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REGULAR ARTICLE

Participation in and provision of public goods: Does granularity matter?

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Abstract
We use public goods games to experimentally investigate the effect of granularity (i.e., the degree of divisibility of the space of feasible contribution options) on participation (whether individuals contribute or not to the public good) and public goods provision (total contribution to the public good). Our results show that granularity has a significant effect on participation, mainly when coarser granularity eliminates the possibility of small contributions. However, this change in participation does not lead to a significant change in the total provision of the public good. These results are aligned with other experimental field results obtained in the context of donations and fundraising.

Keywords Public good · Granularity · Participation · Total provision · Lab-experiment

JEL Classification C91 · C92 · H41

1 Introduction

Many institutions and organizations request contributions from citizens to provide goods and services that have, to a certain extent, characteristics of public goods: consumption is non-rival and non-excludable. This is the case of health-related institutions (e.g., the American Cancer Society, the American Autism Association and their equivalents in other countries) or environment-related institutions (e.g., Greenpeace, the World Wildlife Fund, the Global Footprint Network or SEO Birdlife), among others. Citizens' contributions are also acknowledged for the preservation of historical buildings or cultural heritage, especially after tragedies like the Brazilian National Museum fire in 2018 or the Notre Dame fire in 2019. The difficulties to obtain public funding

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for the goals of these health and environment-related institutions or an insufficient public budget to ensure the proper maintenance of historical buildings make private donations worth considering.

Leaving aside the contributions of philanthropists and great fortunes, all these institutions seek to increase fundraising among ordinary citizens; funds that allow them to provide public goods such as health care research, the preservation of natural resources and the environment or the maintenance of historical buildings. On many occasions, however, it is precisely the characteristics of these public goods that make it difficult to obtain funds: the ordinary citizen acts as a free rider, benefiting from the achievements without contributing. In this setting, the above institutions look for strategies to increase fundraising either by increasing the number of individuals who donate and/or increasing the amount of individual donations.

Most public goods games literature focuses on the level of provision of the public good. However, participation, understood as the act of contributing any positive amount, has generally received little attention as an intrinsically valuable end in this literature. Authors such as Cialdini and Schroeder (1976), Weyant and Smith (1987), Doob and McLaughlin (1989), Desmet (1999), Martin and Randal (2008) observe, both, participation and provision of the public good. There are various reasons why the very act of participation is worthy of consideration: (i) efficacy of extensive participation in the public good, (ii) participation as social capital, (iii) signaling, (iv) group identification and monitoring, and (v) the value of civic virtue.

Efficacy of extensive participation in the public good The provision of public goods is typically the result of a sustained act of contribution, such as in the case of charity fund-raising or management of the commons. In such cases there is a much higher risk that the provision of the public good will not persist when it is in the charge of a few major contributors than when it is the result of an extensive contributive strategy.[1] In addition, there are good reasons to believe that the probability of participating in the future in the provision of a public good is higher when individuals have already interacted in the past (see Freedman and Fraser 1966; Bowles and Gintis 2002; Sobel 2002; Anderson et al. 2004).

Participation as social capital Since the publication of the studies by Robert Putnam in the 90's there has been broad acceptance among sociologists, political scientists and economists that social capital deserves attention as a source of economic development and growth (Knack and Keefer 1997; Grootaert 2003). There are numerous definitions of social capital, but all agree that voluntary participation in the configuration of a social network that serves to share resources and coordinate actions is an inherent characteristic of social capital. Attributes such as the horizontality of social interaction and trust are also basic ingredients of social capital. In this sense, participation in the provision of a public good is, perhaps, the most genuine form of creation of social capital (see, for instance, the various examples of "community governance" in Bowles and Gintis (2002)).

[1] An example of the risk of the provision of a public good depending heavily on large contributors is the withdrawal of US funding to the WHO following the onset the Covid-19 pandemic. Through assessed contributions (dues paid by member countries based on income and population) and voluntary contributions, US contributions account for 20% of the WHO budget (Huang 2020).

Without neglecting the importance of the extent of contributions, the very act of participating has the dichotomous effect of either activating the network connection or not. Social capital grows when people just participate. In fact, numerous empirical studies use the scope of participation (in terms of the number of affiliations or membership of voluntary groups) as an indicator of social capital (see, for example, Putnam 2000; Anderson et al. 2004; Carpenter et al. 2004).

Participation in pursuit of the provision of a public good creates a cooperative institution: The more concentrated the participation the weaker the institution is. Putnam (1993, 2000) argues that it is extensive networks, rather than narrow and dense ones, that leads to a cohesive and well-functioning society (see also Leonard et al. 2010). Meinzen-Dick (1997) and Ostrom (1995) show practical examples of how extensive community participation overcomes the free riding problem in local and regional projects. Wollebaek and Selle (2003) find that the scope of involvement in associations is a more powerful predictor of civil engagement than the intensity of involvement.

Signaling In addition, participation signals individual types. In a standard public goods game, those who participate, even with small quantities, reveal that they do not belong to the *Homo oeconomicus* type. This information can be used to implement redistributive policies that help assure the future provision of public goods (Andreoni 1990) or to create "warm lists" of donors who have previously given, to be considered for future charitable fund-raising projects (Lange et al. 2007).The frequency of interactions also helps to refine the expectations of community members in a social environment with frequent cooperation opportunities (Bowles and Gintis 2002).

Group identification and monitoring Fehr and Gachter (2000) find that people who belong to an identifiable group are more strongly motivated to punish free-riding. The very act of participation creates a sense of identification and commitment to an end (Wollebaek and Selle 2003). One way in which social connections contribute to cooperative social interaction is, precisely, by providing a vehicle for the multilateral monitoring of free-riding behavior.

The value of civic virtue Last but not least, a long tradition in political philosophy dating back to Aristotle stresses the value of civic virtue, understood as the intrinsic and instrumental values of participation in politics and social affairs which, typically, take the form of public goods, such as participation in electoral processes and political associationism.

