Authority and Centrality
Leadership and Cooperation in Networked Teams

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Abstract: We experimentally investigate the effects of two different forms of leadership – *authority* and *centrality* **-** on cooperation in teams. A leader with authority can allocate funds between him/herself and the rest of the team, while leaders with centrality keep a team together by having a pivotal position in a network. In some treatments, players can vote to exclude others and prevent them from further participation in the team. We find that teams with authority reach low cooperation levels, and that leaders with authority are typically excluded early on in the game. In stark contrast, teams with centrality keep up high levels of cooperation, despite tolerating free riding by leaders with centrality.

JEL Codes: C91, D02, D03, H41
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1 Introduction

This paper explores how different forms of leadership affect cooperation and how individuals respond to leadership.[1] Leadership has the potential to be an effective means of raising productivity and cooperation in organizational/team settings (Brandts et al. 2014; Cappelen et al. 2015). A widely observed form of leadership is where a manager (the leader) has the 'authority' to allocate returns to team members. Authority is observed in many organizations, ranging from wage determination in small firms to government spending at the national level. Previous work (e.g., van der Heijden et al. 2009 and Stoddard et al. 2014) has found that this form of leadership has the potential to raise effort by team members: leaders incentivize cooperation by rewarding effort and penalizing shirking.

A second important function of managers has received little attention in the literature. This is their role in connecting otherwise isolated individuals or teams, enabling them to work together. Think of a firm where a manager brings together two teams with diverse skill sets. Synergies may arise due to social connections, particular skills or locations. By connecting entities, the leader becomes central in the organization.

A potential problem with leadership, however, is the temptation on the part of leaders to appropriate surplus for themselves. It has long been a widely shared 'truism' that the possession of 'power' leads to the dilution of an individual's moral character (see DeCelles et al. 2012 and the references therein). A common presumption is that the actions of powerful individuals like leaders will be more strongly motivated by self-interest than the actions of others (e.g., Persson et al. 2003). In the case of authority, leaders have an incentive to keep a larger portion of the generated surplus for themselves (van der Heijden et al. 2009). Also, a central leader might exploit her pivotal position in the organization with little fear of retaliation, because others need her to reap the benefits of the synergies that her position creates. Such opportunistic behavior – or even the potential for such behavior – by leaders can be harmful to the team at large.

Successful cooperation thus requires individuals to rely on their leaders to act cooperatively. Casual observation suggests that such reliance on leaders cannot be taken for granted. Indeed, many social and public bodies are designed to divide responsibility among individuals and across levels within the institution. Further, leaders are often required to be accountable to the bodies that they serve. For example, CEOs of firms are accountable to their Boards of Directors. Elected representatives are accountable to Parliament and to their constituents. In many cases, as in the above examples, individuals can be excluded if others perceive, or expect, them to be unreliable.

In this paper, we address the following research questions: (i) How is cooperative behavior

[1] The term 'leadership form' is sometimes used in the sense of 'leadership style' (e.g., Miller and Toulouse 1986 in empirical studies and Rotemberg and Saloner 1993 for a theoretical approach), which distinguishes between incentive schemes (such as democratic versus hierarchical leadership or leading by example) endogenously chosen by the leader (e.g., Güth et al. 2007 and Levati et al. 2007, Chaudhuri et al. 2015). As will become clear shortly, our use of the term refers to the actions available to the leader, as determined by their environment.

affected by having a leadership role? (ii) How do followers respond to the use or (potential) abuse of leadership? In answering these questions, we focus on the two aforementioned forms of leadership. Different forms may have distinct effects – leaders with authority may appropriate a larger share of surplus than those with centrality given their more direct control over generated surplus. Even if they have similar effects on leaders, followers may respond differently to the (ab)use of these distinct kinds of leadership.

Empirical answers to these questions are scarce in the literature because reliable data are difficult to obtain in the field (for one thing, because most people do not like to report that they have abused their position). We use laboratory experiments to collect data that allow us to investigate the consequences of different forms of leadership. We choose an environment where there is a tension between one's own interest and the common good – social dilemma games. An important advantage of our approach is that cooperation and free riding in social dilemmas are phenomena that are reasonably well understood.

In the experiment, subjects play social dilemma games (in particular, public goods games or multi-person trust games) on an exogenous network structure. This allows us to create, in a natural way, the two forms of leadership that we are interested in: *authority* and *centrality*. To create *authority*, subjects play a five-player game of trust where one player has discretion over how the surplus created by voluntary contributions is distributed among the members of the team. This is compared to a classic voluntary contribution mechanism (VCM), where every player automatically receives an equal share of the team surplus. Other than this difference in how proceeds are distributed, the two games are equivalent.

In addition to simply altering their contributions, followers may also respond by holding their leaders accountable. In some treatments, we allow players the opportunity to exclude others using a majority-voting rule (as in Cinyabuguma et al. 2005).[2] Excluding people from a team is a natural way in which accountability can be implemented.[3]

The opportunity to exclude team members also allows us to investigate the team building role of leaders - *centrality*. This occurs in teams where pivotal players are essential for keeping the team connected (Bonacich 1987).[4] Leaving out the central player causes the team to fall apart, which is costly

[2] This is distinct from using majority voting to appoint 'legitimate' leaders in the first place (e.g., Güth et al. 2007, and Baldassari and Grossman 2011). Voting to appoint leaders represents an ex-ante expectation of who would make an effective leader while voting to exclude leaders represents an ex-post reaction to what might be perceived as selfish or opportunistic behavior. We believe the latter better captures holding leaders to account, which is the focus of our study.

[3] Alternative mechanisms to implement accountability are available. These include: endogenous sorting, freedom to leave a team, mergers, and redemption. A review of these mechanisms and their respective behavioral effects can be found in Charness and Yang (2014).

[4] We use the term 'centrality' in a network in the way that is common in this literature; i.e., it is characterized by maximal betweenness, nearness, degree or influence (Freeman 1979; Jackson 2008). Betweenness measures the frequency with which a point (i.e., player) falls between pairs of other points. Nearness is defined by the distance of a point to all other points. A point's degree measures the number of other points it is connected to. Influence measures the fraction of the network that is affected by changes in a point (e.g., decisions by a player).

for others involved. Centrality is closely related to the idea of structural holes in networks, bridged through central players and the fact that such central players will benefit from their position with the consent of others (Burt 1992; Goyal and Vega-Redondo 2007). As far as we are aware, this hypothesis has hitherto not been experimentally studied in the economics literature.

Our results show that leaders with authority do try to lead their teams towards more efficient outcomes; in the absence of exclusion, they act even more cooperatively than those without authority. However, followers do not respond positively to such leadership; their cooperation levels decrease compared to a situation where returns are automatically distributed equally. With exclusion, leaders with authority initially cooperate as much as followers but are often excluded, and typically very early in the game. Centrality, on the other hand, is often used by leaders as a license to act less cooperatively: central players contribute less than others. Followers tolerate such behavior: their cooperation levels are unaffected and they do not vote to exclude central players.

Previously, leadership has been shown to have the potential to *raise* cooperation in teams (van der Heijden et al. 2009 and Stoddard et al. 2014). However, this previous work has not considered how followers react to the presence of such leaders in their teams, *other than* in the own cooperation decisions. Our results thus provide a new perspective on leadership. In the case of authority, followers strongly disapprove of this form of leadership and prevent the realization of this potential.[5] In contrast, central leaders who take advantage of their position manage to get away with this.

The introduction of players with either form of leadership creates heterogeneity across players. In the literature on social dilemmas, there are several papers that study other forms of heterogeneity (without studying leadership), starting with the seminal work of Ostrom et al. (1994) – e.g., Fisher et al. (1995), Cherry et al. (2005), Tan (2008), Tan and Noussair (2011). However, the picture of how heterogeneity affects cooperation between different types of players is not clear and depends on the particulars of the game (see Reuben and Riedl 2013 for a recent overview of the literature). Most of these studies are on VCMs or common pool resource games. There are very few studies of heterogeneity in trust games, partly due to the predominant restriction to two players (an exception is Anderson et al. 2006 who show that heterogeneity in show-up fees does not affect choices).[6]

[5] In addition, the fact of not being appointed the 'leader' with authority has been reported to demotivate agents in principal-agent problems (Fehr et al. 2013).

[6] Also related to our authority treatments are the 3-person trust games studied by Cassar and Rigdon (2011) and Buskens et al. (2010), where the 'senders' play *separate* trust games with one 'receiver'. In this paper, we emphasize the *joint* generation of surplus by the team.

TABLE 1: SUMMARY OF TREATMENTS

		No Authority	Authority
No Exclusion (⇒ no Centrality)		*nAnE* N = 85 (n = 6)	*AnE* N = 85 (n = 6)
Exclusion	**No Centrality**	*nAnC* N = 75 (n = 6)	*AnC* N = 65 (n = 6)
	Centrality	*nAC* N = 90 (n = 6)	*AC* N = 75 (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.

