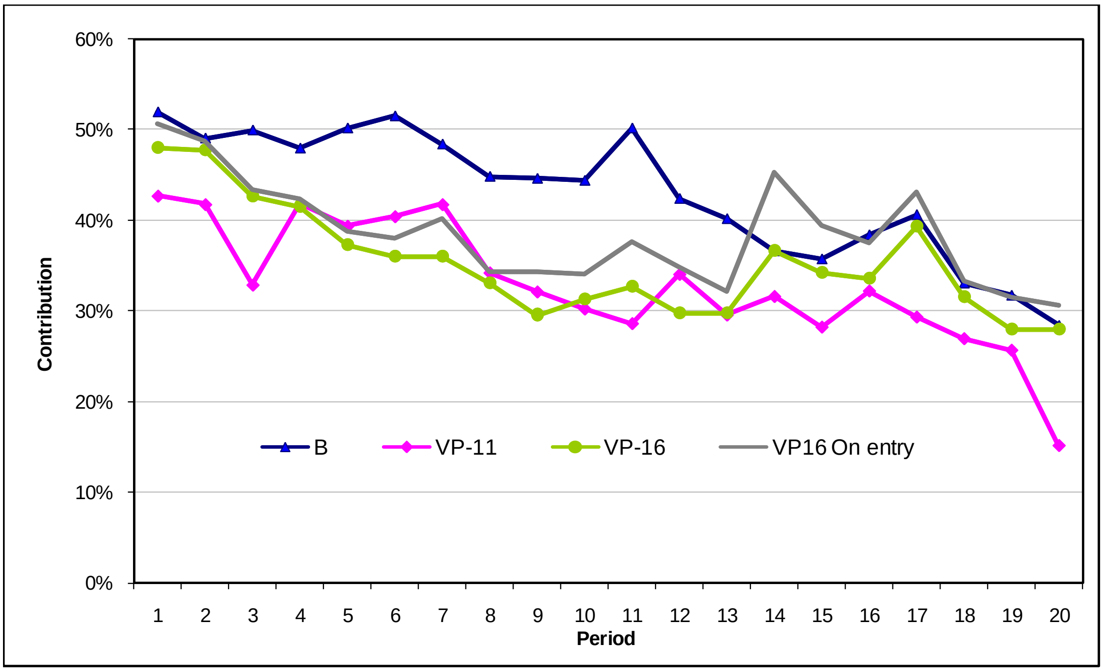

Figure 1: Temporal dynamics of the averagee contributions.

In the three treatments we also observed a wide variety of individual sequential choices. They range from pure free-riding [3] (around 20% of cases in each treatment, around 10% of players for treatment *B* and *VP-11*, and 6% of players for treatment *VP-16* including free-riders who eventually exited) to full contribution (around 10% of all cases and 8% of all players choosing full contribution most of the time), and from unit-by-unit fluctuations to nothing-to-all alternations. We can notice here that in both VP treatments, subjects overwhelmingly failed to recognize that it was a dominant strategy to exit: the exit option was chosen only in 3.5% of all cases in *VP-11* and 16% in *VP-16*. As Ashley, Ball, and C.Eckel (2002) we found a positive correlation between player's first round contribution and their average contribution in the other rounds (Pearson's rho: 0.62). In line with Keser and van Winden (2000) we could also detect a tendency of players to adjust their contributions in the direction of the average contribution of the other players (see Table 3). Almost no random behaviour is identifiable and groups exhibit strong homogeneity in the evolution of contributions, with higher contributing groups tending to keep a high and more sustained average contribution level.

[3] Following Isaac, Walker, and Thomas (1984) and Burlando and Guala (2005) definitions of free-riding, we only use the terms 'free-riders', 'free-riding' or 'pure free-riders' to denote players who contributed nothing since the very first round of the game.

Table 3: Observed reactions to the situation of the player's contribution relative to the average contribution of the other players in his group.

Treatment	Situation	Own contribution	Increase	Decrease	No change
	1	> others	19% (78)	55% (226)	26% (105)
B	2	< others	48% (200)	16% (67)	36% (149)
	3	= others	40% (12)	13% (4)	47% (14)
	1	> others	21% (68)	50% (163)	30% (98)
VP-11	2	< others	32% (61)	14% (140)	54% (235)
	3	= others	34% (12)	11% (4)	54% (19)
	1	> others	17% (52)	55% (167)	28% (84)
VP-16	2	< others	47% (152)	17% (56)	36% (117)
	3	= others	35% (7)	40% (8)	25% (5)

4.2 Treatments *VP* vs. treatment *B*

4.2.1 Average contribution levels

At every period, treatment B exhibits a higher average contribution level than treatment VP-11, though the *Wilcoxon* rank-sum test for group contributions averaged over all periods shows only weak evidence (*p-value* of 0.17), so that the persisting difference can be imputed to uncontrolled heterogeneity of the players. To be sure, a low exit option does not have any positive effect on contribution levels. One possible explanation is that the exit option can induce players to behave more strategically, as if entering the game was associated with an opportunity cost (i.e. losing the fixed pay-off from opting out). This would be an undesirable effect of our VP settings, creating a bias towards lower contributions. It is worth noticing that the exit option was chosen only in 3.5% of all cases in *VP-11*, showing that players mostly failed to recognize or did not play the Nash equilibrium choice when the payoff associated with the exit option was 11. At that level the exit option yields only 1 (10%) more than the Nash equilibrium of the public good game.

