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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Network Structure and Collective Political Action

A dissertation submitted in partial satisfaction
of the requirements for the degree
Doctor of Philosophy

in

Political Science

by

Daniel Price Enemark

Committee in charge:

Professor David Lake, Chair
Professor Mathew McCubbins, Co-Chair
Professor Gary Cox
Professor Jasjeet Sekhon
Professor Joel Sobel

2012

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The Dissertation of Daniel Price Enemark is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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Chair

University of California, San Diego

2012

To Mom, for her instruction, dedication, and unconditional love.

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ABSTRACT OF THE DISSERTATION

Network Structure and Collective Political Action

by

Daniel Price Enemark

Doctor of Philosophy in Political Science

University of California, San Diego, 2012

Professor David Lake, Chair
Professor Mathew McCubbins, Co-Chair

The United States is rich with political and social institutions, which create networks over which politicians and citizens communicate, coordinate, and cooperate. Traditional positive political theory, with its emphasis on two-player games as models for strategic interaction, often ignores the complexity of networked coordination and cooperation. This dissertation argues that network structure influences strategic outcomes in complex ways. Specifically, more network connections do not necessarily help groups to solve collective problems, as is often claimed in the deliberation, social capital, and social networks literatures.

Chapter 1, “Bad Connection,” shows that when individuals attempt to solve a distributed coordination problem (in which connected dyads must adopt compatible actions), adding connections can actually inhibit coordination. This chapter identifies

the theoretical conditions under which additional connectivity is likely to degrade group performance in a common coordination problem, and presents experimental evidence to support the theory. The need to avoid the negative externalities of an over-connected network has bearing on a range of real-world political problems, such as the design of American executive agencies and the allocation of policy portfolios in parliaments.

Chapter 2, “Segregation and Compromise,” shows that players of a networked, 16-player battle of the sexes are much more likely to reach consensus when the actors with conflicting preferences are integrated in the network than when these actors are segregated. I argue that this suggests that social sorting may be a driving force behind political polarization in the US; as social sorting segregates liberal and conservative Americans, compromise and consensus become increasingly difficult.

In Chapter 3, “Does Social Capital Habituate Cooperation,” I draw a distinction between two popular theories of how denser networks generate cooperation; the social habits theory (dominant in political science) assumes that participation in social organizations acculturates members to cooperative norms, while the social incentives theory states that the shadow of the future makes cooperation rational. I show that social connectedness does not predict subjects’ anonymous choices to cooperate in the lab, contradicting the popular social habits theory, and calling into question the argument that a more connected society is a more cooperative society.

Chapter 1.

Bad Connection: When a Denser Network Inhibits Coordination

with Nicholas Weller

The need to solve decentralized coordination problems among connected individuals is a universal feature of social interaction. On this subject scholars have presented theoretical and observational arguments both that adding connections between individuals can facilitate coordination and that adding connections can hinder coordination. The ambiguous effect of network density has never been tested in a setting in which the treatment effect of additional edges can be clearly identified. We present a theoretical argument that, in a distributed coordination problem, some additional connections decrease the number of solutions to the collective problem. These "bad connections" inhibit coordination, explaining the negative externalities that sometimes arise from adding connections. We test this theory with an experiment, showing that we can predict which connections decrease performance in a coordination task.

Coordination is ubiquitous to human experience. Social scientists have studied coordination in the context of adopting technological standards, choosing and implementing public policies, and using a shared resource like roads or oceans. In all types of coordination games there is an interdependence in the actions of players, and there is no dominant strategy a player can pursue. One way to model the structure of interdependence is to embed a coordination game in to a network to allow us to model the structure of interaction. In this network setting nodes represent actors and an edge between two actors represents the ability to communicate and the existence of constraints on each others' actions. The presence of information and constraint suggests that edges in a network can have both positive and constraining externalities. For example, an edge could mean that two individuals can communicate with each other, but that they cannot simultaneously use the same resource. If an edge has a positive externality it means that joining two nodes together improves the performance of the overall network and coordination is more likely. If an edge has a negative externality, then joining two nodes degrades the performance of the network and coordination is less likely.

The presence of both negative and positive effects of edges raises an important, unanswered question: Under what conditions will networked coordination games be solvable? What makes it more likely that people will achieve a coordinated outcome? In this paper we present an experimental test of the effect of different network structures on a general anti-coordination game in which players must choose different actions from others to achieve a coordinated outcome. We find that constraining edges, which reduce the number of coordination outcomes to a game, make it much harder for groups to solve the coordination game. At the same time, the

addition of non-constraining edges, which do not reduce solutions but do connect actors, significantly improves coordination, and these edges can allow groups to solve problems that were nearly impossible in their absence. One implication of these findings is that in the design of political and economic institutions we want to encourage the addition of non-constraining edges that do not reduce solutions to a coordination task, or if we cannot avoid constraining edges, then institutions must be able to build a sufficient number of non-constraining edges to overcome the effects of the constraining edges in the network.

We turn now to a discussion of the ubiquity of coordination and networks in social settings. Then in Section 2 we discuss how network structure can affect the likelihood of coordination. Our experimental design is presented in Section 3, and in Section 4 we present the results from our experiments. Finally, we conclude with a discussion of the implications from this research.

Coordination in Networks

Coordination is ubiquitous in politics. As Niou and Ordeshook (1994) point out, “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 (p. 210).”¹ Despite the ubiquity and necessity of coordination the conditions that encourage successful coordination have not received

¹ Particularly informative discussions of cooperation and coordination occur in Snidal (1985) and Stein (1982). McCubbins et al. (2009) focused directly on situations that involved elements of cooperation and coordination such as the Battle of the Sexes. In this paper we focus solely on the difficulty of the coordination task.

much attention.² Koremenos et al. (2001) point out that “Multiple equilibria are a major obstacle to cooperation that was downplayed by the early emphasis on 2X2 games.” When scholars have studied coordination the standard approach is a two-player, two-choice consensus model that yields the conclusion that pure coordination problems are likely solvable as long as players can discuss or observe each others’ choices or find a focal point in the game. These consensus models, however, lack an approach for dealing with any coordination problem that involves more than one, universal constraint (e.g. everyone must take the same action).

Coordination games that require actors to take different actions are not uncommon in social science. For instance, scholars have studied driving as an example of consensus-style coordination used (Lewis 1969). However, even when that problem is solved (usually by political fiat), drivers on a daily basis face a much more vexing coordination problem for which centralized, political solutions do not exist – how to time one’s use of the roadway to minimize travel time, subject to a variety of external constraints. The goal in this coordination problem is to not drive at the same time as everyone else, because everyone does better if we schedule our driving schedules so as not to overuse the roadways.

There are many other examples of the need to take different actions in social settings (see Bramoulle 2007), and these tasks can be collectively called anti-coordination games. Anti-coordination games can represent a situation in which

² See Hoel (1997) for a model and discussion of the conditions when there is a need for international policy coordination to resolve environmental issues.

players are using a shared resource (like a road or an ocean) and the value of the resource declines if too many people use it. Therefore, there is a reason for players to take different actions from others in trying to solve the underlying coordination task. This important class of coordination problems has been understudied, and we focus upon it in this paper. The chicken game is a well-known example of an anti-coordination task. The Chicken game features two drivers headed towards each other and each one must decide to stick to or swerve from their current lane. The drivers prefer not to crash in to each other and die, and if either one swerves then they both survive, which is the best joint outcome although each actor would prefer to be the one that sticks rather than swerves. The Chicken game involves anti-coordination combined with individuals having different preferences over the outcomes (each player prefers that the other swerve).

Another example of anti-coordination is a situation in which individuals in a firm, political party or team must divide their labor among a variety of tasks or skills. For instance, in parliamentary governments a crucial part of developing a portfolio of cabinet ministers is a division of labor based on policy specialization of the various ministers (Laver and Shepsle 1994). In general, division-of-labor problems occur across a wide variety of social situations (Becker 1985; Becker and Murphy 1992).

The need for executive agencies in the United States to take actions that are different than other executive agencies is also an example of anti-coordination in politics. For instance, the Trade Promotion Coordinating Committee established in 1993 by President Clinton involves representatives from twenty agencies in the federal

government and is tasked to “provide a unifying framework to coordinate the export promotion and export financing activities of the United States Government and to develop a governmentwide strategic plan for carrying out such programs. (Executive Order 12870, September 30, 1993). One of the chief duties of the committee is to “prevent unnecessary duplication in Federal export promotion and export financing activities.” The various agencies communicate with each other to improve U.S. exports and are tasked with choosing different actions (that is anti-coordinate) to avoid duplicating the tasks being conducted by other agencies.

In any situation where coordination is important there are typically many actors who must solve the task via decentralized action. Networks provide one way to model the structure of interaction between many actors and when combined with a basic coordination game can provide a useful way to model social situations. Our approach comports with Easley and Kleinberg (2010) who argue that graph theory and game theory are “theories of of structure and behavior respectively: Graph theory is the study of network structure, while game theory provides models of individual behavior in settings where outcomes depend on the behavior of others.” Networks have many functions, but two of the most important functions in the context of coordination are to determine how information moves among actors and to define the set of constraints that determines successful coordination.

Recent studies of coordination in a network seem to confirm the two major conclusions of the traditional consensus stage games: (1) more communication (a denser network) seems to make the game easier to solve, and (2) conflicting incentives

make the game much harder to solve. Kearns et al. (2006) argue that while adding edges “makes the problem more difficult from the isolated viewpoint of any individual subject ... it apparently makes the collective problem easier by reducing the number of edges coloring conflicts must travel to be resolved.” That is, denser networks speed information flow, facilitating coordination.

McCubbins et al. (2009) agree that more connections help subjects coordinate and show that conflicting incentives inhibit coordination. Further bolstering the traditional view that pure coordination is easy with adequate communication, McCubbins et al. find that “when subjects have common...incentives to coordinate they can successfully achieve coordination regardless of the network structure.” This accords with a broader literature showing that experimental subjects easily solve coordination games with pre-play communication, even when the game requires simultaneous coordination by many players (see for example Blume and Ortmann, 2007). As described above, Kearns et al. and McCubbins et al. both argue that increases in the number of network edges improve coordination.³

Simply adding links to a network may not improve performance, however. Scholars noted years ago in studying road networks that adding a new road to the existing network of roads could actually degrade overall performance (Braess 1968).

³ Enemark et al. (2011) use computational complexity theory to show that the conclusions of Kearns et al. (2006) and McCubbins et al. (2009) are not applicable beyond bipartite graph-coloring promise problems. For the purpose of modeling coordination, however, the important thing to understand (not discussed by Enemark et al. [2011]) is that the tasks analyzed by Kearns et al. and McCubbins et al. have the characteristics of a consensus problem: all marginal edges are positive, the constraints are global, and the number of solutions is equal to the number of alternatives.

