1-1-2012

The Diffusion of Politically Expert Opinion Within and Among Groups

Rober Huckfeldt
University of California - Davis, rhuckfeldt@ucdavis.edu

Matthew T. Pietryka
University of California - Davis, mtpietryka@ucdavis.edu

Jack L. Reilly
University of California - Davis, jlreilly@ucdavis.edu

The Diffusion of Politically Expert Opinion Within and Among Groups

Robert Huckfeldt
Yoonjung Lee
Matthew T. Pietryka
Jack Reilly

University of California, Davis

This paper employs a small group experiment to study the process of political influence within social networks. Each experimental session involves seven individuals, where privately obtained information is costly but communication within the group is free. Hence, individuals form prior judgments regarding candidates based on public and private information before updating their priors through a process of social communication. In general, individuals select expert informants with political preferences similar to their own, and we consider the dynamic implications for individual and group preferences. In particular, we address the diffusion of information based on a DeGroot model which provides a dynamic formulation of the influence process. We are particularly interested in the implications that arise due to varying levels of information among participants for (1) the construction of communication networks, (2) the relative influence of better informed individuals; (3) relative levels of reliance on priors and communicated messages; (4) the consequences of memory decay for the influence of experts; and (5) the diffusion of information and patterns of persuasion.

This paper is prepared for delivery at the annual meeting of the Political Networks Conference, Boulder, CO, June 2012.

This paper addresses the role of politically expert citizens as primary movers within a democratic political process characterized by patterns of interdependence among citizens. The concept of political expertise is normally restricted to political elites and elite decision making – to the politicians, consultants, bureaucrats, and handlers who populate the corridors of power. While important efforts have certainly been made at introducing the role of expertise into discussions of grass roots politics among the citizens populating the corridors of everyday life, these efforts have been notable for their failure to penetrate the dominant, enduring vision of democratic politics held among political scientists.

This failure is especially striking in view of early efforts in political science and sociology that focused attention on differentiated levels of political capacity among citizens via "opinion leaders" and a "two step flow" of communication (Lazarsfeld et al. 1948; Berelson et al 1954; Katz and Lazarsfeld 1955; Katz 1957). Expertise and the opinion leadership have been slow to penetrate research on voting, public opinion, political communication, and political participation primarily as a consequence of the historical reluctance to consider citizens as interdependent actors in politics. The primary historical model of a voter in the empirical literature is a socially disembodied individual whose decisions, judgments, and voting choices are based on individually held preferences, opinions, beliefs, attitudes, and identifications. This atomistic model is probably best seen as an unintentional byproduct of particular observational strategies that have been dominant in political research – most notably randomized sample surveys of large populations that divorce individuals from their social and political environments (Huckfeldt and Sprague 1993, 1995). While relatively few students of politics would advocate an atomistic model on its intellectual merits, traditional methods of data collection have resulted in a ***de facto*** adherence to a model that separates and isolates one citizen from another in a way that is both theoretically unsatisfying and empirically inadequate.

The observational challenges in studying expertise and opinion leadership extend beyond the difficulties of studying citizens within their ongoing patterns and networks of communication and social interaction. In particular, problems of endogeneity plague any effort to establish causality in post-hoc observational studies of social and political influence. Without experimental control over the flow of communication, it becomes difficult to make uncompromised assertions regarding the effects of expertise on either the flow of communication or its influence, and hence observational studies confront substantial problems with respect to their internal validity.

At the same time that post hoc observational studies make it difficult to address endogeneity problems, they are also poorly suited to studying higher order consequences of individual expertise. That is, some inroads have been made in addressing the implications of expertise for political influence and the formation of relationships at the level of dyads (Huckfeldt 2001), but relatively little has been accomplished in addressing the diffusion of expertise through larger populations. That is, what are the implications for you if your life partner regularly discusses politics with a knowledgeable person at his or her work place? What are the implications of this same fact for the coworkers with whom ***you*** discuss politics?

In short, this paper takes a first modest step toward understanding an important micro-macro problem in democratic politics. Do individual levels of political expertise serve to inform the aggregate through the patterns of communication that exist among interdependent individuals who create this aggregate electorate? We address this question based on a series of small group experiments addressing the dynamic implications of the communication networks that develop among members of these groups.