As for treatment *VP-16*, no significant difference with treatment B can be found. *P-values* for the *Wilcoxon* rank-sum test are 0.4 if *VP-16* average group contribution values are computed for the whole group, with $N = 5$, and 0.56 if the values are computed conditional on entry. Here again, players largely failed to recognize or did not play the dominant strategy (16% of all cases), even though the payoff associated with the exit option was substantially higher than the Nash equilibrium of the public good game.

4.2.2 Evolution rates

Though we did not find any significant difference between the baseline and voluntary participation treatments in terms of average group contributions, the evolution of contribution levels displayed on the *VP-16* graph let one think that the usual decay observed in public good games was somehow contradicted in this setting. In order to get some clue about the possible difference between treatments concerning the evolution of contribution levels we computed chronologically symmetric average contribution levels. We first compared contribution levels averaged over the ten first rounds and the average over the ten last rounds, for each treatment. In order to take into account the potential bias generated by the end-effect we repeated the same computation using shorter time spans.

Indeed, the final-round tendency towards zero contribution usually observed in public good experiments triggers a general decrease of contributions, which can be solely attributed to the finite horizon of the game. We are rather interested by settings where a possible end of the game for a player is to exit, but where the game can be infinitely repeated. We identified the end-effect rounds according to the evolution of the proportion of players choosing the dominant strategy. From round 17 on we observed a sharp and constant increase of the number of players choosing to contribute nothing in the Baseline, and of the number of players opting out in *VP-16* (from 8% in round 17 up to 22% in round 18). Accordingly, we computed adjusted evolution rates excluding the three last rounds of the time series. We also excluded the three first rounds so as to keep time spans symmetric and to leave first round errors out of the analysis. The evolution rates of average contribution levels are presented in Table 4. The first and the last rounds of the series included in the computation are indexed on *ER*.

Table 4: Evolution of contribution levels by treatment.

Treatment	ER_{1-20}	ER_{4-17}
B	-22%	-14%
VP-11	-25%	-18%
VP-16	-16%	-4%
VP-16(on entry)	-10%	3%

When all rounds are included in the computation, we can see that the rate of decrease of average contributions conditional on entry in treatment *VP-16* is less than half than the decrease rate observed in the Baseline treatment. In absolute value the difference is equivalent to less than one token per player in *VP-16*, as compared to around two tokens per player in Baseline. The difference between the two treatments is weaker if the computation for *VP-16* contribution levels is made relative to the whole group, but the decay is still more limited in *VP-16* than in Baseline. *VP-11* exhibits the strongest decrease rate, suggesting that voluntary participation *per se* is not sufficient to counteract the general decay of cooperation in public good games.

If the time-span is reduced in such a way as not to include the end-effect (evolution rates are computed excluding the three first and the three final rounds), the evolution rates of the three treatments are ranked in the same order as previously but the difference between *VP-16* and Baseline is sharper. In addition, the evolution for *VP-16* is positive if contribution levels are computed conditional on entry.

These observations are confirmed by Spearman's rank correlation between periods and treatment average contributions ($rho = -0.89$ for *B* and $rho = -0.62$ for *VP-16* when the test is run aver all rounds, and respectively $rho = -0.82$ and $rho = 0.03$ when the test is run over rounds 4 to 17).

Using Page's trend test on average contributions per treatment per round, we found similarly that the null hypothesis of the absence of a decrease trend can be rejected at the 0.05 level for all three treatments when all rounds are considered. When the end-effect is isolated, the result of the test is the same for treatment *B* and *VP-11* but the null hypothesis cannot be rejected for treatment *VP-16* (*p-value*: 0.368).

These findings support our hypothesis that an attractive exit option has a positive effect on the evolution of contribution levels since no tendency towards decreasing contribution can be identified in VP-16 average contribution conditional on entry when the end-effect is isolated.

Table 5 displays a finer description of the evolution dynamics observed in each treatment. We divided the whole time span into four blocks of five rounds and computed for each block the evolution rate, using the first round in the block as a benchmark. The first and the last rounds of the corresponding time block are indexed on *ER*. As we will discuss below (see 4.2.3), VP-16 exhibits a much drastic adjustment during the first five rounds than B. Though evolution rates are quite similar in the second time block, the subsequent reversal of the contribution trend observed for VP-16 in the third block contrasts sharply with the highest decreasing rate observed for B. Finally, the end effect seems stronger in B than in VP-16, though no significant difference can be found.