Closest to our study is a recent paper by Cox et al. (2013) who study social dilemmas with authority. They find that the presence of a player with authority (their 'King') leads to significantly lower contributions by the other players compared to the baseline VCM. However, in their setting, there is no room for centrality or exclusion (or any other mechanism that allows others to respond to authority). To the best of our knowledge, we are the first to study the effects of asymmetries in roles derived from authority *and* network centrality in social dilemmas; and how followers react to this.[7]

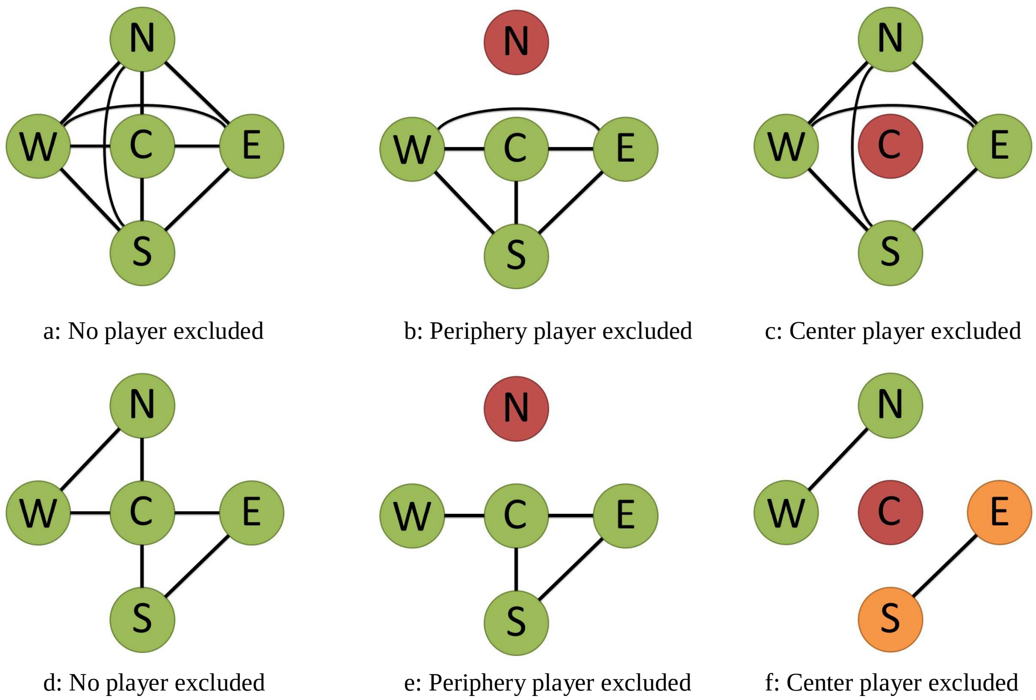
2 Experimental Design and Procedures

In the experiment, players are matched in fixed groups of five and interact with each other for one block of five rounds. Each session consists of five blocks, with random re-matching between blocks to minimize the possibility of long-term reputation formation. The stage game in the baseline is the symmetric linear VCM where players allocate an endowment between a private and a common fund. We vary three dimensions to implement *authority*, *exclusion* and *centrality*. The first dimension is how the generated surplus is divided – either automatic equal division (*No Authority*) or distributed by a leader (*Authority*). The second dimension is whether groups can remove members by majority voting (*Exclusion*) or not (*No Exclusion*). The last dimension concerns the network structure – either every player is linked to each other (*No Centrality*) or one player (the leader) connects two separate groups (*Centrality*). The resulting treatments are summarized in Table 1, which also shows the treatment labels for, and number of observations in, each treatment.[8]

[7] There are several experimental studies that investigate public good provision in a network. 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 leadership heterogeneity.

[8] 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 combinations no-authority/centrality/no-exclusion and authority/centrality/no-exclusion therefore do not exist.

FIGURE 1: NETWORK STRUCTURES



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 without player C.

In all treatments, players are labeled 'Center' (C), 'North' (N), 'East' (E), 'South' (S) and 'West' (W). Only C can be a 'leader'. 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 connection 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 treatments with Authority, C is the player with authority and, in treatments with centrality, C is the player with centrality.

In each round, players participate in a social dilemma game. Each player i receives an endowment of 50 points and all players, including the leader, simultaneously decide how much, $x_i \in [0,50]$, to invest in a common fund. The payoffs for player i are given by:

$$\Pi_i = 50 - x_i + F_i.$$

where F_i is the return from the common fund. In all treatments, players are informed at the end of each round of the individual contributions of all other players in their group of five.

Authority

In treatments with No Authority (*nAnE*, *nAnC* and *nAC*), the returns from the common fund are given by a standard VCM mechanism, with an MPCR of 0.6. This gives:

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

where N_i denotes the set of players in i's component.

In the treatments with Authority (*AnE*, *AnC* and *AC*), total contributions of all players in the component of the leader (C) are multiplied by a factor $\alpha = 0.6|N_C|$. This is, if no player is excluded the contributions are multiplied by a factor $\alpha = 3$. The value of the common fund is then $F = \alpha\ (x_C + \sum_{j \neq C \in N_C} x_j)$. After the individual contributions have been announced publicly, the player with authority decides how much, R, of the common fund, to return to the periphery players, which is then divided equally among them.[9] Thus the returns from the common fund are $F_C = F - R$ for C and $F_P = R/|N_C - 1|$ for each periphery player. This specification ensures that the maximal sum of payoffs is the same in all treatments. Note that the VCM without authority is captured by this specification as well: if the C player keeps $F_C = 1/|N_C|$, all players will receive an equal share, just like the VCM without authority.

Exclusion

Our second dimension concerns the possibility for players to exclude others from further interaction with the group. In the treatments with no exclusion (*nAnE* and *AnE*), all five players participate in every round. In all other treatments (*nAnC*, *nAC*, *AnC* and *AC*), 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.[10] 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, 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.

If a player is excluded, all links with other group members are removed. They can no longer contribute to, or receive any benefits from, the common fund, or vote to exclude others. They 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.

Exclusion in our design represents means that a player can no longer participate in the group interactions. Outside of the laboratory, group members might not always have such an extreme tool at

[9] Since followers' returns are contingent on the decision of the authority, this setting resembles a modified trust game with four trustors and one trustee, who (to maintain comparability with the VCM) can also contribute and cannot discriminate between players. Note that this allows the authority to punish and reward the periphery players collectively, but not individually. An interesting extension to our design would be to allow the leader to differentiate returns across the members of the periphery.

[10] We allow players the option to vote to exclude themselves as well. This was observed in only 16 out of 6,100 instances of voting.

their disposal. Often, however, individuals have more subtle means to express discontent with a co-member's choices; think of sabotage, reduction in production or demonstrations.

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.[11] In the treatment with No Authority (*nAnC*), the remaining players play a four-person VCM. In the treatment with Authority (*AnC*), player C continues to determine the distribution of the generated surplus among the four players if she has not been excluded. Otherwise, periphery 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). When the player with centrality is excluded, 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. In the treatment with No Authority (*nAC*), the remaining players play a four-player VCM after exclusion of a periphery player and two-player VCMs if C has been excluded. In the treatment with Authority (*AC*), as in *AnC*, the player with centrality continues to determine the distribution of the generated surplus among the four players if she has not been excluded. Otherwise, as in *nAC*, periphery players play two-player VCMs.

Procedures

The computerized experiment was run in the CREED laboratory of the University of Amsterdam. In total 475 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.[12] Each session lasted approximately one hour.

In order to study the causal effect of positions, roles (C or periphery) were randomly assigned at the beginning of a session. To avoid behavioral spill-over effects, these roles remained fixed

[11] We discuss here the situation after the first exclusion. This is presented in Figure 1. The cases for subsequent exclusions are straightforward.

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

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.

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 10.60 and 30.70 euro, with an average of 15.90 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. The only exception is player C in the treatments with authority. She will contribute her entire endowment and will return nothing. 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 in the VCM games.[13] This is different in the authority treatments with exclusion. Here, the threat of exclusion affects C players with authority as the stage-game Nash payoff is strictly higher than their exclusion payoff. This opens the door for repeated game equilibria where C shares some of her surplus and where periphery players make positive contributions. In addition, repeated play of the stage-game equilibrium is still an equilibrium of the repeated game. We will use the latter predictions as a benchmark 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. However, this 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. The crucial parameter of our model is p, the probability of a player being a cooperative type. Self-interested types free ride unless this harms (their own) payoffs. Cooperative types unconditionally cooperate and also vote to exclude anyone who does not. This two-type model is developed and analyzed in Appendix B. Here, we discuss the main conclusions and the hypotheses that follow from the analyses.

[13] In some settings, costless voting could lead to repeated game equilibria with positive contributions (Hirshleifer & 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.

In Appendix B we identify three key regions of the parameter space: (1) $p \in [0, \frac{1}{6}]$, (2) $p \in \left(\frac{1}{6}, \frac{1}{2}\right)$, and (3) $p \in [\frac{1}{2}, 1]$. We argue that cases (1) and (3) are empirically implausible. Case (1) prevents exclusion from raising cooperation, contrary to the evidence in Cinyabuguma et al. (2005). Case (3) assumes that an implausible fraction of at least half of the players are unconditional co-operators. In similar environments, Fischbacher et al. (2001) have shown that even the number of *conditional* co-operators may only reach half of the subjects. There are even fewer unconditional cooperators. Thus, we focus on the intermediate parameter range ($p \in \left(\frac{1}{6}, \frac{1}{2}\right)$) to derive our hypotheses.