Economic and social psychology experiments, both in the laboratory and in the field, have provided a methodology to test different alternatives for fundraising and to study how different factors affect giving behavior in a public goods context. One of the first strategies that was tested was the legitimization of paltry contributions, also known as the "even a penny will help" strategy (Cialdini and Schroeder 1976; Brockner et al. 1984; Weyant and Smith 1987; Doob and McLaughlin 1989; Shearman and Yoo 2007, among others). This strategy tests whether legitimizing small donations increases the likelihood of giving and whether it affects the amount of individual donations. Using a field experiment, Cialdini and Schroeder (1976) found that small requests lead to a significantly higher frequency of donations and to no difference in the mean donation per active contributor ending, therefore, in greater fundraising. Similar results have been obtained by Brockner et al. (1984) and Shearman and Yoo (2007).

Following this hypothesis, Weyant and Smith (1987) conducted two field experiments in which donations were requested for the American Society under three conditions: (i) standard request for contributions (control treatment); (ii) suggesting small amounts and (iii) suggesting large amounts. In both experiments, suggesting large amounts decreased participation, while only in the first experiment suggesting small amounts increased participation. On the other hand, the total size of the contributions did not increase or decrease significantly across the treatments. Doob and McLaughlin (1989) replicated the same kind of field experiment, but unlike Weyant and Smith (1987) found no difference in participation.

Another well known strategy is the use of social information about other donors and donations (Martin and Randal 2008; Shearman and Yoo 2007; Croson and Shang 2008; Shang and Croson 2009; Name-Correa and Yildirim 2016, among others). This strategy tests whether social information about the giving behavior of others affects the rate of giving or the amount of the donation. Martin and Randal (2008) performed a field experiment in an art gallery where admission was free but donations could be deposited in a transparent box. The different treatments consisted in manipulating what was visible in the donation box: either an empty box, a large amount of coinage, a few \$50 bills or several \$5 bills, with the last three containing the same amount of money. By doing so, they provided signals about the social norm regarding donations. The highest propensity to donate (participation) was obtained in the coinage treatment, but no significant pairwise differences were found in the total amount collected among the three non-empty treatments. The authors found that treatments that increase the propensity to donate reduce the average donation size.

Shearman and Yoo (2007) introduced the social proof condition or the “people like you are likely to donate” condition and found that including this information increases active donation in both field and laboratory experiments. Croson and Shang (2008) used a field experiment where donors to a radio station who were asked to renew their memberships received information about another donor’s contribution. Those who received higher social information than their previous contribution increased their donation, while those who received lower social information than their previous contribution decreased their donation. Similar results were obtained by Name-Correa and Yildirim (2016) with a social norm about donations. This analysis is related to the theory of conditional cooperation in public good games (Fischbacher et al. 2001; Frey and Meier 2004).

Other studies have examined the effect of suggested donations on contributions (Desmet 1999; Reiley and Samek 2015). Desmet (1999) used different scales of suggested contributions and showed that the donation scale has a real but small effect on both the frequency and the amount of donations. Reiley and Samek (2015) analyzed a common practice in fundraising, namely to provide a vector of suggested donation amounts to potential donors in addition to the option of writing in an amount. Using a field experiment, they showed that higher suggested donation amounts reduce the probability of giving.

Suggested donations are now a widely spread practice. Door-to-door, face-to-face or phone fundraising have been swallowed up by online fundraising platforms, most of which provide a vector of suggested donations. Moreover, one of these suggestions is ticked by default, which can be seen as an anchor point. For example, the American

Cancer Society provides alternative donation amounts of $50, $75, $100 or $250 and then the option of writing in an amount. The anchor point is $75, as it is the default option.[2]

Focusing on this last idea, in this work we analyze how *granularity* affects the participation and contribution of individuals involved in a standard public goods game. By granularity we mean the degree of divisibility subjects are allowed in the space of feasible contributions to be made by individuals. In particular, we experimentally examine the effect of granularity in a public goods game by means of four different treatments that differ in terms of the degree of divisibility in the allowed space of contributions. Granularity differs from the aforementioned suggested donations approach in that the option of writing in an amount that differs from the suggested amounts is not available. In two of the treatments, small contributions are possible while in the other two they are not. Moreover, to consider the effect of social information about other donors' behavior, the game is played repeatedly, so players have information about the funds collected in previous contributions.

As regards other works that have used a similar approach to ours, Cadsbya and Maynesb (1999), Gangadharan and Nikiforakis (2009) and Zhang et al. (2013) compared extreme cases of divisibility in different contexts, that is, the continuous[3] versus all-or-nothing contribution in public goods games. In Cadsbya and Maynesb (1999), the public goods game had a threshold (minimum total contribution necessary for the provision of the public good). This introduces the possibility of equilibria different to the pure free riding equilibrium. The threshold was combined with a money-back guarantee. With respect to the divisibility issue, the authors found that allowing for continuous contributions facilitated the provision of the public good. Gangadharan and Nikiforakis (2009) studied how each of the two treatments affects the choice to contribute, where "contribution" means contributing all in the dichotomous case and contributing more than half of the endowment in an almost-continuous case. They found that contributions defined in this manner are higher in the dichotomous case. The cooperative response to peers' contributions is also higher in the dichotomous case. The authors do not provide information about the total provision of the public good. In Zhang et al. (2013), the public goods game is nonlinear. The all-or-nothing contribution is interpreted probabilistically (as the mixed strategy of contributing all or nothing). They study evolutionary adaptive dynamics in both cases by means of different simulations, finding that nonlinearity is what makes the difference in the final results. Schniter et al. (2015) studied the continuous versus all-or-nothing comparison in "trust games", where the investor decides to invest and the trustee decides how much to return. Their results show that in the all-or-nothing case investors invest more but this does not imply that the trustee reciprocates with more money. The treatments that we run in this paper include the all-or-nothing treatment and the continuous treatment as particular cases.