Expert Citizens and Political Communication

One of the enduring innovations of the political economy literature on citizenship is to take information costs seriously in the analysis of political communication and expertise. Within this context,

Downs (1957: 229) argues that political discussion minimizes the information costs of political engagement. That is, rather than obtaining and analyzing political information on their own, people can operate more efficiently by relying on the efforts of other, politically expert individuals. According to Downs' view, sensible people search out ***well informed*** associates who possess ***compatible*** political orientations, and hence citizens become efficiently informed – both individually and collectively.

Calvert (1985a) also focuses on the utility of socially communicated information, but he argues that information can be useful if it is acquired from someone with a well identified bias, independent of the recipient's own bias – even when the informant has a point of political orientation that is not compatible with the person who is obtaining the information. In contrast, Lupia and McCubbins (1998) and Boudreau (2008) argue that information from a source with whom you disagree is only useful if the source is compelled to tell the truth – either through sanctions or some other means for verifying the information. These issues become still more complex because, even if citizens do communicate with others based on perceived levels of political expertise, the possibility exists that they might respond to divergent opinions by over-estimating the expertise of those with whom they agree and under-estimating it among those with whom they disagree (Lord, Ross, and Lepper 1979; Lodge and Taber 2000).

In this context, observational studies of information flows within communication networks suggest that the distribution of expertise plays an important role in affecting patterns of political communication (Huckfeldt 2001). First, citizen judgments regarding the political expertise of others are based in reality, driven primarily by ***actual levels of expertise defined in terms of knowledge and interest on the part of potential discussants***. The capacity of individuals to render meaningful judgments regarding the expertise of various informants is quite striking. People are not lost in a cloud of misperception when they engage in social communication about politics, and neither is the information they obtain simply a mirror of their own preferences. Perceived expertise is driven primarily by the characteristics of the discussant being perceived – ***not*** the respondent who is doing the perceiving.

Second, citizens communicate about politics more frequently with those whom they judge to be politically expert, quite independently of agreement or disagreement. People talk more with those who know more! Hence, one of the reasons that "democracy works" might be that citizens rely on "horizontal networks of relations" for meaningful political engagement (Putnam 1993; Mondak and Gearing 1998), thereby reducing information costs and enhancing democratic efficiency. At the same time, there is no evidence to suggest that people weight discussants' opinions by perceived discussant expertise in forming their own judgments (Huckfeldt and Sprague 1995). Hence, the point is not that individuals listen more respectfully to experts, but rather that expert opinion dominates the air time within political communication networks, and that experts are more likely to take their own views more seriously in arriving at summary judgments (Lodge and Taber 2000; Huckfeldt 2001).[1]

Indeed, the observational evidence not only suggests that expertise trumps shared preferences in the formation of communication networks, but that expertise exposes individuals to diverse preferences and points of orientation. First, people may choose to communicate with experts and thus tolerate the wrong-headed viewpoints that are sometimes communicated as a consequence. Second, experts are often activists – they are individuals who care deeply about politics and discuss it with very high frequency. The first alternative points to intentional activity as a consequence the search criteria employed for constructing a communication network. The second alternative points to an unintentional process in which some people, the expert activists, cannot easily be avoided in our day to day lives.

---

[1]An alternative view is that individuals weight a discussant's opinion by the extent to which other discussants hold the same opinion (Huckfeldt, Johnson, and Sprague 2004).

In either event, while individuals exercise choice in the construction of communication networks, ***choice is subject to supply!*** And supply looms particularly large with respect to the distribution of both shared preferences and expertise levels within communication networks. The supply of potential discussants is, in turn, a stochastic function of proximate populations – families, work places, places of worship, sports clubs, and so on. Here again we see an endogeneity problem that is not easily resolved absent an experimental design.

Experimental Strategy

The use of experimental research strategies based in laboratory settings is nothing new to studies of political communication, and a great deal of progress has been accomplished (Boudreau, Coulson and McCubbins 2008; Druckman and Nelson 2003; Lupia and McCubbins 1998).[2] Our own work pursues an experimental framework based on a Downsian spatial model of political preference and competition. Such a spatial model offers several advantages. First, it allows the explicit modeling of heterogeneous political preferences among citizens, as well as among candidates in an election. Correspondingly, it becomes possible to address the "distance" between any pair of citizens or candidates on a continuum. Second, uncertainty in politics and the level of political expertise can be directly incorporated within analyses. Third, the level of political expertise can be represented in various ways, including the amount of information voters have acquired. Fourth, the level of expertise can be conveniently endogenized by assigning variable information costs among the voters. Finally, an experimental framework built on spatial models provides the opportunity to address a growing literature on communication among agents with heterogeneous preferences (Crawford and Sobel 1982), leading to a focus on "cheap talk" (Austin-Smith 1990; Johnson 1993).

