Centrality and Cooperation in Networks

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Abstract: We investigate the effects of centrality on cooperation in groups. Players with centrality keep a group together by having a pivotal position in a network. In some of our experimental treatments, players can vote to exclude others and prevent them from further participation in the group. We find that, in the presence of exclusion, central players contribute significantly less than others, and that this is tolerated by those others. Because of this tolerance, teams with centrality manage to maintain high levels of cooperation.

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1 Introduction

Many organizations and groups have some form of network structure defined by who can interact with whom. Links between members are often formal. For example, a hierarchical chain of command typically creates a well-defined network structure. Network links might, however, also be of a more informal nature. Some individuals, for instance, might benefit from information provided by others even if these others are not from the same formal organization. Think of an employer A looking for suggestions from other employers about suitable candidates to recruit (Gërxhani et al. 2013). Even if she is not involved in any formal organization connecting her to other employers, A might receive suggestions from employer B who happens to be her golf partner. In fact, if B knows employer C, A might even receive information from C without knowing C. In this way, some individuals might connect others who are otherwise separated. Separation can occur, for instance, by location or lack of direct social connections. Individuals who connect others in this way are in a sense more 'central' in the network than those who do not connect strangers.

Networks with central players might occur in formal organizations (for example, connecting two departments of the same firm), but intuitively, they seem more likely to be observed in informal organizations. This is because formal organizations typically try to avoid specific individuals becoming too central. Indeed, if distinct subgroups are only connected via a central player, then – in both formal and informal networks – her presence is essential for these groups to mutually benefit from each other's actions. In their study of 50 large organizations, Cross and Prusak (2002) find that informal networks are ubiquitous, and that such networks often have central players who play a crucial role by connecting other individuals and subgroups in the organization.

At the same time, many organizations have mechanisms allowing members to be expelled if they somehow fail in their obligations towards other members. An extreme example would be how, historically, military personnel would face serious consequences (possibly execution) if they shirked on the job. Less dramatic examples of exclusion are observed in firms, political parties, supporters groups, and clubs. Managers can be fired, politicians can be expelled, hooligans can be banned from visiting games, and club membership can be revoked. In some cases, the impact of this exclusion can also be substantial to the group as a whole (e.g. a complete government can fall due to the acts of a single politician). A common theme is that exclusion from these groups is costly to the person involved and possibly also to the group as a whole.

When the member's position is characterized by centrality, however, her exclusion may be even more costly to other members of the organization, who are now no longer connected. The powerful position that centrality thus brings might then lead central players to exploit their pivotal position with little fear of retaliation. Cross and Prusak (2002) find that 'central connectors' sometimes "use their roles for political or financial gain" (p. 8). The notion of centrality is closely related to the idea of structural holes in networks. In our framework a central player bridges a structural hole, which enables her to extract the rents from this position (Burt 1992; Goyal and Vega-Redondo 2007). This rent seeking is acceptable to those being connected because the connections she creates are valuable. It is a price they might well be willing to pay, as "it is not easy for the other members of the network to supplant an ineffective central connector" (Cross and Prusak 2002, p. 8).

In this paper, we study how network positions affect cooperative behavior. We design an experiment that allows us to study the effects of centrality and how this relates to the possibility of excluding players from a network. Our setup creates a network where centrality is valuable while cooperation can be enforced by the threat of exclusion. In particular, we address the following research questions: (i) How is cooperative behavior affected by being central in a network? (ii) How do other players respond to the use or (potential) abuse of a central position?

In the experiment, subjects play a voluntary contribution mechanism (VCM) game where group members are connected on a network. Payoffs from individual contributions accrue to all, without rivalry. As is usual in these games, full contribution by all members is efficient but selfish individuals have a dominant strategy to free ride by contributing nothing. In one of our treatments, contribution constitutes a public good because no group member can be excluded from benefitting. An example is the collection of voluntary contributions amongst neighbors, to install safety cameras at the neighborhood's periphery. In another treatment exclusion from group benefits is possible and contributions are best seen as constituting a 'quasi' or 'impure' public good (Cornes and Sandler 1996). Here, one can think of contributions amongst members of a club to build a new clubhouse, where membership of non-contributors can be revoked.

The networks we design provide a formal structure on who can contribute and who enjoys the benefits of any individual's contribution. Without centrality the network is complete; there is a connection between each pair of players. This means that a player's departure from the network has no consequences for the possibilities of the remaining players to interact and benefit from each other's contributions. With centrality, one player connects the other group members. Note, however, that centrality only creates a pivotal role if the player concerned could somehow leave or be removed from the network. This would break (some of) the connections between other group members. To study the effects of network structures with centrality, we therefore include a treatment with exclusion. Here, every player may vote to exclude specific group members (as in Cinyabuguma et al. 2005 and Charness and Yang 2014). Excluding the central player causes the group to fall apart, which is costly for all involved.[1]

Several other experimental studies investigate public good provision in a network. In these studies, the network determines which contributions can be accessed (Rosenkranz and Weitzel 2012; Charness et al. 2014), who can monitor whom (Eckel et al. 2010; Fatas et al. 2010), who can punish whom (Leibbrandt et al. 2015) or a combination of these (Carpenter et al. 2012). However, none of these studies involves centrality. To the best of our knowledge, we are the first to study the effects of network centrality in social dilemmas.

Our results show that centrality is often used as a license to free ride; central players contribute less than others. Other players tolerate such behavior: they contribute more than the central player and they tend not to vote to exclude central players. As a result, players with centrality earn higher payoffs than others. In other words, we find that central players take advantage of their position and manage to get away with this.

The introduction of players with centrality creates heterogeneity across players. This is important, because homogeneity within organizations is unlikely to be found outside the laboratory. People differ along many dimensions, including their position in the network. A large body of previous work has found that heterogeneity in endowments, productivity and/or returns frequently reduces cooperation in VCM games (e.g. Cherry et al. 2005, Anderson et al. 2008, Tan 2008, Nikiforakis et al. 2012, Fischbacher et al. 2014, Hargreaves Heap et al. 2016, Gangadharan et al. 2017).[2] This is primarily due to a multiplicity of norms that underlie the behavior of players with different characteristics. The introduction of additional features such as a punishment mechanism or the activation of group identity allows groups to overcome this decrease in cooperation (Reuben and Riedl 2013, Weng and Carlsson 2015). However, not all

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[1] It is important to note that exclusion is not the only mechanism that might affect the structure of a network. Many networks, for example, form endogenously with members joining and leaving at their own discretion. Endogenous group formation has been shown to positively affect contributions in experimental public goods environments (e.g., Ehrhart and Keser 1999, Coricelli et al. 2004, Page et al. 2005, Gunnthorsdottir et al. 2007, Ahn et al. 2008). The changes in network structure that arise from this endogeneity, however, will typically not affect players' centrality; the networks in such experiments are designed to be complete, with every pair of members being directly linked. In contrast, our experimental networks either have one central player or have none. This provides control over the centrality and allows for clean inferences on the effects of centrality on contributions.

[2] Several other papers also study heterogeneity in VCM games but have no baseline with homogenous players. Examples include Buckley and Croson (2006), Noussair and Tan (2011) and Dekel et al. (2017).

additional mechanisms are equally effective. For example, Gangadharan et al. (2017) find that communication increases cooperation in both homogeneous and heterogeneous groups, but the positive effect of communication is stronger in homogeneous groups. Finally, not all studies find that heterogeneity is detrimental to efficiency, and not under all circumstances. Fisher et al. (1995) find that heterogeneity in MPCRs does not affect efficiency and Chan et al. (1999) find that heterogeneity in endowments and/or returns from the public good increase cooperation in a nonlinear environment. Our study tests the effects of a different kind of heterogeneity – that is, in network position – on overall efficiency.

Our results show that heterogeneity due to centrality does not affect efficiency. In our setting, periphery (that is, non-central) players understand the positive value of being connected via central players and appear to be willing to pay a price for these connections. Central players seem to restrict their free riding to a level that periphery players find acceptable and thereby avoid being excluded.

The remainder of this paper is organized as follows. The next section presents our experimental design and section 3 presents our testable hypotheses. We describe our results in section 4 and section 5 concludes.

2 Experimental design and procedures

In the experiment, players are matched in fixed groups of five that interact with each other for one block of five rounds. Each session consists of five such blocks, with random re-matching between blocks to minimize the possibility of long-term reputation formation. The stage game in the baseline is a symmetric linear VCM where players allocate an endowment between a private and a common fund. We vary treatments across two dimensions to implement *exclusion* and *centrality*. The first dimension is whether groups can remove members by majority voting (*Exclusion*) or not (*No Exclusion*). The second dimension concerns the network structure – either every player is linked to each other (*No Centrality*) or one player connects two separate groups (*Centrality*). The resulting treatments are summarized in Table 1, which also shows the treatment labels for, and number of independent observations (matching groups; see below) in each treatment. Centrality can only exist if exclusion is possible; if a central player cannot be removed from the network, she will always connect the others. The treatment combination no-exclusion/centrality therefore does not exist.[3]

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[3] We also conducted an additional set of treatments where the central player decides on the allocation of the surplus created in the VCM games. For more details, see van Leeuwen et al (2015).

TABLE 1: SUMMARY OF TREATMENTS

	No Exclusion	Exclusion	
	No Centrality	No Centrality	Centrality
Treatment acronym	*nEnC*	*EnC*	*EC*
Participants	N = 85 (n = 6)	N = 75 (n = 6)	N = 90 (n = 6)

Notes. New groups in each block are formed from a 10- or 15-person matching group. N is the number of subjects and n is the number of independent matching groups. By design the combination of Centrality with No Exclusion cannot exist.

In all treatments, players are labeled 'Center' (C), 'North' (N), 'East' (E), 'South' (S) and 'West' (W). Only C can be central. We will refer to the other four as 'periphery players'. Each player interacts with all others to whom she is directly or indirectly connected, i.e., players in the same network component. Figure 1 presents some possible connections among players – a complete network (1a), a network with centrality (1d) and subsequent examples of the consequences for the network of excluding a player.