As a measure for cooperation at the individual level, we consider how a player's choice affects the payoffs of others. For players without authority, this simply means that the measure should be perfectly (linearly) correlated with the contribution to the common fund. Thus, cooperation of players without authority is measured by contributions as a proportion of endowment. For a player with authority, cooperation entails more than just contributing to the common fund. Since she will contribute her complete endowment even if self-interested, a more informative measure is her return to the periphery players.[14] For a player with authority, we define a fully cooperative distribution, R_{equal}, as one that divides the surplus equally among *all* players. Our benchmark for cooperative behavior is thus the VCM where this happens by default. The measure of cooperation for players with authority, then, is the fraction of this fully cooperative distribution they implement. To quantify, we define:

$$\rho_C \equiv R/R_{equal}.$$

Standardizing different forms of cooperation (contributions and return rates) allows us to make comparisons between players with and without authority.[15]

We now discuss the hypotheses that we will test using our experimental data. These hypotheses follow from the two-type model analyzed in Appendix B. We focus on behavior in the last two rounds of a block. We base our hypotheses on the fraction of cooperative types that is needed to induce cooperative behavior by self-interested types.

First, we establish the effectiveness of the possibility of exclusion to raise cooperation levels in the absence of any form of leadership. Previous evidence shows that the ability to exclude players from the group raises cooperation (Cinyabuguma et al., 2005). The intuition here is that, without exclusion (*nAnE*), free riders have no incentive to contribute. In the presence of the threat of exclusion (*nAnC*),

[14] The assumption of full contribution turns out to be a good approximation in our data, where across treatments the average contribution by players with authority is 91% of their endowment. In any case, we relax this assumption in Appendix C and our results are qualitatively the same.

[15] We realize that contributions and return rates are inherently difficult to compare. Nevertheless, contributions in public good games and reciprocity in trust games have been found to be correlated within individuals (Peysakhovich et al. 2014). The main technical constraint of our comparison is that the data could show ρ_C>1 in Authority. This possibility was observed in 4% of the cases.

positive contributions by free riders can be sustained in the penultimate round. This yields the following hypothesis.

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

> *The threat of exclusion increases contributions: Cooperation levels in nAnC > Cooperation levels in nAnE.*

Now consider the effects of introducing authority. In the absence of exclusion (*AnE*), cooperation by free riders cannot be sustained in equilibrium. Hence, we expect that the introduction of authority will not affect cooperation in the absence of exclusion. Even in the presence of exclusion (*AnC*), players with authority have no material incentive to cooperate in the final round. As only cooperative leaders will return funds in the penultimate round, any periphery investment in the common fund will be lost with probability (1 - *p*). Appendix B shows that for the range of probabilities we consider, periphery players will then also vote to exclude a *cooperative* player with authority. Given that players with authority will be excluded regardless of their behavior, cooperation by players with authority cannot be sustained in equilibrium. Since self-interested players with authority are expected to keep all the contributions to themselves, it is costlier for self-interested periphery players to act cooperatively in the presence of authority than in its absence. To induce cooperation by periphery players, a higher fraction of cooperative types is then needed in the treatments with authority than in those without. This gives:

Hypothesis 2 (effects of authority):

> (a) *In the absence of exclusion, authority does not affect cooperation levels of players with and without authority, i.e., cooperation levels in AnE = cooperation levels in nAnE.*
>
> (b) *In the presence of exclusion, authority lowers the cooperation levels of periphery players without authority, i.e., cooperation levels by periphery players in AnC < cooperation levels by periphery players in nAnC.*
>
> (c) *In the presence of exclusion, authority does not affect the cooperation levels of C-players, i.e. cooperation levels by C-players in AnC = cooperation levels by C-players in nAnC.*

We now move to the effects of centrality. Recall that exclusion is a necessary condition for player C to become a player with centrality. Thus, we compare situations where groups can exclude members in the absence (*nAnC*) or presence (*nAC*) of a player with centrality. Excluding a free-rider without centrality (any player in *nAnC* or a periphery player in *nAC*) will not affect expected payoffs. Hence, centrality does not change the effect 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.

Hypothesis 3 (effects of centrality):

(a) *Cooperation levels by players with centrality in nAC* < *Cooperation levels by periphery players in nAC.*

(b) *Cooperation levels by players with centrality in nAC* < *Cooperation levels by players with centrality in nAnC.*

Finally, we consider how the votes to exclude are affected by the treatments. Specific hypotheses follow directly from the previous hypotheses and underlying model. For cooperation to work as a disciplining mechanism (Hypothesis 1), players should vote to exclude those with low cooperation levels. Moreover, as argued above, players with (only) authority are expected to be excluded even when they act cooperatively while, players with centrality will abuse their position and will be excluded less often.

Hypothesis 4 (voting to exclude):

(a) *Players with higher cooperation levels receive fewer votes for exclusion.*

(b) *Conditional on cooperation level, the number of votes against players with authority* > *the number of votes against periphery players.*

(c) *Conditional on cooperation level, the number of votes against central players with centrality* < *the number of votes against periphery players.*

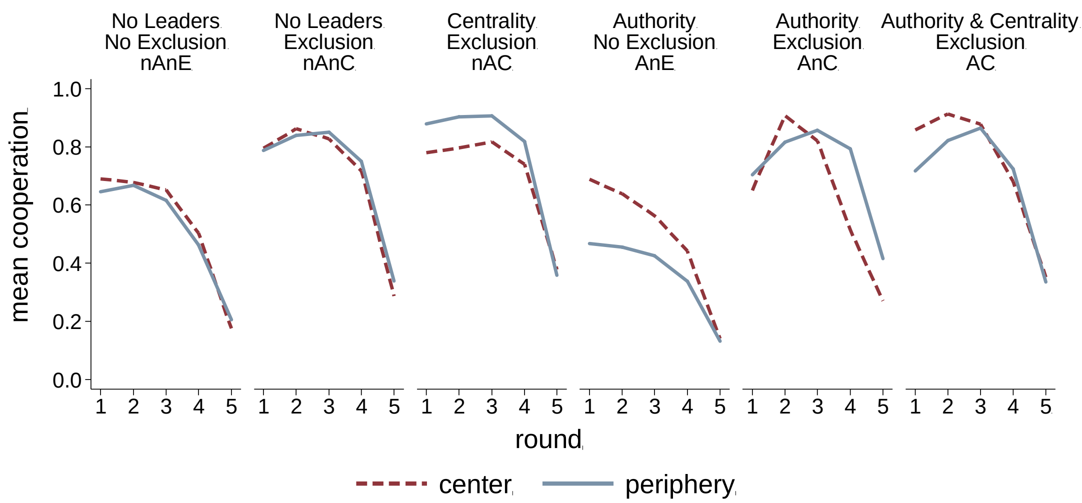
4 Results

We start with a general overview of our results. Figure 2 presents mean cooperation levels over rounds in our various treatments. For this overview we combine data from all blocks.[16] In Appendix C we provide a table with the mean cooperation levels per round. As described in the previous section, we measure cooperation for players without authority as the fraction of the endowment they contribute to the common fund, while for players without authority we measure it by their return rate. The figure shows that cooperation is higher with exclusion than without and that differences in cooperation between subject C and the periphery occur only when C has leadership from either authority or centrality. In what follows, we analyze these differences in more detail. Unless stated otherwise, all reported statistics come from two-sided tests using matching groups as the unit of analysis, and averages over all rounds and blocks.[17] The number of observations is thus six in each comparison sample.

[16] We do not observe any differences in cooperation levels across blocks, except in *nAnE*, where we observe a downward trend across blocks.

[17] The results from these conservative tests remain qualitatively the same when we exclude the last round of each block.

FIGURE 2: MEAN COOPERATION BY PLAYER POSITION



Notes. The three panels on the left denote the treatments without authority and the three panels on the right show the cases with authority. For each round, the cooperation 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.

4.1 Exclusion in the absence of leadership

Figure 2 shows the usual pattern of declining cooperation levels over time in the standard public goods game (*nAnE*) in the absence of leadership and exclusion (see, for instance, Fehr and Gächter, 2000). In the absence of leadership, the only difference between subjects is one of framing, where subject C is presented as being in the 'middle' of the group. A Wilcoxon signed ranks test (henceforth, W) shows no significant difference in cooperation between subjects C and periphery subjects in *nAnE* (W, p = 0.463). Thus, we find no evidence of framing due to the network representation.

Once we allow for exclusion (*nAnC*), again no significant differences between subjects C and periphery subjects arise (W, p = 0.463). For both, we do observe that cooperation levels increase with respect to *nAnE*. Mann-Whitney tests (henceforth, MW) show that the increase is significant for periphery subjects (MW, p = 0.016), and marginally significant for subject C (MW, p = 0.078). As a consequence, average cooperation level in the group as a whole is higher (MW, p = 0.010). This replicates findings in Cinyabuguma et al. (2005) and gives our first result. [18]

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

[18] This, and all other results are qualitatively the same if we only consider the first round of each block. This means that the positive effect of the threat of exclusion on cooperation also exists before exclusion has taken place.

We thus find support for Hypothesis 1.

4.2 The effects of authority

Figure 2 shows that, in the absence of exclusion, the addition of authority (*AnE vs nAnE*) reduces the cooperation levels of periphery subjects (marginally significant, MW, p = 0.055) but not that of subject C (MW, p = 0.749).[19] Taken together, average group cooperation levels are significantly lower (MW, p = 0.037). The introduction of a leader with authority does not stem the steady decline over time. Further, authority drives a wedge between the cooperation levels of the subjects with authority and periphery subjects – C subjects present significantly higher cooperation levels (W, p = 0.028).