Such an experimental framework also combines the advantages of small group dynamics with network representations of communication in the context of an experimental design (Ahn, Huckfeldt, and Ryan 2010; Ahn, Huckfeldt, Mayer, and Ryan 2008). In the experiment employed here, a group of seven subjects communicate with one another via networked computers within a quasi-electoral context. Subjects choose between two "candidates," neither of whom are real human subjects. Rather, these candidates are represented as fixed positions on a one-dimensional policy space, but the candidate positions are unknown to the subjects. The policy space varies from 1 to 7, and each subject has an integer position on the policy scale that remains constant across the rounds in an experimental session. The candidate positions are reset at each round, and all subjects are accurately informed that Candidate A's position always lies in the interval between 1 and 6 inclusive, while Candidate B's position always lies in the interval between 2 and 7 inclusive.

The subjects are rewarded with a cash incentive if the candidate closest to them wins the election, and thus they are motivated to obtain information in two different ways. First they have an opportunity to make private investments in the acquisition of information, followed by an opportunity to request information from other subjects. Private investments in information vary across subjects because the cost of information is experimentally manipulated, with the cost of information assigned to each individual held constant across rounds.[3] In contrast, information taken from other members of the same group is

---

[2] While laboratory experiments are advantageous because of their increased internal validity, survey experiments, quasi-experiments and field experiments have provided important insights into when interpersonal influence is more likely (Nickerson 2008).

[3] The relationship between private information costs and preferences is established randomly, and for these experiments is held constant across all experimental sessions. Position 1 is associated with cost 20, position 2 with cost 0, position 3 with cost 20, position 4 with cost 0; position 5 with cost 5; position 6 with cost 20, and position 7 with cost 0.

free. Privately purchased information is unbiased but noisy, while socially communicated information is noisy and potentially biased because informants need not provide accurate information.

In selecting an informant, subjects know the individual preferences of the other subjects, as well as the amount of information purchased by each subject. A potential dilemma faces the subjects regarding the relative weights to place on preference proximity and expertise in the selection of an informant. No dilemma exists for subjects who have the opportunity to select expert informants with preferences close to their own, but some subjects must choose between an expert informant with divergent preferences versus an inexpert discussant with shared preferences.

A Summary of the Experimental Procedure

Before the experiment begins, participants are randomly assigned their integer preferences, and information costs that remain unchanged for the duration of the experiment. Additionally, all participants are informed that Candidate A's position is between 1 and 6, while Candidate B's position is between 2 and 7. Then, in each round of the experimental session, the following steps occur:

1. Participants receive 100 ECUs, of which 50 ECUs can be spent on information. (This means that subjects with an information cost of 20 ECUs can only purchase two "pieces" of information, where each piece includes an unbiased estimate of each candidate's position.)

2. The two candidates' positions are drawn from the respective intervals.

3. Participants may purchase information at their assigned cost.

4. After the subjects receive the information, they are asked to provide a prior judgment regarding each candidate's position, and they are truthfully told that their judgments will not be communicated to other participants.

5. After being shown all other participants' preferences and information purchases, they are allowed to make a first request for information from one other subject. Potential informants are not required to comply with the request, and they are told that they need not provide the same information to all requestors. Participants almost always agree to provide information, consisting of a single message regarding each candidate.

6. After receiving the information, subjects are asked to update their prior judgments – to offer a new judgment regarding the position of the candidate.

7. Steps 5 and 6 are repeated two more times. Hence subjects have the opportunity to make three information requests from other subjects, and they update their priors at each step.

8. After communication is completed and subjects record their last updated prior, participants are provided a final opportunity to purchase a final piece of information at a cost of 10 ECUs. And at that point subjects vote for the candidate of their choice. The subjects are never provided with a summary of the information they have received – they assess and evaluate the information as it becomes available. All information is provided sequentially and incrementally, and the subject's challenge is to integrate and assess the information in order to cast a vote for the candidate whose position is closest to their own.