This is not just a theoretical curiosity, either. In 1990, New York City closed 42nd street in preparation for Earth Day festivities and many expected traffic to get much worse (Kolata, 1990). However, traffic actually improved with the removal of the street from the traffic network. Recently, computer scientists have turned to studying the phenomenon called Braess's Paradox across a host of network structures and they find that it is likely to occur quite commonly (Chung and Young 2010).

Political scientists have also noted in observational settings that adding edges to a network may either improve or worsen outcomes:

connectedness may impose constraints on autonomy as well as offer opportunities for influence. ... States that are part of an alliance network may find themselves in conflicts they would rather avoid; trade ties can be used for economic sanctions; normative bonds are deployed to force compliance through naming and shaming; and telephone and email records can be used to destroy a terrorist network. (Hafner-Burton, Montgomery and Kahler, 2009, p. 571)

The possibility that an edge in a network can have constraining effects on collective outcomes has been noted theoretically before (Chwe 2000; Fowler 2005; Siegel 2009; Jackson et al. 2012; Buechel and Hellman 2011). Across a variety of theoretical and empirical settings these scholars have all noted that adding/deleting edges in a network can have important externalities on the overall performance of the network.

Externalities of edges are hypothesized to exist in both coordination and cooperation tasks, so the findings cover a large amount of commonly-studied social science settings. All of these results should caution us against assuming that adding edges to a network will improve the overall performance of the actors in that network.

2. A model of networked coordination

To study how networks, and in particular the positive or constraining effects of additional network edges, influence coordination we use a model of coordination in which actors must choose an action that differs from those to whom they are connected.⁴ As discussed earlier there are many social and political situations in which coordination requires us to take different actions than some (perhaps not all) of the others in the setting. It turns out that there is a well-studied task that captures the need to take different actions than others -- the distributed graph-coloring problem. The graph-coloring problem takes a given network (or “graph”) and asks how to color the nodes of the network so that no two connected nodes share the same color. For example, if there are three available actions, red, blue, and yellow, an actor who chooses red essentially forbids his neighbors to pick red. Any assignment of colors such that no two connected actors share the same color is called a *proper coloring* of the graph, and represents a solution to the coordination problem. Following standard definitions of coordination (Myerson 1997; Rasmusen 2006), graph coloring is a coordination game, because there are multiple pure-strategy Nash equilibria to the game (each proper colorings constitutes a PSNE). We utilize the graph coloring problem in an experimental setting (described in detail in section 5) to test the

⁴ The results we report utilize the graph-coloring problem, but the hypotheses and experimental results we present in this paper do not depend on the specific coordination task, be it graph coloring, consensus, or matching (e.g. finding a marriage partner). We have experimental results on all of these tasks that suggest the findings from this paper are robust to all of these tasks.

relationship between network structure and coordination; the experimental adaptation of the GCP was first developed by Kearns et al. (2006).

We use the graph-coloring problem in an experimental to study how networks affect coordination for four reasons. First, graph coloring allows us to explicitly model the tradeoff between constraints and communication. As in the example of overlapping jurisdictions among U.S. executive agencies, a connection between nodes implies both that the connected nodes are mutually constrained and that the connected nodes are in communication with each other. Thus, adding edges to the network both constrains the solution space and increases information flow. In a standard consensus game this is not true because additional connections do not affect the number of solutions in a consensus game.

Second, in the graph-coloring problem we can modify the number of solutions while holding constant the number of actions available to each subject. This cannot be done in a consensus game, where the number of solutions is solely a function of the number of actions from which actors choose, and it is possible that providing too many available actions may simply overwhelm our subjects' perceptual or cognitive abilities, which is not our focus in this experiment.

Third, the graph-coloring problem is easy to explain to subjects. This is not to be taken lightly; in a complicated experimental task it is possible that subjects spend much of their time confused by the actual task. We quiz our subjects to ensure that they understand the task and how they earn money, and subjects invariably understand the instructions.

Fourth, given that we are interested in the way that networks affect coordination we want to use a coordination problem that is amenable to a network environment. The graph-coloring problem is an exact analogy to a networked coordination problem, therefore we do not have to adapt a non-network problem into a networked setting. Although the experiment, like all lab experiments, requires simplifying reality, this anti-coordination problem presents a compelling tradeoff between characteristics making it a good experimental design and the problem's ability to capture interesting, real-world phenomena.

3. Constraining Edges, Non-Constraining Edges and Coordination

We begin with the simple observation that coordination games—even those without any conflict—are not always easy. In the classic two-player coordination stage game, it is immediately obvious to both players which outcomes represent successful coordination. Of the four cells in the driving game, depicted in Figure 1.1, two represent success (*Right, Right* and *Left, Left*). In this game, the search for equilibria is trivially simple. The challenge is for each player to guess which action the other will take, and the players can easily solve this problem with a moment of pre-play communication.

$P_1 \backslash P_2$	Right	Left
Right	1, 1	0, 0
Left	0, 0	1, 1

Figure 1.1. A two-player coordination stage game

Not all coordination problems are so easy to solve, however. Computer scientists have shown that coordination problems like the GCP can be an extremely difficult computational problem even for a centralized decision-maker who can see the entire network (Khanna, Linial, and Safra, 2000). Consider a 16-player decentralized, graph-coloring game on a network that can be solved with two colors. Sixteen subjects each have two choices, so there are 2^{16} cells—65,536 possible outcomes. And just like the driving game, only two of those outcomes represent success. In this case the search process represents a serious obstacle to coordination. And that's only a two-color game; a three-color game with 16 nodes has 43 million possible outcomes, a four-color game 4.3 billion. In these games, the difficulty is for all subjects to *find* the same solution to the coordination problem. Even with ample communication and no conflict, the distributed search for solutions hidden among millions of outcomes makes graph-coloring a challenging coordination problem.⁵

⁵ In a pure coordination game we conceptualize the process of solving the GCP as a distributed search process in which the players attempt to find a solution to the coordination problem. Watts (2003) also conceptualizes network coordination problems as a search process.

The players' distributed search for equilibria becomes more difficult when the number of equilibria decreases,⁶ and the number of equilibria in this anti-coordination game is determined by the structure of the network. When we add an edge that constrains two nodes so that they no longer can use the same color, we decrease the number of solutions. We call such an edge a constraining edge, because the externality of this edge is that the overall coordination task becomes more difficult.

Not all edges, however, decrease the number of solutions; if the existing edges in the network constrain two *unconnected* nodes so that any proper coloring would require those nodes to have different colors, then adding an edge between those nodes does not decrease the number of solutions to the GCP. We call this type of edge a non-constraining edge, because by increasing the number of nodes the average subject can see this type of edge creates an externality for the entire network by making coordination easier. Buechel and Hellman (2011) also categorize edges based on the externality they create for the rest of the network, but their results are theoretical and they do not test the actual effects of different types of edges.

⁶ This is true because equilibria in graph-coloring, as in the driving game, are symmetric across any player's actions, meaning that there are an equal number of equilibria associated with each available action for each player. For example, the driving game has 2 equilibria, one if Player 1 plays Right and one if he plays Left. Similarly, for a k-color network with s solutions, the GCP has s/k equilibria for each color that Player 1 could pick. If we were able to remove solutions in a way that reduced symmetry, such as eliminating the (Left, Left) option in the driving game or eliminating any single solution to the GCP, the problem would become easier. This is because each player could eliminate one of the available actions from consideration, as it would be less likely to yield a positive outcome. In the GCP, however, solutions are defined by relational constraints (such as Node 1 \neq Node 2), so for each solution in which Node 1 is red and Node 2 is blue, there is a permutation of colors that yields an isomorphic solution, in which Node 1 is blue and Node 2 red.

To see the effect of network structure on the number of solutions to the networked coordination game, consider the simple network in Figure 1.2A, a line with a single added edge.⁷ This is a minimally-constrained connected three-color graph.⁸ If subjects pick colors in order from left to right, and each subject is given three colors from which to choose, then the leftmost node can pick any one of the three colors, the next can pick either of the two remaining colors, and the third node must pick the one color unused by the first two. The rest of the 13 nodes can choose either one of the two colors not chosen by the preceding node. The number of solutions to the GCP on this network is $3 \times 2 \times 1 \times 2^{13}$, or 49,152.⁹

⁷ The graph in Figure 1.2A contains a single triadic relationship, as we move from Figure 1.2A to 2H we are increasing the number of triadic relationships in the network.

⁸ Any graph that connects all of n nodes using $n - 1$ edges (the minimum) is called a “tree.” Since the line, like all trees, is two-colorable, one extra edge is required to achieve the minimally-constrained connected three-color graph.

⁹ Previous experiments using the distributed graph-coloring problem (Kearns et al., 2006; McCubbins et al., 2009) focused on two-color networks that did not allow for triangles, and were thus built based on the idea of dyadic relationships. However, there is good empirical reason to believe that networks based on other types of relationships are important to study. As Watts (2003) says in summarizing Anatol Rapoport’s work:

In social networks, the basic unit of analysis is the dyad, a relationship between two people. But the next simplest level of analysis, and the basis of all group structure, is a triangle, or triad, which arises whenever an individual has two friends who are also friends of each other.

A triadic relationship occurs when an individual is connected to two other nodes that are also connected to each other (i.e. a person’s two friends also know each other). To understand generally how changes in network structure affect collective outcomes, it is important to consider networks built on non-dyadic relationships. In the next section we discuss the graph-coloring problem when networks are based on triadic or quadratic groups.

If we add an edge between the second and fourth nodes of the graph in Figure 1.2A, the number of choices available to the fourth node decreases from 2 to 1, reducing the number of solutions from 49,152 to 24,576. We can continue adding constraining edges between all pairs of nodes v_i and v_{i+2} , reducing the number of solutions by half with each new edge, until we arrive at the graph in Figure 1.2H, a line of tessellated triangles, for which there are only six solutions. This is a maximally-constrained three-color graph; a three-color network can have no fewer than six solutions because there are six permutations of three colors. (Graph theorists call these graphs uniquely-colorable, because without isometric permutations, there is only one solution.)