In the presence of exclusion, the introduction of authority (*AnC vs. nAnC*) does not affect the cooperation levels of subject C or periphery subjects (MW, p = 0.149 and p = 0.749, respectively).

Result 2 (effects of authority):

(a) *In the absence of exclusion, the introduction of authority does not affect the cooperation levels of subjects with authority. However, it decreases that of periphery subjects. Subjects with authority cooperate more than those without.*

(b) *In the presence of exclusion, the introduction of authority does not affect the cooperation levels of periphery subjects.*

(c) *In the presence of exclusion, the introduction of authority does not affect the cooperation levels of subjects with authority.*

In sum, we find partial support for hypothesis 2(a), no support for hypothesis 2(b) (which predicts reduced cooperation by periphery players) and support for hypothesis 2(c) (which predicts no effect for C-players). Hence, we find support for the hypothesized effects of authority on cooperation by C-players but not by periphery players.

Though we have not developed hypotheses on the effects of exclusion when there is authority, we can check whether there are any such effects. It turns out that the introduction of exclusion (*AnC vs AnE*) raises cooperation levels unambiguously for periphery subjects (MW, p = 0.004). While cooperation initially increases for players with authority, the overall effect is not significant (MW, p = 0.631).[20] Overall, exclusion raises average group cooperation levels (MW, p = 0.010). Hence, the effect of exclusion (cf. Result 1) is robust to adding a player with authority.

[19] The periphery subjects' reaction (reduced cooperation levels) is reminiscent of the Falk and Kosfeld (2006) finding that subjects dislike being controlled.

[20] This result may be affected by the fact that few subjects with authority are left in the group after the first round. We document this later when we discuss exclusion.

4.3 The effects of centrality

Figure 2 shows that, in the presence of centrality alone (*nAC*), there is a difference between cooperation levels of the subjects with centrality and periphery subjects. Subjects with centrality seem to 'abuse' their position; their relative cooperation levels are 10 percent lower than those of periphery subjects, and this is statistically significant (W, $p = 0.028$). Figure 2 suggests that the introduction of centrality (*nAnC vs nAC*) does not affect subjects C's cooperation levels but increases that of periphery subjects. Tests show that the effect is not significant for subjects C or periphery subjects (MW, $p = 0.873$ and $p = 0.262$, respectively).

Result 3 (effects of centrality):

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

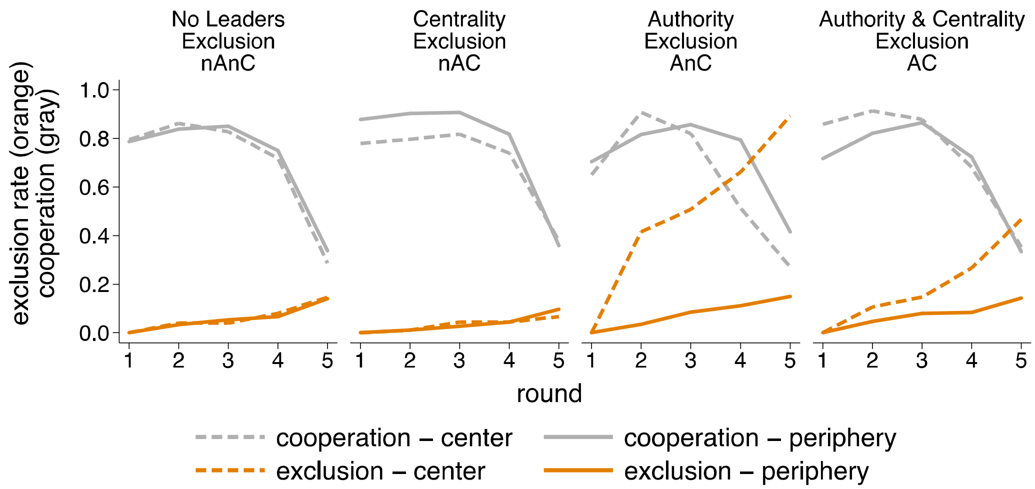
(b) *Cooperation levels of both subjects with centrality and periphery subjects are not affected by the introduction of centrality.*

This provides support for hypothesis 3(a) but not 3(b). Finally, our setup also allows us to directly compare the two types of leadership (*nAC vs AnC*). This shows that average group cooperation is higher with centrality than with authority. The difference is marginally significant (MW, $p = 0.055$). We will return to this comparison when we discuss efficiency in section 4.6.

4.4 The effects of authority *and* centrality

So far, we have isolated the effects of centrality and authority in order to address our research questions. Next, we will turn to the treatment when leaders have both authority *and* centrality. This allows us to investigate the effects of adding authority to centrality or vice versa. In the presence of exclusion, we compare cooperation levels in *AC* with that in treatments where only one source of leadership exists. Compared to the case where leaders only have authority (*AnC*), Figure 2 suggests that leaders cooperate more in *AC* (at least in the first round) while periphery subjects' behavior is unaffected. However, tests show no significant differences across all rounds (MW, $p = 0.150$ for leaders and $p > 0.999$ for periphery subjects). On the other hand, compared to the case where leaders only have centrality (*nAC*), Figure 2 suggests that cooperation for leaders in *AC* is unaffected, while periphery subjects cooperate less. This is confirmed by statistical tests, although the latter is only marginally significant (MW, $p = 0.631$ and $p = 0.078$, respectively). Finally, while Figure 2 suggests that leaders act somewhat more cooperatively than periphery subjects in *AC*, the statistical test also shows no significant difference (W, $p = 0.463$). Thus, we do not find that leaders take *additional* advantage when they have both authority and centrality.

FIGURE 3: EXCLUSION AND COOPERATION LEVEL BY PLAYER POSITION



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

4.5 Voting and exclusion

Figure 3 presents the *cumulative* proportion of C subjects and periphery subjects excluded over rounds in the exclusion treatments. To see the relationship between cooperation and exclusion, the figure also replicates the cooperation levels over rounds from Figure 2. In the absence of leadership (*nAnC*), cumulative exclusion rates remain under 20% to the end. Further, there is no discernible difference in cooperation levels or in the rate of exclusion between subject C and periphery subjects. With centrality (*nAC*), 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.

With authority (*AnC*), the picture shows a stark difference. Here, cumulative exclusion rates differ considerably between roles. In initial rounds, subjects with authority cooperate as much as periphery subjects, but are *much* more likely to be excluded. At the end of round 1, over 40% of subjects with authority are excluded while less than 10% of periphery subjects are. This difference is only magnified over time; by the end of round 4, over 90% of subjects with authority have been excluded while less than 20% of periphery subjects have been. This difference in exclusion rates does not correspond with the observed difference in cooperation levels.

When there is both authority and centrality (*AC*), there is no significant difference in cooperation levels between subjects. Nevertheless, as in *AnC*, leaders face higher exclusion rates. Once again, this is evident from the very first round and is magnified over time. By the last round about 50% of the leaders have been excluded while less than 20% of the periphery subjects have been.

TABLE 2: VOTES RECEIVED FOR EXCLUSION

	No Leaders (*nAnC*)	Centrality (*nAC*)	Authority (*AnC*)	Authority & Centrality (*AC*)
Cooperation	-3.436***	-3.522***	-2.993***	-2.969***
	(0.161)	(0.171)	(0.157)	(0.165)
Center	-0.247	-0.498*	0.336***	0.521***
	(0.201)	(0.297)	(0.129)	(0.191)
Center × Cooperation	0.099	0.797**	1.774***	0.926***
	(0.326)	(0.386)	(0.204)	(0.246)
# players in subgroup	0.165	0.526***	0.292***	0.547***
	(0.133)	(0.149)	(0.086)	(0.076)
Round	-0.166***	0.114**	0.027	0.029
	(0.043)	(0.045)	(0.039)	(0.041)
Block	0.095***	0.032	0.041	0.0002
	(0.032)	(0.035)	(0.028)	(0.031)
Constant	0.515	-2.000**	-0.549	-2.070***
	(0.720)	(0.778)	(0.481)	(0.425)
Observations	1442	1758	1136	1385

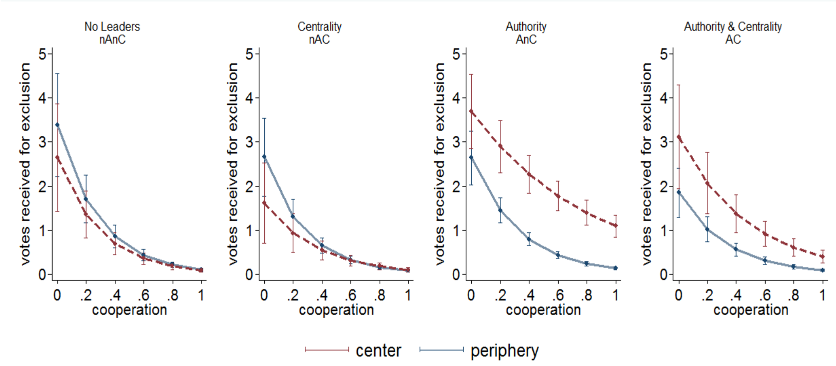
Notes: We allow for random effects at the matching group and the subject level. Standard errors clustered on matching groups in parentheses. *, ** and *** indicate significance at 10%, 5% and 1% respectively.

