The Elements of Protest: Combining Coordination, Cooperation, and Communication in the Lab

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Abstract: Collective political action, such as protests, riots or social movements, requires the resolution of both cooperation and coordination problems. Solutions to these problems are widely seen to depend on the network that connects individuals to each other, because this network is a way for individuals to learn about the actions of others and decide if they want to participate. Although there is a general sense that networks and communication are important for collective political action there is little research exploring the relationship between network structure and group behavior. We address that gap in the literature by utilizing an experimental approach that combines both coordination and cooperation in a networked setting. We find that there are considerable differences in collective behavior based on the network structure that connects individuals. In particular, we find in our experiments that more connections in a network and the presence of highly connected nodes can both facilitate solutions to collective problems. This suggests that in building networks for collective political action, it would be useful to either build many connections or create recognizable leaders that can facilitate coordination.

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Recent political protests throughout the world are a powerful reminder that citizen action can significantly affect politics in democratic and non-democratic countries alike. Political scientists have long understood cooperation to be a core challenge facing protest movements; a successful protest movement may benefit aggrieved citizens, but participation in protest is a costly activity with significant risks to the individual. Less common in the literature on citizen activism is the acknowledgment that coordination is also a core challenge of protest; once citizens choose to participate, they must as a group choose one of multiple possible courses of action. Recently, scholars have come to see that collective action plays out over a network of decentralized actors. As of yet, few experimental studies have have combined these three elements—cooperation, coordination, and networked communication—in a way that is simple enough for use in laboratory experiments.

In this paper, we use an experimental approach to study collective action that combines cooperation and coordination over a network with asynchronous decision-making. Because of the complexity of any model involving rich communication and asynchronous action, and because we know that individuals facing novel strategic dilemmas rarely employ equilibrium strategies (Simon 1957; Kahneman and Tversky 1979; Elster 1983; Berg et al. 1995; Gigerenzer and Goldstein 1996; Camerer 2003) we do not solve for equilibria; instead we use an experimental approach to see how subjects respond to the kind of strategic environments that citizens face in protest movements.

**Three Elements of Protest**

To the aggrieved citizens participating in the Arab Spring, each additional protestors on the street exalted the hope of reform incrementally higher. To these individual protestors, the
choice to take a public stand carried known costs and predictable risks. Political theorists have long used the concept of cooperation—the pursuit of social welfare at the cost of individual utility—to explain protest and other collective action (Hobbes 1651; Olson 1965; Hardin 1971; Oberschall 1973; Opp 1989; Heckathorn 1996). The Prisoner’s Dilemma is so frequently used to illustrate the tension between individual gain and collective good that Axelrod (1997) dubbed it “the E. coli of the social sciences.” Despite the ubiquity of cooperation problems in social settings, coordination problems are also endemic in social settings. Niou and Ordeshook point out that, “Because every ongoing social process possesses a multiplicity of equilibria, opportunities to cooperate and the concomitant problem of coordinating to one of these equilibria are omnipresent (Niou and Ordeshook 1994, p. 210).”

The protests of the Arab Spring largely took place among decentralized, non-governmental actors, but it would be a mistake to consider them uncoordinated. The protesters in each location went to great lengths to coordinate the activities of citizens with the idea that this would make their demands and actions more impactful. Coordination is defined in game theory by the presence of multiple equilibria, a challenge that requires each player to choose among (or mix) multiple equilibrium strategies. A wide variety of scholarship has used games with multiple equilibria to model the need for coordination when citizens participate in collective action (Weingast 1997; Chong 1991, 1993; Siegel 2009; Chwe 2000).

In such situations there is a benefit if citizens take mutually supportive actions. However, this does not occur by luck or by chance, but rather is, at least in part, a function of the connections between decentralized actors (Chwe 2000, Chong 1991, 1993; Siegel 2009). Although there is a nebulous, general agreement that communication structure (i.e. who talks to
whom) affects the success or failure of decentralized collective action, we lack valid, empirical results about how communication structure affects actual decentralized decision-making, and even fewer results that speak to the specific features of networks that might influence coordination. Therefore, we turn to an important, understudied question: How do communication structures that connect people affect a group’s ability to solve a cooperation and coordination problem?