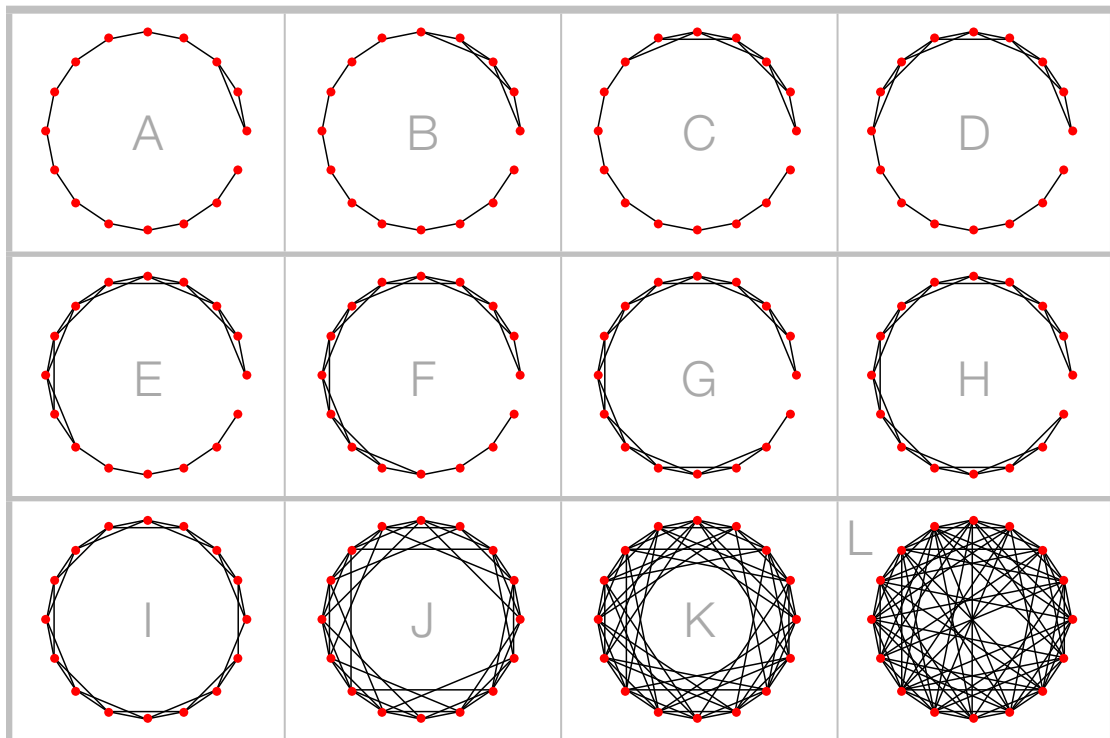


Figure 1.2. Three-color graphs used in the experiments

Finally, starting with a maximally-constrained network like the one in Figure 1.2H, we can add non-constraining edges between any two nodes of a different color.¹⁰ These edges are positive, because they do not affect the conditions required to solve the coordination problem. In our experiments, where the network also defines the information available to each node, adding non-constraining edges gives subjects more information about each other's actions.

3.1 The absence of equilibrium strategies

In our discussion of the graph-coloring problem we have not presented an extensive form of the game and derived equilibrium strategies. Instead, we focus on whether the group, as a whole, can properly color the graph. There are two reasons for this. First, our experiments are designed to study collective outcomes. Second and most importantly, 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 2009; Choi et al. 2011; Echenique and Yariv 2011). To see why, consider that each proper coloring for a network constitutes a pure-strategy Nash equilibria. In the least constrained three-colorable network this implies there are over 49,000 pure strategy equilibria and countless more mixed strategy equilibria. Given that subjects lack knowledge of others' choices it is hard to understand how they could even be aware that they are playing an equilibrium strategy. Finally, a limitation of game-theoretic equilibrium concepts is that in a

¹⁰ A network needn't be maximally constrained in order to add a non-constraining edges, but if a network is maximally constrained, all edges that don't increase chromatic number are positive.

multiplayer context, any outcome for which more than one actor would have to change in order for everyone to benefit is a Nash equilibrium, since no one person could unilaterally improve his payoff by adopting a different action. For example, if each of 100 people earn \$10 when all 100 choose “green,” and 98 choose green while 2 choose blue, that outcome is a pure-strategy Nash Equilibrium.

3.2 Expectations

We make two a priori predictions based on our theory of constraining and non-constraining edges. First, adding constraining edges to a network will make a coordination task on that network harder for our subjects to solve. Second, adding non-constraining edges to a network will make a coordination task on that network easier for our subjects to solve.

We measure how “hard” or “easy” it is for subjects to solve coordination problems by the likelihood with which they find solutions before a three-minute time limit expires. Networks that our subjects are unlikely to solve are assumed to be harder, since subjects are only paid for trials in which they achieve coordination, and thus highly incentivized to achieve it when possible.

The coordination tasks used in these experiments—three- and four-color distributed graph coloring—had never been used before in our lab. Moreover, the only previous attempt by experimentalists to understand the effect of network architecture on the difficulty of these tasks was unsuccessful (Kearns et al. 2006). Finally, none of the networks used in these experiments had been previously tested in our lab (nor anywhere, to our knowledge). Because our expectations were derived from our theory

without any previous experience with either the tasks or the networks, these experiments represent a strong test for our theory about the differential effects of edges.

4. The Experimental Test

Our experiments used a within-subjects design. We had 144 subjects participate in one of nine two-hour experiments, each involving 16 subjects. In each experiment, the group of subjects attempted to solve 30-40 instances of the graph-coloring problem, yielding us 301 trials across the nine groups. In each trial, subjects were randomly assigned to a node in the network. Each subject must pick a color for his node, and the group's goal was for every node to pick a color such that no two connected nodes shared the same color. Subjects could change their colors as often as they wished, and could view their neighbors' colors in real time. If the group completed their task within three minutes, each subject received \$1 for that trial; otherwise they received no payment for that trial.¹¹

Figure 1.3 shows the interface subjects used to control their nodes. Note that this interface provides subjects with a few additional pieces of information. Inside each of his neighbors' nodes is the number of nodes connected to that node. At the top

¹¹ Subjects also earned money for each correct answer provided on a quiz on the instructions before the trials began. With an average number of trials per experimental group of 36, and an average success rate of 68%, subjects earned on average \$24.50 plus earnings from the quizzes.

of the screen there is a progress bar showing the portion of the network already solved, and a time bar showing the amount of time remaining.¹²

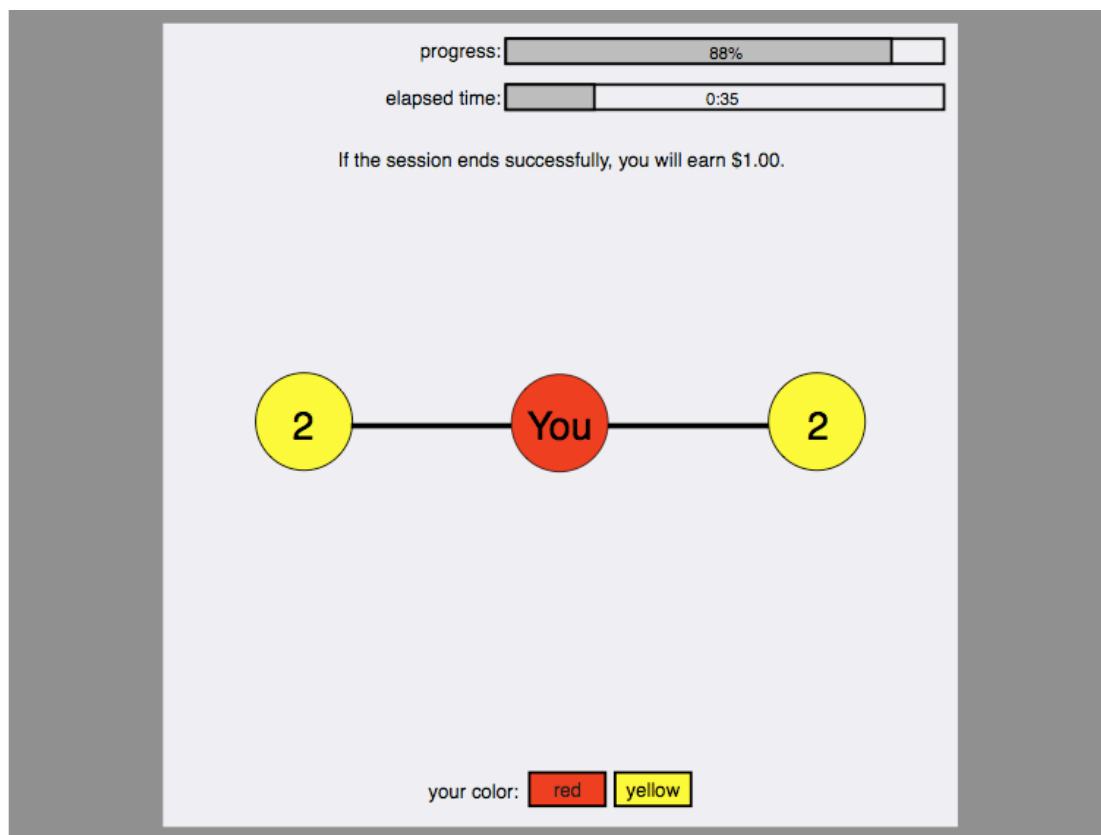


Figure 1.3. Computer interface subjects use to control the color of their nodes

There are two treatments in our experiment: the number of constraining edges in the network and the number of non-constraining edges in the network. We used 12 three-color networks and 17 four-color networks, all of which delivered different “dosages” of the two treatments, as described below. Each subject group received every network at least once, and the order of the networks was randomized. The outcome of interest—whether a group solves a trial of the graph-coloring problem—is

¹² More information on the experimental protocol is available on the authors’ websites.

measured by the frequency with which subject-groups solved networks with any given dosage of the two treatments. We estimate the effects of constraining and non-constraining edges for three-color graphs separately from the effects of those treatments for four color-graphs, to ensure that the effects are consistent across networks of different chromatic number.

To develop the networks used as the treatments, we used graphs requiring more than two colors, because every connected two-colorable graph has no room for additional constraining edges. We began with a connected three-color graph that has the largest number of solutions (shown in Figure 1.2A). We then added constraining edges, two at a time, decreasing the number of solutions so that each successive graph yields 1/4 the number of solutions of the preceding graph. We added these edges until we arrived at the minimally-connected maximally-constrained graph (shown in Figure 1.2H), a tessellated line of triangles.

We then added non-constraining edges to the maximally-constrained graph. These edges do not change the number of solutions to the GCP, but they do increase the amount of information available to the players. We first connected the ends of the tessellated line to form a ring-lattice of triangles, and then inserted additional non-constraining edges, approximately 16 at a time, until we reached the maximally connected three-color graph (shown in Figure 1.2L). At this point no more edges could be added without violating three-colorability.

The process of adding constraining edges (two at a time) and then non-constraining edges (approximately 16 at a time) yielded 12 three-color graphs. We

used the same method to generate 17 four-color graphs, which use tetrahedrons instead of triangles to constrain players to the use of four colors.¹³

5. Results

The results of our experiments confirm both of our hypotheses: constraining edges clearly hinder coordination, and non-constraining edges clearly help it.¹⁴ Successful coordination depends crucially on the number of constraining and non-constraining edges in the network connecting players. At the minimum number of constraining edges, both three- and four-colorable graphs were solved in nearly every trial. With the addition of more constraining edges, success rates dropped precipitously, and without non-constraining edges, subjects were very unlikely to solve maximally-constrained graphs of either three or four colors.¹⁵

¹³ Figure 1.2 shows all 12 three-color graphs used in this experiment. A Figure 1.1 showing the 17 four-color graphs is available at the authors' websites.