9. The outcome of the election is revealed to the voters. If the winning candidate's position is closer to a voter than the losing candidate's position, the voter earns 50 extra ECUs. If the winning candidate's position is farther away from the voter's position than the losing candidate's position, 50 ECUs are

subtracted from the voter's account. If candidates are equally distant from the voter or if the election ends in a tie, the voter neither gains nor loses. A voter could thus earn as much as 150 ECUs in a round, but only if they did not purchase any information. The minimum payoff is 0 ECUs – when a voter spends 50 ECUs on purchasing information and her candidate loses the election.

10. Participants are informed of their net earnings, which accumulate across rounds.

11. Candidate positions are reset, and participants proceed to the next round. At the end of the experiment, subjects are paid the show-up fee plus their total earnings in cash, where 100 ECUs equals a U.S. dollar.

Thus, the voters have three potential sources of information on which to base their votes. First, the public information that the two candidates' positions are drawn from different intervals could potentially help a voter in the absence of other forms of information, and this information should be particularly helpful to voters with more extreme positions. Second, voters are allowed to purchase unbiased but noisy information on candidates' true positions. Third, each participant has an opportunity to request information from other participants – information that is both noisy and potentially biased. They not only depend on the reliability of information that serves as the basis for *the informants'* judgments, but also on the ability and willingness of the informant to compile and provide the information in an unbiased manner. The proximate consequences of the experimental manipulations meet our expectations. First, participants with higher costs obtain less private information. Second, participants who purchase more private information are better able to make informed choices – the quality of judgments increases (at a decreasing rate) as information purchases increase (Ahn et al. 2010).

Our interests in this paper reach beyond these first-order consequences, however. The communication process is complex, based on interdependent actors. In the spirit of Downs (1957), Festinger (1957), Berelson et al. (1954), Katz and Lazarsfeld (1955), and others, we expect the process to be contingent on the preferences and expertise of informants, but we are not only concerned with the direct efects that occur within dyads, but also with the higher order effects that arise due to the informants of informants. Earlier analyses of this experiment focus on the updating process within rounds (Huckfeldt, Pietryka, and Reilly 2010). In this paper, we are concerned with the higher order term dynamic implications of each round.

The Basic Model

We base our analysis on variations of a DeGroot model of social influence (DeGroot 1974; Jackson 2008) that draws on basic theorems regarding Markov chains. In the basic model, individuals formulate prior beliefs and then update these beliefs on the basis of information taken from other individuals. The updating process is not random, but rather occurs through networks of communication within a larger population. The basic model is

$$p_{t+1} = Tp_t \qquad (1)$$

where:

p_t= is a Nx1 column vector, where each of the entries is an individual's belief regarding a particular candidate, where p_0 is the vector of individual priors. For example, each entry might be the probability that the nth individual favors Candidate A.

T = a row stochastic matrix, such that T_{ij} is the weight of the jth individual's opinion at t on the ith individual's opinion at t+1. Each row sums to unity, where the main diagonal is the weight that the

i_{th} individual places on her own prior attitude (at t) in the formulation of her current updated opinion (at t+1).

We are less interested in the p_t vector than we are in the T matrix, as well as its long term dynamic consequences. The focus of this analysis is not about the formation of initial beliefs, but rather on the relative weights that individuals place on their own prior beliefs versus the beliefs of others. In particular, we are concerned with the ways in which the evolution of beliefs in the aggregate depends on the distribution of expertise within the aggregate. We can readily obtain an estimate of T based on our experimental data, but before we do so, it will be helpful to consider the T matrix as an endogenous structure of social communication that depends on the characteristics of the individuals in the experimental microenvironment.

Patterns of Association and Persuasion in the Experimental Data

Table 1 employs a logit model in which the units of analyses are all the potential dyads that existed at every round in every session of the experiment. This creates 4,494 opportunities for social interaction. In every session, each of the seven subjects selects three out of the other six individuals from whom to obtain information, and hence they choose positively in 21 out of the 42 dyadic opportunities and negatively in the others.[4] We do not forbid subjects from requesting information from the same individual multiple times in the same period, but in general they ask for information from three separate individuals out of the six individuals in each period.

The first issue we consider is the set of factors that lead to the formation of dyadic relationships. Table 1A considers the effects of information levels and preference similarities among subjects on the formation of communication dyads. As the model shows, divergence in a dyad's preferences reduces the probability of communication, and the level of a potential informant's information level increases the probability of communication. In short, the subjects ***do*** look for expert informants who hold preferences similar to their own (Downs 1957).