To further study the exclusion decisions Table 2 presents, for each treatment, estimates of individual-level (mixed) random effects Poisson regressions of the number of received votes in rounds 1-4. The independent variables include the subject's cooperation in the round, a dummy for the subject with centrality, the interaction between the two, the number of members in the subject's component in the round, a time trend for rounds and a time trend for blocks. For each subject, we only include rounds in which she had not been excluded or isolated. Since the estimated coefficients of Poisson regressions are not readily interpretable, we plot the estimated number of received votes as a function of cooperation levels in Figure 4.

In all treatments, there is a strong negative effect of cooperation levels on the number of received votes (see the cooperation variable in Table 2 and the negative slope in Figure 4). In addition, the first regression shows that in the absence of leadership (*nAnC*), there is no discrimination between roles.[21] The second regression shows that leaders with centrality receive fewer votes for exclusion, even after controlling for cooperation levels. Moreover, the interaction term is positive and significant. Figure 4 illustrates the net effect: for low cooperation levels, subjects with centrality receive fewer votes for exclusion than periphery subjects.

[21] The number of received votes in *nAnC* decreases across rounds in a block and increases across blocks. Whereas the latter could indicate learning, the former is likely attributable to the fact that exclusion has less effect as the number of rounds remaining decreases. These time trends mostly disappear in the other treatments.

FIGURE 4. ESTIMATED VOTES RECEIVED FOR EXCLUSION



Notes: Estimated number of votes received as function of cooperativeness for center and periphery players. Estimations based on the regressions reported in Table 3.2. Error bars indicate 95% confidence intervals.

In the presence of authority (third and fourth regressions), leaders with authority receive significantly *more* votes than periphery subjects. The interaction term is positive and significant. Figure 4 shows that leaders with authority (*AnC*), receive more votes for exclusion than periphery subjects, at *every* cooperation level. Even when subjects with authority are fully cooperative, they can expect to receive a positive number of votes. This 'negative discrimination' explains the divergence in exclusion rates between subjects with authority and periphery subjects evident in Figure 3. In *AC*, leaders receive more votes than periphery subjects, but the effect is smaller than in *AnC*. This suggests that centrality mitigates the negative discrimination leaders face and explains why the divergence between exclusion rates for the two roles is smaller in *AC* than in *AnC*.

Result 4:

(a) *In all exclusion treatments, there is a negative relation between the number of received votes and cooperation levels.*

(b) *Controlling for cooperation levels, leaders with authority receive more votes than periphery subjects.*

(c) *Controlling for cooperation levels, leaders with centrality receive fewer votes than periphery subjects.*

Together, this provides support for Hypotheses 4(a), 4(b) and 4(c).

TABLE 3: MEAN NET EFFICIENCY GAIN

		No Authority	**Authority**
No Exclusion (⇒ no Centrality)		*nAnE* 0.521 (0.075)	*AnE* 0.358 (0.112)
Exclusion	**No Centrality**	*nAnC* 0.636 (0.140)	*AnC* 0.378 (0.171)
	Centrality	*nAC* 0.705 (0.052)	*AC* 0.487 (0.195)

Note. Standard deviation in parentheses. The unit of analysis is the matching group.

4.6 Efficiency

To examine the impact of leadership on group-level performance, we construct a measure of cooperation at the group level, which we call the '*net efficiency gain*' (NEG):

$$NEG \equiv \frac{(realized\ surplus - Nash\ surplus)}{(750 - Nash\ surplus)},$$

where 'Nash surplus' is the surplus in the Nash equilibrium for self-interested players and 750 is the maximum aggregate surplus in a round. Note that for the VCM, NEG correlates perfectly with aggregate contributions. In authority treatments, it corrects for the fact that, in theory, even self-interested players with authority contribute fully in the Nash equilibrium. Finally NEG only measures the *gain* in efficiency and says nothing about how the surplus is distributed (which is especially relevant for the authority treatments).

Table 3 presents summary statistics on NEG in each treatment.[22] In the absence of leadership, efficiency is higher when exclusion is available, and the difference is marginally significant (*nAnC vs nAnE*: MW, p = 0.078). This is in spite of the fact that surplus may be lost if subjects are actually excluded. The increase in cooperation levels thus dominates the cost of excluding subjects. This is different in the presence of authority: here, exclusion does not increase NEG despite the increase in cooperation levels (*AnE vs AnC*: MW, p >0.999). This is because almost all players with authority are excluded at some point.

Table 3 also shows that the addition of authority is always detrimental to NEG. When exclusion is unavailable, including only authority reduces NEG (*AnE vs nAnE*; MW, p = 0.025) because periphery subjects cooperate significantly less. With exclusion, we again observe that adding authority reduces NEG, both with and without centrality and the differences are (marginally) significant (*AC vs nAC*:

[22] Summary statistics on absolute earnings themselves are presented in Appendix C.

MW, p = 0.055 and *AnC vs nAnC*: MW, p = 0.007). This is because periphery subjects often exclude subjects with authority early in the game, thus reducing the surplus that groups (can) generate.

In contrast, centrality is not harmful for efficiency. The addition of centrality somewhat increases NEG, though not significantly (*nAC vs nAnC*: MW, p = 0.150 and *AC vs AnC*: MW, p = 0.262). Finally, *replacing* authority with centrality significantly increases NEG (*nAC vs AnC*: MW, p = 0.007).

5 Concluding remarks

We study two sources of leadership (centrality and authority) in a controlled setting and investigate how leaders and others react to these sources of leadership. We find evidence that leaders with authority act more cooperatively when compared with their counterparts in the baseline or with the followers. Nevertheless, followers do not even allow leaders a sporting chance of success and exclude them almost immediately, hurting long-term cooperation and efficiency. So, while a positive effect of leadership on cooperation within teams may exist (e.g., Güth et al. 2007; van der Heijden et al. 2009; Stoddard et al. 2014), our results suggest that there may be reasons for this effect not to be realized. Our preferred interpretation is that followers strongly distrust this form of leadership (when exogenously imposed).

In contrast, leaders with centrality abuse their position but they are not held any more accountable than other individuals because the benefits from bringing different teams together are prominent for everyone. This result is not trivial: other sources of heterogeneity in VCM games have been found to harm cooperation (Reuben and Riedl 2013).

Both the nature of leadership and how leadership appears to others have important implications for cooperation and efficiency within an organization. Our experiment suggests that a cooperative leader is not enough to improve a team's performance. Bringing different teams together, however, creates value for others within the organization.

Our results are important for understanding the role of managers (leaders) in organizational performance. The key to understanding this role is the kind of leadership that a manager has. Managers whose leadership is based on their power to allocate resources may face resistance in the form of reduced cooperation in the organization. Even if the manager herself acts cooperatively, her position becomes untenable; the result is lower efficiency than in the case where the manager has no discretionary power over the allocation of output/returns. By design our results are relevant for situations where the leader cannot discriminate between employees by individually rewarding good behavior and punishing bad behavior. This environment creates opposition between the leader and the other players. Note however, that the leader can punish and reward team members collectively. Although not every firm operates in this manner, there are many (public) firms (especially in Europe) where discrimination within the firm in terms of workers' contribution has limited applicability. Workers in the same position will receive the same payment independently of their production.

In contrast, managers who derive their power from centrality – i.e., the fact that they act as a bridge between otherwise separated groups in the organization – enable additional value creation within the organization by stimulating cooperation amongst team members. Our design provides an arena to study the role of key players in bridging structural holes. Such key players could be observed within organizations (linking distinct departments, for example), but also between organizations (think of joint ventures). Managers who take this position can afford to be less cooperative, without the risk of the team falling apart and without negatively affecting the efforts of others in the organization(s).

Of course, more factors are likely to be at play in real-world organizational settings than in our experimental setting. Selecting leaders, or letting leaders compete to obtain attractive leadership positions might shift the effects we have shown here and may have different implications for efficiency. However, our results with exogenously imposed leaders suggest that the fundamentally different effects of the two distinct forms of leadership are important phenomena that need to be accounted for when exploring the potential for leadership to enhance organizational performance, and when designing organizational structures.

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ELECTRONIC CUPPLEMENTARY 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**.
- <nAnE, nAnC, nAC> 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.
- <AnE, AnC, AC> Earnings from the **group account**: First, the **total number of points invested in the group account** by all group members is determined. Then, this is **multiplied by 3**. Finally, the **group member in the center (C)** determines how to divide the total amount. S/he determines **how much to keep** for her- or himself. **The remainder is equally divided** among the other group members.

<nAnC, nAC, AnC, AC> 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.

<AnC> If someone is excluded, your **earnings from the group account** will depend on the total points invested in the group account by participants in your **sub-group alone**. The amount in the group account will now be multiplied by a factor of 0.6 x (number of sub-group members). If the Center is not excluded, she decides on how much to keep for her/himself and how much to divide equally among the other sub-group members. If the Center is excluded, the amount in the group account is equally divided between the remaining sub-group members.

<AC> If someone is excluded, your **earnings from the group account** will depend on the total points invested in the group account by participants in your **sub-group alone**. The amount in the group account will now be multiplied by a factor of 0.6 x (number of sub-group members). If the Center is not excluded, she decides on how much to keep for her/himself and how much to divide equally among the other sub-group members. If the Center is excluded, the amount in the group account is equally divided between the remaining sub-group members. You will **not earn anything from the group account investments of participants in other sub-groups.**

<nAnC, nAC, AnC, AC> To decide on who will be excluded, the group members will **select candidates for exclusion.**

<nAnC, nAC, AnC, AC> 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.