In each round, players participate in a VCM (e.g., Isaac and Walker 1988). Each player i receives an endowment of 50 points and all players, simultaneously decide how much, $x_i \in [0,50]$, to invest in a common fund. The payoffs for player i are given by:

$$\Pi_i = 50 - x_i + (0.6)\left(x_i + \textstyle\sum_{j \neq i \in N_i} x_j\right),$$

where N_i denotes the set of players in i's component and 0.6 is the Marginal Per Capita Return (MPCR). In all treatments, players are informed at the end of each round of the individual contributions of each other player in their group of five.

Exclusion

Our first dimension concerns the possibility for players to exclude others from further interaction with the group. In the treatment with no exclusion (*nEnC*), all five players participate in every round. In the other two treatments (*EnC* and *EC*), each of the first four rounds in a block ends with a voting stage that can lead to one or more players being excluded from the group. After having observed others' decisions in the current round, each non-excluded player may cast votes, anonymously and at no cost, to exclude any remaining players in her component.[4] She may cast at most one vote for each player. If a player has received votes for exclusion from at least half of the players in her component, she is excluded until the end of the block. Hence, in a group of five, a player is excluded if she receives three or more votes,

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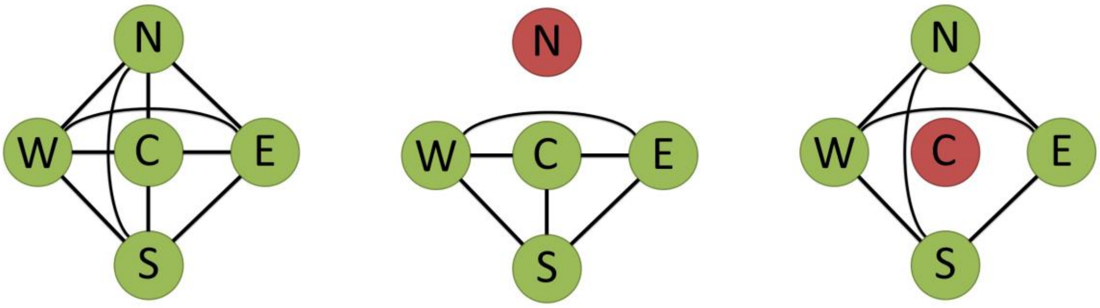
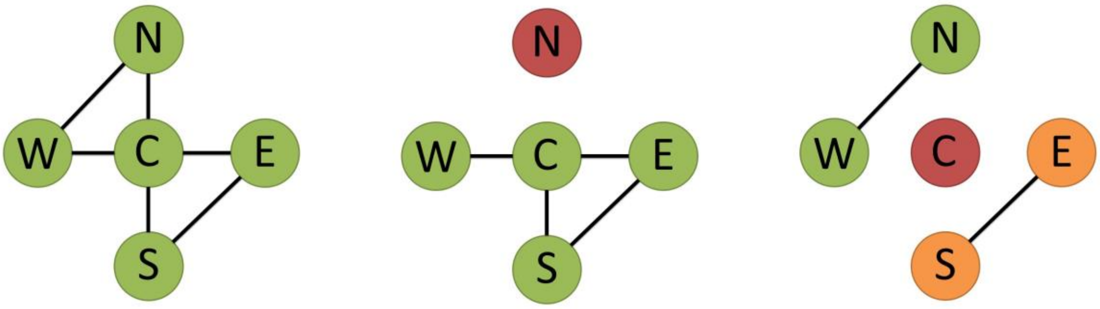
[4] We allow players the option to vote to exclude themselves as well. This was observed in only 6 out of 3,203 instances of voting.

and in a group of four, two votes suffice. More than one player can be excluded in a round. At the end of the round, excluded players are announced as well as the number of votes cast by each subject.

FIGURE 1: NETWORK STRUCTURES



a: No player excluded b: Periphery player excluded c: Center player excluded



d: No player excluded e: Periphery player excluded f: Center player excluded

Notes. The top and bottom panel shows the network structure for the cases when there is no centrality and when there is centrality, respectively. The three cases per panel distinguish between the network comprising of all players, the network without player N and the network(s) without player C.

If a player is excluded, all her links with other group members are removed. She can no longer contribute to, or receive any benefits from, the common fund or vote to exclude others. Excluded players only receive a fixed sum –equal to the endowment– in each of the remaining rounds. The consequences for the remaining players depend both on the player concerned and the network structure.

Of course, in many organizations outside the laboratory exclusion of a member does not require a formal vote. Allowing every member in the group to cast a vote, however, gives us an individual measure of how they view the choices made by others. In this way, we elicit the preferences and norms that likely underlie many of the formal exclusion processes outside the laboratory.

Network structure – Centrality

The network structure determines with whom a player interacts. We have two initial network structures. The first is a complete network as in Figure 1a where every player is connected to every other player and, therefore, no player's presence is essential to keep the group together. If a player is excluded, remaining players are still connected in a group of four, irrespective of whether a periphery player (1b) or player C (1c) has been excluded.[5] In the treatment without centrality (*EnC*), the remaining players play a four-person VCM.

The second is an incomplete network where two pairs of periphery players (N&W and S&E) are connected only via C, as in Figure 1d. Centrality occurs because C is necessary to keep the two pairs connected to each other. Now, the consequences of removing a player depend crucially on her position. If a periphery player is excluded (Figure 1e), the remaining four players remain connected. If the player with centrality is excluded (Figure 1f), her absence creates two separate groups (N&W and S&E). In this case, the periphery players not only lose her future contributions (this also occurs when a periphery player is excluded), but also those of the two other periphery players. Thus, excluding the player with centrality is more costly than excluding a periphery player. The remaining players play a four-player VCM after exclusion of a periphery player and two-player VCMs if C has been excluded.

Procedures

The computerized experiment was run in the CREED laboratory of the University of Amsterdam. In total 250 subjects drawn from the general student population participated in at most one session each. For each treatment, data were collected in 3 sessions, each with 20, 25 or 30 subjects. Subjects received on-screen instructions and then had to correctly answer a quiz in order to proceed.[6] Each session lasted approximately one hour.

Roles (C or periphery) were randomly assigned at the beginning of a session. To avoid behavioral spillover effects, these roles remained fixed throughout. In all treatments, subjects' contributions in a round were identified by their position in the network, i.e., North, South, etc. To maximize the number of independent observations, re-matching between blocks takes places with two matching groups of either 10 or 15 subjects, depending on the number of participants in the session. After the experiment, subjects were requested to fill out a short demographic questionnaire.

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[5] We discuss here the situation after the first exclusion. This is presented in Figure 1. The cases for subsequent exclusions follow straightforwardly.

[6] Summaries of the experimental instructions are provided in Appendix A. Full instructions and the test questions are provided in Appendix D.

At the end of each session, one block was randomly selected and subjects were paid their earnings from all rounds within this block. Earnings in points were converted to cash using an exchange rate of 60 points to one euro. Subjects earned between 11.40 and 19.50 euro, with an average of 16.30 euro, including a show-up fee of 7 euro.

3 Hypotheses

The stage-game equilibria of these games are straightforward for the case of self-interested preferences. Players will not contribute to the common fund across treatments. In the experiment, we implement a (finitely) repeated game and we add exclusion in some treatments. There are no repeated game equilibria with positive contributions.[7] We will use this as the benchmark prediction yielding the null hypotheses for our statistical tests.

If we assume that (some) players have social preferences or if (some) players believe that some fraction of the population is willing to exclude free-riders, cooperative repeated game equilibria may exist in all treatments. This, however, leads to a plethora of equilibria, depending on the specific assumptions. Instead of deriving all equilibria and searching for refinements, we derive comparative statics for our treatments using a simple setting with self-interested and cooperative types *a la* Kreps et al. (1982). The results of this exercise will serve as alternative hypotheses. Details about the two-type model can be found in Appendix B. We proceed with presenting the hypotheses that we will test using our experimental data. These hypotheses are supported by the two-type model of Appendix B.

First, we consider the effects of the possibility of exclusion on contribution levels in the absence of centrality. Previous evidence shows that the ability to exclude players from the group raises contributions (Cinyabuguma et al., 2005). The intuition here is that, without exclusion (*nEnC*), free riders have no incentive to contribute. This yields the following hypothesis.

Hypothesis 1 (effect of exclusion in the absence of centrality):

> *The threat of exclusion increases contributions: Contribution levels in nEnC < Contribution levels in EnC.*

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[7] In some settings, costless voting could lead to repeated game equilibria with positive contributions (Hirshleifer and Rasmusen 1989). However, in our study, excluded players still earn their endowment (which equals the Nash stage-game payoff). For this reason, there exists no subgame perfect equilibrium with positive contributions if all agents are self-interested.

Next, recall that exclusion is a necessary condition for player C to become a player with centrality. Thus, for the effects of centrality, we compare situations where groups can exclude members in networks without (*EnC*) or with (*EC*) a central player. Excluding a free rider without centrality (any player in *EnC* or a periphery player in *EC*) will not affect expected payoffs. Hence, centrality does not change the effects of a threat of exclusion on periphery players. Excluding a free rider with centrality does come at a cost, however; players can no longer benefit from the contributions by cooperative types connected via the player with centrality. This reduces the chances that a free rider with centrality will be excluded, allowing her to 'abuse' her position. This is summarized in Hypothesis 2.