¹⁴ Our experimental protocols and data are available online at the authors' websites. An annotated Stata do-file with our analysis is also available online.

¹⁵ We also suspect that easier graphs are solved more quickly and harder graphs more slowly, because we believe subjects are motivated to solve problems as quickly as possible. Subjects should attempt to complete problems quickly for two reasons: First, if there is a risk that they will not complete the task within the three-minute deadline, they should work toward a solution as quickly as possible. Second, subjects simply value their own time. We do not, however, create any explicit, controlled incentives for solving problems quickly, so we do not include in this chapter a test of the relationship between constraining and non-constraining edges and time-to-completion. We do, however, include a simple OLS model of this relationship [in our R code](#), which the reader can reproduce if he is interested. The model shows that constraining edges do in fact increase time to completion, and non-constraining edges decrease it.

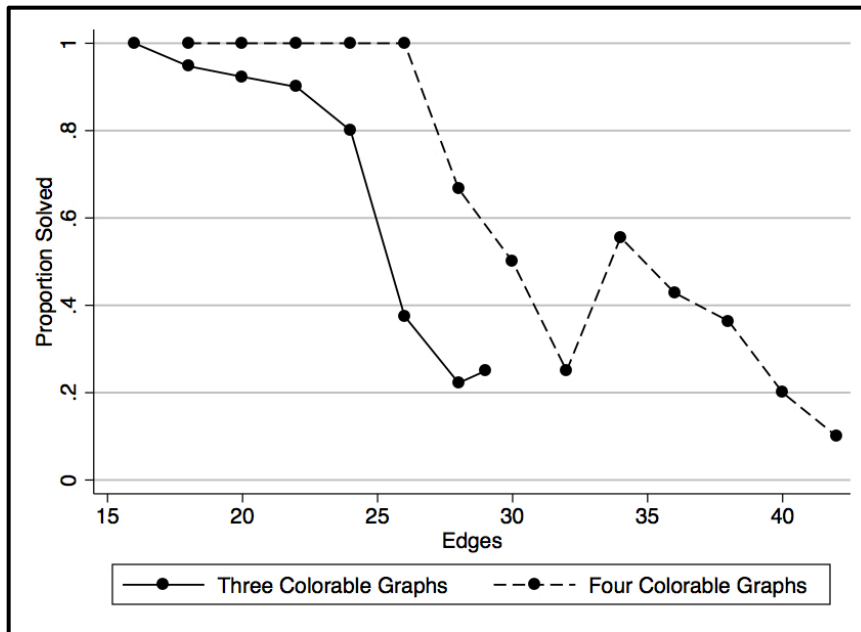


Figure 1.4. Constraining edges make coordination more difficult

Figure 1.5 displays along the x-axis the number of constraining edges in a network and along the y-axis the proportion of networks solved. Each data point represents a particular network, and the number by the data point is number of observations for that particular network. As we move from left to right along the x-axis, each additional edge reduces the number of solutions. As predicted, increases in the number of constraining edges cause groups to be less successful at solving the coordination problem. For both 3 and 4 colorable graphs once we move beyond the addition of a few constraining edges we observe a sharp decline in the proportion of networks solved. This demonstrates quite dramatically how changing network structure by adding edges can impede coordination.

Perhaps the most impressive result, however, is that non-constraining edges can make a very difficult problem quite easy to solve. Adding these edges does not

change the actions, outcomes, incentives, or equilibria of the game; they simply increase the amount of information available to actors. Nonetheless, the frequency with which subjects solved maximally-constrained graphs rose sharply with the addition of non-constraining edges.

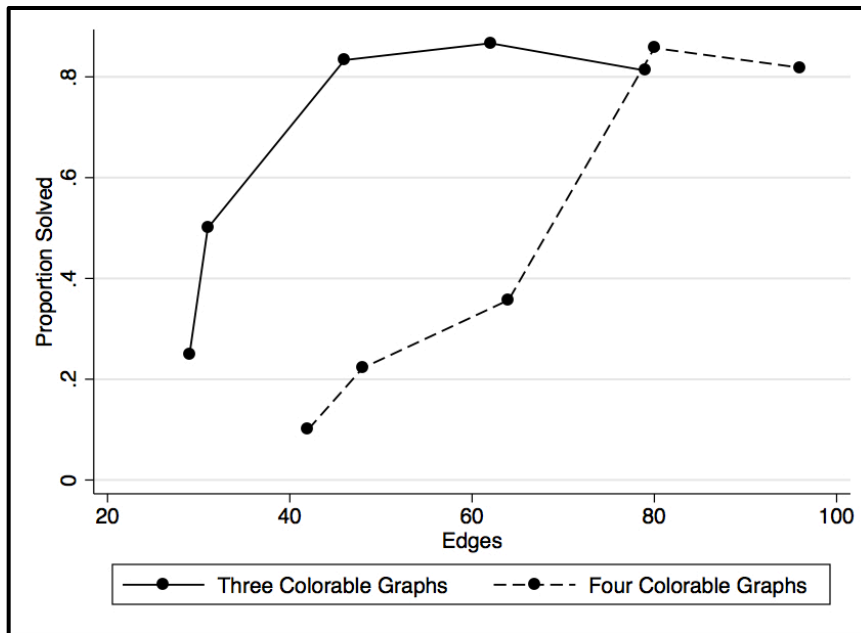


Figure 1.5. Non-Constraining Edges make coordination easier

Although the visual results are clear, we also present a statistical analysis of the data to confirm that the effects are statistically significant. Table 1.1 displays the logit coefficients for the effect of constraining and non-constraining edges, showing that

these effects are significant in the expected direction.¹⁶ These results provide clear evidence that increasing the number of edges that constrain actors in a coordination game can trump the increase in communication that comes along with these new edges. However, if new edges add communication pathways but do not increase constraint, then the edges facilitate coordination.

Table 1.1. Positive and Constraining Edges Significantly Affect Coordination

	Graphs with No Non-Constraining Edges		Graphs with Every Constraining Edge	
	3-Color	4-Color	3-Color	4-Color
Intercept	11.6*** (2.46)	9.31*** (1.61)	-0.116 (0.438)	1.96** (0.599)
Number of Constraining Edges	-0.448*** (0.0983)	-0.274*** (0.0475)		
Number of Non-Constraining Edges			0.0457** (0.0173)	0.0772*** (0.0200)
N (Trials)	84	118	62	59

Entries are logit coefficients, with standard errors in parentheses.

* $p < .05$ ** $p < .01$ *** $p < .001$

¹⁶ Each entry represents the effect of either constraining or redundant edges on likelihood of completion. The four treatment effects shown below were estimated in four separate regressions with the appropriate subset of the data. Just one independent variable was used in each regression, and there were no covariates or controls, as recommended by Freedman (2008a, 2008b). We have also analyzed the data using a random-effects logit that allows for varying intercepts for each experimental group (Gelman and Hill 2007) and controls for trial order. The results are nearly identical to those reported in Table 1.1. Our code is available at http://polisci2.ucsd.edu/denemark/data/BadConnection_Code.R.

6. Discussion and Conclusion

To understand large-scale coordination problems, it is essential to consider the network that connects the individuals attempting to coordinate. Our experiments demonstrate that adding constraining edges to a network can make coordination very difficult. At the same time, enough non-constraining edges can make even the hardest problems solvable. These findings show clearly that adding or removing edges from a network can have significant externalities on the overall performance of the network.

A large number of scholars across many different domains have recognized that edges can have positive or negative externalities. Watts (2003) asks, “If adding links at random isn’t a good way to reduce information congestion, what is? In general, this is a hard question to answer, requiring as it does a balance between local capacity constraints and global (system-wide) performance (p. 278).” Our experiment provides the first rigorous test of this theoretical argument and finds that indeed edges can have significant negative externalities for system performance.

Prior work had found a more straight-forward, perhaps intuitive relationship between increases in the number of connections and coordination both without conflict (Kearns et al. 2006) and with conflict (McCubbins et al. 2009). At first blush the previous results appear contradictory to our current finding that additional edges may impede coordination. This only happens, however, when the new edge affects the number of solutions to the coordination problem. Because the prior experiments primarily used two-color graphs, and all connected two-color graphs are maximally constrained, these experiments essentially held constraint constant while adding non-

constraining edges. The results from these prior experiments are perfectly consistent with our second hypothesis, that adding non-constraining edges makes coordination easier.

These results have important implications for social scientists who study networks and coordination. In any coordination problem that takes place in a network it is possible that some edges reduce the number of solutions available to actors. For instance, in adopting a particular public policy the number of solutions will depend on which actors participate in the policy-making process. The addition of an edge to a new actor may improve collective decision making (i.e. achieving coordination) if the new edge increases communication and does not reduce the number of solutions to the coordination problem. However, if the new link simultaneously increases constraint and communication then it is possible that the increase in constraint will swamp the improved communication.

Our experiments also suggest that empirical studies of networks (i.e. Scholz, Berardo and Kile 2008) may benefit from understanding whether edges in a network have the same effect on the underlying problem facing networked actors. Because we find that there is an ambiguous relationship between increases in network connections and coordination it may be insufficient in observational research to treat all connections identically. We may want to identify connections that reduce the number of solutions available to other actors, because these types of connections can impede problem solving even if they also improve information flow in the network. Our research

suggests that identifying which edges constrain the number of solutions is critical to fully understanding the way that the network impacts collective outcomes.

In political settings we observe that actors attempt to avoid the creation of constraining edges when building networks. For instance, Congress attempts to limit the degree to which agencies overlap—that is, to prune constraining edges from the network. For example, the FDA Food Safety Modernization Act of 2011 specifies that "the Secretary [of Health and Human Services] shall not duplicate other Federal foodborne illness response efforts" conducted by the Department of Agriculture. In the event that constraining edges cannot be eliminated or avoided, our results indicate that it is possible to make distributed coordination problems easier by adding edges in a way that do not increase the number of constraints on the solution. These types of connections only facilitate information flow and making it possible for decentralized actors to solve very different coordination tasks.

Perhaps the most important implication is that if we cannot avoid adding constraining edges in building a network then we may need to also add sufficient non-constraining edges to make coordination still possible. If it is costly to add edges between actors, then this means that before we begin to add potentially constraining edges we should ensure that we could afford any non-constraining edges that are necessary to overcome the externalities of the constraining edges.

Chapter 1 is material currently being prepared for submission for publication, of which Nicholas Weller is a co-author, and it is with his permission that I have included our joint work in this dissertation.

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Chapter 2.

