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COOPERATION IN LARGE NETWORKS: AN EXPERIMENTAL APPROACH[1]

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Abstract

We present a new design of a simple public goods experiment with a large number of players, where up to 80 people in a computer lab have the possibility to connect with others in the room to induce more cooperators to contribute to the public good and overcome the social dilemma. This experimental design explores the possibility of social networks to be used and institutional devices to create the same behavioral responses we observe with small groups (e.g. commitments, social norms, reciprocity, trust, shame, guilt) that seem to induce cooperative behavior in the private provision of public goods. The results of our experiment suggest that the structure of the network affects the players' ability to communicate –and through it, their cooperation levels–, and also their willingness to engage in a more costly type of collective action, namely the endogenous creation of new links to individuals previously out of reach. Finally, the information flows in the network seem to reduce uncertainty in the players: players with more links tend to have more stable play strategies.

Keywords: Social capital, social networks, collective action, cooperation, VCM, experiments, public goods provision, information flows.

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COOPERACIÓN EN REDES EXTENSAS: UN ENFOQUE EXPERIMENTAL

Resumen

Presentamos un nuevo diseño de un experimento de bienes públicos simplificados para un número grande de jugadores, donde hasta 80 personas en el laboratorio tienen la posibilidad de comunicarse con otros jugadores para inducir más contribuyentes al bien público y así solucionar el dilema social. Este diseño experimental explora la posibilidad de que las redes sociales y mecanismos institucionales creen las mismas respuestas de comportamiento que se observan con pequeños grupos (e.g. compromisos, normas sociales, reciprocidad, confianza, pena y culpa), que al parecer inducen el comportamiento cooperativo en la provisión de bienes públicos. Los resultados de nuestro experimento sugieren que la estructura de la red afecta de un lado la posibilidad del jugador de comunicarse, y de otro su disposición a involucrarse en acciones colectivas más costosas –la creación endógena de nuevas conexiones con individuos que inicialmente fuera de su alcance en la red. Finalmente, el flujo de información en la red parece disminuir la incertidumbre que enfrentan los jugadores: jugadores mejor conectados tienden a tener estrategias de juego más estables.

Palabras clave: Capital social, redes sociales, acción colectiva, cooperación, VCM, experimentos, provisión de bienes de públicos, flujos de información.

Clasificación JEL: C92, D7, D85, H4.

Introduction: Cooperating in large groups and making use of social networks

Many public goods need to be produced by, and/or benefit, large number of individuals (tax compliance, charities, global warming, air pollution in cities). Public goods are difficult to produce through voluntary contributions because of the divergence between individual and collective interests and the free-riding problem. This has been widely studied experimentally by economists and social psychologists using the so called Voluntary Contribution Mechanism (VCM) and a there is now a vast amount of experimental data on the factors that trigger contributions, including the material and non-material incentives, social norms, information available, etc.

However, most of this literature is based on experiments conducted in rather small groups of 3 to 5 people. Very little experimental evidence exists for experiments with more than 10 players[4]. For a typical linear public good problem, as group size increases the gap between the returns from not contributing and contributing also increases, for a given number of contributors. On the other hand, the larger the group, the more difficult is to gather information on the critical mass or minimum number of contributors required for any player to be indifferent between contributing or not to the public good.

In such setting –a large group that needs contributions for the provision of the same public good– what is the role of a social network through which information can flow?

We present a new design of a simple public goods experiment with a large number of players, where up to 80 people in a computer lab have the possibility to connect with others in the room to induce more cooperators to contribute to the public good and overcome the social dilemma. This experimental design explores the possibility of social networks to be used and institutional devices to create the same behavioral responses we observe with small groups (e.g. commitments, social norms, reciprocity, trust, commitment, shame, guilt) that seem to induce cooperative behavior in the private provision of public goods.

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[4] An exception is the work conducted by Isaac and Walker in the 1990s with groups of 40 to 100 people. Also Cinyabuguma, Page and Putterman (2005) run experiments with 16 players.

We have 80 people in a computer lab to play the following game for actual money: each player receives a token that can be kept in a private account or invested in a group account. The decision is made individually, in private and confidential. Only the group outcome will be announced at the end of the game. The incentives are simple: If you keep the token you get 10 USD for it. Also, you will get, regardless of keeping or investing it, 0.25 USD for each token that is invested in the group account by the group of 80 players.

Therefore, your total earnings at the end ($10 or $0) + ($0.25 x Sum.Tokens invested by the group). We have thus a social dilemma where the Nash equilibrium is that nobody contributes, and you produce 80 x $10 = $800 of social efficiency. The social optimal is that every one contributes and could yield 80 x $0.25 x 80 = $1600 instead.

In a first baseline round our participants can decide whether to invest in the private o group account without any possibility to communicate with others in the group. The outcome of this round is not announced to the players until the end of the experiment. We then proceed to the more interesting part of our experiment in the next round of the game.

Before she chooses her action, each player can write (not talk) to some of the others using one-on-one chat software. We control who can talk to whom and keep the logs of the written communication. The contacts are anonymous: no player is allowed to know the identity of her counterparties. We thus control the structure of the network and have access to the content of the communication. In a third round of the game we again allow the players to communicate through the one-on-one chat rooms, but this time they can acquire addresses of other parties so that they can endogenously create more links with more players in their session.

The results of our experiment suggest that the structure of the network affects the outcome of the game in several ways. Firstly, and trivially, it directly relates to the extent of communication feasible among players. The players seem to use this feasible communication channels in a uniform manner, so availability and use of connections are closely correlated. Secondly, we confirm that the communication itself is crucial in understanding the level of cooperation in the group.

Thirdly, we find that the local connectivity structure of the network has an important role as determinant of the willingness of the players to engage in a more costly type of collective action, namely the endogenous creation of new links to individuals previously out of reach. Investment in creating new links seems to accord to some law of diminishing returns. However, these returns are not in terms of the game at hand, for the new links do not increase overall cooperation in the game.

A theoretical framework

Social capital

The concept of social capital has faced some resistance by mainstream economics, in part because there is no consensus about its definition. At least two views exist. On one side, social capital is viewed as the array of social networks that exist in a community and that can be used by individuals both for private uses and for coordination in collective action. The other view regards social capital as a widespread willingness of individuals to trust other individuals based on prior beliefs. Since both concepts of social capital are difficult to quantify, empirical testing to ascertain their relevance is always controversial.[5]

This paper is built on the idea that both views are correct and complement each other, but also that they miss an important additional element, which we call transferability. Social capital consists of a set of underlying community networks that can be used by individuals for private or public benefit. To be used effectively for public good production, these networks have to be associated with a "trust endowment", i.e. the individuals in it must be willing to trust its other members a priori. In principle, however, this trust endowment is purpose specific: a social network that is effective to mobilize people for an environmental initiative may not be useful to organize an anti-war rally. Thus the social network is a sort of communication infrastructure that is only useful if a specific type of trust is present –a production technology for public goods. Only if this trust is transferable, i.e. if it is possible to use it for provision of other public goods, the social network becomes true social capital.

The communication infrastructure is the first element of social capital, and in a sense it is a prerequisite for the other two. The effect of network parameters on the onset and outcome of collective action –particularly large-scale collective action– is likely to be non-linear and feature emergent properties.[6] In particular, local network structure probably determines

[5] See Bowles and Gintis (2000), Durlauf (2000), Durlauf (2002) and Glaeser, Laibson and Sacerdote (2000).

[6] For instance, Jaramillo (2005) shows that the connectivity of the network influences the likelihood of success of large-scale cooperation and thus determines whether individuals engage in collective action in the first place. In Jaramillo's model, the individuals are embedded in a social network that enables them to communicate. They have information about the global connectivity of the network and the number of other

whether small-group behavior appears among clusters of individuals, but it also affects how quickly information spreads and which emergent properties can appear upon aggregation.

The role of the network structure is not only one of communication, however. In an important sense, the structure may also influence its members' prior beliefs about (i) the network itself and (ii) the characteristics of the other individuals in it. Both affect the likelihood of success of collective action, and the willingness of the individuals to engage in it.

The individual beliefs about the likelihood of success of collective action depend on the beliefs about the connectivity of the network, which is a network-wide parameter, not easily observable by its individual members. How do these beliefs about connectivity relate to the true connectivity? If, as seems plausible, the individuals form their beliefs using information about their immediate neighbors, then local network structure is also relevant for the emergence of collective action, even though only global structure really affects the likelihood of success.[7]

Similarly, an individual's beliefs about the characteristics of other network members may be driven in part by what she sees in her neighbors.[8] Thus, the number of neighbors is the sample size upon which those beliefs are formed, and it affects their accuracy.