Our results show that granularity has a relevant effect on participation in public good provision. The proportion of free riders is higher with coarser granularity, especially

[2] The case of the American Heart Association is similar. The options are $40, $60, $100, $250 or introduce another amount. The anchor point here is $100. This is a general strategy that can be found in other institutions like Greenpeace, the World Wildlife Fund or the Global Footprint Network.

[3] Almost-continuous in the case of Gangadharan and Nikiforakis (2009).

when small donations are not available. However, the experiments also show that this decrease in participation has no significant effect on the total provision of the public good.

Our findings help to advance understanding of the mechanisms and factors that foster the efficient provision of public goods. In this sense they are of interest to social planners, for example to make better predictions when granularity of the contribution space is an institutional constraint of the problem. The results are also of interest to managers and/or community members involved in public goods game dilemmas. In particular, they show that the granularity design makes no difference if total provision is what matters, but does make a difference if participation has to be promoted.

As a particular case, these results may serve as a guide for charity managers. Charities crucially depend on private donations, so designing effective messages to attract donors becomes a central concern, to which substantial resources and effort are devoted. At individual level, a finer granularity seems to encourage small contributions from those who would otherwise not have participated, but on the other hand it facilitates the reduction in contributions from those who would otherwise have participated with more money. The trade-off is not clear and, probably for this reason, different strategies can be observed in the day-to-day practice of charities, with a lack of unanimity. At this point, our results may help managers to effectively direct their efforts in the correct design of funding request strategies. The main recommendation in this regard is that, if total revenue is what is at stake, it is not worth devoting much effort to thinking about the correct "granularity" of the request because the overall response seems to be unaffected by it. However, if for any of the aforementioned reasons, encouraging participation is one of the objectives of an organization, then facilitating sufficiently small options to contribute is an effective means.[4]

The paper is organized as follows. The next section defines the public good experiment and how granularity is described within the game. Section 3 introduces the experimental design and procedure and the different treatments that are implemented. Section 4 presents the main results, distinguishing between participation and total provision. Finally, the conclusions of the experimental analysis are presented in Sect. 5.

2 Granularity in the contribution to public goods

Let us consider a standard public goods game with a group of n agents, $i = 1, \ldots, n$, each of whom has an endowment e. This endowment can be invested in a private project or in a public project. The private project has a marginal return a for the subject making the investment and the public project has a marginal return b for all the subjects in the group, including the one that is investing.

Let X be the space of feasible investment options in the public project. Any investment option $x \in X$ should be $x \leq e$ in order to be individually affordable. In addition, it is not possible to make a negative investment in the public project, that is, any option $x \in X$ should be $x \geq 0$. In the space of investment options in the public good, $x = 0$ and $x = e$ are always available. In this context, we define granularity of the public

[4] The meaning of "sufficiently small" is explained more explicitly below.

goods game as the degree of divisibility of the space of feasible investment options between 0 and e. Thus, the set $[0, e]$ has a finer granularity than the set $\{0, \frac{e}{3}, \frac{2e}{3}, e\}$ and this set has a finer granularity than the set $\{0, \frac{e}{2}, e\}$.

Let $x_{it} \in X$ be the investment in the public project of subject i in period t. $(e - x_{it})$ is the investment in the private project. Therefore, the profit of subject i in period t is

$$\pi_{it} = a(e - x_{it}) + b \sum_{j=1}^{n} x_{jt}$$

We assume that $a > b$ and $a < nb$, that is, from the individual perspective it is better to invest in the private project, but from the social (group) perspective it is better to invest in the public project. Whenever $x_{it} = 0$, we say that the agent does not participate in the public project; while if $x_{it} > 0$, we say that the agent participates in the public project.

In this setting, the Nash solution is reached when no subject participates in the public project ($x_{it} = 0\ \forall i, \forall t$), while the socially efficient solution (maximization of group payoff) is reached when every subject participates in the public project with the maximum possible investment ($x_{it} = e\ \forall i, \forall t$). Observe that the Nash solution and the social solution are independent of the granularity.

For those that promote the provision of the public good (public authorities, charitable organizations, volunteers, etc.), the goal is to maximize the total provision of the public good, but also to involve or engage citizens in social participation. In our setting, total provision of the public good can be defined as the total investment in the public good of a group j. Therefore, *total provision* of the public project in group j in round t is $TP_{jt} = \sum_{i \in j} x_{it}$. Observe that the maximization of the public good provision also maximizes the group payoff.

3 Experimental design and procedure

We implement four different treatments, all with the same parametrization except for the granularity of the set of investment options in the public project (see Table 1). In treatment ∞ ($T\infty$), the granularity of the set is maximum as the agents can choose any number between 0 and 12 (the endowment). In treatment 2 ($T2$), the granularity is minimum as the agents can only choose between not participating in the public project and investing all the endowment in the public project.[5] In treatments 3 ($T3$) and 4 ($T4$), granularity falls somewhere between these two (3 options and 4 options, respectively). In all the treatments, the game is played in groups of 4 individuals over 10 rounds. Given the common parametrization in Table 1, the Nash solution is $x_{it} = 0, \forall i, \forall t$ and the social solution is $x_{it} = 12 \forall i, \forall t$ in every treatment. We say that an individual participates in public good provision if $x_{it} > 0$ and does not participate otherwise. In any treatment, the total provision of the public good of group j in round

[5] Among the literature, $T\infty$ and $T2$ are known as the continuous and the all-or-nothing settings, respectively (Cadsbya and Maynesb 1999; Gangadharan and Nikiforakis 2009; Zhang et al. 2013).