Segregation and Conflict: Diverse Network Neighborhoods Help Players Solve a Multiplayer Battle of the Sexes

Political scientists have expressed growing concern that the clustering of partisan preferences in social networks exacerbates partisan polarization in the United States. Unfortunately, causal claims on this subject have been difficult to justify because social networks are difficult to measure or manipulate. This paper presents an experiment in which actors with conflicting preferences are connected in a network and asked to solve a coordination problem. The results show that when the two conflicting “types” of actors are segregated in the network, they are less likely to achieve consensus. The experimental results are an analogy that helps to explain how the geographic and social clustering of partisan preferences may make compromise and consensus more difficult in American politics.

Mounting evidence suggests that Americans live and work within ideologically segregated social networks, so that the typical American interacts primarily with those who share his own beliefs. Scholars and journalists alike have expressed concern that this segregation increases the polarization of political preferences among voters, and decreases the ability of opposing partisans and their political representatives to overcome their conflicting preferences for the sake of consensus. However, there is no compelling evidence that, in a coordination game with conflict (of which policy deliberation is an example) segregating the actors by their preferences actually impedes their ability to reach consensus.

This paper provides the first experimental evidence that when individuals share a collective goal to reach consensus but disagree over the ideal outcome, segregating actors according to their preferences can prevent them from reaching consensus. This empirical evidence lends support to the concern among scholars of American politics that social sorting by partisanship within American voters' social networks may represent a serious obstacle to successful deliberation and compromise.

American Democracy and the Battle of the Sexes

Conflicting preferences over collective alternatives is the fundamental problems of democratic politics. For American voters, electing representatives and choosing policy via direct democracy requires many individuals to sacrifice their preferences for the sake of consensus. Since republican government and the rule of law are public goods, all voters benefit from the enforcement of a coordinated equilibrium—the election of a single representative in each district or the imposition

of policy initiatives supported by a majority. However, different voters gain very different utilities from the two alternative coordinated outcomes in any given electoral contest. This type of strategic environment, a coordination game with conflict, is typified by Luce and Raiffa's (1957) *Battle of the Sexes*, in which two players must choose independently to attend a ballet or boxing match, with both players preferring consensus but disagreeing over the ideal outcome.

Juries often face a similar consensus problem with conflict. Due to the high cost of a hung jury and the frequent lack of a clear right answer, jurors often value a consensus that diverges from their own preferred outcome to a lack of consensus in which they assert their preference.¹⁷ Federal judges are even authorized to charge dissenting jurors to reconsider, and these so-called "dynamite charges" have been demonstrated to elevate the desire for consensus over the desire for a juror's preferred outcome (Kassin et al. 1990). In a famous laboratory experiment, Asch (1951) found in panels of six to eight participants, individual subjects (jurors of a sort) often agree to an obvious falsehood when all other participants profess to believe that falsehood.

Yet another example of the *Battle of the Sexes* in democratic politics is the selection of policy goals and candidate endorsements among groups of activists. When the Family Research Council decided to endorse a conservative candidate for the 2012 Republican presidential primary, they had to reach consensus—to coordinate by

¹⁷ A recent real-world example is juror Aldo Davico in the Fairfax, VA trial of Alfredo Prieto, who admitted after assenting to a guilty charge that he was not in fact convinced of the defendant's guilt, but conceded to the majority after succumbing to "peer pressure" (Jackman, 2007). Of course, the most famous counter-example is fictional: Henry Fonda's Juror 8 in *12 Angry Men*.

endorsing a single candidate. At the outset, members held conflicting preferences (Charles, 2012); some preferred to endorse Newt Gingrich, and some Rick Santorum. They all felt, however, that a unified endorsement of one of these candidates would help prevent the nomination of their least-favored candidate, Mitt Romney.¹⁸

Protestors in Zucotti Park participating in the “Occupy Wall Street” movement face a similar problem of reaching consensus in the face of conflict. Occupiers, as they call themselves, reach consensus decisions via deliberation in a “General Assembly.” From September 2011 through January 2012, the General Assembly passed 102 proposals and allocated about \$372,000 via consensus decision-making.¹⁹

Consensus with conflict is also a prominent feature of American government. In the federal and state legislatures, the vast majority of bills are passed by unanimous consent (Cox and McCubbins, 2011), including contentious bills such as the recent 2011 payroll tax-cut extension. Since 1990, executive agencies have been authorized (and even exhorted by presidential memorandum) to use “negotiated rulemaking”—a method of consensus decision-making in which representatives from the agency and impacted interested groups negotiate a mutually acceptable administrative rule. The Bureau of Land Management uses a wide variety of consensus-oriented decision processes, which they call “collaborative stakeholder engagement,” for natural

¹⁸ Ultimately, the Family Research Council endorsed Santorum, with Gingrich supporters sacrificing the “bonus” they would receive for endorsing their favorite candidate in order to achieve the benefit of coordination by endorsing a slightly less-preferred candidate.

¹⁹ This calculation is an estimate based on the General Assembly’s own records. See http://polisci2.ucsd.edu/denemark/data/Enemark_OccupyWallStreetData.csv

resource projects and even internal workplace disputes (BLM 2009). Administrative rulemaking often involves stakeholders with nearly diametrically opposed preferences, but the high cost of lobbying and litigation creates a baseline preference for consensus.

Ideological Segregation and the Battle of the Sexes

In a traditional two-player Battle of the Sexes, each actor plays directly against the partner with whom his preferences conflict. In the real world, however, conflicting actors are often segregated by type. The extensive literature on coordination with conflict often ignores the fact that large-scale coordination problems must be solved over a network of actors that typically exhibits clustering of types, so that actors who prefer some particular outcome are more likely to communicate with each other than those whose preferences differ. While homophily and social sorting are well documented phenomena of American civil society and geography, the implications for coordination are underdeveloped.

Recent work by McCubbins et al. (2009) explores the effect of conflict on a dynamic, networked coordination problem. The mechanism used to generate conflict in their experiments (withholding payment to the entire group for any outcome that involves two immediate network neighbors earning bonuses) brings every actor into conflict with his immediate neighbors. But in real-world coordination problems, conflict is not so perfectly distributed across every edge of the network; there is preference clustering, so that most individuals are allied with their network neighbors in a conflict against more distant nodes. What impact does the segregation of

preference types have on the ability of individuals to compromise and reach consensus?

American voters are increasingly isolated from disagreement in their social networks. Bishop and Cushing (2008), who define “landslide counties” as those in which one presidential candidate beat the other by more than 20 percentage points, show that the proportion of voters living in such counties has increased steadily since 1992. Political geographers have argued recently that American migrants prefer destinations populated by copartisans, based on evidence from voter registration data (Cho et al., 2009) and the U.S. Postal Service’s change-of-address database (McDonanld, 2011). Mutz (2002) argues that when Americans discuss politics, they primarily talk with people who share their candidate and policy preferences. Even Huckfeldt et al. (2004), who argue that political disagreement is commonplace in social networks, provide data that seems to indicate otherwise. For example, NES respondents were asked in 2000 to name up to four people with whom they discussed politics. Of those who provided names, two thirds did not list anyone who voted for the opposing candidate. Moreover, the likelihood of agreement was highest for those discussants named first, decreasing monotonically thereafter, which suggests that a voter’s most common discussion partner may be the partner least likely to disagree.

Like Americans voters in general, members of the Occupy Wall Street Movement may be segregated by preferences, with more educated, wealthy protestors on the east side of the park, and poorer, less-educated protestors on the west side (Shapiro 2011). It is likely that a protester’s wealth has implications for the priorities

he sets between immediate needs such as the kitchen budget (\$10,501 for a week) and more extravagant endeavors such as the assembly's decision to send a delegation to Egypt (\$29,000). Shapiro argues that there is less communication between the "micro-neighborhoods" of Zucotti Park than within them, and that this segregation is at times an obstacle to consensus decision-making in the Occupy movement's General Assembly.

In the government, too, individuals with conflicting interests are less connected than those with shared preferences. In Congress, interactions are highly segregated between liberals and conservatives, in the partisan whip system and the cosponsorship network (Zhang et al. 2008). In "negotiated rulemaking," actors with conflicting interests are often segregated. For example, in its execution of the Clean Water Act, the Environmental Protection Agency requires communities with Combined Sewer Overflows (CSO) to mitigate the pollution caused by these systems. The National League of Cities created a CSO Partnership to connect the 772 communities with CSOs for the purpose of negotiating with the federal government, leaving a network highly segregated between federal and municipal actors (Mee 1997). When the BLM engages in "collaborative stakeholder engagement" to manage a timber sale, groups such as the logging industry and conservation and community organizations are largely segregated, communicating within and not across ideological lines (BLM 2009).

Experiment

This paper presents a series of experiments in which the distribution of conflict across the network is varied by segregating conflicting types to a greater or lesser degree. The treatment is the level of exposure actors have to neighbors with conflicting preferences, and the outcome of interest is the subjects' ability to reach consensus. The treatment is measured by the proportion of each node's neighbors that are of opposite type, taken as an average. (Variance in this proportion across nodes is usually 0 and always less than 0.5, so the results are not significantly affected by the choice of central-tendency measure.) The outcome is measured by the time taken to reach consensus, with time ranging from 0 to 180 seconds. (Trials not solved in 180 seconds cut off, resulting in 20% of trials being censored at 180. Results are robust across a wide range of time values assigned to failed sessions.)

Experiments proceed as follows: each of 16 subjects chooses between two alternatives, with the group's objective being for all 16 subjects to settle on the same alternative. In the experiment, these alternatives are represented by two colors drawn randomly from a color palette (with each subject seeing the two alternatives represented by a different pair of colors). The three possible outcomes, then, are consensus on Color 1, consensus on Color 2, and failure to reach consensus. Each subject can see the color currently chosen by his immediate network neighbors (updated in real time), and can change his color costlessly as often as he pleases. The interface is shown in Figure 2.1.