Table 5: Evolution of contribution levels within time blocks, by treatment.

Treatment	ER_{1-5}	ER_{6-10}	ER_{11-15}	ER_{16-20}
B	-3%	-14%	-29%	-26%
VP-11	-8%	-25%	-1%	-53%
VP-16	-22%	-13%	+5%	-17%
VP-16 (on entry)	-23%	-10%	+5%	-18%

4.2.3 Group dynamics

Since the differences we found between treatments could have been generated by one or few extreme group values we applied the same procedure to the average group data and ran Wilcoxon rank-sum tests to compare each VP treatment with the baseline (Table 6).

Table 6: Evolution of contribution levels by treatment and by group.

				***Treatment* B**					
Group	1	2	3	4	5	6	7	8	9
ER_{1-20}	-22%	-22%	-51%	-32%	-2%	-33%	-11%	-15%	-26%
ER_{4-17}	-8%	-21%	-35%	-24%	**0%**	-29%	-5%	-13%	-9%
				***Treatment* VP-11**					
Group	10	11	12	13	14	15	16	17	18
ER_{1-20}	-13%	-73%	-15%	-45%	-11%	-62%	-64%	**14%**	-32%
ER_{4-17}	-8%	-73%	**2%**	-27%	**1%**	-44%	-66%	**18%**	-29%
				Treatment* VP-16 *(overall)					
Group	19	20	21	22	23	24	25	26	27
ER_{1-20}	-44%	-64%	-25%	-39%	**4%**	**2%**	-67%	-15%	**58%**
ER_{4-17}	-26%	-26%	-1%	-34%	**11%**	**1%**	-48%	-10%	**68%**
				Treatment* VP-16 *(on entry)					
Group	19	20	21	22	23	24	25	26	27
ER_{1-20}	-41%	-45%	-4%	-15%	**2%**	-1%	-47%	-14%	**60%**
ER_{4-17}	-25%	-2%	27%	-7%	**11%**	-1%	-31%	-8%	**71%**

We can immediately see that none of the nine groups under the Baseline treatment exhibits positive evolution rates between the first and the second time series. By contrast, in treatment *VP-16*, the evolution is positive for three groups whatever the time span used. Within the VP-11 groups, the group with highest contribution increases its average contribution level by 14% and two others exhibit a positive though weak evolution rate if the time-span is reduced. This can be interpreted as more evidence that the exit option is not a neutral feature and can even, at the group level, trigger a reversal of the 'downwards spiral' of declining contributions usually observed in public good experiments.

If we compare the number of groups where average contribution either increases or decreases by less than one token (evolution rate between -10% and 0%), there is only one out of nine in Baseline as compared to four out of nine in VP-16 conditional on entry with the ten-period time span, and respectively four (less than half) and seven (more than half) with the seven-period time-span. This tends to support further the idea that voluntary participation can sustain contribution levels in such a way that they may even increase over time.

We further found that the evolutions of the averaged group contributions were significantly higher in treatment *VP-16* than in treatment B (*Wilcoxon* rank-sum test), rejecting the null hypothesis that the two treatments showed no difference on the evolution of the average group contributions with a p-value of 0.08. We did not find a significant difference between *B* and *VP-11*, in either time span.

We also observed over all three treatments that in the highest contributing groups, contribution levels tended to stabilize more than in other groups. Running Page's trend tests on group average contributions we found that the groups for which the null hypothesis of no decreasing trend could not be rejected also exhibited the highest average contributions over the whole time span. We obtained the same result for all treatments. Among those groups, in the ones in the voluntary participation treatment, the average contribution and the homogeneity among contributions were thus high enough through all periods to dominate the choice to opt out. By contrast, and expectedly, players in lowest contribution groups opted out much faster in *VP-16* than in *VP-11*, and much more (16% vs. 3.5% of all choices). This can also be one of the reason why the average contribution level in treatment *VP-16* follows a more decreasing path than in treatment Baseline at the beginning of the game: players exit non-profitable collective-good games as soon as the exit option is more attractive, instead of progressively decreasing their contribution as players in the Baseline treatment usually do. Conversely, since pulsing is the only available mean for players to influence others' contributions in treatment Baseline, it creates an incentive to increase their own contribution that would be ruled out by the exit choice in treatment *VP-16*.