Hypothesis 2 (effects of centrality):

(a) *Players with centrality contribute less than periphery players: Contribution levels by C-players in EC < Contribution levels by periphery players in EC.*

(b) *C-players contribute less when they are central: Contribution levels by C-players in EC < Contribution levels by C-players in EnC.*

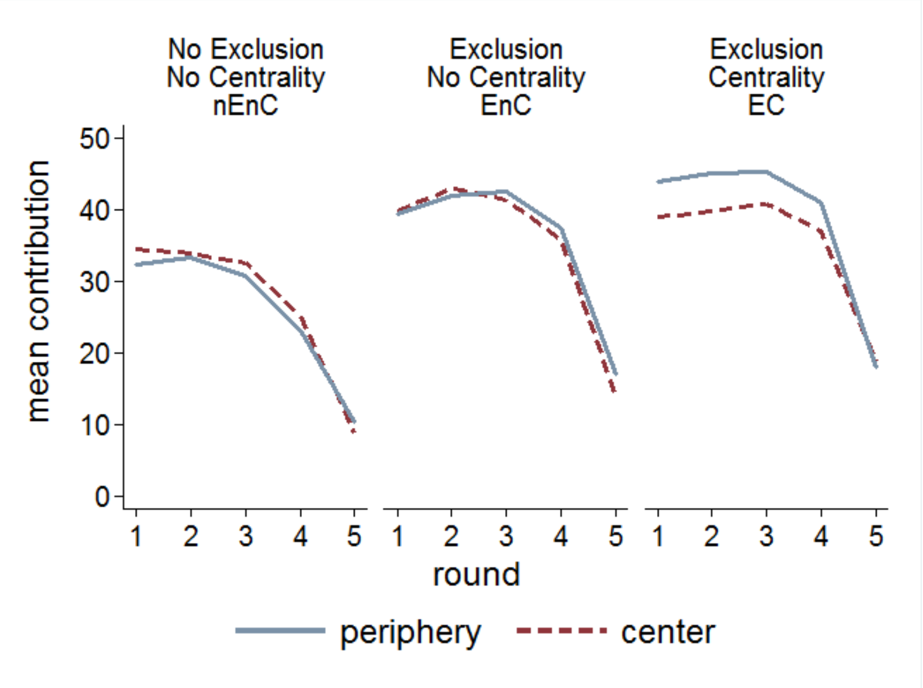
Finally, we consider how the votes to exclude are affected by the treatments. For exclusion to work as a disciplining mechanism (Hypothesis 1), players should vote to exclude those with low contribution levels. However, players with centrality will be excluded less often.

Hypothesis 3 (voting to exclude):

(a) *Players with higher contributions are less likely to receive votes for exclusion.*

(b) *Conditional on contributions, players with centrality are less likely to receive votes for exclusion than periphery players.*

FIGURE 2: MEAN CONTRIBUTIONS BY PLAYER POSITION



Notes. For each round, the contribution level is averaged across five blocks. The graphs are based on decisions by individuals who have not been excluded from their group and who are not isolated.

4 Results

We start with a general overview of our results. Figure 2 presents mean contribution levels per round across treatments. For this overview we combine data from all blocks. Table 2 shows the mean contribution levels across all rounds and in the first round. Overall, the figure and table suggest that contributions are higher with exclusion than without, and that differences in cooperation between subject C and the periphery occur only when C has centrality. In what follows, we analyze these differences in more detail. Unless stated otherwise, all reported statistics come from two-sided permutation *t* tests using matching groups as the independent unit of analysis, and averaging over all rounds and blocks. The number of (independent) observations is thus six in each comparison sample (cf. Table 1). Permutation *t* tests allow for testing for differences in means in small samples while the more conventional Mann-Whitney and Wilcoxon signed-rank tests test for differences in distributions (see, for example Moir 1998 and the discussion in Appendix 3 of Schram et al. 2018). Nevertheless, our results and conclusions are robust to using Mann-Whitney and Wilcoxon signed-rank tests instead (see Table C.1 in Appendix C).

TABLE 2: MEAN CONTRIBUTIONS

	No Exclusion	Exclusion		Effect of exclusion (p-values)	Effect of centrality (p-values)
	No Centrality *nEnC*	No Centrality *EnC*	Centrality *EC*	*nEnC* vs *EnC*	*EnC* vs *EC*
All rounds					
All subjects	26.0 (3.8)	35.0 (5.7)	37.8 (2.8)	0.010	0.299
C-subjects	26.7 (5.6)	34.6 (6.8)	34.7 (4.5)	0.059	0.968
Periphery	25.9 (3.8)	35.0 (5.5)	38.6 (2.7)	0.009	0.183
C vs periphery (p-value)	0.678	0.473	0.003		
First round					
All subjects	32.9 (5.1)	39.3 (4.7)	42.9 (2.7)	0.046	0.127
C-subjects	34.9 (8.0)	40.2 (6.6)	39.0 (4.0)	0.248	0.698
Periphery	32.4 (5.7)	39.1 (4.9)	43.9 (2.8)	0.053	0.068
C vs periphery (p-value)	0.427	0.652	0.001		

*Note*s. Cells give mean contributions across blocks and rounds in points, with standard deviations in parentheses. Top panel: entries based on all rounds and blocks, and players that were not excluded or isolated. Bottom panel: Entries based on the first round of each block, before any exclusion could occur. P-values come from permutation *t* tests. The unit of analysis is the matching group.

4.1 Exclusion in the absence of centrality

Figure 2 shows the usual pattern of declining contribution levels over time in the standard public goods game (*nEnC*) without centrality and exclusion (e.g., Fehr and Gächter, 2000). In the absence of exclusion and centrality, the only difference between subjects is one of framing, where subject C is presented as being in the 'middle' of the group. A one-sample permutation *t* test (henceforth, 1PtT) shows no significant difference in contributions between subjects C and periphery subjects in *nEnC* (1PtT, p = 0.678, n = 6). Thus, we find no evidence of framing due to the network representation.

Once we allow for exclusion (*EnC*), again no significant differences between subjects C and periphery subjects arise (1PtT, p = 0.473, n = 6). For both, we do observe that contribution levels increase with respect to *nEnC*. Two-sample permutation *t* tests (henceforth, 2PtT) show that the increase is significant for periphery subjects (2PtT, p = 0.009, n = 12) and marginally significant for subject C (2PtT, p = 0.059, n = 12). As a consequence, average contribution levels in the group as a whole are higher (2PtT, p = 0.010, n = 12) when exclusion is possible. This replicates findings in Cinyabuguma et al. (2005).

Conceivably, these findings could be attributed to selection effects because after round 1, some subjects might be excluded. To investigate this, we considered only first-round choices in every block (see the bottom panel of Table 2). The results are qualitatively similar, though the effect of exclusion for periphery players is no longer significant at the 5%-level (p = 0.053).

Result 1 (effects of exclusion): *In the absence of centrality, the opportunity to exclude group members raises contribution levels of both subject C and periphery subjects.*

This result provides direct support for Hypothesis 1.

4.2 The effects of centrality

Figure 2 shows that in the presence of centrality (*EC*) there is a difference between contribution levels of the subjects with centrality and periphery subjects. Subjects with centrality seem to 'abuse' their position; their contributions are 10 percent lower than those of periphery subjects, and this difference is statistically significant (1PtT, p = 0.003, n = 6). Figure 2 and Table 2 suggest that the introduction of centrality (*EnC vs EC*) does not affect subjects C's mean contributions across rounds but increases those of periphery subjects. Tests show that the effect of centrality on contributions is not significant for both (2PtT, p = 0.968, n = 12 for C-players; p = 0.183, n = 12 for the periphery). Once again, the results are qualitatively the same when considering only round 1 (cf. bottom panel Table 2).

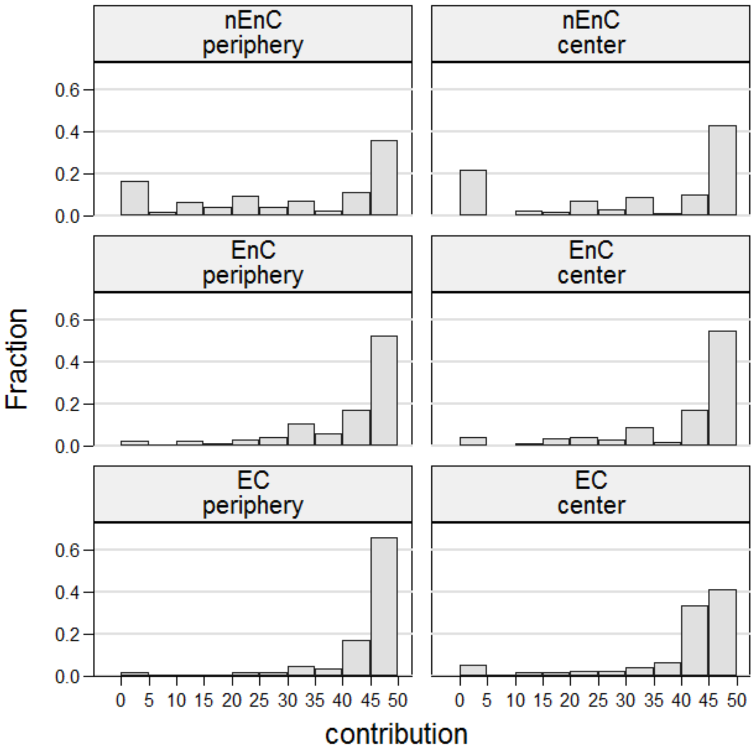
Result 2 (effects of centrality):

(a) *Contribution levels of subjects with centrality are lower than those of periphery subjects.*

(b) *Contribution levels of neither subjects with centrality nor periphery subjects are significantly affected by introducing centrality.*

This result provides support for hypothesis 2(a), but not for 2(b).

FIGURE 3: CONTRIBUTIONS

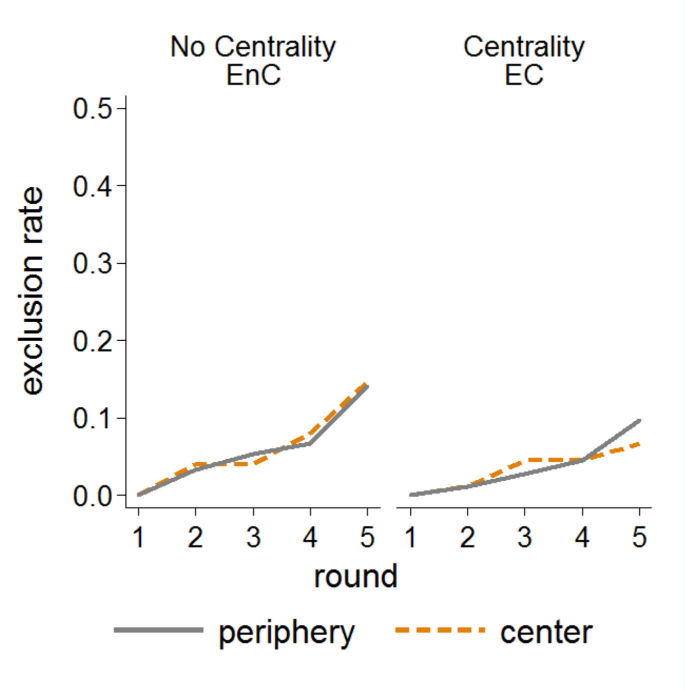


Notes: Histograms of individual contributions in rounds 1-4. The graphs are based on decisions by individuals who have not been excluded from their group and who are not isolated.