In this paper we advance our understanding of collective action by combining the three fundamental elements of protest: cooperation, coordination, and communication. Specifically, we present a set of experiments in which subjects must achieve consensus around one of two possible actions, but choosing an action is costly. Because the experimental task requires both unanimous participation and successful consensus, it mirrors the twin challenges of cooperation and coordination faced by protestors. Subjects make their choices asynchronously over a network, as do citizen activists. We present results from hundreds of experimental trials that demonstrate how communication structure (modeled as a network) can affect a group’s ability to resolve cooperation and coordination problems. We find that more edges in a network and the ability to identify key actors can improve coordination, even when the underlying coordination task features substantial costs to take an action. These findings shed light on some of the actions taken by decentralized actors attempting to engage in protest and may help us understand why some groups succeed and others fail at achieving collective action.

Communication and Collective Action

Scholars and political activists have both noted that communication among decentralized actors is an important factor in whether or not individuals can coordinate their political action.
Communication plays an important role, because in many political settings the value of taking an action depends on beliefs about how many others will take a complementary action (Schelling 1960, Olson 1965, Siegel 2009) and communication is one way people form beliefs about the likelihood of others taking similar actions. Scholars, political activists and observers have all noted the role that communication networks can play in facilitating collective political action.

Shirky (2011) argues that social networks can play an important role in helping groups achieve coordination and that governments attempt to disrupt social networks in part to hinder coordination. Likewise, Lynch (2011) argues that “Secure and cheap tools of communication lower transaction costs for the organization of collective action, with social media in particular allowing like-minded members to find one another and to make their true beliefs known in a semi-public setting.”

The role of communication networks was a crucial factor in the Egyptian protests in the Spring of 2011.

“Before Egypt shut off the Internet and mobile phones, before it even started blocking Twitter and Facebook, those tools were used to coordinate and spread the word about the demonstrations that were scheduled for January 25. Without these mass organizing tools, it’s likely that fewer people would have known about the protests, or summoned the kind of courage that’s made possible by knowing you’re not the only one sticking your neck out.”

Although recent advances in technology highlight the role of communication networks in the coordination of political action, the role of communication was also important in the political revolts of the early 1990s in Eastern Europe. In that setting communication networks helped the

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opposition “coordinate strikes, demonstrations and other activities. For example, one of the most effective ways that Solidarity leaders in Poland transmitted information was to provide foreign radio networks with details about their strike activities, which would then be broadcast in news reports throughout the country (Chong 1993, p. 135).” Although all of the various political movements and actions differ in their particulars, in each case it seems that communication among the decentralized actors somehow helped to facilitate coordination.

One of the reasons that coordination is important in many types of political action is that it is costly to participate and success requires the participation of more than one actor, which means that it will only be in an individual’s interest to participate if she believes a sufficient number of others will do the same. In these settings political action involves elements of both coordination and cooperation, which as Chong (1993) points out makes them similar to assurance games. The key point about assurance games is that participation only makes sense if a sufficient number of others will also participate and therefore individuals’ assessments about the likely behavior of others is a critical piece of the decision to take part in a collective activity. The coordination element reflects the fact that the benefits of participation depend on how many other people will also take part, and because participation is costly with no guarantee that the benefits exceed the cost, successful political action also requires that players cooperate in the production of the activity.

It is worth noting that the need to resolve both coordination and cooperation problems occurs in many settings, not just collective political action. The difficulty of and possible ways to resolve coordination problems have been largely neglected by existing research. Koremenos et al. (2001) argue that coordination problems have been incorrectly trivialized: “Multiple
equilibria are a major obstacle to cooperation that was downplayed by the early emphasis on 2X2 games.” In this paper we study coordination games that differ from the standard 2X2 models, and in particular we focus on how the communication structure and the costs to taking an action affect the likelihood a group can solve a coordination problem that also requires cooperation among the actors.

In an assurance-style game the task facing actors differs from pure coordination in some important ways. In a standard pure coordination game the basic goal is for all actors to choose the same action, and in the absence of conflict between players this game does not involve any elements of cooperation. However, if it is costly to take an action, then the task involves both cooperation and coordination. Individuals must first elect to participate in the coordination attempt, and then they must coordinate; if not all individuals initially choose the same action, they must again decide whether to volunteer to take a costly action in order to overcome the impasse and achieve coordination.