4.2.4 Individual behaviour: the exit option as a (non-)credible threat?

As for the net effect of the exit option on players' contribution choices, closer observation is needed. In the *VP-16* treatment, the average contribution level over all nine groups is similar to the Baseline treatment for the two first periods. It then decreases rapidly down to the level observed in the VP-11 treatment, up to period 13 where it visibly increases and reaches again the level displayed by the Baseline treatment. In between, the difference between the two treatments is only marginally significant, and from period 14 onwards the difference between average contribution levels is negligible. Looking at the individual data of treatment *VP-16*, we could observe one recurrent pattern of the use of the exit option that differs from *VP-11* and that could explain the unusual evolution of the average contribution level in *VP-16*: first some higher contributors (defined as the players exhibiting average contributions to the collective project since the first period higher than group average, *HC*, as opposed to low contributors, *LC*) exit, leaving the others in a situation very similar to the "low contribution" groups where contribution is still decaying. Contrarily to what happens in *VP-11* settings, though, the exit option becomes immediately highly attractive and the remaining players either exit or increase their contribution to the collective project. For some reason (*LC* may observe that they had been much better off before opting out, *HC* may notice that total contribution level is increasing again) exiting players join back. This dynamic process fully occurred in groups exhibiting middle contribution levels, which could be described as "mixed population" groups and represent one third of our observations in *VP-16* treatment. In those groups, thus, the voluntary participation mechanism did not properly drive the *LC* out of the project, but rather induced them to join back and contribute higher than their "natural" level ("natural" meaning corresponding to their level before or without the exit option). Since only a rough indication of other players' individual profits is available to players, as long as *HC* are better off in the project *LC* (and among them pure free-riders) are induced to reproduce their choice. From the point when the *HC*'s interest is to opt out, the *LC* are faced with the choice of increasing their contribution (pulsing or signalling) or opting out too. The outcome is a noticeable and durable impulse on the average contribution level in those groups, which can clearly be seen at the aggregated inter-group average too (see Fig. 1). In the VP-11 treatment, the exit option was too low to be used to create this kind of credible threat.

The described dynamics do not directly support the hypothesis of the use of the exit option as a systematic signalling or punishment tool, and do not imply a net positive impact of voluntary participation on inter-group average contribution levels. However, it has been shown that the existence of an attractive exit option could trigger a reversal of the decaying tendency of contribution levels in groups where free-riding behaviour would have otherwise hindered sustainable cooperation.

5 Conclusion

Our results provide some evidence that the freedom to participate or not in public good games has some positive effect on players' contributions over time and can counteract the decay of contribution levels usually observed. More precisely, a positive evolution of contribution levels was observed in the third part of the whole time span in treatment *VP-16* where an attractive exit option was available. It also appears that the possible alternatives need to be attractive enough compared to the potential payoffs associated with participating in the game, otherwise the exit option has no positive effect.

Two kinds of implications follow. First, though the exit option per se was not enough to reach the social optimum contribution levels, it fostered sustained cooperation in some groups without resorting to coercive mechanisms. Thus, the voluntary contribution mechanism should be considered as a possible candidate for the provision of collective goods involving small groups, and in a way as a first candidate to be tested before the implementation of costly coercive mechanisms. The latter may furthermore hamper trust and motivation.

Second, considering the large range covered by public good situations where agents can effectively choose to enter the game or to exit, experimental settings where participation to the public good game is compulsory may generate an important bias. Moreover, the heterogeneity among players that explains inter-group differences is not visible in the aggregated data, which calls for a careful examination of the interplay between treatment effects and group effects in experimental studies since treatment effects may not be homogenous across groups.

Many contributions are still needed to refine the behavioral assumptions used to build models explaining the emergence of cooperation in the context of small group production and to disentangle experimental framing effects from the real case features reproduced.

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Appendix A. Additional figures