Trust is the second element of social capital. To some extent, the willingness of an individual to trust somebody in a network is driven by a sense of a common interest. Thus membership in an environmental network presumable informs about an interest in matters environmental, but not about your views on foreign policy. In this sense, a network is like a club, and being in it signals private information about preferences.

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individuals in it that share their goal, and thus infer the likelihood that an eventual collective action be successful. For some parameter values, small increases in connectivity yield a discrete jump in the chances of success in large-scale collective action. Thus, while changes in connectivity have small impact on the emergence of small-scale collective action, they may have large effects on the provision of public goods that require community-wide cooperation.

[7] It is possible that prior experience about the effectiveness of the network also plays a role. Thus, a network that was able to organize a political rally in the past is likely to be of high connectivity.

[8] It may also be related to the membership in the network itself, as we explain below.

However, common interest cannot be the whole story. For a network to act effectively as a cooperation device, the potential free-riding members must be deterred. The literature on cooperation suggests a number of ways for this to happen, relying usually on the observability of free-riding, repeated interaction and non-anonymity of the players. Alternatively, there is the idea of strong reciprocity: a predisposition of the network members to cooperate and to punish those who don't, even at a personal cost. This is what we call the trust endowment of the social network.

A social network like this is not yet social capital. Or better, it is specific social capital, not applicable for general purposes and limited in scope –very much like a club. A final element is required for the network to constitute true social capital. The network and its trust endowment must be applicable to uses different from those it was initially intended to serve.[9] That is, it must be transferable to some extent to a different context –it must be flexible enough to allow for other collective action goals.

The inferred characteristics of the network members are relevant for transferability. To the extent that they are correlated with other characteristics, the information is useful for other collective action initiatives. So, if this is a successful environmental network, and if being environmentally minded is correlated with being on the political left, the network members may infer that this social network is transferable to leftist political action. Again, the degree of transferability may be inferred from –or even tested on– the immediate neighbors.

On the structure of social networks

The social network is thus important as a means of communication, but it also carries information that allows its members to form priors about the characteristics of its members and the likelihood of success of collective action. Thus, its structure, both global and local, is important to understand the determinants of the emergence and eventual success of collective action.

[9] These ideas are more common (and developed) in the sociology literature. Granovetter (1974) introduces the concepts of weak and strong links, which are related to the ability of the network to convey different types of information. The importance of links to people who are not in our own circle –acquaintances, as opposed to friends– is stressed by Burt (1992). For an overview of these ideas, see Granovetter (2005).

The literature on social networks is large. Starting with graph theory in mathematics, the study of global (topological) features of networks has evolved to become an interdisciplinary program with numerous applications (Barabasi, 2003; Dorogovtsev y Mendes 2003, Ch. 1).

One can think of a graph as consisting of a set of elements called vertices and a set of elements called edges. Each edge is in turn a pair of vertices. It is useful to visualize this as points (the vertices) joined by lines (the edges), as in Figure 1. Thus, the edge {x,y} joins the vertices x and y. A random graph is one where the edges are chosen randomly with some probability from the universe of all possible pairs {x,y}. Exactly how they are chosen is determined by the particular model used.

Several concepts developed in the context of random graphs are useful for our purposes. The *degree of a vertex* is the number of edges that attach to it. So, for example, the vertex 35 in Figure 1 has a degree of 4. The *degree of the graph*, on the other hand, is the average degree of its vertices, and it is a first approximation to how well-connected the vertices are. The graph in Fig.1 has a degree of 1.85. A *path* from vertex *x* to vertex *y* is a way to get from one to the other via the edges –in a sense, extended edges. There may be several such paths, or none. The *path length* is the number of edges the path has, and the *minimum path* between two vertices is the shortest path that joins them.

In each experimental session in this paper, each link was assigned randomly with a constant probability, so the associated graph is a uniform random graph. Graph theory was originally concerned with precisely this type of graph (Erdös and Rényi 1959): they have a relatively homogenous structure (with analytical results in the limit of many vertices). Notably, the degree distribution of links among vertices is of the Poisson type, which means that the number of vertices with large degrees is relatively small –they are thin-tailed. Poisson-type degree distributions are indeed a robust feature of random graphs.

In the last ten years, however, empirical evidence about real networks has shown at least three features that run counter to random graphs. First, their degree distribution often follows power laws, which means they are fat-tailed, i.e. that many vertices have large degrees (the so-called *hubs*). This is the case of some social networks, the internet and the WWW.[10] Second, the average path length between pairs of vertices is relatively small. This is the *small-world effect*. The third feature is *clustering*, that is, groups of vertices that are highly interconnected among them –Harry knowing Sally and Sally knowing Marie makes is very likely that Harry knows Marie.[11]

These empirical findings have introduced dramatic changes to the perceived global features of networks, but they have also brought attention to their local (or micro) structure. Intuitively, hubs and clustering are local features that fit well with several popular ideas in social networks.[12] But they are appealing in a dynamic sense as well. To the extent that the creation of links in social networks is endogenous and non-random, individuals could be expected to reinforce clustering and hubs. If I need to find a business partner in a new environment, I'll probably go to a visible community member (i.e. link myself to a hub, thus adding a link to her rolodex), who will connect me to some other person with similar interests –one of the roles of prominent political figures. To the extent that this person introduces me to others in this community, I will add to a cluster.

Small path lengths, on the other hand, are a global feature of the network, and thus more difficult to observe for individual network members. They may be, however, related to hubs. The literature has shown that an effective way to reduce the path lengths in a lattice[13] is to introduce shortcut links randomly. To the extent that these long-distance connections link individuals who are otherwise separated in society, they may correspond to acquaintance connections.

In the context of collective action, both the global and the local features of networks are likely to be relevant. The degree of the social network probably affects the chances of success, in particular for large-scale collective action, where the existence of a giant component may be necessary.[14] Clustering and hubs, on the other hand, may be relevant

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[10] For the internet and the WWW, see Dorogovtsev y Mendes (2003), Ch. 1. See also Watts and Strogatz (1998).
[11] When Harry Met Sally (1989).
[12] For instance, political figures in a community are well-known and well-connected. Also, my friends know me, but they usually also know each other.
[13] A lattice is an ordered graph, like the molecules in a crystal.
[14] A component is a subset of the vertices such that (i) all its elements are interconnected via paths, and (ii) none of its elements is connected to any other element of the graph outside the component. Thus components are islands of vertices. The size of the largest component in the graph, relative to the graph itself, is a well-studied feature of graphs. For some graphs, the expected size of the largest component is

for success in small-scale cooperation –and they may also affect the likelihood that a giant component exists. And, as we argued above, clustering and hubs may also affect the priors of the network members about the global features of the network. The experiment presented in this paper allows us to examine the relevance of some of these channels.

An experimental design for exploring collective action in large groups.

We are concerned with social interactions within large groups that act in a decentralized manner, that is, with no central planner or device to coordinate the actions of the members. However, we are focusing on a setting where all group members are engaged in the same production process.[15] In particular, we are interested in social interactions immersed in a process of production of a public good, that is, a good that is non-excludable and non-rival, and therefore difficult to provide through voluntary contributions. Because the private cost of contributing to the public good is higher than the private return from the public good, there are no individual (Nash) incentives to contribute. However, at the social optimum, all players would be better off if all players had contributed. This is the case of a typical N-prisoners dilemma or any social dilemma where individual and group interests are in conflict.

In the context of our study, we have adapted the conventional version of the public goods provision game or Voluntary Contributions Mechanism (VCM) for the context of our research question. We created a setting for 60-80 players who face the choice of contributing or not to the same pure public good, that is, every player will receive the same amount of the public good provided regardless of having contributed or not. Secondly, we simplified the action set for the players to a dichotomous choice of investing one token to the private account (not contributing) or to the group account (contributing).

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vanishingly small compared to the graph itself. In contrast, other graphs exhibit a giant component, i.e. a component that is unique and of the same order of magnitude of the graph itself.

[15] Most experimental designs that involve networks settings and cooperation situations involve simultaneous two-person interactions of prisoners' dilemmas or coordination games.

The Voluntary Contributions Mechanism (VCM)

In our design each player *i* of *m* players have a choice set of two options, $x_i = \{0,1\}$ keep or contribute a token to a public account. If the token is kept it yields a payoff of *p* to player *i* only. If the token is invested in the public account it yields a payoff of *a* to every player *j* including *i.* Summarizing, the payoffs function is given by:

$$y_i = p(1 - x_i) + a\left(\sum_{j=1}^{m} x_j\right)$$

If we analyze the ratio of the marginal return from the private account to the marginal return from the public account we obtain:

$$\frac{\left(\partial y_i \Big/ \partial\left(\sum_{j=1}^{m} x_j\right)\right)}{-\left(\partial y_i / \partial x_i\right)} = \frac{a}{p}.$$

This is the MPCR (Marginal per Capita Return of the public account to the private account) as defined by Isaac, Walker and Thomas (1984). As long as the MPCR < 1, there will be no incentives to contribute to the group account and therefore the Nash strategy will be $x_i^{nash} = 0$. In such case each player obtains $y_i = p$, and the group outcome would be $\sum y_i = mp$.