Table 1 Treatments: differences in granularity

Treatment	Agents Per group	Endowment	Investment Options	Marginal return Private project	Public project
T∞	4	12	$x_i \in [0, 12]$	1	0.5
T4	4	12	$x_i \in \{0, 4, 8, 12\}$	1	0.5
T3	4	12	$x_i \in \{0, 6, 12\}$	1	0.5
T2	4	12	$x_i \in \{0, 12\}$	1	0.5

t is $TP_{jt} \in [0, 48]$. Let z_{jt} be the number of participants in group j and round t, the average amount of individual contribution in group j and round t is $\bar{x}_{jt} = \frac{TP_{jt}}{z_{jt}}$.

Observe that in $T\infty$ and T4 it is possible to contribute less than half of the endowment to the public good, that is, small contributions to the public good are possible.[6] On the other hand, in $T3$ the lower contribution to the public good is half of the endowment, while the only possible contribution in $T2$ is the full endowment. By comparing participation in $T\infty$ and $T4$ with participation in $T3$ and $T2$, it is possible to study the effect of allowing small donations in public good involvement. Similarly, we can study the effect of such possibility in the total provision of the public good and average contributions.

At the end of each round, the participants received summary information about investment decisions and consequences in that round: own investment in the public project, total investment of the group in the public project (i.e., total provision) and own earnings in the round. With this information, the participant receives social information about others' contribution to the public good. The behavior of the participants in subsequent rounds allows us to analyze whether this social information affects future participation and/or contribution to the public good.

We ran four different sessions (one per treatment) that were conducted using the z-tree program (Fischbacher 2007) at Lineex; an experimental laboratory located in Valencia (Spain). There were 32 participants (8 groups) per treatment, which made for a total of 128 participants. During the experiment, the public project and the private project were called project A and project B, respectively. Subjects were told that the points obtained during the experiment would be exchanged for cash at a pre-specified exchange rate at the end of the experiment. After completing the ten-rounds of investments, the participants completed a short, 15-item Raven test.[7] The average payoff was €20.19, the minimum payoff was €13.80 and the maximum payoff was €25.30.

[6] In treatment $T\infty$ contributions in fractions of units were permitted, so it was possible to contribute less than 1.

[7] The participants received a payment of 0.25 Euros per correct answer.

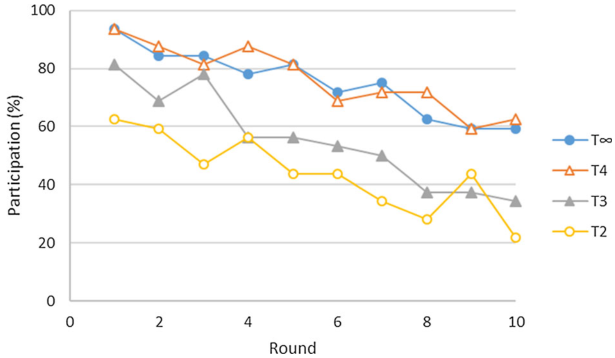

Fig. 1 Proportion of agents that participate in the public project

Table 2 Proportion of participants

Treatment	$T\infty$	$T4$	$T3$	$T2$
$T\infty$		46.0 (0.7901)	85.0 (0.0089)	96.5 (0.0004)
$T4$			86.5 (0.0006)	98.0 (0.0003)
$T3$				67.5 (0.1971)
$T2$				

Mann–Whitney tests. *p* value in parentheses

4 Results

4.1 Participation in public projects

We have already defined participation in the public project as an investment $x_{it} \geq 0$. Figure 1 shows the proportion of agents that participated in the public project in each of the four treatments for the different rounds. As can be seen, in the four treatments participation in the public project decreases with repetition. In addition, we can observe that participation seems to be lower when the granularity of the set of investment options in the public project is coarser, except for $T\infty$ and $T4$ where the participation levels are quite similar.

Statistically, there are significant differences in the proportion of participants (Kruskal–Wallis test $\chi^2 = 21.525$, p value $= 0.0000$); therefore we can say that granularity makes a difference in participation in public projects. Additionally, if we compare the treatments by pairs, we find some interesting results. In $T\infty$ and $T4$ the proportion of participants is quite similar; the decrease in granularity from $T\infty$ to $T4$ is not enough to affect participation. However, participation decreases significantly when we compare $T\infty$ with $T3$ and $T\infty$ with $T2$ and when we compare $T4$ with $T3$ and $T4$ with $T2$ (see Mann–Whitney tests in Table 2). The differences in participation are not significant when we compare $T3$ and $T2$.

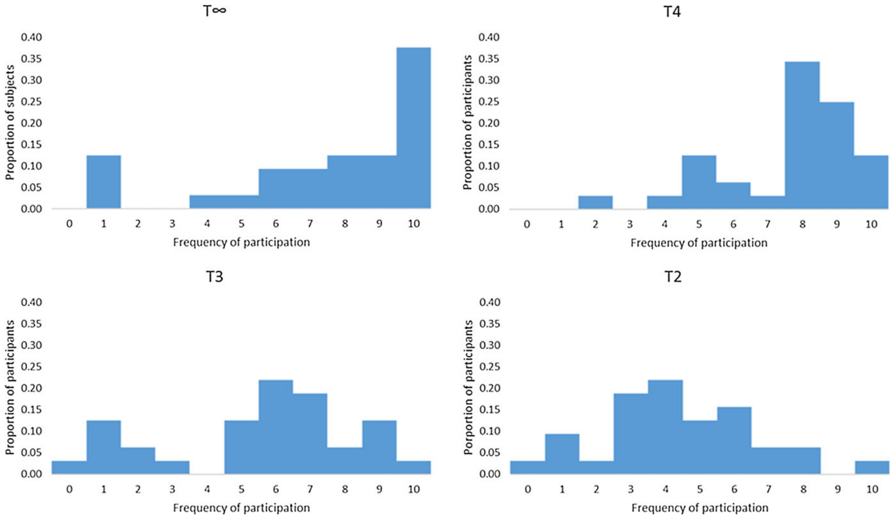

Fig. 2 Participation per subject

Therefore, $T\infty$ and $T4$ are quite similar in participation and something similar happens with $T3$ and $T2$. Recall that in $T3$ and $T2$ granularity prevents small investments as it is not possible to invest an amount lower than half the endowment in the public project, that is, an amount x_i such that $0 < x_i < \frac{e}{2}$. In $T\infty$ and $T4$, granularity is less restrictive and allows investments below half the endowment. Granularity proves to have a significant effect on participation only if we compare a set of contribution possibilities in which small donations are not available with a set of contribution possibilities in which small donations are available.