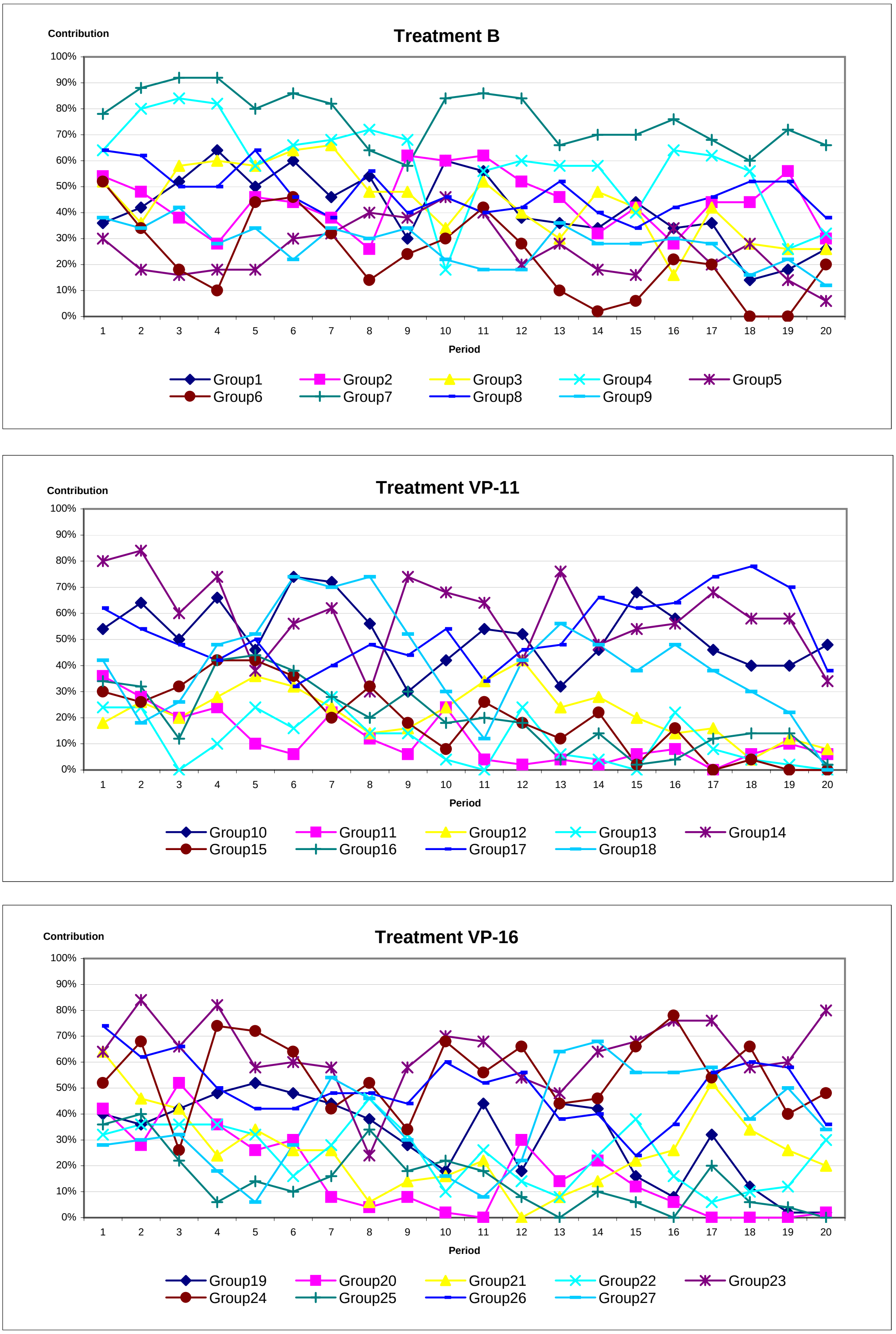

Figure 2: Temporal dynamics of the average contributions by group in each treatment.

Appendix B. Translated instructions

The original instructions were written in French. Here we include only the translation of the instructions used in treatment (VP-11). The instructions for the other treatments involve only minor changes from those reprinted here. Please note that these translated instructions from French are not necessary for a publication and they could be made available on a specific webpage if necessary.

Welcome

You are going to take part in a social science experiment. If you follow thoroughly these instructions, your choices will allow you to earn some amount of money. All your answers will be collected through a computer network and handled anonymously.

You are insistently asked **not to communicate with the other participants**. If you have questions concerning these instructions, please raise your hand when you are invited to do it. You will directly fill in your choices on the computer in front of which you are sitting. It will inform you of your realized payoffs as the experience goes on.

Your realized payoffs will depend on both the decisions you take and on the decisions taken by the other members of your group. These payoffs will be counted in points. The total amount of points you will earn during the experiment will be converted in euros, at the end of the experiment, and will be paid to you. The exact conversion procedure from points to euros is exposed at the end of these instructions.

General setting of the experiment

15 people are participating to this experimental session. These 15 people will be randomly attributed to three groups of five persons each. You will thus be a member of one of these groups of **5 people**. You cannot know the identity of the other members of your group, either during the experiment, or after. You will interact only with the four other members of your group all along the experiment and never with the other people in the room.

The experiment will last for **20 rounds**.

One round

At the beginning of each round, every member of your group including yourself is endowed with **10 tokens**. This endowment will be the same whatever choices have been made at the previous rounds.

Each round is composed of two steps:

First step

At this step you can choose to participate to a common project.

- If you choose not to participate to the project the round is over for you. Your gain for the round will be 11 points (10 points from your tokens plus 1 extra point).
- If you choose to participate you will be informed of the number of members of your groups participating to the project as soon as all them have made their choice. The second step will then start.

Second step

At this step you, for each token from your endowment you can choose to attribute it to a common project or to keep it. You will type in the number of tokens, between 0 and 10, which you attribute to the common project.

Your total gain (number of points) for the round is the sum of:

- a revenue generated by the tokens you kept: one point from each kept token.
- a revenue generated by the common project, equalling 0.75 times the total amount of tokens attributed to the project by all the members of your group participating in the project. It is thus equal to: 0.75 x Total contribution of all the participating members.