<nAnC, nAC, AnC, AC> 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.

<nAnC, nAC, AnC, AC> **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

In this appendix, we study a simple two-period model with cooperative types (similar to Kreps et al. 1982) to derive comparative statics for the effects of exclusion, centrality and authority.

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 and also vote to exclude anyone who does not. Cooperation means here contributing the full endowment to the common fund, and for those with authority splitting the common fund equally among all non-excluded players. The proportion of cooperative types is given by p, which we assume to be a minority, i.e. $p \in \left[0, \frac{1}{2}\right)$. We are interested under which range of p self-interested types will act cooperatively in the first period. We consider three types of cooperative equilibria: (i) cooperation by all players, (ii) cooperation only by periphery players and (iii) cooperation only by C-players.

In all treatments, in the second (i.e. final) period, self-interested players will simply play according to the stage-game Nash equilibrium: players without authority will not contribute anything and players with authority will contribute their complete endowment and keep the entire group account. Next we will consider the behavior in the first (i.e., penultimate) period.

No Authority and No Exclusion (nAnE)

Without authority and exclusion, self-interested players will not cooperate in the first period, 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 self-interested types will act cooperatively.

No Authority and No Centrality (nAnC)

Note that in this case, self-interested players are willing to exclude players that do not act cooperatively, as excluding a free-rider is costless. Cooperative types do so by assumption. 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 will not vote to exclude cooperative players by assumption. Hence, a strategy profile where free-riders are excluded and cooperators are not, can be part of an equilibrium.

Given that all other players are either a cooperative type or mimicking a cooperative type, for a self-interested player, mimicking a cooperative type in the first period is optimal if:

$$\big(0.6(5 \cdot 50)\big) + \big(50 + 0.6(4 \cdot 50p)\big) > \big(50 + 0.6(4 \cdot 50)\big) + 50,$$

i.e. when $p > \frac{1}{6}$. Hence, cooperation by all players can be part of a repeated game equilibrium if $p > \frac{1}{6}$.

For equilibria where only a subset acts cooperatively, the tradeoff between free-riding or mimicking remains unchanged. Hence, cooperation by a subset of players (for example only the center or the periphery) can also be sustained in a repeated game equilibrium if $p > \frac{1}{6}$.

No Authority and Centrality (nAC)

Excluding an uncooperative periphery player will not affect expected payoffs in the second period. Excluding an uncooperative central player comes at a cost though: one can no longer benefit from the contributions by cooperative types who were connected via C. Hence, self-interested periphery players will not be willing to exclude an uncooperative player with centrality for *any* $p > 0$. Hence, center players will only be expected to be excluded if there are three or more cooperative types among the periphery players, which happens with probability $q = p^4 + 4p^3(1 - p)$. This implies that the center will act cooperatively if:

$$\big(0.6(5 \cdot 50)\big) + (50 + 120p) > \big(50 + 0.6(4 \cdot 50)\big) + q50 + (1 - q)(50 + 120p).$$

Solving gives $pq = p^5 + 4p^4(1 - p) > \frac{1}{6}$, which holds if $p > 0.50961$. Hence, cooperation by all players cannot be sustained in a repeated game equilibrium if $p \in \left[0, \frac{1}{2}\right)$.

The tradeoff for a periphery player is the same as in the nAnC case. Acting cooperatively comes at a cost of 20 in the first period and an expected benefit of 120p in the second period. Hence, a periphery player will act cooperatively if $p > \frac{1}{6}$ and an equilibrium where only the periphery contributes can be sustained as long as $p > \frac{1}{6}$.

Authority and No Exclusion (AnE)
As in nAnE, self-interested types will never act cooperatively in the first period, as their payoff in the second period is unaffected by their behavior as they cannot be excluded. Hence, for no value of p self-interested types will act cooperatively.

Authority and No Centrality (AnC)
First, consider the center player with authority. Excluding an uncooperative center player does not come at a cost, but will in fact lead to *higher* payoffs in the second period when $p > 0$. This is because a self-interested center player will keep all the proceeds of the common fund to herself. Excluding an uncooperative center player will then be beneficial, because by doing so, a 4-player VCM will be played in the second period and one might benefit from the presence of cooperative types amongst the other periphery players. Hence, self-interested periphery players are willing to exclude an uncooperative center player, and cooperative types do by assumption.

If the center player acts cooperatively in the first period, she could be a cooperative type or self-interested. Periphery players may wish to exclude her, again yielding a 4-player VCM in the second period. The expected payoffs for a self-interested player in this 4-player VCM game are $50 + 0.6(3 \cdot 50p) = 50 + 90p$. Leaving the center in the group means that the self-interested player will only benefit from (others') contributions to the group fund if the center player is cooperative (which occurs with probability p). This gives an expected payoff in the second period of $50 + p\big(0.6(50 + 3 \cdot 50p)\big) = 50 + 30p + 90p^2$. Hence, self-interested periphery players will prefer to exclude a center player with authority who cooperated in the first period if

$$50 + 90p > 50 + 30p + 90p^2,$$

which is the case for $p < \frac{2}{3}$.[23]

This means that a self-interested center player who acts cooperatively expects to be excluded if there are at least three self-interested players in the periphery. This occurs with probability $z = (1-p)^4 + 4p(1-p)^3$. A self-interested center will thus act cooperatively if:

$$\frac{1}{5}\big(3 \cdot (5 \cdot 50)\big) + z50 + (1-z)3(50 + 4 \cdot 50p) > \big(3 \cdot (5 \cdot 50)\big) + 50.$$

Solving gives $p > 0.8139$. Hence for any $p \in \left[0, \frac{1}{2}\right)$, periphery players will want to exclude center players *even if they act cooperatively* and there is no repeated game equilibrium where all players act cooperatively.

Can there be an equilibrium where the center free-rides (and is excluded) and the periphery cooperates? Note that excluding an uncooperative periphery player does not come at a cost, while excluding a cooperative periphery player is costly if $p > 0$. Hence, self-interested players will only vote to exclude periphery players who act uncooperatively (and so do cooperative types by assumption). Given that a self-interested center will be uncooperative in the first period (and that the center will be excluded in any case), a periphery player will mimic a cooperative type if:

$$p\big(0.6(5 \cdot 50) + 50 + 0.6(50 + 3 \cdot 50p)\big) + (1-p)(0 + 50 + 0.6(3 \cdot 50)p)$$
$$> \Big(50 + p\big(0.6(4 \cdot 50)\big)\Big) + 50,$$

which holds for $p > \frac{1}{3}$. Recall that without authority, mimicking the cooperative type is a best response for $p > \frac{1}{6}$. Hence, under the threat of exclusion periphery players require a greater proportion of cooperative types in order to sustain cooperation when authority is introduced.

Authority and Centrality (AC)

[23] Note that by voting to exclude cooperatively acting players, one is revealed as being self-interested. This has no effect in the two-period game, but it could matter in the 5-period game.

Like in AnC, excluding an uncooperative acting center player will lead to higher expected payoffs than leaving the center in. Unlike in AnC, excluding a cooperative acting center does not lead to higher expected payoffs. Excluding a cooperative center will only lead to higher expected payoffs if:

$$\frac{1}{5}\left(3\cdot(5\cdot 50)\right)+\left(50+0.6(50p)\right)>\frac{1}{5}\left(3\cdot(5\cdot 50)\right)+50+p\left(\frac{1}{5}\cdot 3(50+3\cdot 50p)\right),$$

which never holds in the presence of cooperative types ($p > 0$). Excluding an uncooperative center does lead to higher expected payoffs for periphery players. This means that an uncooperatively acting center will be excluded and a cooperatively acting center will not. Thus, a self-interested center player will mimic a cooperative type if:

$$0.6(5\cdot 50)+3(50+4\cdot 50p)>3(5\cdot 50)+50,$$

which holds if $p > \frac{5}{6}$. Hence for $p \in \left[0,\frac{1}{2}\right)$, there is no equilibrium where the center acts cooperatively in the first period.

As in the other treatments, exclusion of free-riding periphery players can be supported. A periphery player will then act cooperatively if:

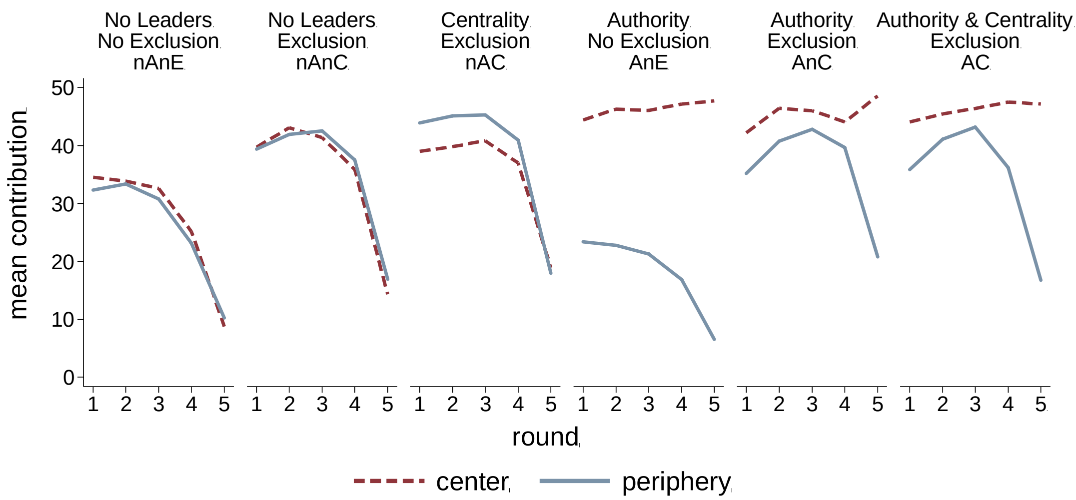
$$p\left(0.6(5\cdot 50)+50+0.6(50+3\cdot 50p)\right)+(1-p)(0+50+30p)>\left(50+p\left(0.6(4\cdot 50)\right)\right)+50.$$

Solving gives $p > 0.3715$. Hence, slightly more cooperative types are needed for periphery players to act cooperatively in AC than in AnC.