However, there seem to be more factors than granularity and small donations in determining participation: in the different treatments, agents decide whether to participate in the public project or not over ten rounds, and most of them change their decisions at least once although the granularity context is the same in every round. If we consider the four treatments, only 14% of the agents always participate and just 1.56% never participate. The rest of the subjects change their participation decision at least once. In Fig. 2 the participants are distributed according to frequency of participation, from 0 to 10 times. In the treatment with finer granularity, $T\infty$, a high proportion of agents (almost 40%) always participates. In $T4$, where granularity is smaller but contributions of less than half the endowment are available, most agents participate at least 8 times. The frequency of participation is clearly lower in treatments $T3$ and $T2$. As expected, a sort of single-peaked shape is observed in all figures, with a "shifting" of the peak (or modal participation) towards a more frequent participation as the granularity increases. In $T\infty$ the "peak" is at 10; in $T4$ it is at 8; in $T3$ it is around 6 and in $T2$ it is around 4. Interestingly, in the four cases, participating once or twice tends to "break" the single-peaked shape. A possible explanation for this is that one-off participations as a way of false signaling during the game are a kind of focal strategy.

To analyze which factors may determine the likelihood of participation in a public project, let us define a dichotomous variable, $Z_{ijt} \in \{0, 1\}$. $Z_{ijt} = 1$ if agent i in group j participates in the public project in round t, while $Z_{ijt} = 0$ if agent i in group j does not participate in the public project in round t. Using a probit model with standard deviations clustered by groups, we estimate $P(Z = 1|\mathbf{x})$ where $\mathbf{x}$ is the vector of explanatory variables.

Since participation decisions are made repeatedly over 10 rounds they could be time dependent. Therefore, the first explanatory variable is *participation in the previous round*, Z_{ijt-1}. In addition, participation in public projects can be affected by the behavior of others (Fischbacher et al. 2001; Frey and Meier 2004; Martin and Randal 2008; Shearman and Yoo 2007). To study whether group behavior affects participation, we distinguish between relative and absolute contribution to public projects. After each round of the game, each subject receives information about total public good contribution from his/her group (absolute contribution). The subject can see how much of the public good is due to his/her contribution and how much to the contribution of others (relative contribution). We include as explanatory variables the *relative contribution of others*: proportion of total provision from group j due to other subjects contribution in round $(t-1)$, $RCO_{jt-1}\left(1 - \frac{x_{ijt-1}}{\sum_i x_{ijt-1}}\right)$ and the *absolute total provision* of the public good from group j in round $(t-1)$, $TP_{jt-1} = \sum_i x_{ijt-1}$.

The possible effect of granularity on participation decisions is analyzed by including *dummies for the different treatments*. $DT4_i$ is a dummy variable that takes the value of 1 for $T4$ and 0 otherwise. Similarly, we define $DT3_i$ and $DT2_i$.

On the other hand, cognitive abilities can be relevant in the strategy used by participants in social settings (Benito-Ostolaza et al. 2016; Gill and Prowse 2016). Those with greater cognitive abilities better understand the intricacies of the game and this understanding can affect their strategy. In order to measure these cognitive abilities, the participants in the experiment completed a short 15-item Raven test.[8] To capture this possible effect, we include the *Raven score* as an explanatory variable.

We also include *dummies for the round* in order to test whether repetition determines the probability of participation.

As can be seen, having participated previously in a public project has a positive and significant effect on the probability of participating. However, a look at the dummies for the rounds also reveals that repeated requests to participate have a negative effect on the probability of participation: The marginal effects are negative in all the rounds, but those effects are only significant from round 6 on. That is, continued requests to participate in public goods projects may participation less likely in the medium/long run.

Group behavior also reveals interesting results. The relative contribution of others has a significant, positive marginal effect, while absolute total provision has no significant effect on participation. In individual decisions whether to participate in the provision of public goods, the contributions made by the reference group may be deci-

[8] The Raven test is a nonverbal multiple-choice intelligence test for abstract reasoning, (Raven 1936). In each item of the test, the participant is asked to identify the missing element that completes a visual pattern. This test is recognized as a leading measure of analytic intelligence (see Brañas Garza et al. 2012; Carpenter et al. 1990; Gray and Thompson 2004, for detailed information).

Table 3 Marginal effects of the determinants of participation

Variable	Marginal effect	p value
Participation in $(t-1)$	0.4120***	0.0000
Relative contribution of others in $(t-1)$	0.3415**	0.0141
Absolute total provision in $(t-1)$	0.0003	0.8540
Treatment $T4$	− 0.0234	0.7028
Treatment $T3$	− 0.1628***	0.0077
Treatment $T2$	− 0.2417***	0.0004
Raven score	− 0.0386***	0.0000
Round 3	0.0004	0.9953
Round 4	− 0.0318	0.5644
Round 5	− 0.0677	0.3127
Round 6	− 0.1292**	0.0283
Round 7	− 0.1208**	0.0129
Round 8	− 0.2078***	0.0016
Round 9	− 0.1616**	0.0320
Round 10	− 0.2308***	0.0000
Observations N	1152	

Probit regressions. Standard deviations clustered by groups (32 groups). *Significant at 10% level, **significant at 5% level, ***significant at 1% level

sive in relative terms, that is, when compared to one's own contribution. This effect is independent of the absolute provision by the group.