Figure 1 represents a simplified two-player assurance game in which taking an action is costly, as represent by c. Each player receives a payoff of 1-c if they both attempt and succeed at coordination and 0 if neither attempts coordination. If a player attempts coordination but the other player does not, then the player that attempted it receives, –c (which is less than 1) and the other player receives 0. There are two different pure-strategy equilibria. In one pure strategy equilibria both players attempt coordination and in the other neither player attempts coordination. It is clear from this that it only makes sense to pay the cost to attempt coordination if one believes that the other player will also attempt coordination.
Since both players of this simplified assurance game have a common interest in solving the problem there is no reason to avoid participation if it becomes clear that the problem is solvable (assuming the benefits for coordination outweigh the individual costs of taking an action). However, if a player believes a sufficient number of actors cannot reach a coordinated solution, then it is not in her interest to pay to make an initial choice and the problem will not be resolved. Note that this simplified assurance game has only one high-payoff outcome, so that the benefits of participating are guaranteed as long as both players attempts coordination. In our experiment, however, there are two high-payoff outcomes, so that even under universal participation, coordination may fail, resulting in negative payoffs for all players.

If the actors’ initial choices lead to coordination, then no one has an incentive to deviate. However, if the initial costly choice(s) do not lead to coordination, then successful coordination will require that at least some players take another action, which will require them to again pay a cost. If coordination is not achieved in the initial set of moves, then each player would prefer if the other player(s) paid the cost to change color and facilitated group coordination. If the game reaches this point there is again no dominant strategy for either player (i.e. it’s still a coordination game). For each player the most preferred outcome is to achieve coordination by the other player(s) paying the cost to change color. The next most preferred outcome is to pay the cost oneself to change color if it leads to coordination. If a player does not think coordination is achievable, then the best option is not to pay the costs to take an action. The least preferred outcome for any player is to pay the cost to take an action and fail to achieve coordination.
The most important point is that the simple addition of costs to the game creates an incentive not to participate, thereby infusing the coordination game with an element of cooperation as well and making the game a rich setting to study collective action.

**Networks and the structure of communication**

In the situations we have discussed the decision to take an action depends on individuals’ assessment of the likelihood that others will also take action and that the group will be able to achieve successful collective action. Because of this, one of the key factors that determines the success or failure of decentralized coordination is communication between actors that allows them to learn what others have done.\(^5\) Prior research has demonstrated that costs to communicate can impede coordination (McCubbins et al. 2010); having a group leader can improve coordination (Wilson and Rhodes 1994); presence of focal points (perhaps through payoffs to the game) can encourage coordination (Schelling 1960); and pre-play communication can make coordination more likely. To model the communication environment among many decentralized actors we utilize a network approach in which node is an actor and a link means the two connected nodes can each observe the others’ actions.\(^6\) Using a network approach we can model any pattern of communication among nodes in a network. An example of the different structures of communication that can exist among just four actors is shown in Figure 2. In our experiment a link is undirected and implies symmetric information (both nodes see each other) along that link.

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\(^5\) Dozens of studies have focused on the factors that influence coordination. A good overview of economic experiments on coordination appears in Camerer (2003). Generally, prior work finds that both greater communication between actors and focal points (of many types) are useful for coordination.

\(^6\) We are not the first to use a network to model communication structure. For instance, see Calvo-Armengol (2001) and Choi et al. (2011) for examples of communication networks combined with standard economic games (i.e. bargaining, public goods).
but in theory links could be directed (i.e. information would be asymmetric) so that only one node could observe the other node, which would increase the number of possible communication structures. \(^7\) It is clear that even with only a small number of nodes and bilateral, undirected links there are many possible communication structures.

**Insert Figure 2 here**

Using a network approach provides us with significant flexibility in the type of communication structures we can study. In Figure 3 we display the six different networks we utilize in this paper all of which involve 16 nodes and varying numbers of edges. In the figure we also display some common network statistics including the number of total edges, diameter, average distance and the variance in degree across nodes in the network.

**Insert Figure 3 here**

Importantly, the explicit use of networks to represent communication structure accords with the claims made by many who study collective action about the importance of connections between actors. Chong (1993) argues that “Preexisting social networks therefore play a central role in the emergence of collective action as uncertainty is removed and coordination facilitated when people belong to the same social and political organization (p. 134).” Although we employ a stripped down form of communication (i.e. there is no actual discussion) the network allows subjects to communicate their choice of actions in the coordination task.