Basically each token in the group account implies a foregone income of (*p-a)* given that no contract has been written between *i* and the rest of the players. However if every player where to contribute to the group account, $x_i^{soc.opt} = 1, \quad \forall i = 1,,m$, the social optimum is obtained. In this case the earnings for each player are $y_i = ma$, and the group outcome would be $\sum y_i = m^2 p > mp$.

In our particular design, we recruited a maximum number of *m*=80 players[16]. Our parameters for the experiment were *p*=$20,000 (~US$10) and *a*=$500 (~US$0.25). That is, our MPCR=0.025, quite low for most VCM designs reported in the experimental literature (Ledyard, 1995), but rather realistic if one thinks of the cost of cooperating for a large group problem of collective action and the benefits accrued by the beneficiaries. Notice that if 40 players were to contribute to the public account, the payoff to any player from the public pot would be equal to the value of her own private token. Keeping the private token is a dominant strategy, but if she were to contribute she would get an amount at least equal to what she could have secured with certainty. For 80 players, therefore, the critical mass would be of 50% of players. Further, for any group size larger than 40 players, the configuration of p=20,000 and a=500 would guarantee that this is a social dilemma. Given the difficulty to recruit large numbers of subjects, this design has the advantage of maintaining the MPCR constant regardless of the number of players as long as it is larger than 40.

An experimental session[17].

Each of our sessions was conducted in the following manner. A maximum of 80 people were recruited to attend a session in a large computer lab. In each session the participants had been recruited from an undergraduate large class, and were told that their participation was voluntary, and that their decisions were confidential. The students participating came from different majors and years and thus we expected that they knew only a fraction of other students in the experiment. Once in the lab, they were seated in a random manner along the lab and were asked to maintain silence throughout the experiment.

The monitor asked every participant to read the screen with the instructions. In the instructions they were told that the game will be played for 3 rounds and that at the end, 5 people would be chosen randomly to receive the amount earned in cash. They were told the number of people attending the session as well as the incentives from investing the

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[16] In some cases not all recruited participants showed up, and the experiment was conducted with the attending people, as long as the total number of people guaranteed that the incentives created a public goods problem.
[17] The protocol shown to the participants can be read in the appendix.

token in the private account or in the group account. The appendix to the instructions included examples of possible actions and outcomes. The three rounds were as follows:

Round 1: The players were asked to make the decision to invest the token in the private or group account, in private and confidentially. Once made, the monitor collected all decision cards privately. They were told that the total number of tokens in the group account would not be announced but until the end of the experiment.

Round 2: Before the decision for round 2 was made, the participants were allowed to communicate for 10 minutes with some of the other players using the Yahoo! Messenger active in the screen of their computers. To do this, they received a list of Yahoo accounts of other players present in the lab, and they were informed that they could establish a one-on-one chat conversation with any other player included in their list of contacts[18] if they wished. The Yahoo accounts were created in advance and were already registered in each particular computer. Since the accounts were created and assigned in a random fashion, this chat conversation was anonymous. They were explicitly asked not to open chat conversations with other contacts different from the ones given by the experimenter, but they could open as many one-to-one chat windows with those in the list of other accounts provided. They were told in the instructions that the chat conversations were being recorded in each computer under that Yahoo! account, and that such conversation was to remain confidential. When the 10 minutes concluded, they were asked to stop the chat conversations and proceed to write down their decision to invest the token in the private or group account, once again in private. The monitor then proceeded to collect the new decision cards. The total number of contributions to the group account was not announced either.

Round 3: The third round proceeded very similarly to round 2. However, the instructions this time included the possibility that the players collected other Yahoo! accounts from other contacts– that is, they could increase the number of links and establish chat conversations with more players in the room. To do this, they were explicitly allowed to ask their existing contacts for more Yahoo! accounts and to establish more chat conversations

[18] See Table 2 for the assignment of links in each of the 4 sessions reported here. Each row in Table 2 shows the number of people who received that number (degree) of other accounts with whom they could connect.

if they wanted. Except for that, every other aspect of the round was equal to the previous one. At the end of the new 10 minutes of chat conversations, they were asked to stop and make their new decisions for round 3.

At the end of the three rounds the monitor announced the total number of tokens in the group account for each round, and each player could then calculate her own earnings. The monitor then proceeded to select the five players to be paid in cash. They proceeded to fill a short socio-demographic survey and wait in silence for the completion of the experiment and payment to the selected participants.

Results

We report here the results of 9 sessions conducted during the academic years of 2006 and 2008 at the Universidad de Los Andes with 553 students from different disciplines and years.

Descriptive statistics by groups

We present descriptive statistics for each round and each group in Table 1. The session (group) size ranged between 42 players (group F) and 80 (group H). Group H has the highest average degree (3.925); group A has the lowest (0.6). In general, the actual (effective) degree of the groups is lower than planned due to non-attendance of recruited players reducing the net degree. For instance, both groups A and B were designed to have a degree of 1 if 80 players had shown up. As fewer players than expected showed up, we chose randomly among the available computers those that stayed empty, so that the network retained its uniform random graph structure.

The resulting configuration of the experimental design is depicted in Fig. 2. Each point is a group-network: the effective degree is the average degree computed after the number of actual players and their locations in the net are known. With this sample we created enough variance and orthogonality in terms of group size and net degree. Figure 3 shows the individual player's degree distribution when all groups are pooled. 98 players are isolated, the rest have degrees between 1 and 9. Only eight players have degree seven or higher.

The absence of some players in some sessions provided thus an additional source of variation in the experiment, one that was unexpected but not detrimental to our exercise. When the players decide if they'll try to communicate with others, they have information about the links assigned to them, but they do not know whether a player is actually sitting on the other end (unless of course all players showed up). Thus we can test separately the effects of the prior information about links on the decision to communicate, and the effects of actually establishing communication on the later choices.

The number of conversations in the second round –those that are constrained to the existing links– indicates a high use of the available links: over 75% in all cases and close to 100% in low connectivity groups. Link creation between rounds two and three is also abundant; it doubles the number of conversations in groups with low degrees. Group size does not seem to have any systematic relationship with communication.

How much of all this translates into cooperation? As expected, cooperation was low in the first round, ranging from 6% to 19% (See Table 1). This is usual for the level of returns to contributing (low MPCR) and the lack of communication. Average network degree makes no difference in the first round either –just as well, since the players were unaware of the communication possibilities at this point (Fig 4).

Also as expected, cooperation increases in the second round in almost all cases (Table 2 and Figures 4 and 5); the exception is the least connected group. Average group degree does not obviously correlate with cooperation levels. Larger groups after a group size of about 50 players do cooperate more. Since they knew the group size from the beginning and the MPCR remained constant, we speculate that a larger group would increase each player's expected absolute number of cooperators and via reciprocity increase the individual willingness to cooperate.

The added links and extra conversations in the third round have no additional cooperation-enhancing effect, however. The change in cooperation between rounds 2 and 3 is slightly positive in three cases and slightly negative in six. Why do people bother establishing new links if they will have little influence on their choices? This may be related to the transferability of social capital that we discussed previously. People may consider the eventuality of a future situation where the new acquaintances may be of use. That is, they assign an option value to the new link. The future situation cannot possibly be in the context of the experiment, so this must be a heuristic strategy –a rule-of-thumb behavior: if you can cheaply make an acquaintance, get a phone number or an e-mail address, do so, even if you have no immediate use for it.

Local network, willingness to communicate and the effect of communication on cooperation

We turn now to the effect of the local (rather than the global) environment on individual actions. Figure 6 shows the link utilization ratio (conversations / exogenous links) and the new link ratio (new links / exogenous links). In the second round, on average, the players have conversations on roughly 80% of their exogenous links. In the third round the players with high degrees (hubs) still account for most of the new links, but the relationship is less than proportional.

Having played G (cooperate) in the first round is correlated with higher cooperation in all rounds. Communication matters, too (or perhaps the existence of exogenous links, since they are closely correlated). While cooperation levels rise in the second round when communication is allowed, they rise more for people who chat more. Surprisingly, they also rise for isolated people –those who do not chat because they have no link.