In treatment *EC*, we observe lower contributions by subjects with centrality than by those in the periphery. To avoid the end effect, we consider only the first four rounds. Then, the average difference is 4.6 points per round (43.8 points for periphery subjects versus 39.2 points for C-subjects). This difference could be driven by a few C-subjects who completely free ride, or by many C-subjects who partially free ride. To investigate this, we plot the distributions of individual contributions in the first four rounds by treatment and position in Figure 3.

Figure 3 shows that the difference in contributions between C- and periphery subjects is mostly driven by a large number of C-subjects who contribute somewhat less than the periphery. In treatment *EC*, 35% of the C observations are between 40 and 44 points as compared to 17% of the periphery observations. At the same time, in *EC*, C-subjects contribute between 45 and 50 points in 41% of the observations, while this is the case for 66% of the periphery observations. Other contribution levels are rarely observed in *EC*. All in all, though very low contributions (5 points or less) are more frequent among C-subjects (6%) than among periphery subjects (2%), the aggregate result of lower contributions by C-players in *EC* is mostly driven by those who partially free ride. Note, however, that the contributions gap resulting from centrality is a diff-in-diff result caused by the combined effects for periphery and C-subjects. The effects of centrality are not significant for periphery and C-subjects separately (see Table 2).

FIGURE 4: EXCLUSION BY PLAYER POSITION



Notes: Cumulative exclusion rates for periphery and center subjects. Exclusion rates reflect the mean proportion of subjects excluded up to the previous round. Means are taken across all blocks.

4.3 Voting and exclusion

Figure 4 presents the cumulative proportion of C subjects and periphery subjects excluded over rounds in the exclusion treatments. In both treatments with exclusion, few subjects are excluded. In the absence of centrality (*EnC*), cumulative exclusion rates remain well under 20% to the end. Further, there is no discernible difference in the rate of exclusion between subject C and periphery subjects. With centrality (*EC*), exclusion rates remain under 20% as well and, again, subjects with centrality are not more likely to be excluded than periphery subjects. This is remarkable, because the cooperation levels of the former are lower than those of the latter (cf. Figure 2).

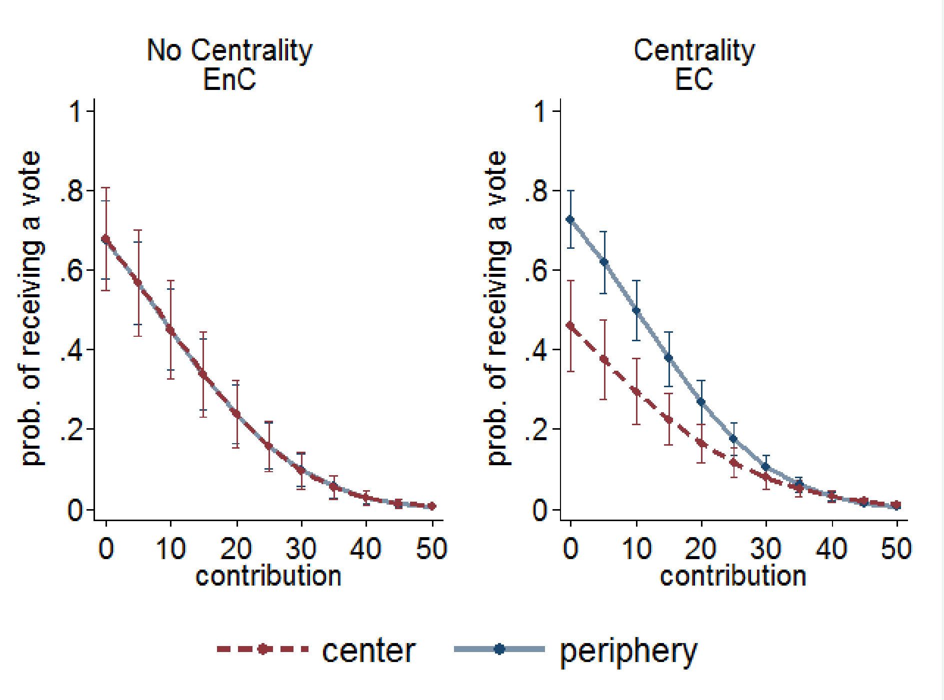
TABLE 3: PROBABILITY OF RECEIVING A VOTE FOR EXCLUSION

	No Centrality (*EnC*)	Centrality (*EC*)
Contribution	-0.060***	-0.063***
	(0.003)	(0.003)
C-subject	0.005	-0.729***
	(0.169)	(0.165)
C-subject × Contribution	-0.000	0.018***
	(0.005)	(0.004)
# subjects in subgroup	0.316***	0.457***
	(0.060)	(0.075)
Round	-0.049*	0.096***
	(0.028)	(0.027)
Block	0.042*	0.018
	(0.022)	(0.021)
Constant	-1.042**	-1.900***
	(0.345)	(0.395)
Observations	5,768	6,978
Pseudo R^2	0.273	0.298
Wald-chi2(6) (p-value)	626.33	724.06
	(0.000)	(0.000)
Chi2(1) test [Contribution + C-subject × Contribution] = 0 (p-value)	173.76 (0.000)	137.28 (0.000)

Notes: We allow for random effects at the matching group and subject level. Standard errors in parentheses. *, ** and *** indicate significance at 10%, 5% and 1% respectively.

To further study the exclusion decisions Table 3 presents, for both treatments with exclusion, estimates of (multilevel) random effect Probit regressions of the probability of receiving a vote for exclusion. The regression estimates the probability that subject *j* votes to exclude subject *i* as a function of *i*'s contribution, whether *i* is located in the C-position, the interaction between the latter two, the number of subjects in *i* and *j*'s subgroup, and the current round and block. We only include observations where *i* and *j* could vote for each other, i.e., neither should be excluded and they should be connected. We allow for random effects at the subject level (of subject *j*) and the matching group level. To visualize the results, we plot the estimated probability that a subject *i* will receive a vote as a function of contribution levels in Figure 5.

FIGURE 5. PROBABILITY OF RECEIVING A VOTE FOR EXCLUSION



Notes: Probability of receiving a vote for exclusion as function of contributions for C-subjects and periphery subjects. Estimations based on the regressions reported in Table 3. Error bars indicate 95% confidence intervals.

In both treatments, there is a strong negative effect of contributions on the probability of receiving an exclusion vote (see the contribution variable in Table 3 and the negative slope in Figure 5). In addition, the first regression shows that in the absence of centrality (*EnC*), there is no discrimination between roles. The second regression shows that subjects with centrality are less likely to receive a vote for exclusion, even after controlling for contribution levels. Moreover, the interaction term is positive and significant. Figure 5 illustrates the net effect; for low cooperation levels, subjects with centrality are less likely to receive a vote for exclusion than periphery subjects. The difference deceases with increasing contribution levels, with the probability of an exclusion vote approaching zero. Based on these estimations, a fully free-riding periphery subject will receive a vote with 73% chance, whereas a fully free-riding C-subject with centrality will receive a vote with only 46% chance. If no one has yet been excluded, the probability of a fully free-riding player being excluded is then 70% for periphery players and 26% for player C.

Result 3:

(a) *In both exclusion treatments, there is a negative relation between contribution levels and the probability of receiving exclusion votes.*

(b) *Controlling for contribution levels, subjects with centrality are less likely to receive exclusion votes than periphery subjects.*

Together, this provides direct support for Hypotheses 3(a) and 3(b).

4.4 Earnings and efficiency

Our results show that the possibility of exclusion raises contributions and that subjects with centrality contribute less than subjects in the periphery. Our analysis was based on subjects that were not excluded or isolated. As excluded players no longer benefit from contributions of others and can no longer contribute themselves, the net effect of exclusion and centrality on earnings is ambiguous. In this subsection we consider these effects.

TABLE 4: EARNINGS

	No Exclusion	Exclusion		Effect of exclusion (p-values)	Effect of centrality (p-values)
	No Centrality	No Centrality	Centrality		
	nEnC	*EnC*	*EC*	*nEnC* vs *EnC*	*EnC* vs *EC*
All subjects	102.1 (7.5)	113.6 (14.0)	120.5 (5.2)	0.112	0.308
C-subjects	101.5 (8.2)	114.0 (14.4)	124.0 (5.6)	0.101	0.140
Periphery	102.3 (7.6)	113.5 (14.1)	119.6 (5.4)	0.111	0.361
C vs periphery (p-value)	0.678	0.736	0.001		

Notes. Cells give mean earnings per round in points, with standard deviations in parentheses. Entries based on all rounds and blocks, and all subjects, regardless of being excluded or isolated. P-values come from permutation *t* tests. The unit of analysis is the matching group.

Table 4 presents summary statistics for earnings in each treatment, both at the group level and for C-subjects and periphery subjects separately.[8] All numbers include earnings by excluded players. Without centrality, group earnings are higher when exclusion is available, but the difference is not statistically significant (*nEnC vs EnC*: 2PtT, p = 0.112, n = 12). This is in spite of the fact that surplus may be lost if subjects are actually excluded. The increase in contribution levels thus roughly cancels out the cost of excluding subjects.

Interestingly, centrality does not lower total earnings. The addition of centrality somewhat increases total earnings, though not significantly so (*EnC vs EC*: 2PtT, p = 0.308, n = 12). The same holds if we compare earnings of C-subjects or periphery subjects; for both, earnings are not significantly different in *EC* than in *EnC* (2PtT, p = 0.140, n = 12 for C-

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[8] In Table C.2 in Appendix C, we also report p-values based on Mann-Whitney and Wilcoxon signed-ranks tests.

subjects and p = 0.361, n = 12 for periphery subjects). With centrality, C-subjects do earn significantly more than periphery subjects (*EC*: 1PtT, p = 0.001, n = 6), which is not the case in the two treatments without centrality (*nEnC*: 1PtT , p = 0.678, n = 6; *EnC*: 1PtT , p = 0. 736, n = 6).