On the table that you have been given you can read the total gain (revenue from kept tokens + revenue from the project) that you can get depending on the number of participants, on your own contribution (number of tokens you chose to attribute to the project) and on the total contribution of the other participants (total amount of tokens attributed to the project by the other participants):

- Select in the first column of the table the number of participants in the project (including yourself) which you know after the end of the first step.
- Select the column corresponding to your contribution to the project and the line corresponding to the total contribution of the other participants. At the intersection you can read the total gain (number of points you get) generated if those values are chosen at the current round.
- Special case: If you are the only participant you simply keep your endowment. Your gain for the round is thus 10 points.

You will not know the decisions taken by the other members of your group before the end of the current round. Once all members of your group have confirmed their choice(s) the revenue generated by the project is calculated, as well as the gain of each member. You are then informed of your own gain for the round and of the total contribution of your group. If you had chosen not to participate in the project you will also know the number of participants at the end of the current round.

The next round begins as soon as all the members of your group are ready.

Illustrative examples:

Example 1: Suppose that at the first step you have chosen to participate to the project and that your computer informs you that 4 members of your group have chosen to participate (you and three other members of your group). The second step starts and you have to choose how many tokens you want to attribute to the common project. Suppose that you choose to contribute 6 tokens. Suppose that the other participants have meanwhile chosen to invest 18 tokens altogether (you will only know this amount at the end of the round). Your total gain would then be of 22 points (4 points from the tokens you kept plus 0.75 $\times$ (18 + 6) = 18 points corresponding to your revenue from the project).

Example 2: Suppose that at the first step you have chosen not to participate to the project. You have no other decision to take for that round. Once all the members of your group have made their choices the last screen of the round is displayed. That screens shows how many members of your group participated to the project, the total contribution to the project, and your gain for that round (11 points).

History table

At any point in the game you can display the history table. It shows for each past round: your decision to participate or not to the common project, the number of participants to the common project (from 1 to 5 out of the 5 members of your group, including yourself if you chose to participate), your own contribution to the project if you chose to participate, the total contribution of your group to the project, your total gain for the round, your cumulated gains.

Payoff

Once the 20th round is over your computer will display the total amount of your gains in number of points cumulated over the 20 rounds. This total amount is simply the sum of the points you earned at each round. It is then converted into euros. The conversion rate is 1 euro for 20 points: one point is valued 0.05 euros. For example, if you earned 300 points at the end of the experiment, you will get 15 euros cash.

Before starting the experiment, the instructions will be read aloud, and you will have to answer a control questionnaire in order to check your understanding of the instructions. If you make too many mistakes when answering the control questionnaire then you will not be able to participate in the experiment.

Good luck!

Table 7: Payoff tables included in the instructions

Your total gain depending on the number of tokens you allocated to the project (from 0 to 10) and on the total contribution of the other participants in the project.

If you are the only member of your group to participate to the project	**your total gain is 10 whatever contribution you choose**

			If your contribution is (number of tokens):										
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
If 2 members of your group participate (you and another one)	**and if the other participant contributes (number of tokens):**	**0**	10	9,75	9,5	9,25	9	8,75	8,5	8,25	8	7,75	7,5
		1	10,75	10,5	10,25	10	9,75	9,5	9,25	9	8,75	8,5	8,25
		2	11,5	11,25	11	10,75	10,5	10,25	10	9,75	9,5	9,25	9
		3	12,25	12	11,75	11,5	11,25	11	10,75	10,5	10,25	10	9,75
		4	13	12,75	12,5	12,25	12	11,75	11,5	11,25	11	10,75	10,5
		5	13,75	13,5	13,25	13	12,75	12,5	12,25	12	11,75	11,5	11,25
		6	14,5	14,25	14	13,75	13,5	13,25	13	12,75	12,5	12,25	12
		7	15,25	15	14,75	14,5	14,25	14	13,75	13,5	13,25	13	12,75
		8	16	15,75	15,5	15,25	15	14,75	14,5	14,25	14	13,75	13,5
		9	16,75	16,5	16,25	16	15,75	15,5	15,25	15	14,75	14,5	14,25
		10	17,5	17,25	17	16,75	16,5	16,25	16	15,75	15,5	15,25	15