Regarding our main question of the effect of granularity on participation decisions, the regression results confirm what the data in the figure seem to indicate: A decrease in granularity has a negative effect on the probability of participation. However, only the negative effects of $DT3$ and $DT2$ are statistically significant. Treatments, $T4$, $T3$ and $T2$ all show a notable reduction in granularity compared to $T\infty$, $T4$ still allow contributions of less than half the endowment while $T3$ and $T2$ do not permit such small donations. Therefore, coarser granularity negatively affects participation when small donations are not available.

Another factor that negatively affects the probability of participation is the cognitive abilities measured by the Raven test. Those who have greater cognitive abilities according to the Raven score have a significantly lower probability of participating in the public project. The probability of being a free rider in a public good context increases with cognitive abilities.

The conclusion reached is that granularity is a relevant factor in decisions as to whether to participate in public goods, especially when granularity eliminates what can considered as small donations. Coarser granularity decreases the probability of participation. It is also interesting to highlight that the relative contribution within the group (me versus the others) is a relevant factor for subsequent participations regardless of the absolute level of provision achieved by the group: A higher relative

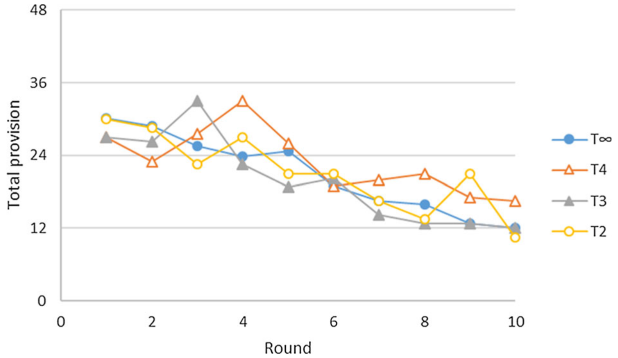

Fig. 3 Average total provision of the public good

contribution from others (or a lower relative own contribution) increases the probability of participation.

4.2 Total provision

We have already seen that reducing the granularity of the possible investment options may reduce participation in a public project, mainly if it does not include small donations. However, another goal in public goods settings is the maximization of public good provision. The open question is whether granularity and the inclusion or not of small donations have an effect on the total provision of a public good. Figure 3 shows the average total provision in each treatment over the different rounds. Recall that $TP_{jt} \in [0, 48]$ for all groups and treatments.

The first visual impression shows that, despite the differences in participation, the total provision in the different treatments does not differ. This seems to indicate that granularity is not a determinant factor in total public good provision. A Kruskal–Wallis test ($\chi^2 = 1.3759$, p value $= 0.7112$) confirms this visual impression; we cannot reject the null hypothesis that total provision in the four treatments has the same underlying distribution. Moreover, there are no statistical differences between treatments when we compare them by pairs (see Mann–Whitney test in Table 4). Therefore, we can also say that the inclusion or not of small donations in the contribution set does not affect total provision of the public good. It is worth mentioning that, on average, total provision is far below the maximum possible amount. In the first periods, it is around 60% of the maximum, but in the last periods it is just 30% of the maximum.

Let us now consider the relationship between participation and total provision. We observe two different facts. On the one hand, there is no difference between treatments concerning the total provision of the public good, that is, the significant differences observed in participation between treatments are not clearly reflected in the total provision of the public good. On the other hand, the decrease in participation over time observed in all the treatments is clearly reflected in the total provision of the public good: within each treatment, a decrease in participation is correlated with a decrease

Table 4 Total provision

Treatment	$T\infty$	$T4$	$T3$	$T2$
$T\infty$		38.5	55.0	49.0
		(0.4055)	(0.7333)	(0.9698)
$T4$			65.0	55.5
			(0.2725)	(0.7042)
$T3$				42.0
				(0.5697)
$T2$				

Mann–Whitney tests. p value in parentheses

in total provision. Figure 4 shows the differences in participation per treatment and per round and the differences in total provision per treatment and per round.

In order to analyze the determinants of total provision in this setting, we resorted to a regression analysis. The dependent variable is total provision per group and, as possible determinants, we include the following independent variables. First, granularity. For this purpose, we include the dummies to distinguish the granularity between treatments: $DT4_j$ takes the value of 1 if group j plays T4 and value 0 otherwise. Similarly, we define $DT3_j$ and $DT2_j$. Given the previous analysis, we expect this factor to have no significant effect on total provision. The behavior of others can influence not only the participation of the subjects, as we have previously considered, but also the contribution size and hence the total provision (Fischbacher et al. 2001; Frey and Meier 2004; Martin and Randal 2008). As we are considering total provision, we include as an explanatory variable the lag total provision, TP_{jt-1}. Again, the cognitive abilities of the participants can be a determinant factor in investment strategies and hence in the total provision. In order to measure the cognitive abilities of the group, we construct the variable *Raven group*, RG_j. The value of this variable is the sum of the Raven score for all the members of the group. We also include a set of dummy variables to account for the possible effect of time and repetition on total provision.

We use a censored regression model, a Tobit model, as it is designed to estimate linear relationships between variables when there is either left or right censoring in the dependent variable (0 and 48, respectively, when the dependent variable is total provision). The results are shown in Table 5. We also include the results of an OLS regression.