All in all, we conclude that centrality has no negative effect on efficiency. Centrality, however, comes at the cost of increased inequality between the central player and those in the periphery.

5 Concluding remarks

We study how network structure and positions –in particular, the presence of centrality– affect cooperative behavior in a VCM setting. Centrality is a valuable position to hold because exclusion of a central player is costly to other players, who stand to lose access to substantial parts of the network. Our experiment is the first to provide a controlled test of the effects of centrality. We find clear evidence that central players ‘abuse’ their position by contributing less than the periphery, but that this only increases inequality, without a negative effect on group efficiency.

Our results are important because –as argued in the introduction– central positions can appear in many networks, especially in informal organizations. Similarly, exclusion of members is a possibility in many organizations. The previous literature (e.g., Cinyabuguma et al. 2005) has seen exclusion as a mechanism by which cooperation norms can be enforced. Our results show that such norms are not set in stone. Periphery players are affected differently by exclusion than those who are central. This asymmetric enforcement of norms has, to the best of our knowledge, not been observed before.

Interestingly, central players only free ride slightly more than those without this position. Although the contributions (earnings) of central players are significantly lower (higher) than the contributions (earnings) of periphery players, the differences are relatively small. We find that the earnings of central players are on average only 3.7% higher than the earnings of periphery players. Whether this reflects an accurate estimate of the extent of free riding that is deemed acceptable by periphery players is at this stage an open question. Central players might have correct expectations about the norm that the periphery is willing to enforce (that is, further reduction in contributions would lead to exclusion) or might be too cautious, leaving opportunities for further free riding on the table. Our experiment was not designed to investigate the extent to which central players are best responding to the periphery's exclusion strategies, but this is certainly an interesting avenue for future research.

Other interesting extensions would further increase the generalizability of our findings. For example, subjects in our design are randomly allocated to central or periphery positions, which could reduce the legitimacy of free riding by a central player. Central positions outside the laboratory are seldom randomly obtained. If such a position is somehow 'earned', then both the player concerned and the periphery might find free riding (even) more acceptable. One could add entitlement to positions to our design to investigate this. Alternatively, individuals in a central position might have higher self-image concerns (Bénabou and Tirole 2006) than those in the periphery, for example because they feel a sense of responsibility for keeping the network together. If so, this might decrease their tendency to free ride. One could add measures of self-image and responsibility to our design to investigate this possibility.

The take away from our study is that even with random assignment and anonymous positions in the network, players with a central position partially free ride, and that this is tolerated by players in the periphery.

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ELECTRONIC SUPPLEMENTARY MATERIAL (ONLINE ONLY)

Appendix A: Summary of the experimental instructions

Below are the summaries of the instructions as it was handed out to the participants in the experiment. Full instructions for all treatments are available in Appendix D. Each paragraph that was included only in some treatments starts with <*treatment acronym*>.

Summary of instructions

Welcome to this experiment on decision-making. You will be paid € 7 for your participation plus whatever you earn in the experiment.

During the experiment you are **not allowed to communicate**. If you have any questions at any time, please raise your hand. An experimenter will assist you privately. You will record your decisions privately and **anonymously** at your computer terminal. Other participants will never be able to link you with your personal decisions or earnings from the experiment.

During the experiment, all **earnings are denoted in points**. At the end of the experiment, your earnings will be converted to euros at the rate: **60 points = € 1**.

The experiment consists of **5 blocks. Each block consists of 5 rounds**. At the end of the experiment, **one block will be randomly selected** and everyone will be paid for their decisions in that block.

The composition of the groups will remain the same for the 5 rounds in a block. At the end of a block, participants will randomly be divided into new groups of five.

At the beginning of the experiment, each participant will randomly be assigned a position - North (N), East (E), South (S), West (W) or Center (C). These **positions will remain fixed throughout the experiment**. For example, if you are assigned the North position, you will be in the north position in each round in each block of the experiment.

At the beginning of each round, each participant receives an **endowment of 50 points**. You decide on how much of this endowment **to invest in each of two accounts**. These are called a "private account" and a "group account". You may invest everything in the private account, everything in the group account, or any combination of the two, as long as you invest 50 points in total.
Your earnings include earnings both from your private account and the group account:

- Earnings from your **private account**: You will earn **1 point for each point invested in your private account**.
- Earnings from the **group account**: Your earnings from the group account are based on the total number of points invested in the group account by all members in your group. Each group member will earn **0.6 points for each point in the group account** regardless of who made the investment.

<EnC, EC> Exclusion of a member means that this player can **no longer invest in the group account and will not receive any earnings from the group account in the remaining**

rounds. The excluded participant will receive an endowment of 50 points in each of the remaining rounds in the block. All 50 points will automatically be invested in the private account.

<EnC, EC> To decide on who will be excluded, the group members will **select candidates for exclusion.**

<EnC, EC> You can **indicate for each member of your (sub-)group whether or not you think that s/he should be excluded** from the group in future rounds in the current block. You can vote for as many or as few participants as you want.

<EnC, EC> If some member(s) of the group have previously been excluded, you can only vote on excluding members of the sub-group you are in. Participants who previously have been excluded cannot vote for the exclusion of others.

<EnC, EC> **If half or more members of the (sub-)group vote to exclude a participant, that participant will be excluded in future rounds in the current block.**

Appendix B: Two-type model

We study a simple model with cooperative types (similar to Kreps et al. 1982) to derive comparative statics for the effects of exclusion and centrality. We assume that there are two types of players: strategic self-interested types and cooperative types. Self-interested types maximize their own payoffs. Cooperative types unconditionally cooperate (contribute the entire endowment) and also vote to exclude anyone who does not (if exclusion is possible). This type of behavior is consistent with '*homo moralis*' preferences described by Alger and Weibull (2013). See Miettinen et al. (2017) for evidence that behavior in a sequential prisoners' dilemma is largely consistent with such preferences.

Players with *homo moralis* preferences maximize a convex combination of self-interest and moral preferences. Moral preferences entail maximizing payoffs conditional on everyone else acting the same, i.e. a player with these preferences maximizes the following utility function:

$$u(x, \mathbf{y}) = (1 - \kappa) \cdot \pi(x, \mathbf{y}) + \kappa\pi(x, \mathbf{x}),$$

where $\pi(x, \mathbf{y})$ denotes the monetary payoff of playing strategy x when all others play strategies $\mathbf{y}$. The parameter $\kappa \in [0,1]$ is the degree of morality and $\pi(x, \mathbf{x})$ the monetary payoff of playing strategy x if all others would use the same strategy x. In our games, the assumed strategy of cooperative types maximizes these payoffs for any player with high enough morality. For $\kappa = 1$, it follows directly from $u(x, \mathbf{y}) = \pi(x, \mathbf{x}) = 50 - x + 0.6 * 5 * x$ that without exclusion, utility is maximized in any round by choosing $x = 50$. Across T rounds, utility is then $150T$. For $\kappa < 1$ full contribution is still utility maximizing as long as not too many others act selfishly (so that the earnings lost to the selfish others is outweighed by the morality term). When $\kappa = 1$, the complete strategy of full contribution in T rounds and exclusion of free riders again yields utility equal to $\pi(50, \mathbf{50}) = 150T$. We conclude that these moral types' preferences are consistent with the behavior assumed for the cooperative types in our model.

The proportion of cooperative types is given by p, which we assume to be a minority, i.e. $p \in [0,0.4)$. The upper bound on p assumes that a plausible fraction of at most 40% of the players are unconditional co-operators. In similar environments, Fischbacher et al. (2001) have shown that even the number of *conditional* co-operators remains below half of the subjects. There are even fewer unconditional cooperators.

We are interested in the range of p where self-interested types will act cooperatively on the equilibrium path. More precisely, we study the range of p under which a subgame-perfect Nash equilibrium can be constructed where self-interested types fully contribute until (and including) the penultimate round. Clearly, there are many other equilibria possible, involving various levels of contribution. For the sake of simplicity, we focus on full cooperation up until (and including) the penultimate period. To start, note that in all treatments, in the final round, self-interested players will simply play according to the stage-game Nash equilibrium and contribute nothing.

No Exclusion and No Centrality (nEnC)

Without exclusion, self-interested players will not cooperate in the penultimate round, as there is no mechanism through which cooperative behavior can be enforced. This is independent of the proportion of cooperative types p. So, for no value of p will self-interested types act cooperatively in the penultimate round, or –by backward induction– in any preceding round.

Exclusion and No Centrality (EnC)
In this case, the following strategy (followed by the self-interested types) is part of a subgame perfect Nash equilibrium:

- All self-interested players fully contribute in any round $t < T$, and contribute nothing in round T.
- All players vote to exclude any player who did not fully contribute in previous rounds and do not vote to exclude any player who always fully contributed.

Note that in this case, self-interested players are indifferent about voting to exclude players that do not act cooperatively, as excluding a free rider is costless. Moreover, self-interested players will not vote to exclude players that act cooperatively as doing so is costly in expectation if $p > 0$. Cooperative types vote to exclude free riders by assumption. Hence, a strategy profile where free riders are excluded and cooperators are not, may be part of an equilibrium. This means that in any round $t < T$, a self-interested player will act cooperatively if the payoff from acting cooperatively until and including the penultimate round plus free riding in the final round (and assuming other self-interested players will do the same) exceeds the payoff from deviating in the current round and being subsequently excluded. Assume this deviation takes place in round *t*. then the condition reads:

$$(T-t)\big(0.6(5\cdot 50)\big)+\big(50+0.6(4\cdot 50p)\big)\geq 50+0.6(4\cdot 50)+(T-t)50,$$

holds. Rewriting this condition yields:

$$p \geq 1-\frac{5}{6}(T-t).$$

Note that if this condition holds for $t = T-1$, it will also hold for all preceding rounds. For $t = T-1$, this gives $p \geq \frac{1}{6}$. Hence, for any $p \geq \frac{1}{6}$ full cooperation up until the penultimate round can be supported as a subgame-perfect Nash equilibrium. As previous work by Cinyabuguma et al. (2005) found that the threat of exclusion increases contributions, we will assume that $p \geq \frac{1}{6}$ from now on.