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\(^7\) The number of possible structures explodes if either 1) links are directed/asymmetric between nodes or 2) positions in the network are not equivalent – that is in a line is the structure simply the connections or also which actors occupy a node. We opt for a simpler approach in this paper.
The effect of communication structure on collective political action

In this section we outline our expectations for how the communication structure (modeled as a network) will influence behavior in a coordination game when it is costly to take an action. It is worth noting that we do not focus on individuals’ equilibrium strategies. As others have noted in coordination games that are dynamic and feature communication there are typically so many possible equilibrium strategies that it is not useful to focus on them (Choi and Lee 2010; Choi et al. 2008; Echenique and Yariv 2011). Although we do not make predictions about individual equilibrium strategies, we do have expectations about the effect of network structure and costs the time it takes for coordination to occur. The predictions are based on prior research about how communication, networks and costs affect coordination in similar, but not identical, settings. (see Kearns, Suri and Montfort 2006; McCubbins, Paturi and Weller 2009; Boudreau, McCubbins, Rodriguez and Weller 2010; Choi and Lee 2010). Additionally, we focus on group outcomes rather than individual predictions because our experiments are designed for group analysis and cannot be used to make valid causal inferences about individual behavior.

Based on prior research on coordination, cooperation and communication we have the following expectations:

1. The addition of a cost to take an action will increase time to solve the coordination problem, and increases in costs will lead to longer times to solve the problem.\(^8\)

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\(^8\) The costs we utilize are equivalent to a “cost to speak” because the cost is only paid by the person changing his color and all the other actors attached to that node see then change in color without paying a cost.
a. The element of cooperation induced by adding costs to the game should make players consider their choices more carefully and be less willing to change colors, both of which should increase the time to coordination.

2. Costs increase the time to the first move.
   a. Players will wait to see if someone else will incur the initial cost and attempt to lead the group to a solution. The action by the first player is a costly signal that at least some person (or people) in the group believes coordination is possible. The delay to first move is similar to Choi et al.’s (2008) notion of strategic delay in a public goods game and Chong’s (1991) argument that in assurance games it may be difficult or slow to start a collective action struggle, but once it gets started it may snowball to mass participation. Delaying the first move is especially valuable when there are multiple high-payoff outcomes, because the greater the variance in wait time, the lower the likelihood that multiple disconnected players will take mutually inconsistent first moves.

3. Costs increase efficiency (i.e. players take fewer actions to achieve coordination).
   a. Because each move reduces a subject’s earnings, they will be more careful not to make wasteful moves

4. Networks with more edges will be solved faster than networks with fewer edges, ceteris paribus.
   a. Edges enable communication and therefore we expect that more edges will improve coordination, as seen in Kearns et al. 2006 and McCubbins et al. 2009.

5. Networks with higher degree variance will be solved more quickly, ceteris paribus.
a. Nodes with a large number of edges can act as a leader in the coordination game, which may improve group performance (Calvert 1992; Wilson and Rhodes 1994). Each of these predictions is drawn from the existing work on decentralized, networked coordination and the idea that coordination with costs creates an element of cooperation in which players will try to determine if coordination is possible before paying to take an initial action and will also try to minimize the total number of moves they make.

**Experimental Setup**

To test the predictions from the prior section we utilize an experiment in which sixteen subjects play a coordination game under a variety of network structures and costs to take an action. The task in the experiment is for every player (representing a node) to choose the same color, and the network defines which players can see each other, because if two nodes are connected then they can observe each other’s choices. If nodes are not connected then they do not observe each other, and subjects do not have any information about the global properties of the network other than the number of nodes.

Subjects were recruited from large public and private universities via email and flyers throughout campus. Interested subjects were then emailed to sign up for an experimental session and on the day of the experiment we chose 16 people who showed up to participate. The sixteen subjects were escorted to a computer lab where they sat at computer terminal with partitions between them to ensure they could not observe each other’s behavior. We read aloud instructions to all the subjects to describe the game and ensure they had common knowledge of the game’s rules. We also quizzed the subjects throughout the session to ensure they understood the rules at any time where we changed the experimental treatment. Subjects were always given two colors.
to choose from during a trial, but the colors varied for each trial and the colors differed for each subject to make the development of a focal color difficult. If the trial was solved successfully each subject earned $1, and if actions were costly then the costs are subtracted from the earnings for that session. If coordination was unsuccessful and actions were costly, then subjects simply lost money for each move. Subjects had three minutes to successfully solve the coordination task, and once the session began subjects could make choices at any time and choices were immediately visible to others (if they share an edge). This makes the game dynamic and asynchronous, not a stage or single-shot game, which is the type of game most of our knowledge of coordination comes from. During the actual experiment subjects know the following information, which is displayed in the sample screen shot in Figure 4:

**Number and Degree of Neighbors**: subjects can observe the other nodes to which they are connected and the color of those nodes at all times. They also know how many connections each neighbor has, which is displayed in the center of the node.