Meaningful play profile

A player's play profile is her sequence of choices in the three rounds. There are eight possible play profiles and they were all observed in the game: GGG, GGP, GPP, GPG, PGP, PGG, PPG and PPP. Fig 8 shows the distribution of play profiles among isolated and connected players. PPP was by far the most common play profile with over half of all players of either group, understandably because of the low MPCR in the game. This however gives us room for increases in cooperation through network mechanisms.

To understand the profiles, it helps to construct plausible narratives of why a player may make certain choices, and how they may relate to the information she acquires during the experiment. The first round choice cannot depend on the communication network as the players did not know of the possibility to communicate with others. The actions in the first round may reflect some underlying player characteristic (altruism or egoism, optimism with regard to cooperation) or common information, like group size and the MPCR. As a player gathers information through conversations, she may reaffirm her choice or change her actions. If the information is more or less consistent, one may observe a steady profile (GGG or PPP)[19] or a monotonic one (GGP, GPP, PGG, PPG), depending on whether the new information confirms or contradicts the initial choice. Of course, the interpretation of the information may vary across players. We will say that a profile becomes cooperative if it starts with P in the first round and ends with G in the third. Conversely, it becomes non-cooperative if it starts with G and ends with P.

Non-monotonic profiles (GPG and PGP) suggest that the player was close to undecided in the first round, got mixed signals when conversing, or both. We treat them separately.

With this manner of interpretation, Fig. 9 shows the distribution of “meaningful play profiles”, i.e. play profiles grouped according to the narratives above, by individual player degree. We group the profiles in steady cooperative (GGG), steady egoistic (PPP), increasingly cooperative (PPG, PGG), increasingly egoistic (GGP, GPP) and non-monotonic or mixed (GPG, PGP).

Higher degrees decrease the frequency of steady egoistic and increasingly egoistic play profiles. They also increase the frequency of steady cooperative and increasingly cooperative ones. That is, higher degrees make people more cooperative, whether they started cooperating in round one or not. This is also illustrated in Fig. 7. Whatever information people get when they talk, it tends to make them more prone to cooperating. Particularly striking is the decrease in increasingly egoistic profiles between isolated players and those with at least one link. Isolation brings despair, apparently.

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[19] Of course, another plausible narrative for the steady profiles is that some people simply stick to one choice regardless of the information based on her personal values and expectations. Some people may be Kantian cooperators, while others may be unconditional egoists. We explore this possibility in Jaramillo et al. (2009).

Mixed profiles also show interesting patterns. They are twice as common among players with one link than among those isolated, suggesting that the acquired information is indeed the cause of some switching in choices. Perhaps the player started with a prior that was contradicted by the one conversation she had. Consistent with the hypothesis that the switching reflects uncertainty, however, more links (and conversations) seem to eliminate it: mixed profiles disappear among players with high degree. Nevertheless, a question remains: why do 7% of isolated players play mixed profiles? For that matter, why do over one third of all isolated players switch action at some point? What kind of information leads them to revise their choice?

Leaving aside the possibility of randomization, the matter of isolated players switching choices suggests that some information does become available to them between rounds. The only candidate we can think of is the aggregate level of communication, reflected in the volume of typing-related noise in the room. However, since the isolated players cannot know what is being typed, it must be that they have priors about the content of the conversations. If so, those priors are evenly distributed, as the increasingly cooperative and the increasingly egoistic are roughly the same proportion among isolated players. This allows us to infer something about the informational content of the conversations. Assuming (plausibly) that such priors about the content of the conversations are uncorrelated with the degree of the players, the fact that increasingly cooperative profiles are much more common than increasingly egoistic ones among connected players, suggests that the content of the conversations (and not only their number) matters, and that it makes people update their priors in a manner that favors cooperation.[20]

[20] We have the logs of the written conversations and can examine their actual contents. However, the literal content of a message in this case is not necessarily the same as the information that a player receives. For instance, one may reason that it is in the interest of any unscrupulous player to say that she is going to cooperate, regardless of her actual intentions. Thus, any information I gather from a conversation must stem from something different than a literal statement of comradeship and invitation to cooperate. What these statistics suggest is that this information is, on average, pro-cooperation.

Conclusions

In this paper, we examine the private, decentralized provision of a public good through a VCM embedded in a social network. We study in different rounds of the game the determinants of two types of activism: communication with people, and endogenous generation of new connections among the members of the network. In the first round the network is exogenously imposed on the subjects –it does not arise through their choices–, so whenever observed behavior correlates with network characteristics, we are able to establish causality. Even in the second round, to the extent that new link creation is correlated with the original network characteristics, the direction of causality is clear. We also study the effectiveness of the two types of activism as means to improve the actual outcome of the VCM game.

We use an experimental setting, adapting the conventional version of the public goods provision game or Voluntary Contributions Mechanism (VCM) for the context of our research question. We create a setting for 50-80 players who face the choice of contributing or not to the same pure public good –every player will receive the same amount of the public good provided regardless of having contributed or not. Secondly, we simplify the action set for the players to a dichotomous choice of investing one token to the private account (not contributing) or to the group account (contributing). Because the private cost of contributing to the public good is higher than the private return from the public good, there are no individual (Nash) incentives to contribute. However, at the social optimum, all players would be better off if all players had contributed. This is the case of a typical N-prisoners dilemma or any social dilemma where individual and group interests are in conflict.

The results of our experiment suggest that the local structure of the network, measured by a player's individual degree, influences her ability to communicate but not her willingness to do so. It does, however, increase her willingness to create new links to other players.

As expected, the communication itself is crucial in explaining the level of cooperation in the group. However, it is the communication on exogenous links that makes a difference. The endogenously created new links do not seem to serve this purpose. Cooperation levels do not increase when the players create new links. We speculate that new links have an option value, that is, they are built on the implicit expectation of eventual use, possibly in other settings.

The manner in which links and conversations influence the players' choices during the game suggests that there is information processing taking place. Players do seem to update some sort of prior as they have conversations, and to reduce their uncertainty with more conversations. Moreover, the content of the conversations seems to be pro-cooperation, in the sense that updating is mostly towards more cooperation.

Finally, the isolated players also do switch choices during the game, suggesting that they infer information from the overall level of communication, even if they do not know the content of that communication.

We have studied in this experiment the effect of connectivity on (a) actual communication, (b) cooperation, (c) endogenous link creation and (d) information flows. It also provides us with additional, yet unexploited information about the demographics of the players and the characteristics and contents of the conversations, as well as higher order statistics of the network (which the literature suggests should be relevant). We expect that further research will allow us to establish whether these additional data explains the observed patterns of communication, activism and cooperation. In particular, we expect to estimate the effect of network clustering and hubs, on one side, and of the content of the conversations on the other.

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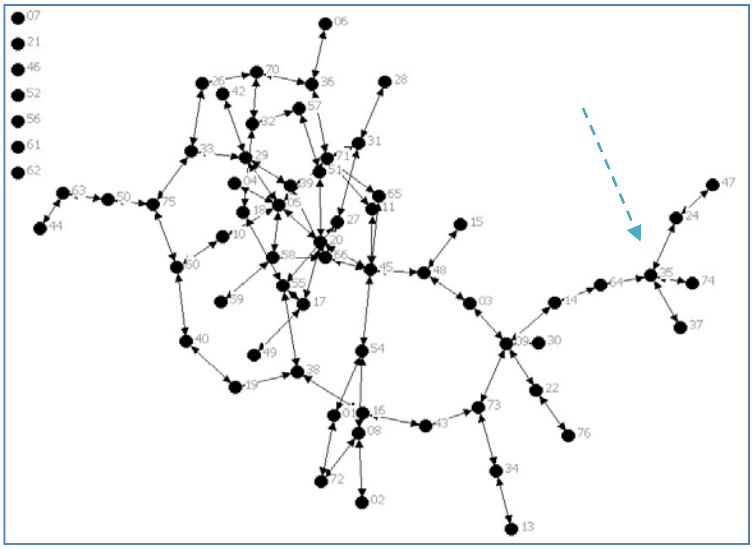

Figure 1: A random graph

Table 1: Group statistics by round

Group	Effective degree of the net	Original links		Number of (additional) conversations	Number of players	Played G	% played G
A	0.6	24	Round 1	0	52	6	12%
			Round 2	24	52	4	8%
			Round 3	22	52	6	12%
B	0.75	30	Round 1	0	62	6	10%
			Round 2	29	62	12	19%
			Round 3	37	62	9	15%
C	1.85	74	Round 1	0	68	9	13%
			Round 2	72	68	23	34%
			Round 3	138	68	28	41%
D	0.75	30	Round 1	0	71	11	15%
			Round 2	28	71	26	37%
			Round 3	23	71	20	28%
E	2.92	73	Round 1	0	50	4	8%
			Round 2	59	50	10	20%
			Round 3	87	50	8	16%
F	1	25	Round 1	0	42	8	19%
			Round 2	16	42	13	31%
			Round 3	19	42	7	17%
G	1.375	55	Round 1	0	48	3	6%
			Round 2	38	48	9	19%
			Round 3	68	48	14	29%
H	3.875	155	Round 1	0	80	15	19%
			Round 2	128	80	43	54%
			Round 3	203	80	40	50%