Exclusion and Centrality (EC)
In this case, we consider the following two strategy profiles (for self-interested types) as candidates for a subgame perfect Nash equilibrium:

Candidate 1 (full contributions by both periphery and C-players)

- All players fully contribute in any round $t < T$ and contribute nothing in round *T*.
- All players vote to exclude any player who did not fully contribute in previous rounds and do not vote to exclude any player who always fully contributed.

Candidate 2 (full contributions by periphery players only)

- All periphery players fully contribute in any round $t < T$ and contribute nothing in round *T*.
- All periphery players vote to exclude any periphery player who did not fully contribute in previous rounds and do not vote to exclude a periphery player who always fully contributed. Periphery players never vote to exclude the C-player.
- The C-player contributes nothing in any round $t \leq T$.

- The C-player votes to exclude any periphery player who did not fully contribute in previous rounds and does not vote to exclude a periphery player who always fully contributed. The C-player never votes to exclude herself.

Excluding an uncooperative periphery player will not affect expected payoffs in future rounds. Excluding an uncooperative player with centrality, however, comes at a cost; one can no longer benefit from the contributions by cooperative types who were connected only via C. Hence, self-interested periphery players will not be willing to exclude an uncooperative player with centrality for *any* $p > 0$. This means that free-riding center players will only be excluded if there are three or more cooperative types among the periphery players (because a majority of votes is needed), which happens with probability $q = p^4 + 4p^3(1-p)$. A self-interested center player will then free ride if there are not too many cooperative types around (in expectation). Precisely, a self-interested center player will free ride in any round $t < T$ if:

$$\begin{aligned}(T-t)\big(0.6(5\cdot 50)\big) + \big(50 + 0.6(4\cdot 50p)\big) \\ &\leq (1-q)\Big((T-t)\big(50+0.6(4\cdot 50)\big) + \big(50 + 0.6(4\cdot 50p)\big)\Big) \\ &\quad + q\Big(\big(50+0.6(4\cdot 50)\big) + (T-t)50\Big).\end{aligned}$$

Rewriting gives:

$$q\big((T-t) + p - 1\big) \leq \frac{1}{6}(T-t).$$

For our experimental parameter $T = 5$, this holds for any $t < T$ as long as $p \leq 0.4$. Hence, if $p \leq 0.4$, Candidate 1 cannot be a subgame perfect Nash equilibrium.

Next consider Candidate 2. After the first round, periphery players will learn whether the center player is a cooperative type or not. First, consider the case where the center turns out to be self-interested, and has not been excluded. Note that if the center acts uncooperatively, all self-interested players will be revealed to be self-interested, as after each round the number of votes cast for exclusion by each player is revealed to all. Hence, after round $t = 1$, it is common knowledge who is a self-interested type or not. There are three sub-cases: with two, three, or four self-interested periphery players (if there were only one self-interested periphery player, an uncooperative center would be excluded). With y cooperative types, and $4 - y$ self-interested players in the periphery, a self-interested periphery player will fully contribute if:

$$\begin{gathered}(T-t)\big(0.6(4\cdot 50)\big) + (50 + 0.6\cdot 50y) \geq 50 + 0.6(3\cdot 50) + (T-t)50, \\ (T-t)70 \geq 90 - 30y,\end{gathered}$$

which holds for any round $1 < t < T$, as long as $y \geq 1$, i.e. as long as there is at least one cooperative type in the periphery.

Second, consider the case that the center turned out to be self-interested and has been excluded. This immediately implies that there is at most one self-interested type in the periphery. Then, in any round $1 < t < T$, this self-interested periphery player will fully contribute if:

$$(T-t)\big(0.6(2\cdot 50)\big) + (50 + 0.6\cdot 50) \geq 50 + 0.6\cdot 50 + (T-t)50,$$

$$(T-t)(10) \geq 0.$$

which holds for any $1 < t < T$.

Next, consider the case where the center turns out to be a cooperative type. In this case, a self-interested periphery player will contribute in any round $1 < t < T$ if:

$$(T-t)\big(0.6(5\cdot 50)\big) + \big(50 + 0.6(50 + 3\cdot 50p)\big) \geq 50 + 0.6(4\cdot 50) + (T-t)50,$$

holds. Rewriting this condition yields:

$$p \geq 1 - \frac{10}{9}(T-t),$$

which clearly holds for any $p \geq 0$.

It only remains to consider the first round, where it is still unclear whether the center player is a cooperative type or not. In this round, a self-interested periphery player will fully contribute if:

$$\begin{aligned} p&\Big((T-1)\big(0.6(5\cdot 50)\big) + \big(50 + 0.6(50 + 3\cdot 50p)\big)\Big) \\ &\quad + (1-p)\Big((1-p)^3(0.6(4\cdot 50) + (T-1)50) \\ &\quad + (1-(1-p)^3)\Big((T-1)\big(0.6(4\cdot 50)\big) + \big(50 + 0.6(3\cdot 50p)\big)\Big)\Big) \\ &\quad \geq p(50 + 0.6(4\cdot 50) + (T-1)50) \\ &\quad + (1-p)(50 + 0.6(3\cdot 50) + (T-1)50), \end{aligned}$$

$$\begin{aligned} p&\big((T-1)150 + (80 + 90p)\big) \\ &\quad + (1-p)\big((T-1)120 + (50 + 90p) \\ &\quad + (1-p)^3(70 - 90p + (T-1)(-70))\big) \geq 140 + (T-1)50 + 30p, \end{aligned}$$

holds. Solving yields that for $T = 5$ this holds for any $p \geq 0.022$.

In sum, for $1/6 \leq p \leq 0.4$ no subgame perfect Nash equilibrium exists in treatment *EC* where all players (including C) fully contribute in the first $T-1$ rounds. However, a subgame perfect Nash equilibrium where all periphery players fully contribute in the first $T-1$ rounds, and where the center free-rides can be supported for $0.022 \leq p \leq 0.4$. Note that for the case where all 5 players turn out be self-interested, no such equilibrium exists, which happens with a probability of $(1-p)^5$.[9]

Our hypotheses for the experiment are supported by the model. For $1/6 \leq p \leq 0.4$, full cooperation cannot be part of an SPNE for all players in *nEnC* and C-players in *EC*. It can be supported for periphery and C-players in *EnC*, and for periphery players in EC.

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[9] For simplicity, we omitted the condition that strategy profile `Candidate 2' should include that self-interested periphery players should only contribute if not all others have been revealed to be self-interested.

Appendix C: Tests based on Mann-Whitney and Wilcoxon signed-ranks tests

TABLE C.1: MEAN CONTRIBUTIONS, MANN-WHITNEY TESTS & WILCOXON SIGNED-RANKS TESTS

	No Exclusion No Centrality *nEnC*	Exclusion No Centrality *EnC*	Centrality *EC*	Effect of exclusion (p-values) *nEnC* vs *EnC*	Effect of centrality (p-values) *EnC* vs *EC*
All rounds					
All subjects	26.0 (3.8)	35.0 (5.7)	37.8 (2.8)	0.010	0.262
C-subjects	26.7 (5.6)	34.6 (6.8)	34.7 (4.5)	0.078	0.873
Periphery	25.9 (3.8)	35.0 (5.5)	38.6 (2.7)	0.016	0.262
C vs periphery (p-value)	0.463	0.463	0.028		
First round					
All subjects	32.9 (5.1)	39.3 (4.7)	42.9 (2.7)	0.078	0.078
C-subjects	34.9 (8.0)	40.2 (6.6)	39.0 (4.0)	0.262	0.936
Periphery	32.4 (5.7)	39.1 (4.9)	43.9 (2.8)	0.055	0.055
C vs periphery (p-value)	0.463	0.600	0.028		

Notes. Cells give mean contributions across blocks and rounds in points, with standard deviations in parentheses. Top panel: Entries based on all rounds and blocks, and players that were not excluded or isolated. Bottom panel: Entries based on the first round of each block, hence before any exclusion could occur. P-values comparing treatments come from (two-sided) Mann-Whitney tests and p-values comparing C vs periphery players come from (two-sided) Wilcoxon signed-ranks tests. The unit of analysis is the matching group.

TABLE C.2: EARNINGS, MANN-WHITNEY TESTS & WILCOXON SIGNED-RANKS TESTS

	No Exclusion No Centrality	Exclusion No Centrality	Centrality	Effect of exclusion (p-values)	Effect of centrality (p-values)
	nEnC	*EnC*	*EC*	*nEnC* vs *EnC*	*EnC* vs *EC*
All subjects	102.1 (7.5)	113.6 (14.0)	120.5 (5.2)	0.078	0.150
C-subjects	101.5 (8.2)	114.0 (14.4)	124.0 (5.6)	0.037	0.150
Periphery	102.3 (7.6)	113.5 (14.1)	119.6 (5.4)	0.109	0.200
C vs periphery (p-value)	0.463	0.917	0.028		

Notes. Cells give mean earnings per round in points, with standard deviations in parentheses. Entries based on all rounds and blocks, and all subjects, regardless of being excluded or isolated. P-values comparing treatments come from (two-sided) Mann-Whitney tests and p-values comparing C vs periphery players come from (two-sided) Wilcoxon signed-ranks tests. The unit of analysis is the matching group.

Appendix D: Full instructions

Below are the transcripts of the instructions and test questions in the experiment. Each paragraph that was included only in some treatments starts with <*treatment acronym*(*s*)>. In the second set of test questions, all the numbers were randomly and independently generated for each participant.

Welcome

Welcome to this experiment on decision-making. You will be paid € 7 for your participation plus whatever you earn in the experiment.

During the experiment you are **not allowed to communicate**. If you have any questions at any time, please raise your hand. An experimenter will assist you privately. You will record your decisions privately and **anonymously** at your computer terminal. Other participants will never be able to link you with your personal decisions or earnings from the experiment.