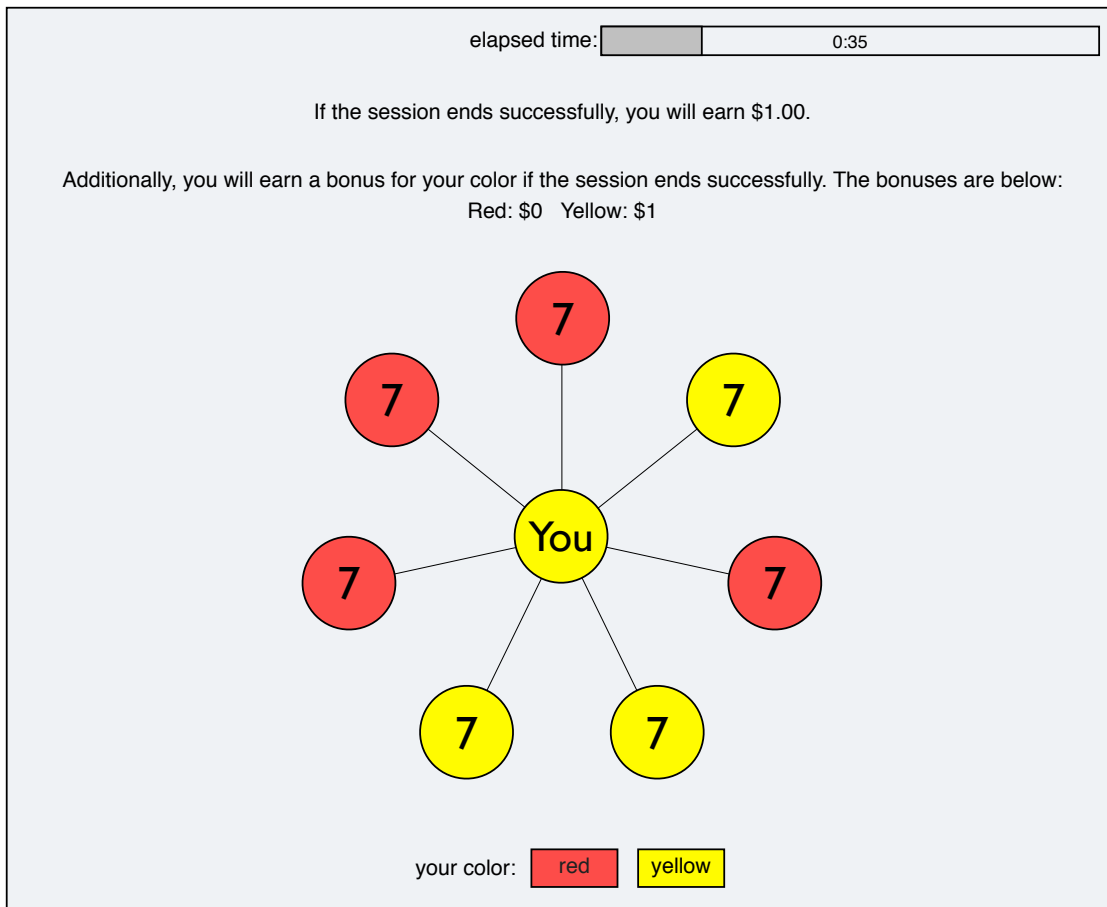


Figure 2.1. The interface subjects use to control their node shows them the elapsed time, the payoffs for each outcome, and the degree and current color of their neighbors.

In each trial, no individual receives payment unless the whole group achieves consensus within three minutes. Conflict arises from the fact that half of the players are paid double for consensus on Color 1 while the rest are paid double for consensus on Color 2. This is essentially a networked Battle of the Sexes, with two types: “males” (those who prefer Color 1) and “females” (those who prefer Color 2). Subjects know which color they prefer and know that some subjects prefer the opposite color. They do not know the distribution of types, nor do they know the type

of their neighbors, but they likely make inferences based on the choices their neighbors make.

In each trial, subjects are embedded within one of three networks, displayed in Figure 2.2: the segregation network, the mixture network, and the integration network. These networks are designed to be as similar as possible, while providing a wide variation in “treatment dosage.”²⁰ Since the treatment here is the level of exposure actors have to neighbors with conflicting preferences, the networks are designed provide three different dosages: virtually no exposure (segregation), a medium level of exposure (mixture), and full exposure (integration).

Although the visualizations in Figure 2.2 are designed to highlight the differences between these networks, the networks themselves are extraordinarily similar. They all have 16 nodes, 56 edges, identical uniform degree distributions (all nodes have degree seven), a diameter of three, and similar average geodesic distances (1.5 for integration and mixture, 1.73 for segregation). Moreover, because subjects never see the full networks, and all three networks have a uniform degree of seven, subjects have no way to differentiate between the networks, nor can they know what

²⁰ One colleague proposed the use of a single network, with the distribution of types within that network varying across trials, to prevent any differences due to network architecture. However, it is not possible to achieve as wide a range of opposite-type exposure using this method, and a smaller range of “treatment dosages” would make the average treatment effect harder to measure. Also, this proposed method would result in individual nodes within each network being exposed to different numbers of opposite-type nodes. Since our experimental trials can only be analyzed at the group level, every node in a particular trial must be exposed to the same treatment. Any other arrangement would result in hopelessly intractable violations of the Stable Unit Treatment Value Assumption required for causal inference.

position they or any other subject occupies in the network. For example, in the segregation network, no subject is aware of the identity of the four nodes that connect the two clusters, nor do they even know that there are a subset of nodes that bridge two clusters. All they ever see is their local neighborhood, as it is displayed in Figure 2.1.

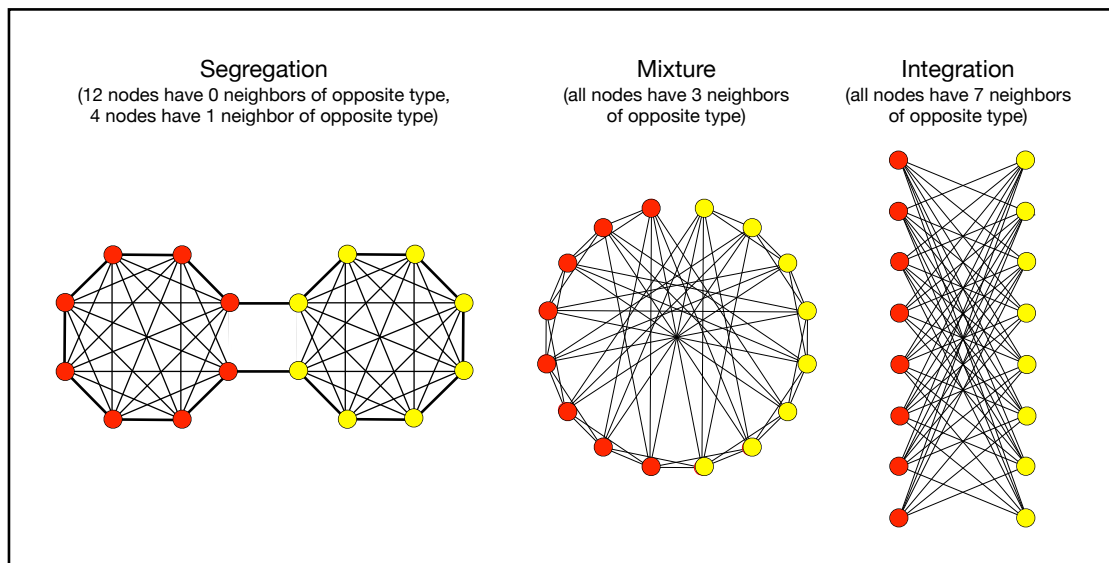


Figure 2.2. Networks used in these experiments

Hypothesis

As described above, I vary the degree to which types are clustered in the network, to create a system with more or less segregation (higher or lower clustering, respectively). Since each subject can only observe the choices of his immediate neighbors, segregation reinforces individuals' existing preferences and prevents actors of one type from gaining information about whether actors of the opposite type appear willing to concede the bonus to achieve coordination. For these reasons I hypothesize that *greater segregation inhibits the group's attempts at coordination.*

Results

The results strongly support the hypothesis that in games of conflict, segregation inhibits coordination.²¹ Table 2.1 shows that without conflict, the distribution of types has no effect. This is a “placebo test,” since there is no actual difference between the two types when subjects are not offered bonuses. The null result is important, because it establishes that segregating some actors from others does not have an independent effect—i.e., that the networks used in this experiment do not, in the absence of conflict, vary in the time required for subjects to reach consensus. In the presence of conflict, however, exposure to opposite-type neighbors dramatically reduces the time subjects take to reach consensus.

Table 2.1. As network neighborhoods contain a larger proportion of opposite-type actors, the conflicted coordination problem is solved more quickly.

	OLS Coefficient (Standard Error)
Intercept	16.8 (10.5)
Conflict	167*** (14.7)
Mean Proportion of Neighbors of Opposite Type, No Conflict	1.98 (16.6)
Mean Proportion of Neighbors of Opposite Type, Conflict	-83.2*** (22.5)
N (number of trials)	82
Adjusted R ²	0.719

* $p < .05$, ** $p < .01$, *** $p < .001$

²¹ The R code for the table and figure in this section can be available at <http://polisci2.ucsd.edu/denemark/data/segregationCode.R>. The data are at denemark/data/segregationData.csv Once again, I would like to thank Mathew McCubbins for funding the experiments discussed in this paper.

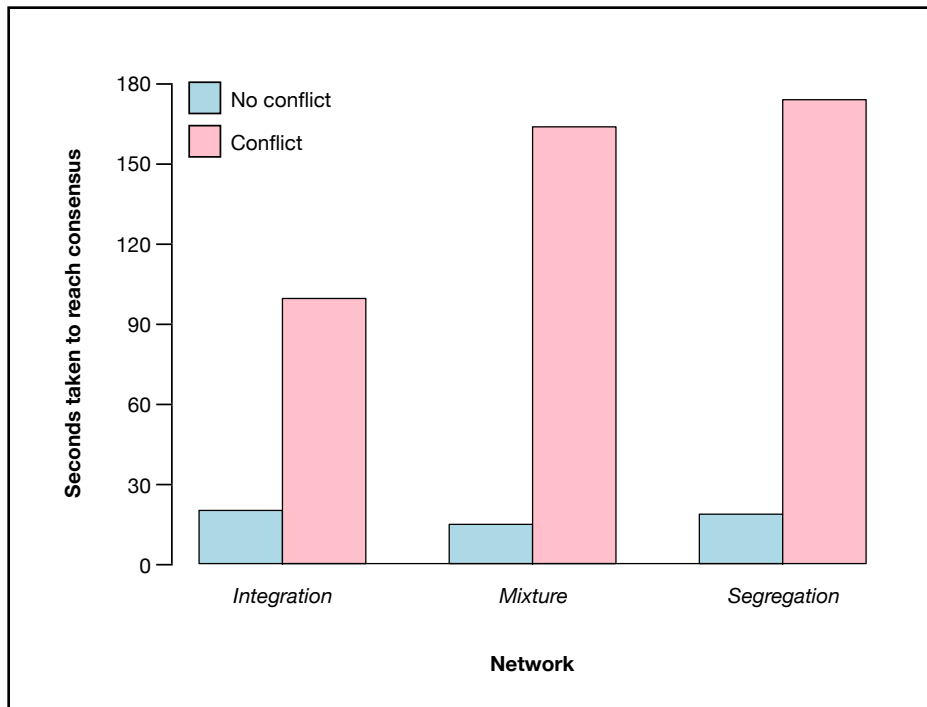


Figure 2.3. A graphical representation of the relationships in Table 2.1.

Conclusions

The widespread phenomenon of preference segregation presents a serious obstacle to consensus-building in American politics. In the experiments reported above, the more subjects were isolated from those with opposite preferences, the more difficulty the subject-groups had solving the consensus problem. This lends credence to the concern among many that the increasing geographic and social segregation between Democrats and Republicans in the American electorate may exacerbate political polarization. It also suggests a possible explanation for the difficulty of consensus lawmaking in Congress, negotiated rulemaking in executive agencies, and consensus decision-making among groups of activists such as the Family Research Council and Occupy Wall Street.