As expected, the coefficients of the variables $DT4_j$, $DT3_j$, $DT2_j$ are not statistically significant, that is, granularity has no effect on the total provision. However, the lag total provision has a positive and significant effect on current total provision. Cognitive abilities contribute negatively to the total provision. In those groups where the sum of the Raven scores of the group members is higher, total provision is lower (see the negative and significant coefficient of RG_j in Table 5). The time variables have negative coefficients from round 5 on, but the negative effect of repetition in total provision is only significant from round 6 on. Observe that there are no significant differences in total provision due to repetition between the first five rounds. There is then a drop due to repetition which is maintained until the last round where the drop

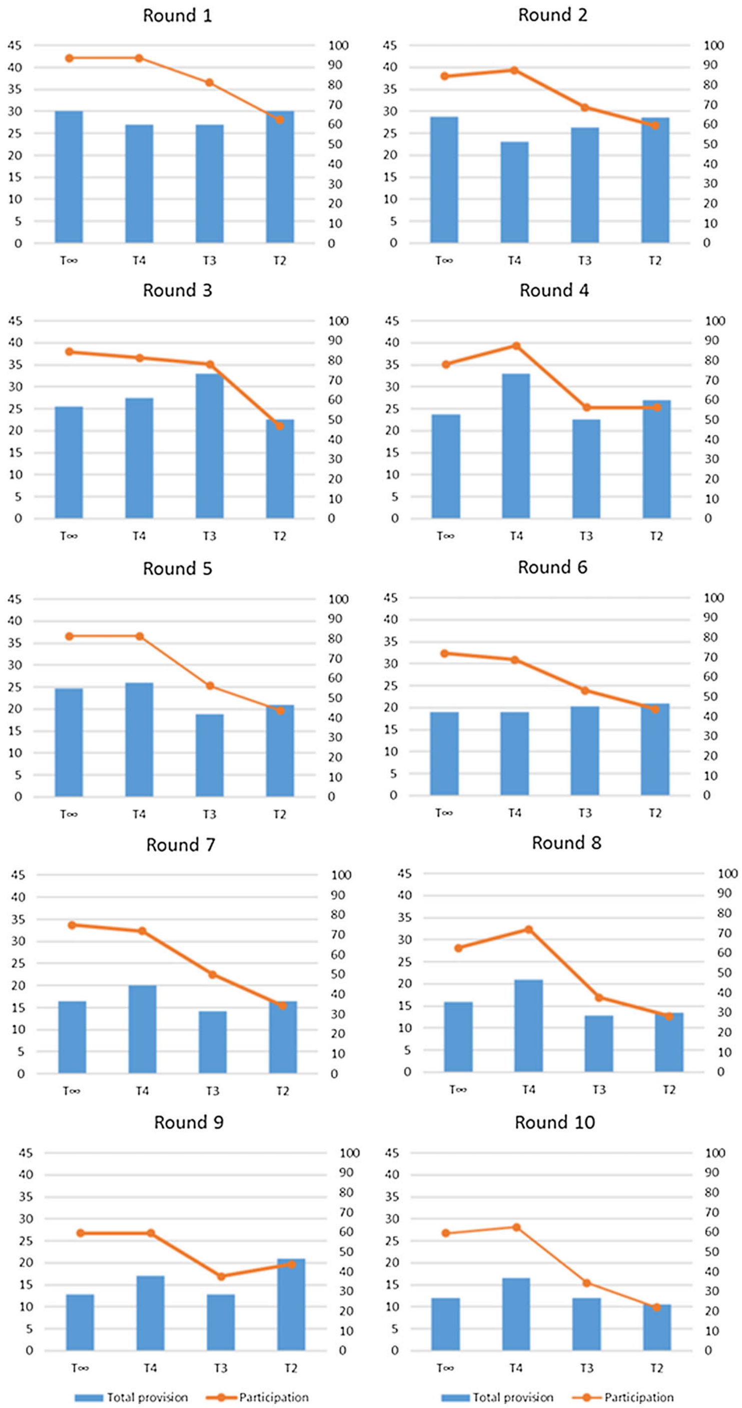

Fig. 4 Total provision versus participation

Table 5 Determinants of total provision

Variable	Tobit	OLS
Constant	39.452***	36.365***
	(9.213)	(8.263)
Total provision in $(t-1)$	0.351***	0.320***
	(0.061)	(0.057)
Treatment $T4$	0.652	0.776
	(1.744)	(1.773)
Treatment $T3$	− 0.233	− 0.165
	(1.894)	(1.809)
Treatment $T2$	− 0.238	0.302
	(2.659)	(2.373)
Raven group	− 0.501***	− 0.419**
	(0.185)	(0.162)
Round 3	1.350	1.089
	(2.589)	(2.446)
Round 4	0.163	0.372
	(2.071)	(2.042)
Round 5	− 3.447	− 3.393
	(2.738)	(2.506)
Round 6	− 5.194***	− 4.935***
	(1.911)	(1.827)
Round 7	− 7.477***	− 7.053***
	(1.802)	(1.721)
Round 8	− 7.421***	− 7.104***
	(2.088)	(2.512)
Round 9	− 7.084***	− 6.685***
	(2.549)	(2.388)
Round 10	− 10.529***	− 9.824***
	(2.388)	(2.243)
Observations N	288	288

Standard errors clustered by groups. Standard errors in parenthesis. *Significant at 10% level,**significant at 5% level, ***significant at 1% level

is more pronounced (the coefficients of rounds 7, 8 and 9 are quite similar and the coefficient in round 10 is higher).

Observing these experimental results, granularity, whether it contains small donations or not, is not a relevant factor in the total provision of public goods. We can observe that the effect on participation is balanced with a greater average amount of individual contribution. These average amounts of individual contributions are shown in Fig. 5. The highest average amount of individual contribution is found in $T2$ (coarser granularity), while the lowest one occurs in $T\infty$ (finer granularity).

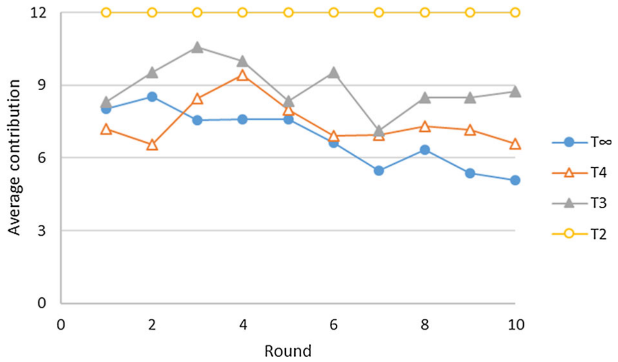

Fig. 5 Average amount of individual contributions

5 Discussion and conclusions

Our results under all the treatments reproduce the widely spread experimental evidence that participation in and provision of the public good decrease with repetition in a standard repeated public goods game, but without reaching the Nash equilibrium. The main focus of this paper is, however, the effect of granularity on both participation in and provision of the public good.