These instructions will explain what you may do in this experiment. If you follow them carefully, you may make a substantial amount of money. How much you make depends on your decisions and the decisions of other participants. Your earnings will be paid to you privately at the end of today's session.

During the experiment, all **earnings are denoted in points**. At the end of the experiment, your earnings will be converted to euros at the rate: **60 points = € 1**.

<nEnC> These instructions are given in 4 pages like this one. While reading them, you will be able to page back and forth by clicking "next page" or "previous page" at the bottom of your screen, or by using the menu on top of the screen. The page may be larger than fits on your screen. In those cases, you can use the scroll bar to move down the page.

<EnC, EC> These instructions are given in 6 pages like this one. While reading them, you will be able to page back and forth by clicking "next page" or "previous page" at the bottom of your screen, or by using the menu on top of the screen. The page may be larger than fits on your screen. In those cases, you can use the scroll bar to move down the page.

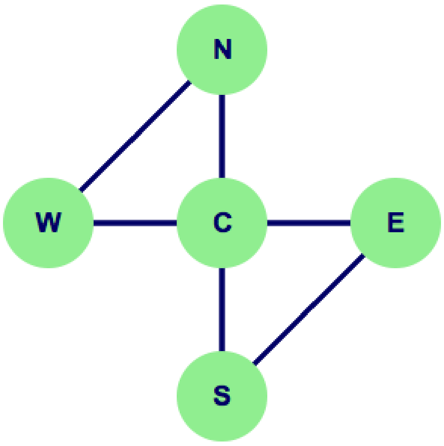
Blocks, Rounds and Positions

The experiment consists of **5 blocks**. **Each block consists of 5 rounds**. At the end of the experiment, **one block will be randomly selected** and everyone will be paid for their decisions in that block.

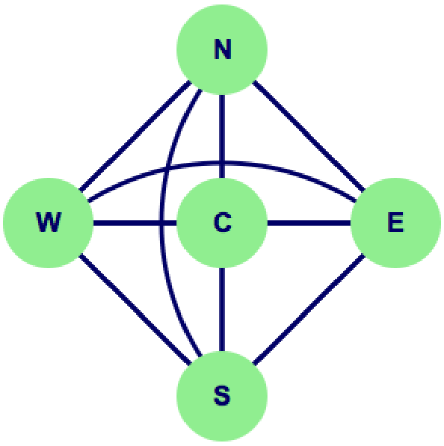
The composition of the groups will **remain the same for the 5 rounds in a block**. At the end of a block, participants will randomly be divided into new groups of five.

Each of the five individuals in a group has a **'position'**. We call these the North (N), East (E), South (S), West (W) and Center (C) positions. These are shown in the following figure. We will explain later how the positions are connected to each other.

<nEnC, EC>



<EnC>



At the beginning of the experiment, each participant will randomly be assigned a position - North (N), East (E), South (S), West (W) or Center (C). These **positions will remain fixed throughout the experiment**. For example, if you are assigned the North position, you will be in the north position in each round in each block of the experiment.

Thus, while there will always be one participant in each position in your group, the participants occupying other positions will change from one block to the next (and remain the same in the 5 rounds of any single block).

Investment Decision

<nEnC> In each round of every block, you will be asked to make **one decision**. We will now describe this decision.

<EnC, EC> In each round of every block, you will be asked to make either **one or two decisions**. Here, we describe the first. Whether or not you need to make a second decision, and what this means, will be explained shortly.

At the beginning of each round, each participant receives an **endowment of 50 points**. This endowment will be the same in each round and for every participant. Your decision is on how much of this endowment to **invest in each of two accounts**. These are called a "private account" and a "group account". You must **invest your complete endowment in these two accounts**. This means that every point must be invested in either the private account or the group account. It is completely up to you how much you want to invest in either of the two. You may invest everything in the private account, everything in the group account, or any combination of the two, as long as you invest 50 points in total.

After everyone has made their investment decisions, you will be **informed of the investment decisions of each of the participants in your group** and your earnings in this round. These earnings include earnings both from your private account and the group account.

- Earnings from your **private account**: You will earn **1 point for each point invested in your private account**.
- Earnings from the **group account**: Your earnings from the group account are based on the total number of points invested in the group account by all members in your group. Each group member will earn **0.6 points for each point in the group account** regardless of who made the investment.

Your **earnings from earlier rounds cannot be carried over to use in the following rounds**. You will receive a new endowment in each round. The same process will be repeated for a total of 5 rounds each in each of the 5 blocks.

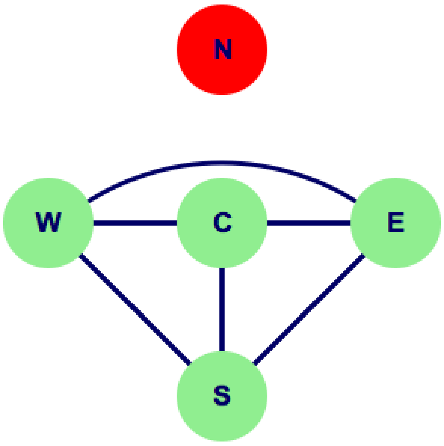
<EnC, EC> **Exclusion of a Group Member**

<EnC, EC> The second decision you may be asked to make is whether to **exclude other players from your group** for the remainder of the block. We will explain shortly how players may be excluded. First, we explain what exclusion means.

<EnC, EC> Exclusion of a member means that this player can **no longer invest in the group account and will not receive any earnings from the group account in the remaining rounds**. The excluded participant will receive an endowment of 50 points in each of the remaining rounds in the block. All 50 points will automatically be invested in the private account. Thus, the excluded participant will earn 50 points in each of the remaining rounds in the current block.

<EnC, EC> We can indicate exclusion of a member by deleting the lines connecting this player to other group members. As an example, the following figure shows the case where player N has been excluded.

<EnC>



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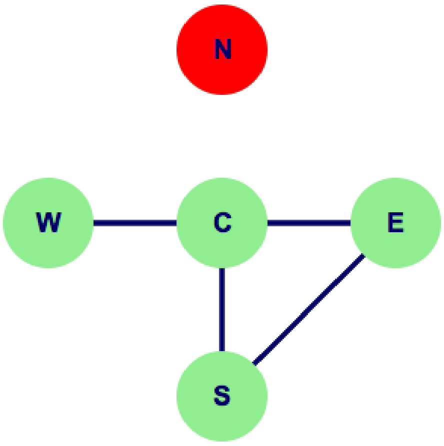
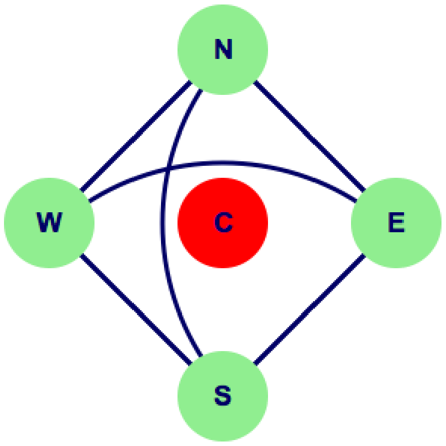


<EnC> Note that after exclusion of N, **a group of four remains**, that can invest in a joint group account. These four players form a **sub-group**. All participants in your sub-group are indicated by a **green circle**, excluded participants are indicated by a **red circle** and participants in another subgroup by an **orange circle**. The round will continue like before with the exception that the excluded participant cannot invest any points in the group account.
If you are not N, your group account earnings will be 0.6 x (points invested in the group account by W, C, E, and S). The same holds if not N, but W, E, S or C is excluded.

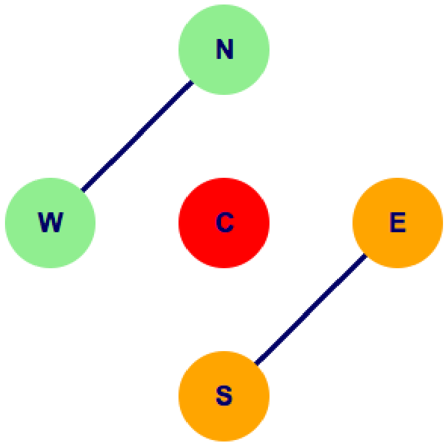
<EC> Note that after exclusion of N, **a group of four remains**, that can invest in a joint group account. These four players form a **sub-group**. All participants in your sub-group are indicated by a **green circle**, excluded participants are indicated by a **red circle** and participants in another subgroup by an **orange circle**. The round will continue like before with the exception that the excluded participant cannot invest any points in the group account. If you are not N, your group account earnings will be 0.6 x (points invested in the group account by W, C, E, and S). The

same holds if not N, but W, E, or S is excluded. If C is excluded, this is different however. In this case, the following case is obtained:

<EnC>



<EC>



<EC> This shows that **exclusion of C leaves two separate sub-groups within your group:**

- participants in the North (N) and West (W) positions
- participants in the South (S) and East (E) positions.

<EC> **Earnings from the group account** will depend on the total points invested in the group by participants in your **sub-group alone**. You will earn 0.6 points for each point invested by the two participants (including you) in your sub-group. For instance, if you are in the North position, your earnings from the group account will be 0.6 x (points invested in the group account by you and the participant in the West position). Similarly, if you are in the South position, your group account earnings depend on the group account investments of yourself and the East participant. You will **not earn anything from the group account investments of the participants in the other sub-group**. Note again that the Center participant cannot invest any points in the group account if excluded.

<EnC, EC> **The Exclusion Decision**

<EnC, EC> To decide on who will be excluded, the group members will **select candidates for exclusion**.

<EnC, EC> You can **indicate for each member of your (sub-)group whether or not you think that s/he should be excluded** from the group in future rounds in the current block. After you have been informed about the others' investment decisions in a round, you will be given the following list.

<EnC, EC>


Click to vote candidate for exclusion

☑ North
☑ East
☑ South
☑ West
☑ Center

<EnC, EC> When deciding, you will have **access to all previous investment decisions** in the current block by the players. You can register your vote to exclude a participant by **clicking the button next to that participant's position**. If you do not want to exclude a participant, leave the button unselected. In this example, we have selected all as candidates, but all buttons will be unselected before you decide. You can change your mind by clicking the button again. You can vote for as many or as few participants as you want. When you finish voting, click the Continue button.