			If your contribution is (number of tokens):										
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
If 3 members of your group participate (you and two other ones)	**and if the two other participants contribute altogether (number of tokens):**	**0**	10	9,75	9,5	9,25	9	8,75	8,5	8,25	8	7,75	7,5
		1	10,75	10,5	10,25	10	9,75	9,5	9,25	9	8,75	8,5	8,25
		2	11,5	11,25	11	10,75	10,5	10,25	10	9,75	9,5	9,25	9
		3	12,25	12	11,75	11,5	11,25	11	10,75	10,5	10,25	10	9,75
		4	13	12,75	12,5	12,25	12	11,75	11,5	11,25	11	10,75	10,5
		5	13,75	13,5	13,25	13	12,75	12,5	12,25	12	11,75	11,5	11,25
		6	14,5	14,25	14	13,75	13,5	13,25	13	12,75	12,5	12,25	12
		7	15,25	15	14,75	14,5	14,25	14	13,75	13,5	13,25	13	12,75
		8	16	15,75	15,5	15,25	15	14,75	14,5	14,25	14	13,75	13,5
		9	16,75	16,5	16,25	16	15,75	15,5	15,25	15	14,75	14,5	14,25
		10	17,5	17,25	17	16,75	16,5	16,25	16	15,75	15,5	15,25	15
		11	18,25	18	17,75	17,5	17,25	17	16,75	16,5	16,25	16	15,75
		12	19	18,75	18,5	18,25	18	17,75	17,5	17,25	17	16,75	16,5
		13	19,75	19,5	19,25	19	18,75	18,5	18,25	18	17,75	17,5	17,25
		14	20,5	20,25	20	19,75	19,5	19,25	19	18,75	18,5	18,25	18
		15	21,25	21	20,75	20,5	20,25	20	19,75	19,5	19,25	19	18,75
		16	22	21,75	21,5	21,25	21	20,75	20,5	20,25	20	19,75	19,5
		17	22,75	22,5	22,25	22	21,75	21,5	21,25	21	20,75	20,5	20,25
		18	23,5	23,25	23	22,75	22,5	22,25	22	21,75	21,5	21,25	21
		19	24,25	24	23,75	23,5	23,25	23	22,75	22,5	22,25	22	21,75
		20	25	24,75	24,5	24,25	24	23,75	23,5	23,25	23	22,75	22,5

			If your contribution is (number of tokens):										
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
If 4 members of your group participate (you and three other ones)	**and if the three other participants contribute altogether (number of tokens):**	**0**	10	9,75	9,5	9,25	9	8,75	8,5	8,25	8	7,75	7,5
		1	10,75	10,5	10,25	10	9,75	9,5	9,25	9	8,75	8,5	8,25
		2	11,5	11,25	11	10,75	10,5	10,25	10	9,75	9,5	9,25	9
		3	12,25	12	11,75	11,5	11,25	11	10,75	10,5	10,25	10	9,75
		4	13	12,75	12,5	12,25	12	11,75	11,5	11,25	11	10,75	10,5
		5	13,75	13,5	13,25	13	12,75	12,5	12,25	12	11,75	11,5	11,25
		6	14,5	14,25	14	13,75	13,5	13,25	13	12,75	12,5	12,25	12
		7	15,25	15	14,75	14,5	14,25	14	13,75	13,5	13,25	13	12,75
		8	16	15,75	15,5	15,25	15	14,75	14,5	14,25	14	13,75	13,5
		9	16,75	16,5	16,25	16	15,75	15,5	15,25	15	14,75	14,5	14,25
		10	17,5	17,25	17	16,75	16,5	16,25	16	15,75	15,5	15,25	15
		11	18,25	18	17,75	17,5	17,25	17	16,75	16,5	16,25	16	15,75
		12	19	18,75	18,5	18,25	18	17,75	17,5	17,25	17	16,75	16,5
		13	19,75	19,5	19,25	19	18,75	18,5	18,25	18	17,75	17,5	17,25
		14	20,5	20,25	20	19,75	19,5	19,25	19	18,75	18,5	18,25	18
		15	21,25	21	20,75	20,5	20,25	20	19,75	19,5	19,25	19	18,75
		16	22	21,75	21,5	21,25	21	20,75	20,5	20,25	20	19,75	19,5
		17	22,75	22,5	22,25	22	21,75	21,5	21,25	21	20,75	20,5	20,25
		18	23,5	23,25	23	22,75	22,5	22,25	22	21,75	21,5	21,25	21
		19	24,25	24	23,75	23,5	23,25	23	22,75	22,5	22,25	22	21,75
		20	25	24,75	24,5	24,25	24	23,75	23,5	23,25	23	22,75	22,5
		21	25,75	25,5	25,25	25	24,75	24,5	24,25	24	23,75	23,5	23,25
		22	26,5	26,25	26	25,75	25,5	25,25	25	24,75	24,5	24,25	24
		23	27,25	27	26,75	26,5	26,25	26	25,75	25,5	25,25	25	24,75
		24	28	27,75	27,5	27,25	27	26,75	26,5	26,25	26	25,75	25,5
		25	28,75	28,5	28,25	28	27,75	27,5	27,25	27	26,75	26,5	26,25
		26	29,5	29,25	29	28,75	28,5	28,25	28	27,75	27,5	27,25	27
		27	30,25	30	29,75	29,5	29,25	29	28,75	28,5	28,25	28	27,75
		28	31	30,75	30,5	30,25	30	29,75	29,5	29,25	29	28,75	28,5
		29	31,75	31,5	31,25	31	30,75	30,5	30,25	30	29,75	29,5	29,25
		30	32,5	32,25	32	31,75	31,5	31,25	31	30,75	30,5	30,25	30