**Time Elapsed**: A bar displays how long until the session expires

**Cost to move**: We implement a cost for each choice a player makes, including his first choice and the cost per move is displayed on the screen.

In addition, subjects can determine if the trial was solved successfully because the trial will end before the time elapsed bar runs out. They do not know the structure of the entire network at any point during these experiments. We utilize both within and between subject designs. During each experimental session (consisting of 30 to 50 trials) subjects play the coordination game with a variety of different costs to take an action. This allows us to observe, within a single group, how
changes in costs affect coordination. At the same time, to achieve enough observations we pool results from experiments that involved different groups.

**Experimental Analog to Collective Political Action**

The value of an experiment is its ability to capture the critical features of the “real-world” phenomena for which the experiment is an analogy. With that in mind, we turn to a brief discussion of the correspondence between the most salient factors of collective political action and our experimental set up. We list the factors that seem most important and how our experiment captures them below.

- **Cooperation**: the choice to participate is costly and carries risk to the individual but increases social welfare.
- **Coordination**: the choice to participate is not sufficient to achieve effective action; individuals must coordinate on one of multiple available courses of action.
- **Communication**: choices are made asynchronously over a network that connects some pairs of individuals but not others; individuals make independent choices with information only about their network neighbors.

Our experimental task is the simplest one we could design that captures all three of these fundamental elements of collective political action: rewarding subjects for achieving consensus but charging them whenever they select an action creates a large social welfare gain that can only be realized through participation, but imposes a cost and risk to participation for individuals; offering two different high-payoff outcomes requires subjects to coordinate; allowing subjects to observe their network neighbors and change their action at any time within a window for action reproduces the communication conditions of citizens attempting to achieve collective action.
Because the task our subjects participate in so closely mirrors collective political action, and because it is simple enough for the subjects to understand clearly (quizzes on instructions prove that we obtained essentially perfect understanding of the instructions) we are confident that our experimental results shed light on how communication structures can affect coordination. At the same time, there are important aspects of political action that are missing in our experiments. In particular, subjects in our experiments lack any intrinsic or non-instrumental rationale for paying the cost to take an action, which may be an important aspect of actual decisions to participate in the type of political activity we are focused upon. However, as long as these attributes are not correlated with the structure of the network or the costs to take an action, then our inferences remain unaffected by these attributes of real political action.

**Experimental Results**

We turn now to the results of our experiment. We have a total of 515 observations at the group level. In Figure 5 we present the most basic result, which is to compare the average time to completion for free choices to costly choices. The addition of costs makes the task take significantly longer ($p<0.001$) when we examine the effect across all networks and cost structures. This is comforting because it comports with our primary prediction. However, in Figure 6 we display the average time to completion broken out by the cost for action (ranging from 0 cents to 50 cents), and surprisingly it appears that the relationship between costs and time to coordinate is non-monotonic. The results suggest that initially costs significantly slow down coordination but as costs exceed some amount coordination occurs more quickly, although never as quickly as when costless. To determine if this was related to subjects learning how to complete the task, we have varied the order of the treatments in the experiments (sometimes
starting with low costs and sometimes with high costs) and we have also had subjects complete a block of tasks with the same cost both early in the experiment and late in the experiment to compare if they perform faster on the later task. We have not been able to identify any effects of the order of the treatments in the research so far.