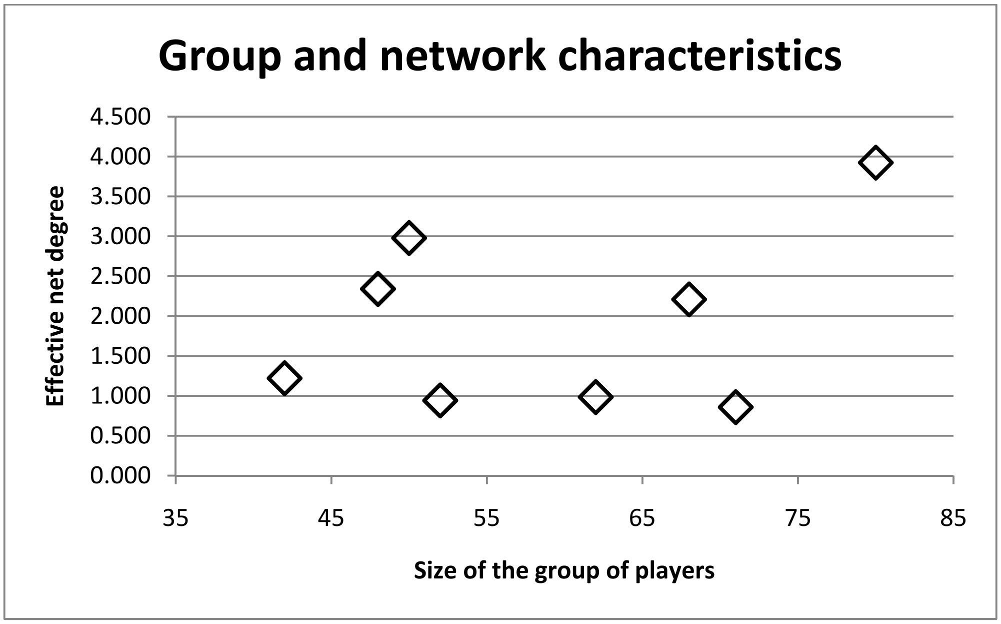

Figure 2. Group and network characteristics

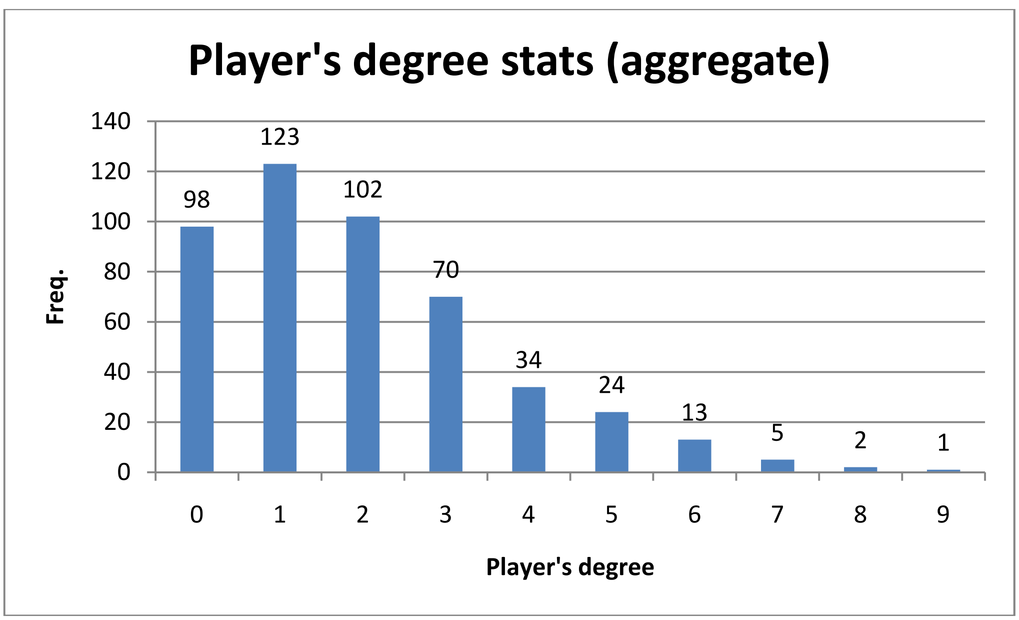

Figure 3. Degree distribution of the players

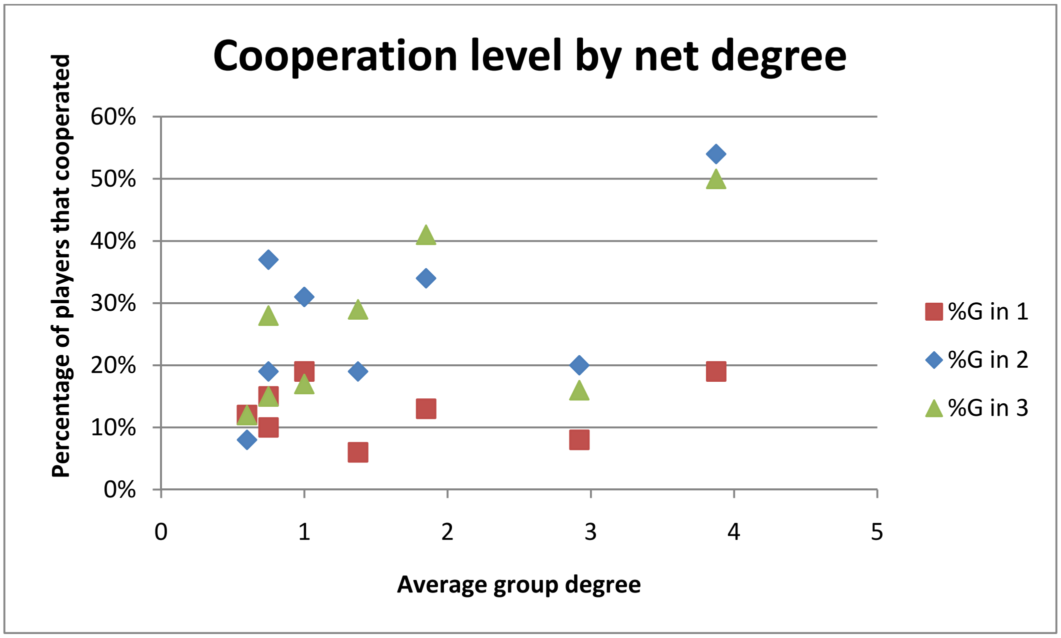

Figure 4. Cooperation level and group size

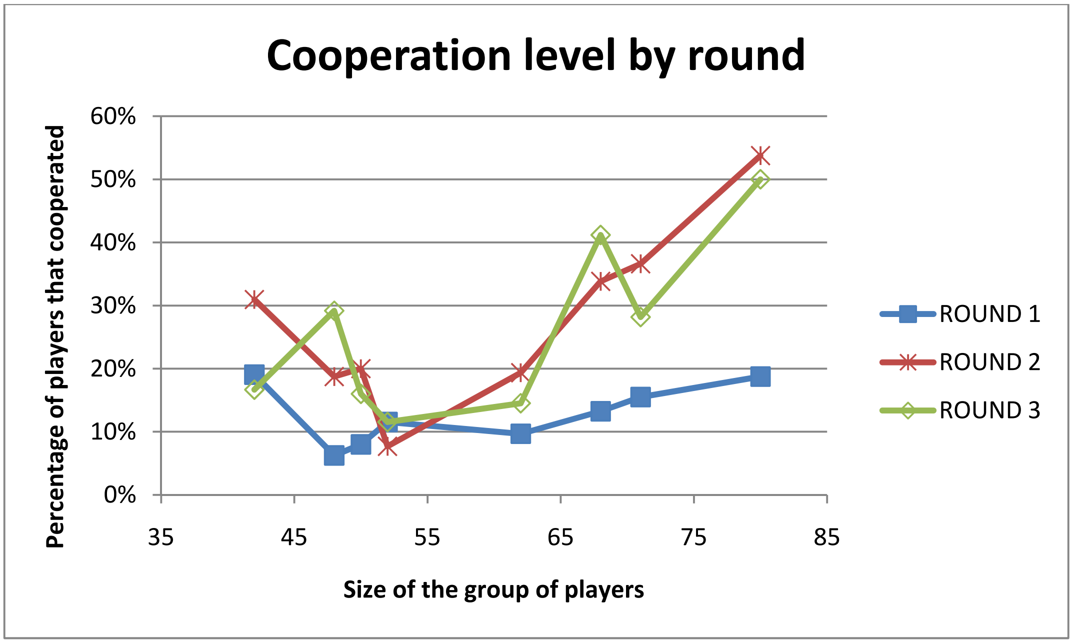

Figure 5. Cooperation level and group size

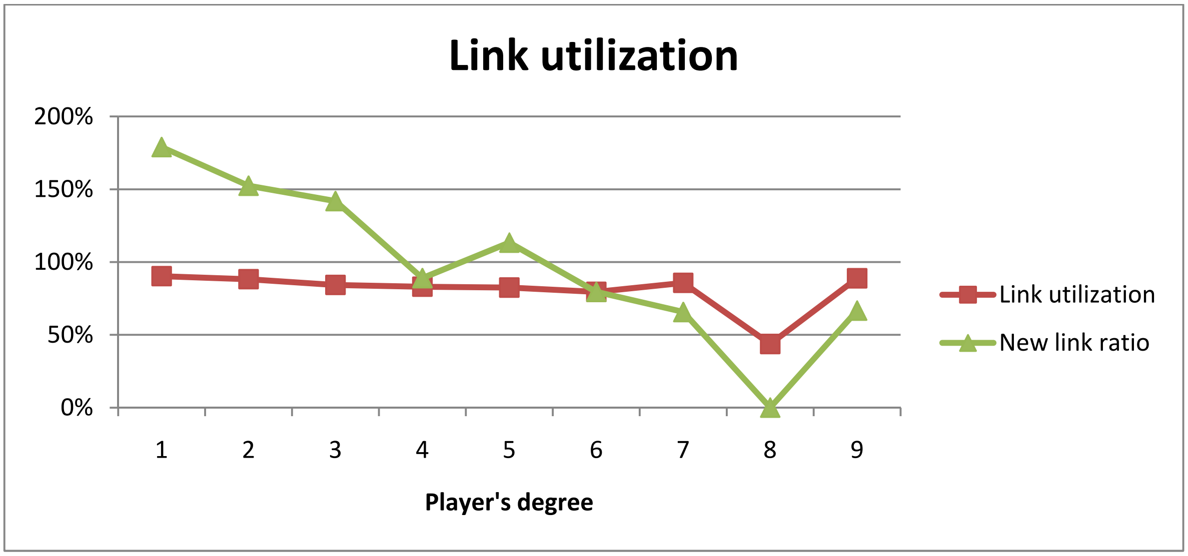

Figure 6. Link utilization and creation by player's degree

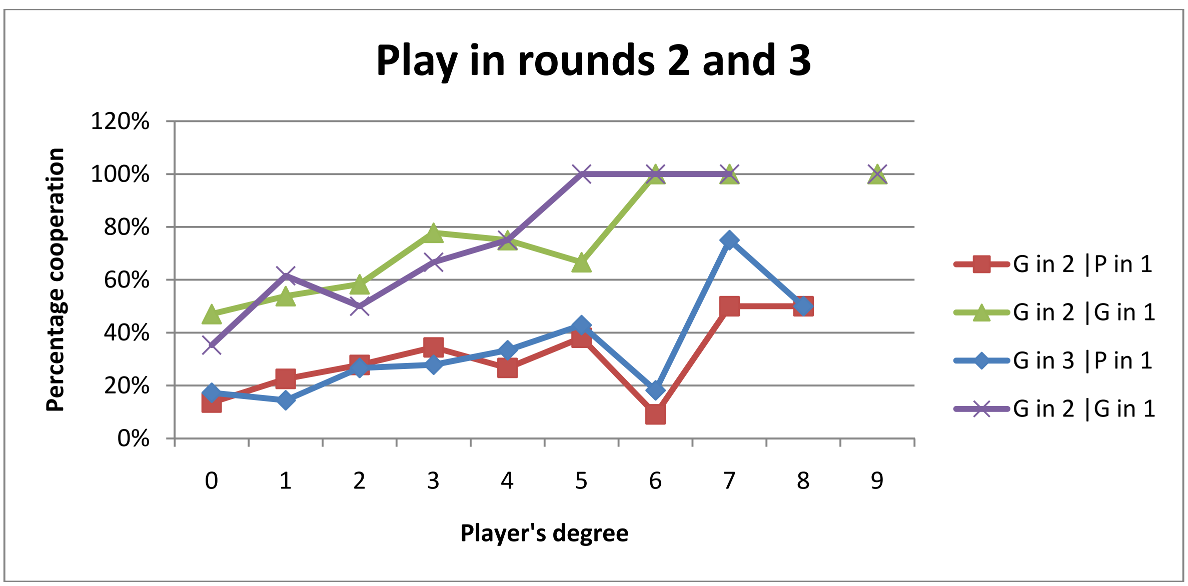

Figure 7. Player's choice by player's degree and first round (baseline) play

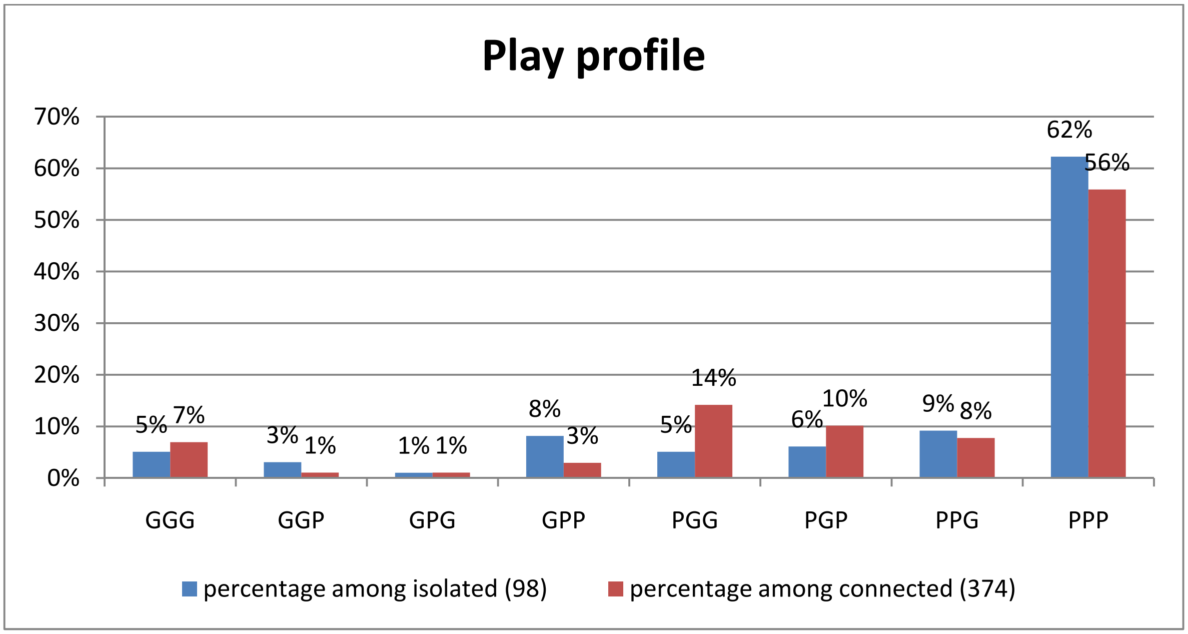

Figure 8. Distribution of play profiles

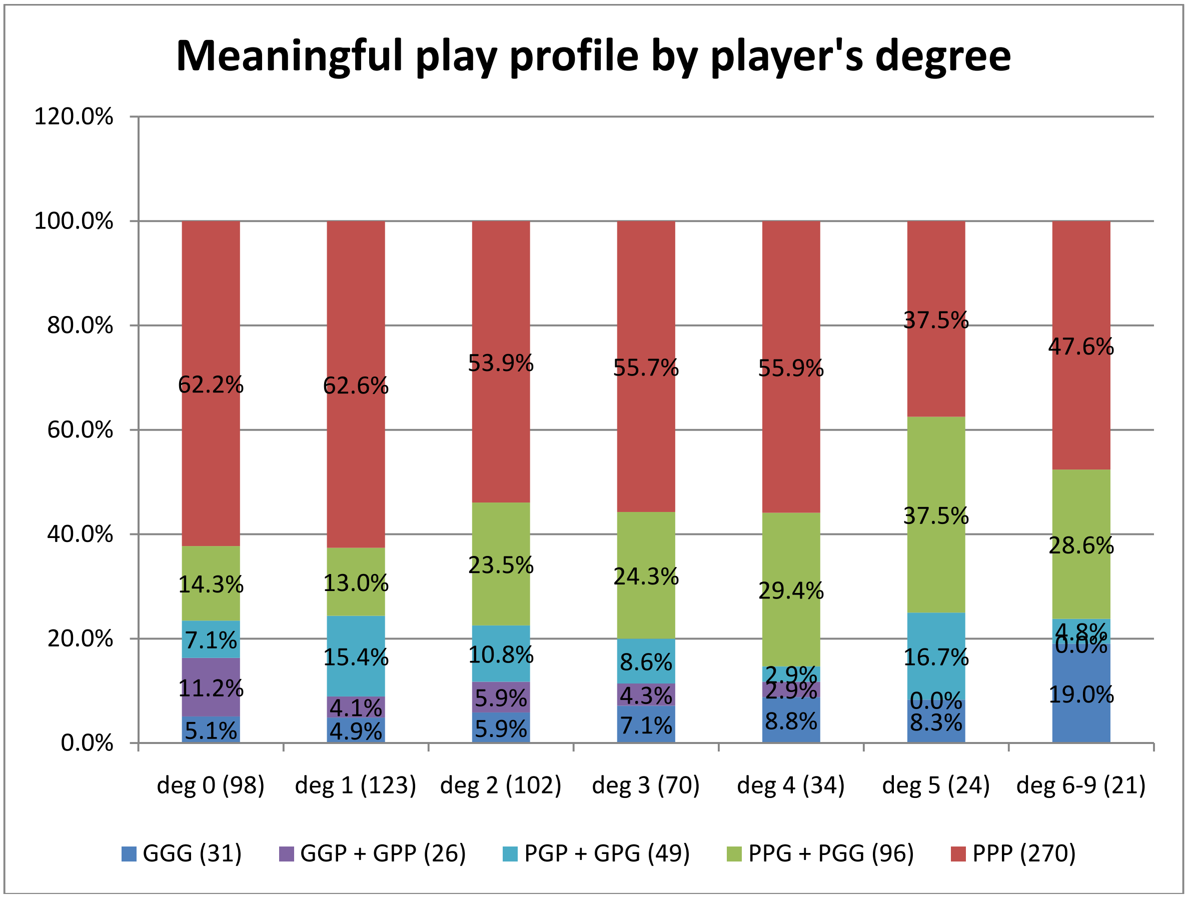

Figure 9. Cooperation by link usage

Appendix:

Protocols and forms

Experimenter Protocol

Los implementos para comenzar la sesión son los siguientes:

a. Red de 80 computadores con acceso a Yahoo! Messenger
b. Cuentas de Yahoo! Messenger activadas y abiertas en cada computador
c. Página de instrucciones (html) abierta en navegador en cada computador
d. Números consecutivos del 1 al 80 para marcar computadores
e. Lista de cuentas de 80 Yahoo! Messenger
f. 80 formatos de decisiones individuales
g. 80 x 3 = 240 tarjetas de decisión individual
h. Hoja de asistencia-pagos
i. 1 Protocolo
j. 80 Consentimientos
k. 80 recibos de pagos para que los participantes los firmen
l. Caja con dinero
m. Un sobre

1. Recibimiento

a. El monitor debe recibir a los participantes en la mesa de entrada. En orden de llegada se le asigna un código a esa persona, se le entrega la tarjeta con su número, recordándole que durante el desarrollo del juego ese va a ser su identificación, y que de ser posible no bote ese número. (Ver hoja de asistencia y pagos finales). Una vez termine de recibir a todos los participantes comenzar a llenar la hoja de redes.

b. Otro monitor va ubicando a las personas en orden de llegada en los computadores.

2. Comenzar instrucciones

a. Finalmente cuando todos los participantes lleguen (Aproximadamente 80 participantes), el supervisor debe comenzar a leer las instrucciones generales.

INSTRUCCIONES

Experimento sobre redes de comunicación y Provisión de Bienes Públicos

Notas para el monitor del experimento:

El diseño actual es para 80 personas.

La decisión individual consiste en invertir una ficha en una cuenta privada o en una cuenta de grupo. La cuenta del grupo provee un bien público, proporcional a las fichas que se inviertan en ella.