			If your contribution is (number of tokens):										
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
If all 5 members of your group participate (you and all the four other ones)	**and if the four other participants contribute altogether (number of tokens):**	**0**	10	9,75	9,5	9,25	9	8,75	8,5	8,25	8	7,75	7,5
		1	10,75	10,5	10,25	10	9,75	9,5	9,25	9	8,75	8,5	8,25
		2	11,5	11,25	11	10,75	10,5	10,25	10	9,75	9,5	9,25	9
		3	12,25	12	11,75	11,5	11,25	11	10,75	10,5	10,25	10	9,75
		4	13	12,75	12,5	12,25	12	11,75	11,5	11,25	11	10,75	10,5
		5	13,75	13,5	13,25	13	12,75	12,5	12,25	12	11,75	11,5	11,25
		6	14,5	14,25	14	13,75	13,5	13,25	13	12,75	12,5	12,25	12
		7	15,25	15	14,75	14,5	14,25	14	13,75	13,5	13,25	13	12,75
		8	16	15,75	15,5	15,25	15	14,75	14,5	14,25	14	13,75	13,5
		9	16,75	16,5	16,25	16	15,75	15,5	15,25	15	14,75	14,5	14,25
		10	17,5	17,25	17	16,75	16,5	16,25	16	15,75	15,5	15,25	15
		11	18,25	18	17,75	17,5	17,25	17	16,75	16,5	16,25	16	15,75
		12	19	18,75	18,5	18,25	18	17,75	17,5	17,25	17	16,75	16,5
		13	19,75	19,5	19,25	19	18,75	18,5	18,25	18	17,75	17,5	17,25
		14	20,5	20,25	20	19,75	19,5	19,25	19	18,75	18,5	18,25	18
		15	21,25	21	20,75	20,5	20,25	20	19,75	19,5	19,25	19	18,75
		16	22	21,75	21,5	21,25	21	20,75	20,5	20,25	20	19,75	19,5
		17	22,75	22,5	22,25	22	21,75	21,5	21,25	21	20,75	20,5	20,25
		18	23,5	23,25	23	22,75	22,5	22,25	22	21,75	21,5	21,25	21
		19	24,25	24	23,75	23,5	23,25	23	22,75	22,5	22,25	22	21,75
		20	25	24,75	24,5	24,25	24	23,75	23,5	23,25	23	22,75	22,5
		21	25,75	25,5	25,25	25	24,75	24,5	24,25	24	23,75	23,5	23,25
		22	26,5	26,25	26	25,75	25,5	25,25	25	24,75	24,5	24,25	24
		23	27,25	27	26,75	26,5	26,25	26	25,75	25,5	25,25	25	24,75
		24	28	27,75	27,5	27,25	27	26,75	26,5	26,25	26	25,75	25,5
		25	28,75	28,5	28,25	28	27,75	27,5	27,25	27	26,75	26,5	26,25
		26	29,5	29,25	29	28,75	28,5	28,25	28	27,75	27,5	27,25	27
		27	30,25	30	29,75	29,5	29,25	29	28,75	28,5	28,25	28	27,75
		28	31	30,75	30,5	30,25	30	29,75	29,5	29,25	29	28,75	28,5
		29	31,75	31,5	31,25	31	30,75	30,5	30,25	30	29,75	29,5	29,25
		30	32,5	32,25	32	31,75	31,5	31,25	31	30,75	30,5	30,25	30
		31	33,25	33	32,75	32,5	32,25	32	31,75	31,5	31,25	31	30,75
		32	34	33,75	33,5	33,25	33	32,75	32,5	32,25	32	31,75	31,5
		33	34,75	34,5	34,25	34	33,75	33,5	33,25	33	32,75	32,5	32,25
		34	35,5	35,25	35	34,75	34,5	34,25	34	33,75	33,5	33,25	33
		35	36,25	36	35,75	35,5	35,25	35	34,75	34,5	34,25	34	33,75
		36	37	36,75	36,5	36,25	36	35,75	35,5	35,25	35	34,75	34,5
		37	37,75	37,5	37,25	37	36,75	36,5	36,25	36	35,75	35,5	35,25
		38	38,5	38,25	38	37,75	37,5	37,25	37	36,75	36,5	36,25	36
		39	39,25	39	38,75	38,5	38,25	38	37,75	37,5	37,25	37	36,75
		40	40	39,75	39,5	39,25	39	38,75	38,5	38,25	38	37,75	37,5