Insert Figures 5 and 6 here

The non-monotonic effect of costs was unanticipated, and it suggests that as the cooperation element of the game becomes more significant players modify their approach to solving the task. Earlier we discussed that the initial choice subjects must make is whether are going to pay the first cost to adopt a color, and they will only take this action if they believe the probability of solving the game is sufficiently high that it is cost-effective to choose an initial color. We expected that costs would lead to a delay in the time until the first subject chooses an action. Accordingly, in Figure 7 we examine the time between the beginning of an experimental trial and the first time someone selects a color. Clearly as the cost to take an action increases subjects wait longer before making the first move. This is consistent with the idea that costs make the initial decision more important and subjects want to wait to let someone else make the initial move. One way to interpret this result is that players are attempting to turn the game in to one of sequential action rather than an asynchronous game. Prior research finds that sequential cooperation games are more easily solved, so this change in approach may help to explain the success in solution even as the costs increase. In fact, the results we find are generally consistent with Potters, Sefton and Vesterlund (2005) who find that in a public goods game where subjects have different information about the good being provided they endogenously choose a sequential contribution mechanism and it is associated with larger donations to the public good game.
We also note in Figure 8 that the introduction of costs causes a significant decline in the number of moves per player, which again seems reasonable given that moves are costly in these treatments and therefore players have an incentive to minimize the number of times they change colors. The dashed line represents 16 total moves, which is the minimum required for successful coordination. Under free actions groups averaged about 30 moves per trial, but when action was costly groups averaged just over 18 moves per trial, a difference that is significant at the 0.001 level. In only 1 of the 84 free action trials subjects took the minimum number of actions (16), but when actions were costly subjects took the minimum number of actions in 142 of the 323 total trials and in 137 of the 265 successful trials subjects took the minimum number of actions. In the 54 costly action experiments that were not solved successfully subjects made an average of 19.7 decisions and in the 238 that were solved subjects took an average of 17.9 actions (p=0.08). This suggests that very few subjects are willing to pay costs multiple times for coordination to occur, which means that for costly coordination to be successful it must require a small number of choices per player. If subjects fail to achieve coordination after an initial move it may be that they believe coordination is unlikely to occur, and therefore may not be willing to pay the additional cost to move again. Overall, the costly treatments cause an increase in the time to move and a decrease in the total number of moves, which as the cost increases seem to be related to more rapid coordination.

The fact that we do not observe any learning or order effects within the experiments suggests that increases in costs causes subjects to adopt a different strategy to solve the game than they use in the free and low cost trials. In addition, we do not find that subjects must “practice” at the higher costs to adopt this strategy, which we take as evidence that they are all
tapping in to a strategy for solving problems like this that they possess prior to arriving at our lab.⁹

**Insert Figure 7 and 8 here**

We turn now to a discussion of how the different network structures affect the time to coordinate and mediate the effect of costs. We expect that both greater numbers of connections and higher degree variance will make coordination occur more quickly. To examine this we need to look at networks where other structural characteristics are held as constant as possible. Therefore, to examine the effect of number of edges we focus on the mixture and no leader networks, which feature no variance in degree. The mixture network features 56 edges and the no leader network has 24. Consistent with this, both the mixture network is completed more quickly than the no leader network when we examine all the network trials across the various cost conditions, as shown in Figure 9. We also examine whether greater numbers of edges mediate the effect of coordination with costs. In Figure 10 we present the average time to coordination for the two aforementioned networks under each cost condition. It does appear that networks with more edges have faster times to coordination. Although the results are not as clean as we might like, they do suggest that more edges lead to faster coordination and attenuate the effect of costs to take an action.

**Insert Figures 9 and 10 here**

Our other expectation is that higher degree variance will facilitate coordination because actors with high degree have more information about the network and can lead the group to a solution (Calvert 1992; Wilson and Rohdes 1997). One might also argue that high degree actors

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⁹ We take this as some evidence that there is ecological validity to the task.
are a focal point (Schelling 1960) to which others might defer. To investigate the effects of
degree variance on coordination we would prefer to have networks that are identical in all
parameters except for degree variance. For now we have to compare networks that differ slightly
in their number of edges, but rather significantly in their degree variance. The most obvious
comparisons in that regard are the star and no leader networks. We compare the average
coordination time across all cost conditions for the star and no-leader networks in Figure 11.
Keep in mind that the no-leader network has zero degree variance, but more total edges than the
star network. Therefore, if number of edges is more significant than degree variance, then we
would expect the no-leader network to be completed more quickly. The results suggest that the
star network is completed more quickly than the no-leader network, which suggests that degree
variance may be more important than number of edges for solving this task; however, the
networks differ in other parameters, too, so we cannot identify degree variance as the sole cause
of the different times for coordination. In addition to the overall difference in time to
coordinate with costs there is a different relationship between costs and coordination in the two
networks, as shown in Figure 12. In the star network there is a small increase in time to
coordinate with the imposition of costs, but in the no leader network the increases in costs leads
to a considerable change in the average time to coordination. This is consistent with the
argument that the structure of the network (degree centrality in this case) can affect the
relationship between costs and coordination.