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Chapter 3.

Does Social Capital Habituate Cooperation?

Proponents of social capital believe that associational institutions encourage mass cooperation, but they disagree on the mechanism giving rise to this effect. Most argue that social ties *habituate* cooperation through acculturation to cooperative norms. Others believe that social ties *incentivize* cooperation through the shadow of the future. I show, through a laboratory experiment and survey, that subjects' behavior is consistent with the incentive-based view of social capital but conflicts with the habit-based view of social capital. Across a wide range of laboratory tasks and real-world decisions, there is very little relationship between a subject's level of "social capital" and his likelihood to cooperate when there is no potential for future interaction.

The theory of social capital—that a dense network of social ties encourages mass cooperation—has spread from sociology to political science, economics, and across the social sciences. Social capital has been claimed as a driving force behind voter turnout, bureaucratic efficiency, policy performance in public health and education, wealth at the local and national level, and even disease rates.

There are two competing views of social capital. The dominant view in political science and economics is that social organizations *habituate* cooperation among their members. In this view, participating in, say, a bowling league gets members in the habit of cooperating with others, leading them to cooperate outside of the original context that fostered their cooperative habits, even when cooperation violates their self-interest. The alternative view, not as widely heralded, is that social organizations *incentivize* cooperation. For example, in this view, religious and family connections among diamond merchants cast a shadow of the future, so that the temptation to cheat is outweighed by the promise of continued exchange.

In this paper, I argue that there is little support for the popular notion that social ties generate cooperative habits transcending the boundaries of the social organizations that generated those ties. I present a laboratory experiment and survey demonstrating that there is no relationship between an individual's level of social capital and his decision to cooperate across a wide variety of laboratory tasks and real-world decisions. Instead, the results are consistent with the alternative view, already demonstrated in the experimental literature, that social ties incentivize cooperation when they increase the likelihood of repeated interactions among strategic actors.

In Section 1, I will define the two theories of social capital. In Section 2, I review a few of the causal claims made by social capital theorists, showing that they predominantly draw on the social habits theory. Section 3 describes the experiment and survey, and Section 4 presents results. Section 5 concludes, tying the results to the larger literature on cooperation.

Section 1. Two Theories of Social Capital: Incentives and Habits

Jackman and Miller (1998) were the first to point out a divergence in the social capital literature between the original conception of Coleman (1988),²² in which a denser social network among strategic actors casts a longer shadow of the future; and the more popular notion of Putnam (1993), that participation in social organizations acculturates members to cooperative norms. I build on this work to identify two competing causal mechanisms, which I call “social incentives” and “social habits.”

The Social Incentives Theory

Coleman (1988) introduced the concept of social capital within the framework of rational choice theory. He described social capital as composed of institutions imbedded in “some aspect of social structures,” that “facilitate certain actions of actors—whether persons or corporate actors—*within the structure*” (emphasis added).

According to this definition, social capital is not an engine for generating positive norms through civic participation; it is merely a resources for developing and maintaining cooperation through the transformation of incentives within a specific

²² Though Jacobs (1961), Loury (1977), and Bourdieu (1986) all used the term social capital before 1988, it was Coleman’s conception of social capital that gained traction and became the foundation of the modern literature.

strategic environment. In describing the wholesale diamond market, Coleman writes, “Close ties, through family, community, and religious affiliation, provide the insurance that is necessary to facilitate” cooperation. “In the absence of these ties, elaborate and expensive bonding and insurance devices would be necessary—or else the transactions could not take place.”²³

Coleman also gives the example of connections among corporate actors allowing them to engage in price-fixing. Note in this example that the connectivity serves only a narrow purpose and is not generating what would typically be understood as positive norms of pro-social behavior. Unlike Putnam’s conception, Coleman’s social capital is not fungible: “A given form of social capital that is valuable in facilitating certain actions may be useless or even harmful for others.”

The Social Habits Theory

The social habits theory builds on a much older view of ethical virtue as the product of habit (see, for example, Aristotle’s *Nicomachean Ethics*, Book 2, Chapter 1). Fukuyama (1995) writes that “acquisition of social capital...requires habituation to the moral norms of a community and, in its context, the acquisition of virtues like loyalty, honesty, and dependability.” Grant (1997) writes that “trust, reputation, and reciprocity” depend on social capital because social engagement “helps create personal integrity, which is the basis for consistent principled action.” This emphasis

²³ The claim that transactions “could not take place” may be an overstatement; even when stakes are high, generalized trust may be sufficient to support cooperation. See for example Darai and Grätz (2010), who show that contestants on a game show playing a very high stakes variant of the Prisoner’s Dilemma unilaterally cooperate about half of the time, although in that case audience costs may be very high.

on ethics is frequently paired with a rejection—implicit or explicit—of rational self-interest as the primary lens through which we should evaluate the actions of individuals. Putnam (2000) identifies cooperative norms as a crucial component of social capital.

The habits theory also diverges from Coleman’s conception of social capital on the question of who benefits from social capital, and at what level of society the resource can be observed. Whereas Coleman describes social capital as a resource shared between individuals in a specific strategic environment, Putnam (2000) defines social capital on two levels: as a resource for entire societies, and as a resource for individuals. Putnam defines social capital with respect to societies as (1) “connections among individuals—social networks,” and also as (2) “the norms of reciprocity and trustworthiness that arise from” those connections (p. 19). He defines social capital with respect to individuals as (3) “whom we know” or the thickness of our respective rolodexes. Summarizing these points, Putnam states that social capital is both a public good (items 1 and 2) and a private good (item 3).²⁴ Item 1 is only observable at the group level, but items 2 and 3 are both observable at the individual level.

The difference between social incentives and social habits is similar to the difference between a waiter serving his customers and a soldier obeying his superior officers. The waiter complies with his customers’ requests because he hopes that he will be rewarded in the future with a larger tip. The institution of tipping creates an

²⁴ By comparison, in Coleman’s conception, social capital might be viewed as a club good.

incentive for waiters to provide good service. The soldier, on the other hand, has been trained to obey orders as a matter of habit, even when obedience violates the soldier's own self-interest.

Section 2. Causal claims made in the social capital literature

The fundamental premise of social capital—that associational institutions foster cooperation, either through habits or incentives—has found scholarly expression in a variety of literatures for the last 175 years at least (c.f. de Tocqueville, 1835/2000); Banfield, 1958; Granovetter, 1973). Modern scholarly use of the term social capital emerged in sociology with Coleman (1988), who asserted that the effect of social institutions on incentives made cooperation possible in a wide variety of social settings, from radical student activism in South Korean to merchant relationships in the Kahn El Khalili market of Cairo. These causal claims, however, were presented as motivating examples for a novel theory, and were not carefully defended because Coleman's aim was not empirical.

The recent literature on social capital has seen an explosion of empirical claims seemingly drawing on the social habits theory. Social capital theorists claim that associational institutions have causal effects on bureaucratic efficiency (Putnam 1993) and citizens' confidence in government (Brehm and Rahn, 1997). They also claim causal effects on policy performance in domains such as education (Putnam 2001) and public safety (with social capital either reducing crime, as in Kennedy et al., 1998; Rosenfeld and Baumer, 2001; and Lederman, 2002; or increasing it, as in Beyerlein and Hipp, 2005; and Messner et al., 2004). Economists argue that social capital

increases wealth at the local and national level (Knack and Keefer, 1997; Narayan and Pritchett, 1997; Saegert et al. 2001); and epidemiologists claim it improves public health (Weitzman and Kawachi, 2000; Lochner et al., 2003; Gladwell 2008).

Work such as this overwhelmingly adopts the social habits theory. Weitzman and Kawachi (2000), for example, measure social capital at four-year colleges by the average time committed by undergraduates to volunteering, and claim a causal relationship between this measure of “social capital” and the prevalence of binge drinking on campus. Obviously, a negative correlation between volunteering and binge-drinking has nothing to do with social capital as Coleman defined it; volunteering does not create a shadow of future interactions among undergraduates, and refraining from binge-drinking is not a form of cooperation among students supported by repeated interactions.

Section 3. Experimental Test of Social Incentives and Social Habits

We gave subjects a wide range of opportunities to behave in an economically irrational, pro-social manner, and then (several weeks later) surveyed them with a series of questions designed to measure their participation in associational institutions. The subjects’ laboratory interactions were anonymous, so the social incentives theory predicts that participation in associational institutions should be unrelated to pro-social behavior in the lab, since in this theory, it is the shadow of future sanctioning that creates such a relationship. By contrast, the social habits theory predicts that participation in associational institutions should be positively related to pro-social

behavior in the lab, since subjects engaged in such institutions have developed pro-social behavioral habits that do not depend on the shadow of the future.

The social incentives and social habits theories are not mutually exclusive, of course; associational institutions could both incentivize and habituate pro-social behavior. Indeed, we already know that the shadow of the future incentivizes pro-social behavior. Dal Bó (2005) shows that laboratory subjects are more likely to cooperate in a Prisoner's Dilemma when games are infinitely repeated—meaning that players are uncertain about when the last round will be but believe it will continue to the next round with positive probability. Although Dal Bó does not tie his results to the debate over social capital, infinitely repeated games capture the driving mechanism of the incentives theory of social capital exactly, and provide strong experimental evidence for the social incentives theory.

The social habits theory of Putnam and Fukuyama does not rule out the incentive-shaping effect of repeated play, but it does focus on the habit-forming effect of social engagement. Thus, testing the social habits theory requires an experiment in which subjects vary in their history of social engagement, but the shadow of the future is perfectly controlled for. The latter we achieve by maintaining complete anonymity between subjects: partners are matched randomly by the experimenter across two different rooms, and subjects are instructed repeatedly that in each task they will be randomly paired with a different, anonymous partner. In addition, for simultaneous games and for the second stage of sequential games, subjects' decisions are never

revealed to their partners, so that each subject learns very little about the others' styles of play.

Experimental Tasks Measuring a Subject's Choice to Cooperate or Defect

In our experiments, subjects participate in eight tasks for which they have an opportunity to engage in pro-social behavior. In these tasks, pro-social behavior is generally not in the subject's economic self-interest. The eight tasks are as follows:

1. **Prisoner's Dilemma:** The subject is paired with a partner from the other room; he must choose whether to take \$2 for himself at a cost of \$3 to his partner. (In some treatment conditions the subject is instructed that the partner can make the same choice, while in others the partner's choice is not discussed.)
2. **Dictator Game:** The subject is paired with a partner from the other room; he is given an endowment that exceeds the partner's endowment by somewhere between \$0 and \$20, and he may transfer any amount of his endowment to the partner. (We control for endowment disparity in our analysis.)
3. **Donation Game:** The subject is paired with a partner from the other room; he and his partner both begin with \$5; the subject may transfer any amount of his own \$5 to the partner, and the partner will receive quadruple the amount the subject transfers.
4. **Trust Game Stage 1:** The subject is paired with a partner from the other room; he and his partner both begin with \$5; the subject may transfer any amount of his own \$5 to the partner, and the partner will receive triple the amount the subject transfers. The subject knows that his partner will find out how much he

received from the subject, and may (but need not) subsequently “return” any amount of money to the subject.