Appendix C: Additional analyses

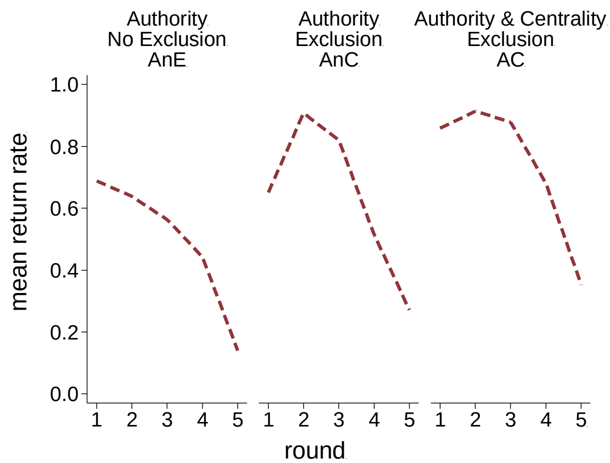
C1 Additional figures and tables

FIGURE C.1: MEAN CONTRIBUTIONS BY POSITION



Notes. The three panels on the left denote the treatments without authority and the three panels on the right show the cases with authority. For each round, contributions are averaged across five blocks. The graphs are based on decisions by individuals who are not excluded from their group and who are not isolated.

FIGURE C.2: MEAN RETURN RATES



Notes. The three panels denote the treatments with authority. For each round, return rates are averaged across five blocks. The graphs are based on decisions by individuals who are not excluded from their group and who are not isolated.

TABLE C.1: MEAN COOPERATION

			No Authority	Authority
			nAnE	*AnE*
No Exclusion (⇒ no Centrality)		All players	0.521 (0.075)	0.401 (0.101)
		Center	0.533 (0.112)	0.505 (0.099)
		Periphery	0.518 (0.076)	0.375 (0.103)
			nAnC	*AnC*
Exclusion	**No Centrality**	All players	0.699 (0.115)	0.662 (0.089)
		Center	0.692 (0.136)	0.554 (0.149)
		Periphery	0.701 (0.110)	0.689 (0.101)
			nAC	*AC*
	Centrality	All players	0.756 (0.057)	0.685 (0.096)
		Center	0.694 (0.091)	0.716 (0.175)
		Periphery	0.771 (0.054)	0.677 (0.098)

Notes. Cells give mean cooperation with standard deviations in parentheses. Entries based on all rounds and blocks, and players that were not excluded or isolated. The unit of analysis is the matching group.

TABLE C.2: MEAN EARNINGS

			No Authority	Authority
			nAnE	*AnE*
No Exclusion (⇒ no Centrality)		All players	102.1 (7.5)	98.7 (8.9)
		Center	101.5 (8.2)	182.6 (17.3)
		Periphery	102.3 (7.6)	77.7 (12.5)
			nAnC	*AnC*
Exclusion	**No Centrality**	All players	113.6 (14.0)	100.3 (13.7)
		Center	114.0 (14.4)	137.9 (29.7)
		Periphery	113.5 (14.1)	90.8 (10.3)
			nAC	*AC*
	Centrality	All players	120.5 (5.2)	109.0 (15.6)
		Center	124.0 (5.6)	163.4 (26.4)
		Periphery	119.6 (5.4)	95.4 (17.5)

Notes. Cells give mean earnings per round in points, with standard deviations in parentheses. Entries based on all rounds and blocks, and all players, regardless of being excluded or isolated. The unit of analysis is the matching group.

C2 Alternative measure of cooperation

In the main text, we define cooperation for players with authority only by their return rates. Alternatively, one could include the contribution rate of these players as well. Here we define this measure and test hypotheses 2 and 4 based on this measure as well.

We denote cooperativeness by γ_i defined as:

$$\gamma_i \equiv \rho_i x_i / 50 , i = C, P$$

where x_i denotes i's contribution level. For players without authority, we adopt the convention that $\rho_i = 1$. For a player with authority, we define it as in the main text, i.e. $\rho_C \equiv R/R_{equal}$.

TABLE C.3: MEAN COOPERATION (GAMMA)

			No Authority	Authority
No Exclusion (⇒ no Centrality)			*nAnE*	*AnE*
		All players	0.521 (0.075)	0.392 (0.105)
		Center	0.533 (0.112)	0.464 (0.124)
		Periphery	0.518 (0.076)	0.375 (0.103)
Exclusion	**No Centrality**		*nAnC*	*AnC*
		All players	0.699 (0.115)	0.651 (0.099)
		Center	0.692 (0.136)	0.497 (0.169)
		Periphery	0.701 (0.110)	0.689 (0.101)
	Centrality		*nAC*	*AC*
		All players	0.756 (0.057)	0.670 (0.105)
		Center	0.694 (0.091)	0.645 (0.161)
		Periphery	0.771 (0.054)	0.677 (0.098)

Notes. Cells give mean cooperation (γ) with standard deviations in parentheses. Entries based on all rounds and blocks, and players that were not excluded or isolated. The unit of analysis is the matching group.

In Table C.3. we provide the mean levels of cooperation based on gamma. Note that (by definition) cooperativeness is only affected for those with authority. Hence, we will only revisit hypotheses 2(a), 2(c) and 4(a).[24] First consider the effects of authority when there is no exclusion. Mean cooperativeness is somewhat lower for C-players but this is not significant (MW, p = 0.150). Hence, we find support for this part of hypothesis 2(a). Also under the threat of exclusion, cooperation levels by C-players are somewhat lower with authority, and this time the difference is marginally significant (MW, p =0.078). This does not support hypothesis 2(c).

[24] Note that the two-type model in Appendix B remains unchanged if we define cooperativeness by gamma.

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**.

<nAnE, AnE> 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.

<nAnC, nAC, AnC, AC> 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.

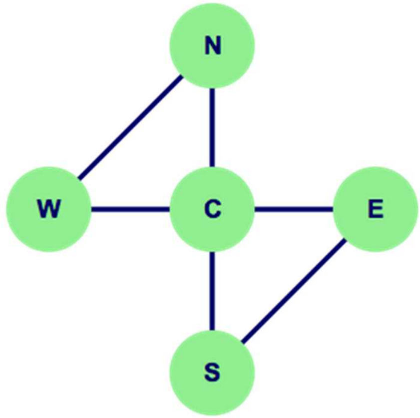
Blocks, Rounds and Positions

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.

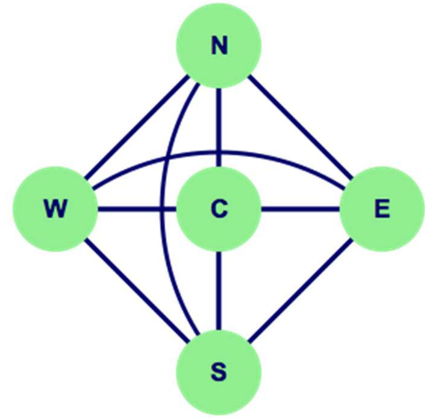
The composition of the groups will **remain the same for the 5 rounds in a block**. At the end of a block, participants will randomly be divided into new groups of five.

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.

<nAnE, nAC, AnE, AC>



<nAnC, AnC>



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

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

<nAnC, nAC, AnC, AC> 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**.
- <nAnE, nAnC, nAC> 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.
- <AnE, AnC, AC> Earnings from the **group account**: First, the **total number of points invested in the group account** by all group members is determined. Then, this is **multiplied by 3**. Finally, the **group member in the center (C)** determines how to divide the total amount.

S/he determines **how much to keep** for her- or himself. The **remainder is equally divided** among the other group members.

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.

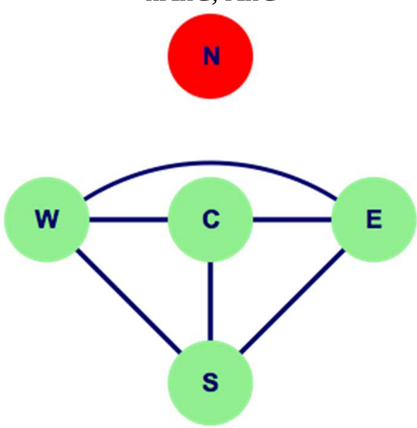
<nAnC, nAC, AnC, AC> Exclusion of a Group Member

<nAnC, nAC, AnC, AC> 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.