Insert Figure 11 & 12 here

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10 In a regression of time to coordinate on costs and costs-squared we find that in the no-leader
network both variables are significant at the 0.05 level, whereas in the star network the variables
are both insignificant. This suggests that the relationship between costs and time to coordinate
differs in the two networks.
One limitation of these results is that it is very difficult to modify the network structure without changing multiple structural parameters in the network, i.e. a change in number of edges changes that parameter and also changes degree variance, clustering, distance or other (perhaps unmeasured) characteristics that affect coordination. As such, in these results we are hesitant to identify a single structural parameter as the mechanism that leads to different coordination behavior between networks.

**Conclusion**

In this paper we focused on a task that is a simple analogy to many real-world settings where coordination is a valuable outcome but taking an action is costly for individuals, thereby creating elements of both cooperation and coordination in the game. We embed the game in to a network setting, which allows us to model the structure of communication among the actors. By using a network approach we are able to investigate a great many different communication structures and their interaction with costs.

Across all of the network structures the addition of costs causes an increase in the time to coordination. This suggests that adding an element of cooperation to a coordination task can make the problem more difficult.\(^{11}\) However, the effect of costs is not constant. A somewhat surprising result is that the time to coordination increases initially with costs, but as costs continue to increase the time to coordination declines. This seems to occur because subjects change their behavioral strategies when taking an action is costly and subjects make far fewer

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\(^{11}\) In a game that features only cooperation (a prisoner’s dilemma) Suri and Watts (2011) recently found that network structure had little to no effect on behavior, which makes sense because in a game with a dominant strategy players’ should play that strategy regardless of the connections between players. Scholz and Ahn (2011) show that if players build a network themselves and then use that network in playing a prisoner’s dilemma the players create a clusters where cooperators connect to each other and cooperation is enhanced by such connections.
choices than when actions are free. In fact, even when the group fails to coordinate successfully they take very few actions in the costly treatment conditions. Instead, what seems to happen is that they reach a state where coordination has not occurred and not enough subjects are willing to pay the cost to make the additional changes required for coordination to occur. This suggests that for costly coordination to occur it requires a setting in which players are reasonably certain that they can solve the problem and therefore are willing to pay the costs to take an action. The institutions that create communication structures\(^\text{12}\) therefore must provide an environment in which players believe the problem can be solved or else players may not take an initial action or continue to take actions until coordination occurs.

\(^{12}\) A large literature in international relations has focused on the conditions that lead to the emergence of international organizations or regimes that can facilitate cooperation (Stein 1982; Koremenos et al. 2001). Our results do not speak to why such institutions might emerge, but they can help to shed light on the relationship between institutions, communication structure and outcomes.
References


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Figure 1: A Type of Assurance Game

<table>
<thead>
<tr>
<th>Player 1</th>
<th>Player 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attempt Coordination</td>
<td>1-c, 1-c</td>
</tr>
<tr>
<td>Don’t Attempt Coordination</td>
<td>0, -c</td>
</tr>
</tbody>
</table>

Represents an assurance game as long as c<1

Figure 2: Possible Communication Structures with Four Actors
Figure 3: Networks used in Experiments and Structural Characteristics

<table>
<thead>
<tr>
<th>Network</th>
<th>Nodes</th>
<th>Edges</th>
<th>Diameter</th>
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<th>Variance in Degree</th>
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Figure 4: Interface Used During Coordination Experiments
Figure 5: Costly action slows coordination

Figure 6: Costs have a non-monotonic effect on time to coordinate

Error bars represent 95% confidence intervals.
Figure 7: Increases in Costs Cause Delay in the Time to First Move

Figure 8: Costs to Move Increases Efficiency of Coordination
Figure 9: More Edges Leads to Faster Coordination

Figure 10: More Edges Attenuate the Effect of Costly Action
Figure 11: Higher Degree Variance Speeds Up Coordination

Figure 12: Higher Degree Variance Also Moderates Effect of Costs