5. **Trust Game Stage 2:** Identical to the previous task, but with the roles reversed, so that the subject must choose how much to “return” to his partner after finding out how much his partner transferred.
6. **Ultimatum Game Stage 1:** The subject is paired with a partner from the other room; the subject has \$10 to split between himself and his partner. If the partner accepts the subject’s split, both parties receive the amounts chosen by the subject. If the partner rejects the subject’s split, the whole \$10 is lost.
7. **Majority-Condition Step Level Public Goods Game:** 10 subjects receive \$5 each. Each subject must choose whether to “keep their \$5” or “put it in the pot.” If 6 or more subjects put their money in the pot, the pot is tripled and all 10 subjects receive an even share of the product. If fewer than 6 subjects put their money in the pot, the money in the pot is lost.
8. **Unanimity-Condition Step Level Public Goods Game:** Identical to the previous task, but all 10 subjects must put their money in the pot for it to be tripled; if any individual chooses not to contribute, any money in the pot is lost.

Subjects’ choices in these games present an ideal test of the social habits theory, because in each game, subjects must choose whether to cooperate or defect, with no social pressure or economic consequences. The social habits theory clearly implies that those more deeply embedded in the social network will have adopted norms of cooperation, and follow those norms as a matter of habit. The social

incentives theory on the other hand, implies that social connectedness only increases the propensity to cooperate when it raises the possibility of repeated interaction, which is impossible in this experiment because of the anonymous nature of the interactions. A substantial literature exists in behavioral economics and, more recently, in political science suggesting that the experimental tasks in which our subjects engage are reliable measures of the tendency to cooperate. Trust Games, originally developed by Berg et al. (1995), have been shown to predict trusting behavior out of the lab and expressions of generalized trust in survey responses (Glaeser et al. 2000; Baran et al. 2010). The Dictator Game predicts real-world charitable giving and voter turnout (Benz and Meier 2008; Fowler 2006).

Questions used to measure individual-level social capital

Recall that Putnam (2000, p. 19) defines social capital as (1) “connections among individuals—social networks,” and also as (2) “the norms of reciprocity and trustworthiness that arise from” those connections. Note that the second item in Putnam’s definition, norms of reciprocity and trustworthiness, is actually a claimed effect of the first component, connections among individuals. This means that social capital is (according to Putnam’s theory) both a cause and an effect of itself. This confusing cause-plus-effect definition is also reflected by Putnam’s state-level index of social capital, which is comprised of 14 standardized scales, listed in Table 3.2. Eleven of these scales (1-11) relate to “connections among individuals.” Two (12 and 13) relate to “norms of reciprocity and trustworthiness that arise” from connections among individuals. One of the scales (14) does not fit clearly in either of these

categories. Is turnout in the 1988 and 1992 presidential elections a form of connection among individuals? Is it a norm of reciprocity and trustworthiness?

The goal of this experiment is to test the social incentives and social habits theories on their own terms. For this reason, I duplicate Putnam's social capital index as nearly as possible, despite the concerns about the measure discussed above. Table 3.2 shows the survey questions used to reproduce Putnam's index. Figure 3.1 shows the dispersion in the resulting index scores among our subjects.

Table 3.2. Components of Putnam's state-level social capital index, and corresponding data from a post-experimental questionnaire of laboratory subjects

	Putnam Measure	Survey Question
1	Served on committee of local organization in last year (percent)	<i>No data</i>
2	Served as officer of some club or organization in last year (percent)	<i>No data</i>
3	Civic and social organizations per 1,000 population	<i>Constant across subjects</i>
4	Mean number of club meetings attended in last year	How many times in the last 12 months have you been to a meeting of a club or similar organization?
5	Mean number of group memberships	Do you currently play any sports (intramural or varsity) or belong to any clubs, student government, at UCSD or elsewhere? About how many of these types of groups do you participate in?
6	Attended public meeting on town or school affairs	<i>No data</i>
7	Number of nonprofit (501[c]3) organizations per 1000 population	<i>Constant across subjects</i>
8	Mean number of times worked on community project in last year	How many times in the last 12 months have you worked on a community project?
9	Mean number of times did volunteer work in last year	How many times in the last 12 months have you done volunteer work?
10	Agree that "I spend a lot of time visiting friends"	Do you agree with this statement? I spend a lot of time visiting friends
11	Mean number of times entertained at home in last year	How many times in the last 12 months have you entertained people in your home?
12	Agree that "most people can be trusted"	Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?
13	Agree that "most people are honest"	Do you agree that most people are honest?
14	Turnout in presidential elections, 1988 and 1992	When it comes to elections, we often find that a lot of people were not able to vote because they weren't registered, they were sick, or they just didn't have time. Did you vote in the 2010 elections?

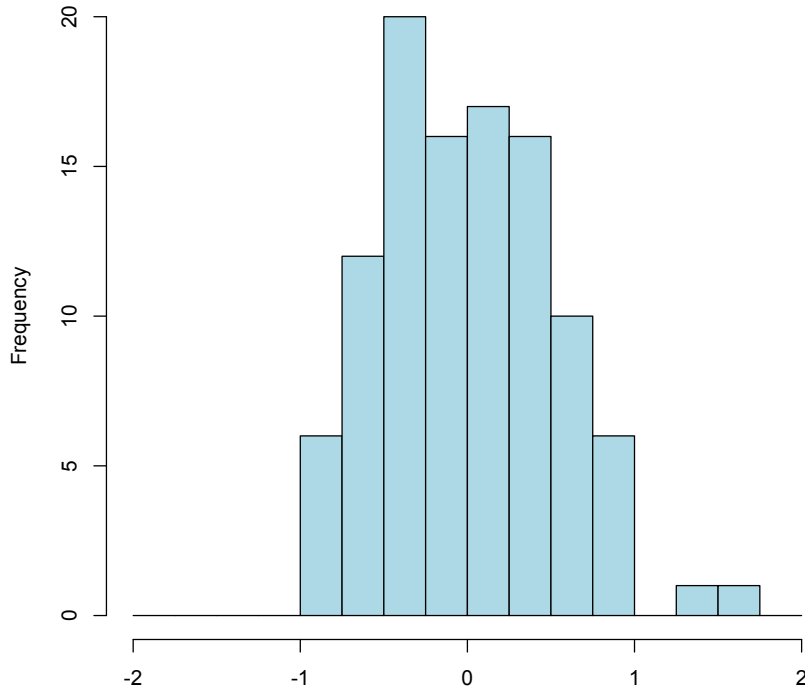


Figure 3.1. Histogram of scores on experimental replication of Putnam's index

Hypotheses

The social habits theory implies that individuals more densely embedded within associational institutions are more likely to be acculturated to norms of cooperation. Those who embrace norms of cooperation will habitually cooperate even in contexts outside of the associational institutions that fostered these norms. One particular testable hypothesis derived from this theory would be the following: subjects who score higher on the social capital index will be more likely to cooperate in a prisoner's dilemma. Below is a list of all eight hypotheses tested in this experiment:

1. Higher index score predicts higher propensity to cooperate in Pris. Dilemma
2. Higher index score predicts higher transfer in Dictator Game

3. Higher index score predicts higher transfer in Donation Game
4. Higher index score predicts higher transfer in Trust Game Stage 1
5. Higher index score predicts higher transfer in Trust Game Stage 2
6. Higher index score predicts higher offer in Ultimatum Game Stage 1
7. Higher index score predicts higher propensity to contribute in Majority-Condition Step Level Public Goods Game
8. Higher index score predicts higher propensity to contribute in in Unanimity-Condition Step Level Public Goods Game

Section 4. Results

The results show that there is very little relationship between a subject's level of social capital and his likelihood to cooperate when there is no potential for future interaction. Only one of the eight null hypotheses can be rejected after applying a Bonferroni correction for multiple comparisons. Higher social-capital index scores predict higher transfers in a donation game, but do not predict greater cooperation in the Prisoner's Dilemma, Dictator Game, Trust Game Stage 1 or 2, Ultimatum Game Stage 1, Majority- or Unanimity Condition Step-Level Public-Goods Game. Table 3.3 presents the results for each hypothesis, showing p-values before and after the Bonferroni correction, which is designed to keep the probability of a Type-I error at 5%. Without the correction, the probability of rejecting one of our null hypotheses when it is in fact true is 40% (see Wright, 1992).

Table 3.3. The predictive validity of the “social habits” theory is very low.

Game	Predicted Action	Social Capital Coefficient	Standard Error	p-Value	p-Value Corrected for Multiple Comparisons
Prisoner's Dilemma	Likelihood of cooperation	0.669	0.419	0.111	0.888
Donation	Amount donated	0.968	0.339	0.00526**	0.0421*
Majority SLPG	Likelihood of contribution	0.366	0.384	0.341	1
Unanimity SLPG	Likelihood of contribution	0.688	0.414	0.0963	0.770
Trust Stage 1	Amount sent	0.744	0.323	0.0231*	0.185
Trust Stage 2	Amount returned to positive sender, controlling for amount sent	0.823	0.594	0.172	1
Dictator	Gift to P2, controlling for endowment difference	0.358	0.445	0.424	1
Ultimatum Stage 1	Amount offered to P2 out of \$10	0.00973	0.285	0.973	1

* $p < .05$, ** $p < .01$

Section 6. Conclusion

Axelrod and Hamilton (1981) famously argued that cooperation could be supported in an environment of pure self interest, with sufficient likelihood of future interaction. An entire literature on collusion in economics offers theoretical justification and empirical evidence for this claim. Dal Bó (2005) offers perhaps the best experimental demonstration of this effect. Although neither Coleman nor the

experimentalists seem to have connected social capital to cooperation under shadow of the future, Coleman's incentive-based theory of social capital is really just an extension of the cooperation literature base on the self-evident observation that dense interaction networks make future interactions more likely. The social incentives theory, therefore, has strong theoretical underpinnings and empirical support.

The social habits theory, however, has never been tested in a controlled environment. The results of this experiment represent a first step toward a rigorous test of this extraordinarily popular theory. The results do not seem to offer strong support for the social habits theory popularized by Putnam. The theory that those more tightly embedded within associational institutions practice cooperation "as a matter of a rational habit" (Putnam, 2000) is only supported by one of the eight hypotheses tested in this experiment. It may be true that denser social networks encourage cooperation among individuals, but when anonymity prevents dense networks from casting a shadow of the future, it is not clear whether social connections will retain their power to induce cooperation.

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