En concreto, los incentivos son los siguientes, en unidades monetarias $:

- Cada jugador tiene una ficha que debe invertir entre dos opciones:
    - Una cuenta privada (P) que le genera una tasa de retorno fija
    - Una cuenta grupal (G) que le genera una tasa de retorno dependiente del número de contribuciones del total de jugadores.
- Las ganancias del jugador dependerán de su inversión, de la siguiente manera:
    - Si el jugador invierte la ficha en la cuenta privada (P) obtiene $20,000
    - Cada jugador del grupo, sin importar en donde invirtió su ficha, recibirá $500 por cada ficha que haya sido invertida en la cuenta del grupo (G).

En este diseño básico los jugadores toman sus decisiones de manera individual, confidencial y anónima. No pueden interactuar con otros jugadores antes, o durante el experimento, y sus ganancias y decisiones se mantendrán confidenciales por parte del monitor. Los jugadores tomarán decisiones en dos rondas y no sabrán el resultado de cada ronda sino hasta el final.

Rondas: Una sesión de este juego constará de 3 rondas. En cada una de las rondas los jugadores deberán depositar en una caja una tarjeta que depende de si invierten su ficha en la cuenta privada (P) o en la cuenta de grupo (G). Esta misma decisión la irán registrando los monitores en las **“Hojas de Decisiones”**. El jugador no podrá calcular sus ganancias individuales totales sino hasta el final de la cada ronda donde el supervisor anunciará en el tablero el total de fichas invertidas en la cuenta de grupo (G).

En la segunda ronda de este juego, el supervisor anunciará que cada jugador tendrá la posibilidad de comunicarse con uno o más de los jugadores del grupo, antes de decidir cómo invertir la ficha en la próxima ronda. La comunicación se hace a través de el servicio de yahoo! Messenger instalado en las máquinas de la sala de computadores. Esta comunicación es totalmente voluntaria Los jugadores cuentan con 10 minutos para comunicarse. Al terminar el tiempo permitido, se suspenden las comunicaciones, y se procederá nuevamente a la decisión individual de inversión de su ficha en la cuenta privada (P) o en la cuenta del grupo (G). Estas decisiones seguirán siendo privadas y confidenciales.