Participation tends to decrease together with coarser granularity, but the differences are only significant when the reduction in granularity is large enough. What seems to make a difference is whether small positive contributions (below half of the endowment) are available or not. Interestingly, there are no significant pairwise differences between treatments $T3$ and $T2$: adding the possibility of contributing 6 when only 0 or 12 was available does not seem to have any effect on participation. Similarly, there are no differences between treatments $T\infty$ and $T4$. Once the agent has the possibility to contribute in the set $\{0, 4, 8, 12\}$, enriching the set to allow any amount between 0 and 12 does not have an effect on participation either. Thus, participation seems to be encouraged only if there is some option below half of the endowment. If this is ensured, then it does not matter how many options below the half are added.

A second important finding is that granularity does not have a significant effect on the total provision of the public good. In general, this is aligned with the results of Cialdini and Schroeder (1976), Brockner et al. (1984), Martin and Randal (2008), Shearman and Yoo (2007), Weyant and Smith (1987) in the context of donations, who showed that requesting or suggesting small quantities encourage the act of giving but not greater fundraising.

A more detailed comparison with Gangadharan and Nikiforakis (2009) is in order, given that they also perform a standard public good experiment with 4 players where two treatments ((U)nrestricted and (R)estricted) coincide with our treatments $T\infty$ and $T2$. The data provided in Gangadharan and Nikiforakis (2009) shows that, as in our study, the number of people who contribute a positive amount increases significantly in the U-treatment. However, they neither provide nor indeed mention any data on total contribution, so there is no way to make any comparison in this respect.

Gangadharan and Nikiforakis (2009) and our study also differ in the target variables studied. They do not focus on participation as we understand it (contributing any positive amount), but on what they call "cooperation", understood as contributing more than half of the endowment in treatment U and the whole endowment in treatment R. They find that the R-domain significantly raises this kind of cooperation (from 12 to 24% of total actions). According to our data, unlike Gangadharan and Nikiforakis (2009) results, the number of subjects who contribute more than half of their endowment in $T\infty$ (the equivalent to U) is not much smaller than in $T2$ (the equivalent to R). The specific figures are 39% of the total number of actions in $T\infty$ and 44% in $T2$.

An important difference between the design of Gangadharan and Nikiforakis (2009) and ours is that in their work the game is repeated 20 times (compared to 10 times in our experiment). This plausibly explains the lower rate of contributive actions in Gangadharan and Nikiforakis (2009), though it is not clear how it may relate to the differences between treatments that they observe regarding contributive actions, which are not observed in our study.

Thus, the two main findings in this work are that granularity does affect participation when small quantities are available, but the effect on the total provision of the public good is not significant. The combination of both can be interpreted in different ways. The first is that increasing participation by means of small amounts is insufficient to have a significant effect on the total provision of the good. The results can also be interpreted from the viewpoint of restricted intermediate contributions. In this regard, the effect on those who are unable to choose the intermediate option and decide to contribute the higher one (12 instead of 6, for example) is set off by the effect on those who decide to contribute the immediately smaller one (0 instead of 6). A bit more sophisticated explanation is that individual decisions at each period are the result of linear mixed strategies. For example, agents who contribute 7 in the continuous treatment ($T\infty$) would have contributed 12 with a probability of $p = 7/12$ and 0 with a probability of $1 - p = 5/12$ in the dichotomous case ($T2$). In other words, individuals adapt to the scarcity of options by using mixed strategies whose expected value is independent of the granularity of the set. Therefore, when the behavior of all agents is aggregated, no differences are observed in the average contribution among the different granularity treatments. A natural development of our experiment would set up the game with a larger group of people (for example 10 people instead of 4). In this case a larger share of small cooperators might be able to win out in the trade-off with no participation by defectors.[9]

The experiment also yields some other results in line with the abundant experimental evidence on the factors that affect participation and contribution in standard public goods games, such as the negative effect of cognitive abilities and the negative effect of time (especially in the last rounds). The results also show that previous group contribution to public goods has a positive effect on current total contribution. However, relative contributions seem to be more significant than absolute total provision when deciding whether to participate.

As a general conclusion, there does not appear to be strong support for a finer granular design of the public goods game if the aim is to increase the total provision

[9] We thank an anonymous referee for this idea.

of the public good. However, if promoting participation is among the designer or social planner's goals, then a finer granularity would contribute to achieving this aim, especially if it allows for small contributions.

Our findings help advance the extensive research program devoted to understanding the mechanisms that foster participation in and provision of public goods. They might be of interest to social planners to improve their understanding of these problems and make better predictions, especially when the granularity of the space of contributions is at stake.[10] The results also show managers and/or community members involved in a public goods game that the granularity design does not seem to make a difference if total provision is what matters, but does if participation has to be promoted.

The results are also applicable to the particular case of charity funding. Our results may help managers find more efficient resource allocations for the design of requesting strategies. If total revenue is the central objective then any effort devoted to the design of granularity is futile, but if broad participation is sought then granularity matters. In particular, providing some sufficiently small opportunities to contribute (in our experiment this means a contribution of less than half the total endowment) is enough to encourage participation.

Moreover, our results show that continual requests for participation may make participation less likely in the medium/long run (in our experiments this happens from the 6th round on). For example, if there is an interest in using "warm lists", managers should know that such lists may have a limited effective lifetime.

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[10] Social planners may possibly have other reasons for facilitating richer spaces of contribution which rely, for example, on theories that defend the intrinsically attainable value of having freedom of choice (see, for example, Sen 1988; Pattanaik and Xu 1990; Gravel 1994; Bartling et al. 2014).

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