<EnC, EC> If some member(s) of the group have previously been excluded, you can only vote on excluding members of the sub-group you are in. Participants who previously have been excluded cannot vote for the exclusion of others.

<EnC, EC> **If half or more members of the (sub-)group vote to exclude a participant, that participant will be excluded in future rounds in the current block.**

<EnC, EC> After all individuals have made their decisions on exclusion, you will be informed of the result of the voting and which participants, if any, are excluded. Specifically, you will be informed about: (i) which members have been excluded (if any); and (ii) for each member, how many other members s/he voted to exclude.

End of the Instructions

You have now reached the end of these instructions. You still have a chance to go back and re-read parts, if you like.

Once you are satisfied that you have fully understood the instructions, you may indicate this by clicking the 'Ready' button at the bottom of this screen.

After you have indicated that you are ready, we will ask you a few questions regarding the decisions you will make in the experiment. These questions will help you check whether you have understood the instructions and will also help to understand the calculation of your earnings. Once everyone has answered all questions correctly we will begin the experiment.

Quiz Questions I

Before the experiment starts, we will ask you some questions to check your understanding. You can go back to the instructions by clicking on the menu at the top of the screen.

Fill in the blanks:

This experiment consists of ___ blocks and each block consists of ___ rounds. This means that there are in total ___ blocks and ___ rounds in this experiment.

Your group of five participants:

- ○ Is the same in all blocks and all rounds
- ○ Changes every block
- ○ Changes every round

Your position:

- ○ Is the same in all blocks and all rounds
- ○ Changes every block
- ○ Changes every round

<EnC, EC> **If you are excluded, you will remain excluded until:**

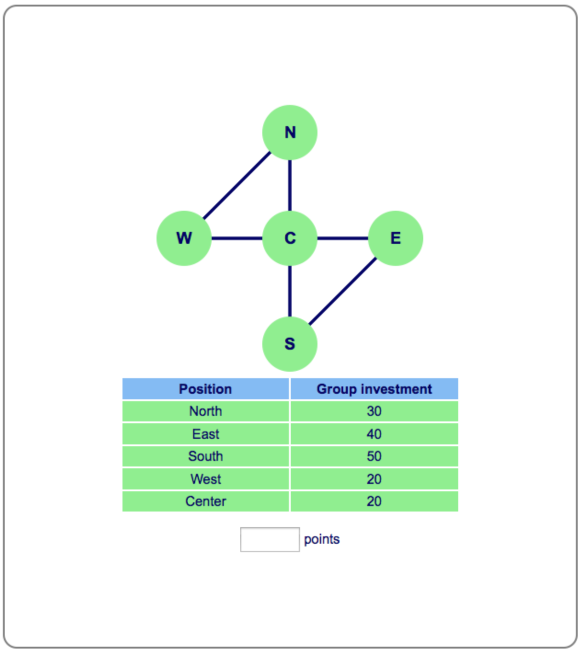
- ○ The end of the experiment
- ○ The end of the block
- ○ The end of the round

Quiz Questions II

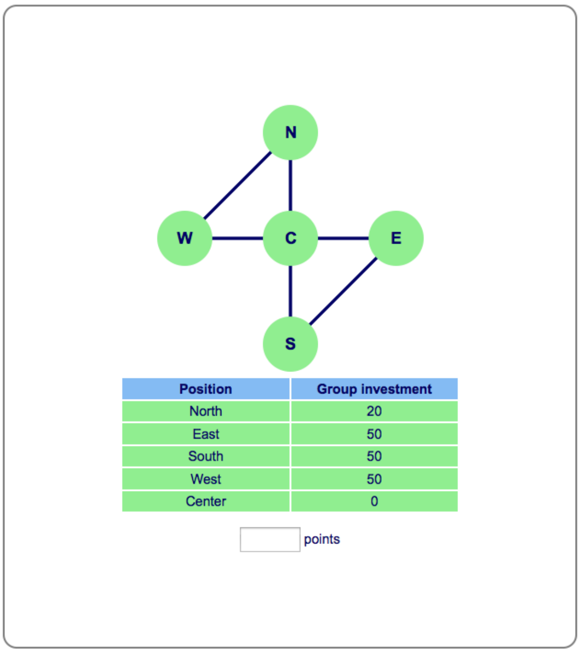
In the figures and tables below two possible outcomes of a round are given. These figures and tables serve only as an example: they are not informative on how you should decide in the experiment.

Suppose that you are in the North position in both situations. What would be your earnings in each situation?

<nEnC>

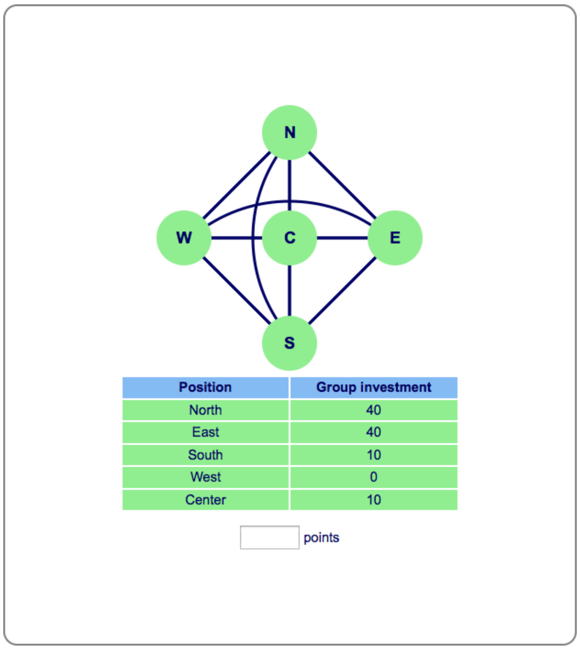


Position	Group investment
North	30
East	40
South	50
West	20
Center	20



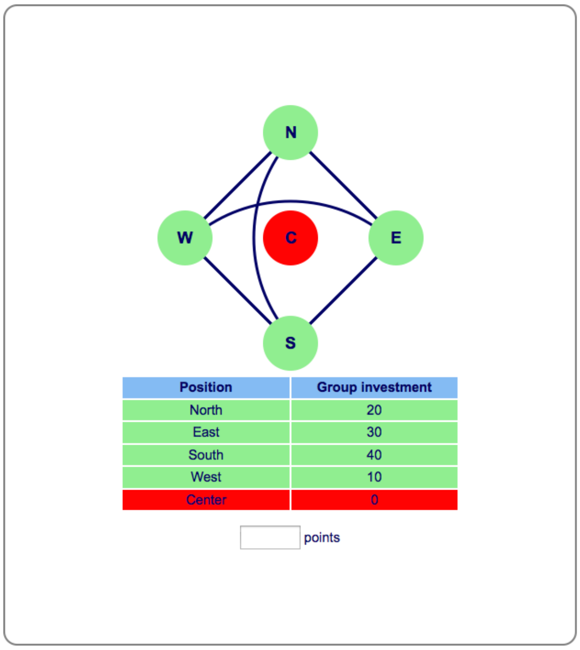
Position	Group investment
North	20
East	50
South	50
West	50
Center	0

<EnC>



Position	Group investment
North	40
East	40
South	10
West	0
Center	10

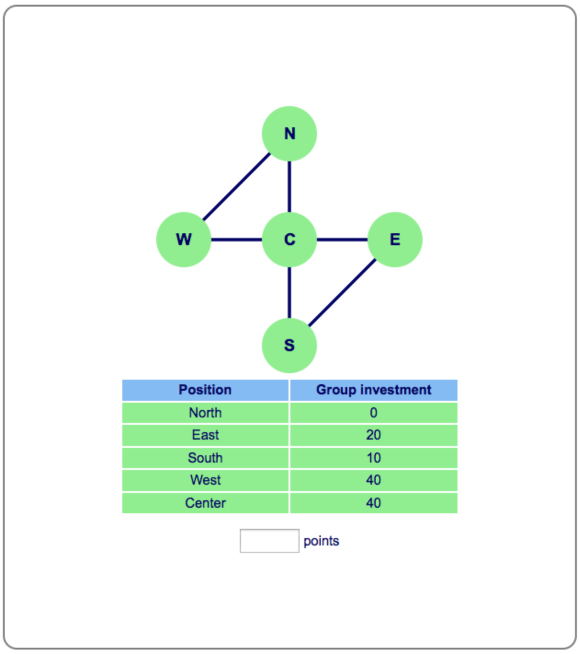
points



Position	Group investment
North	20
East	30
South	40
West	10
Center	0

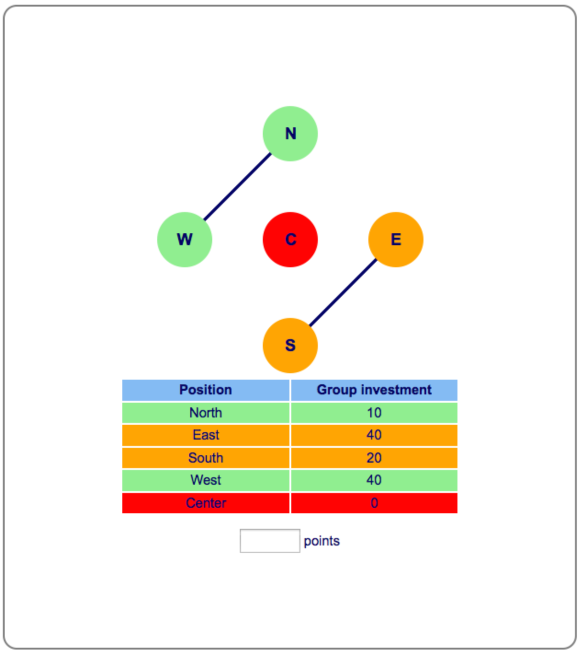
points

<EC>



Position	Group investment
North	0
East	20
South	10
West	40
Center	40

points



Position	Group investment
North	10
East	40
South	20
West	40
Center	0

points