Para registrar esta decisión cada jugador tendrá una tarjeta, donde decide si invierte en “P” o “G”.

Al final de las tres rondas, el monitor anunciará el total de fichas invertidas en la cuenta de grupo (G) en cada ronda para que cada jugador pase con un monitor y este último pueda calcular sus ganancias individuales en cada ronda y sus ganancias individuales totales.

El monitor se encargará de realizar los pagos al finalizar todos los experimentos.

Juego de Inversión

Instrucciones para los Participantes

Gracias por participar en este experimento el día de hoy. El ejercicio se hará en una sola etapa con varias rondas de un juego. Por su participación Usted podrá ganar una cantidad considerable de dinero y por ello es importante que preste mucha atención a las instrucciones. La cantidad que se puede ganar depende de las decisiones que Usted y los demás participantes tomen durante el ejercicio.

Al final del ejercicio vamos a escoger a 5 personas y les pagaremos sus ganancias en efectivo y de manera privada y confidencial.

Usted va a hacer parte de un experimento en el que 80 personas en este salón tomarán decisiones, de manera individual, simultánea y en silencio. En este ejercicio Usted va a tomar decisiones en 3 rondas del juego.

Cualquier decisión que usted tome durante este ejercicio será estrictamente confidencial. Para asegurar que sus respuestas sean confidenciales, le pedimos que **no hable con nadie hasta que el experimento haya terminado completamente, de lo contrario, el experimento podrá ser cancelado.**

Decisiones: Al comienzo de cada ronda Usted tendrá disponible una ficha que podrá invertir en dos posibles alternativas o cuentas:

Cuenta Privada (P)

Cuenta de Grupo (G)

Al comenzar la siguiente ronda Usted tendrá disponible una nueva ficha para invertir.

Ganancias: De acuerdo a sus decisiones y las decisiones de los demás del grupo Usted podrá obtener una cantidad de unidades monetarias experimentales E$. Sus ganancias en cada ronda se calcularán de la siguiente manera:

Usted gana E$20,000 si invierte su ficha en la Cuenta Privada (P)

Por cada ficha que Usted y los demás del grupo inviertan en la Cuenta de Grupo (G) Usted obtendrá E$500

Al finalizar el juego completo elegiremos una de las tres rondas al azar y le pagaremos a las cinco personas seleccionadas el dinero en efectivo que obtuvo. Este pago se hará en privado y de manera confidencial.