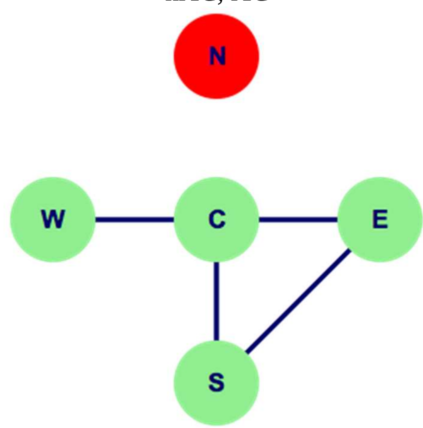
<nAnC, nAC, AnC, AC> Exclusion of a member means that this player can **no longer invest in the group account and will not receive any earnings from the group account in the remaining rounds**. The excluded participant will receive an endowment of 50 points in each of the remaining rounds in the block. 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.

<nAnC, nAC, AnC, AC> 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.

<nAnC, AnC>



<nAC, AC>



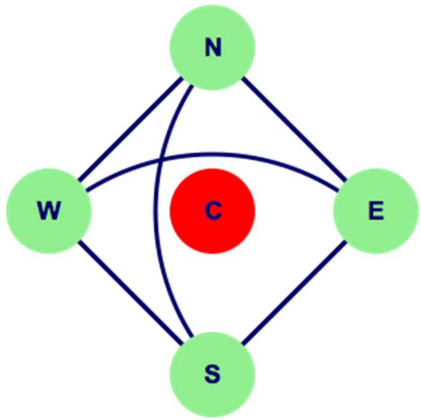
<nAnC> Note that after exclusion of N, **a group of four remains**, that can invest in a joint group account. These four players form a **sub-group**. All participants in your sub-group are indicated by a **green circle**, excluded participants are indicated by a **red circle** and participants in another 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.

<nAC> 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:

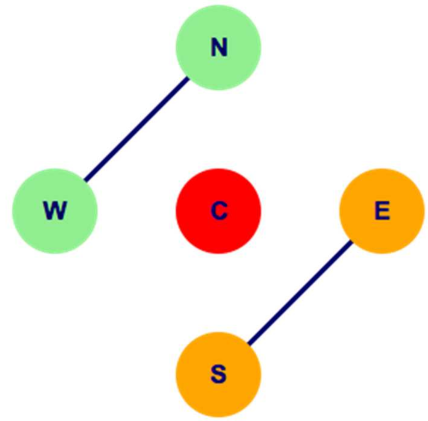
<AnC, AC> Note that after exclusion of N, **a group of four remains**, that can invest in a joint group account. These four players form a **sub-group**. All participants in your sub-group are indicated by a

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. Further, the amount in the group account will now be **multiplied by a factor of 0.6 x (number of sub-group members)**. The rest remains the same and the participant in the Center decides on how much to keep for her/himself and how much to divide equally among the other three participants. 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:

<AnC>



<nAC, AC>



<nAC, AC> 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.

<nAC> **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.

<AnC> Because the Center participant has been excluded s/he will not manage the division of the proceeds from investments in the group account. Instead, an automatic mechanism will be used. The amount invested in the group account by you and the other member of your subgroup is **multiplied by 0.6 x (number of sub-group members)**. Then, it is **equally divided between you and the other members**. This means that you will earn 0.6 points for each point invested by the four 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 participants in the West, East and South positions. Note again that the Center participant cannot invest any points in the group account if excluded.

<AC>**Earnings from the group account** will depend on the total points invested in the group by participants in your **sub-group alone**. Because the Center participant has been excluded s/he will not manage the division of the proceeds from investments in the group account. Instead, an automatic mechanism will be used. The amount invested in the group account by you and the other member of your subgroup is **multiplied by 0.6 x (number of sub-group members)**. Then, it is **equally divided between you and this other member**. This means that 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

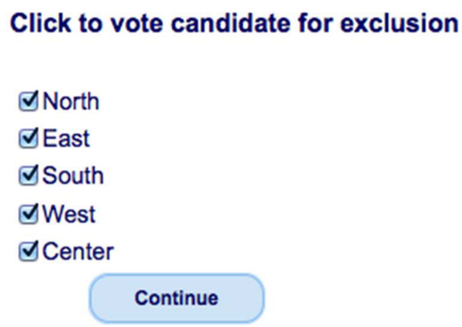
the participant in the West position). Similarly, if you are in the South position, your group account earnings depend on the group account investments of yourself and the East participant. You will **not earn anything from the group account investments of the participants in the other sub-group**. Note again that the Center participant cannot invest any points in the group account if excluded.

<nAnC, nAC, AnC, AC> The Exclusion Decision

<nAnC, nAC, AnC, AC> To decide on who will be excluded, the group members will **select candidates for exclusion**.

<nAnC, nAC, AnC, AC> 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.

<nAnC, nAC, AnC, AC>



<nAnC, nAC, AnC, AC> 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.

<nAnC, nAC, AnC, AC> 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.

<nAnC, nAC, AnC, AC> **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.**

<nAnC, nAC, AnC> 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:

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

Your position:

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

<nAnC, nAC, AnC, AC> **If you are excluded, you will remain excluded until:**

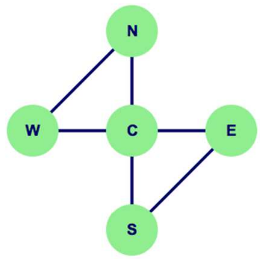
- o The end of the experiment
- o The end of the block
- o The end of the round

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.

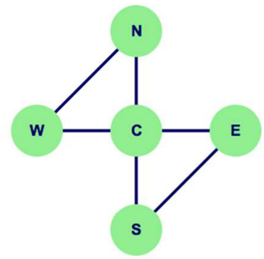
Suppose that you are in the North position in both situations. What would be your earnings in each situation?

<nAnE>



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

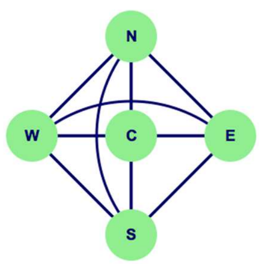
points



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

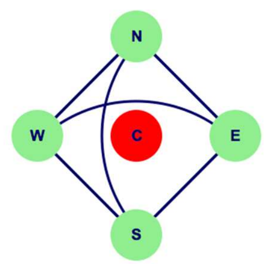
points

<nAnC>



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

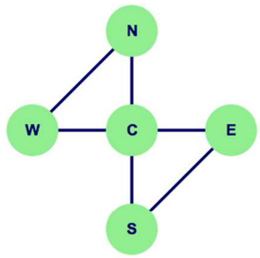
points



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

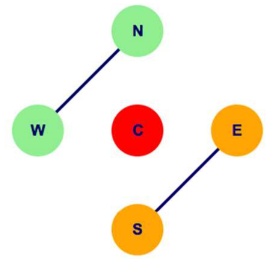
points

<nAC>



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

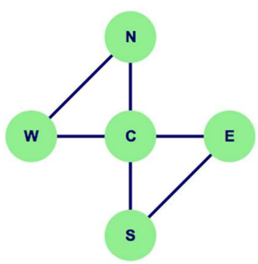
points



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

points

<AnE>

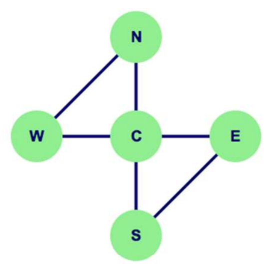


Position	Group investment
North	10
East	10
South	40
West	0
Center	50

The total value of the group account is thus 330 points.

The participant in the C position decided to keep 0 points and to return 330 points to the other group members.

points



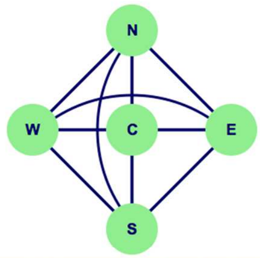
Position	Group investment
North	40
East	20
South	40
West	20
Center	50

The total value of the group account is thus 510 points.

The participant in the C position decided to keep 306 points and to return 204 points to the other group members.

points

<AnC>

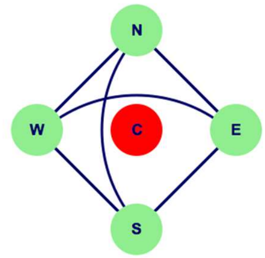


Position	Group investment
North	50
East	0
South	10
West	30
Center	20

The total value of the group account is thus 330 points.

The participant in the C position decided to keep 33 points and to return 297 points to the other group members.

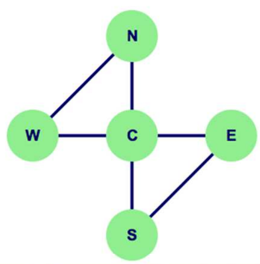
points



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

points

<AC>

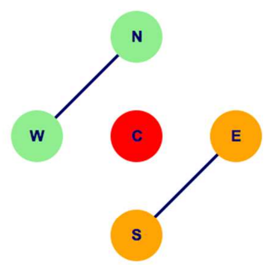


Position	Group investment
North	10
East	10
South	40
West	20
Center	40

The total value of the group account is thus 360 points.

The participant in the C position decided to keep 216 points and to return 144 points to the other group members.

points



Position	Group investment
North	0
East	0
South	30
West	0
Center	0

points