Cada uno de Ustedes va a decidir de manera individual y privada en donde invertir su ficha en cada ronda: (P) o (G). Esas decisiones serán registradas en las “Tarjetas de Juego” que serán recogidas por los monitores después de cada ronda, para contar el número de fichas invertidas en cada cuenta. Al final de las tres rondas, el monitor anunciará al grupo el total de fichas invertidas en la cuenta de grupo (G) durante cada ronda, y así, Usted podrá saber sus ganancias de acuerdo a su decisión, llenando las casillas de su “Hoja de Cuentas”.

Ejemplos: Los siguientes ejemplos le pueden dar una idea de las posibilidades que tiene.

En una ronda Usted invierte su ficha en la cuenta privada (P), y después de sumar el total de fichas del grupo se anuncia que 65 fichas fueron consignadas en cuentas privadas (P) y 15 personas habían invertido en la cuenta de grupo (G). Por lo tanto sus ganancias son $20,000 por la ficha invertida en la cuenta privada y 15x$500, lo cual le da unas ganancias totales de $27500

En una ronda Usted invierte su ficha en la cuenta de grupo (G), y después de sumar el total de fichas del grupo se anuncia que 65 fichas fueron consignadas en cuentas privadas (P) y 15 personas habían invertido en la cuenta de grupo (G). Por lo tanto sus ganancias son 15x$500 = $7500.

En la ronda especificada Usted invierte su ficha en la cuenta privada (P), y después de sumar el total de fichas del grupo se anuncia que 25 fichas fueron consignadas en cuentas privadas (P) y 55 personas habían invertido en la cuenta de grupo (G). Por lo tanto sus ganancias son $20,000 + 55xE$500 = $47,500.

Usted invierte su ficha en la cuenta privada (P), y después de sumar el total de fichas del grupo se anuncia que 20 fichas fueron consignadas en cuentas privadas (P) y 60 personas habían invertido en la cuenta de grupo (G). Por lo tanto sus ganancias son $20,000 por la ficha invertida en la cuenta privada y 60x$500, lo cual le da unas ganancias totales de E$50,000.

Recuerde que todos en el grupo se benefician de igual forma de las fichas invertidas en la cuenta de grupo, pero solo Usted se beneficia de la ficha que invierte en la cuenta privada.

Hemos diseñado el ejercicio de manera que usted pueda tomar sus decisiones en privado y tal que nadie más conozca sus decisiones. Solo Usted sabe en cual cuenta invierte su propia ficha y ningún otro participante podrá ver esta información durante o después de finalizado el experimento. La única información que se da al grupo es el total de fichas invertidas al grupo.

Es importante que usted entienda cómo funciona el ejercicio. ¿Hay alguna pregunta sobre cómo se procederá en el ejercicio? Si tiene alguna pregunta levante la mano y ésta será respondida por un monitor para todo el grupo. No consulte ni discuta las instrucciones o cualquier otro aspecto del juego con los demás participantes.

Cuando se aclaren las preguntas pasaremos a la decisión de la primera ronda.

Instrucciones segunda ronda del juego

Antes de decidir cómo invertir la ficha en la próxima ronda, Usted tendrá la posibilidad de comunicarse con uno o más de los jugadores del grupo. Esta comunicación es totalmente voluntaria. Sin embargo debe permanecer en silencio durante el resto del experimento. Es absolutamente prohibido comunicarse verbalmente con los demás miembros del grupo.

La única forma permitida de comunicarse con los demás del grupo, si lo desea, es **usando la aplicación de Yahoo! Messenger© para chatear**, y obviamente solo con aquellos cuya cuenta de Yahoo! le entregaremos. No es permitido obtener información adicional sobre las cuentas o contactos de otros destinatarios durante el experimento.

La información que fluya en el Yahoo! Messenger será grabada en el computador bajo la cuenta asignada a Usted. Esta información es anónima y confidencial también.

Ustedes cuentan con 10 minutos para enviar los mensajes que deseen.

Al terminar el tiempo permitido, suspenderemos las comunicaciones, y procederemos nuevamente a la decisión individual de inversión de su ficha en la cuenta privada (P) o en la cuenta del grupo (G). Estas decisiones seguirán siendo privadas y confidenciales.

A continuación le damos algunos detalles de cómo usar el Yahoo! Messenger.

Instructivo de Yahoo! Messenger

1. Para ingresar al programa: inicio +programas + Yahoo! Messenger

2. Para iniciar la sesión: En la ventana entrar (conectarse a Yahoo!) en ID: ingresar el nombre de la cuenta que le fue asignada y en contraseña la contraseña asignada.
3. Para fines del experimento sus conversaciones serán gravadas, para verificar si esta opción esta activa:
    - Messenger + preferencias+ En el cuadro categorías escoger la opción archivo +al lado derecho escoger la opción si, guardar mis mensajes.
4. Para agregar los contactos (dentro de este experimento solo podrás agregar los contactos asignados si no te fue asignado ningún contacto no podrás agregar ninguno en tu cuenta pero otras personas trataran de comunicarse contigo, los cuales serán los contactos con los que podrás hablar)

    - Contactos + agregar contactos, en esta ventana deberás escribir la dirección de correo de tu contacto+hacer clic en siguiente hasta que aparezca la opción finalizar la cual debes seleccionar para terminar el proceso.
5. Para iniciar la comunicación con alguno de tus contactos:

    Haz clic con el botón derecho del Mouse en su nombre y selecciona la opción enviar mensaje instantáneo, luego aparecerá un recuadro en el que debes escribir lo que quieras decir y seleccionar la opción enviar para que pueda ser leído por tu contacto.

Instrucciones tercera ronda del juego

Antes de decidir cómo invertir la ficha en la tercera ronda, Usted tendrá la posibilidad de comunicarse de nuevo con uno o más de los jugadores del grupo. Esta comunicación sigue siendo voluntaria. Sin embargo debe permanecer en silencio durante el resto del experimento.

La única forma permitida de comunicarse con los demás del grupo, si lo desea, es **usando la aplicación de Yahoo! Messenger para chatear**. En esta nueva ronda Usted puede obtener información adicional sobre las cuentas o contactos de otros destinatarios durante el experimento. Si Usted quiere conseguir nuevas cuentas de Yahoo! para establecer nuevos contactos puede conseguirlas a través de otros jugadores y podrá establecer nuevas charlas.

La información que fluya en el Yahoo! Messenger será grabada en el computador bajo la cuenta asignada a Usted. Esta información es anónima y confidencial también.

Ustedes cuentan con 10 minutos para enviar los mensajes que deseen.

Al terminar el tiempo permitido, suspenderemos las comunicaciones, y procederemos nuevamente a la decisión individual de inversión de su ficha en la cuenta privada (P) o en la cuenta del grupo (G). Estas decisiones seguirán siendo privadas y confidenciales.

Una vez terminadas las tres rondas del juego, procederemos a sumar las ganancias de cada jugador y haremos el sorteo de la ronda que se pagará y de los cinco estudiantes que recibirán sus ganancias en efectivo.

INDIVIDUAL DECISIONS SHEET

A	B		C	D	E	F	G
Ronda	Mi decisión (cuenta privada o cuenta de grupo)		Total fichas en cuenta de grupo (anuncia el monitor)	Mis ganancias en la cuenta privada ($20.000 si escogí P)	Mis ganancias en la cuenta de grupo ($500 cada G)	Ganacia total individual en esta ronda (Columnas D+E)	Ganancias acumuladas totales
1	**P**	**G**					
2	**P**	**G**					
3	**P**	**G**					

DECISIONS FORMS

No. de jugador	**1**	
Ronda	**1**	
Mi decisión	**P**	**G**

No. de jugador	**1**	
Ronda	**2**	
Mi decisión	**P**	**G**

No. de jugador	**1**	
Ronda	**3**	
Mi decisión	**P**	**G**

No. de jugador	**2**	
Ronda	**1**	
Mi decisión	**P**	**G**

No. de jugador	**2**	
Ronda	**2**	
Mi decisión	**P**	**G**

No. de jugador	**2**	
Ronda	**3**	
Mi decisión	**P**	**G**

No. de jugador	**3**	
Ronda	**1**	
Mi decisión	**P**	**G**

No. de jugador	**3**	
Ronda	**2**	
Mi decisión	**P**	**G**

No. de jugador	**3**	
Ronda	**3**	
Mi decisión	**P**	**G**