How large are these effects? Table 1b uses the estimates to calculate the predicted probabilities across the range of the two explanatory variables, showing a high level of comparability in effects. The effects of a potential informant's preference divergence (the differences across the rows) are nearly as large as the effects of a potential informant's investment in information (the differences down the columns). In short, within the constrained setting of this seven-person context, where preferences are distributed uniformly and information is randomly distributed independently of preference, the subjects take account of both factors in constructing a network of interaction that is weighted toward experts as well as shared preferences.

Correspondingly, we address the subject's final updated judgment, at each round, regarding the evaluation of Candidate "A" in Table 2. (The results for Candidate "B" are highly comparable.) In each part of the table, these judgments are regressed on the subject's prior judgment and each of the three messages that the individual obtained from other subjects.[5] (We suppress the constant in order to translate the combined effects into a unit interval. Part A of the table shows the pattern of simple direct effects for all subjects, independently of individual information levels. The coefficients suggest that the effect of the prior is

[4] Eighty-four subjects participated in a total of 107 rounds with a total of 7 subjects participating at each round. Each of the 7 individuals had 6other individuals from whom to request information (or, 7X6X107==4494). In the statistical analyses, we correct for multiple observations on the same subject.

[5] For purposes that will become clear below, we suppress the constant in the Table 2 models.

roughly equal to the cumulative effect of the three communicated messages, with comparably sized message effects. In parts B and C of Table 2, the model is re-estimated for high and low information consumers respectively. We see that the effect of the prior judgment is nearly twice as large among the more informed subjects, with an average message effect that is almost twice as large among the less informed subjects. We explore the implications of these results in the remainder of this paper.

Estimates for the Model

The first step is to arriving at estimates for the rows of T – the relative weights that are attached on an individual's own immediately previous judgment, as well as the judgments of others, in arriving at that individual's contemporaneous judgment. The empirical results in Part A of Table 2 suggest that roughly 50 percent of current judgments are based on the immediately prior judgments, with the remainder depending approximately equally on the three messages obtained from other participants in the experiment. Hence, the nonzero elements of each row in the T matrix should consist of .5 on the diagonal, with three of the remaining six entries set to .167. (The final message effect is set to .166 in order that the rows sum to 1.)

This raises the obvious question, which three entries? We pursue the objective of considering the long term implications of the communication choices selected by the participants in two randomly chosen sessions – round 6 of session 5 and round 3 of session 8.[6] These sessions are shown in the directed network graphs of Figure 1, where each node is numbered according to the individual's preference, and where the size of the node is indexed on the amount of information purchased by the individual.

These networks graphs tell a similar story to the empirical results of Table 1. Larger nodes (better informed participants) attract more requests for information, and higher levels of communication generally occur among individuals with similar preferences. The graphs also include surprises, and some of these seeming aberrations can be explained on the basis of expertise and preference proximity as competing criteria. At the same time, the choice of informants is complex, and the process is inherently stochastic.[7] For purposes of illustration, the T matrix implied by part A of Table 2 and Part A of Figure 1 is shown below.

$$T = \begin{matrix} .500 & .167 & .167 & .166 & .000 & .000 & .000 \\ .000 & .500 & .167 & .000 & .167 & .000 & .166 \\ .167 & .167 & .500 & .000 & .000 & .000 & .166 \\ .000 & .167 & .167 & .500 & .000 & .166 & .000 \\ .167 & .167 & .166 & .000 & .500 & .000 & .000 \\ .000 & .167 & .167 & .000 & .000 & .500 & .166 \\ .000 & .167 & .000 & .167 & .000 & .166 & .500 \end{matrix} \qquad (2)$$

Each row is a vector of weights corresponding to the network's contemporaneous, single period effect on a particular individual's judgment update. Based on the results of Table 2A, we set each participant's

[6] Each of 12 sessions involved seven subjects and the number of rounds (each of which constituted a separate election) varied from 7 to 10.

[7] The stochastic component of participant choices is well illustrated in these two sessions of the experiment. If we regress information purchases on information costs for the all the subjects in each round of every session, the R^2 is .23. In contrast, the R^2 for the session in Figure 1A is .05 and the R^2 for the session in Figure 1B is .20. In short, while the information cost incentives we have established are clearly related to information purchases, the strategic choices participants make include a significant idiosyncratic component.

current judgment as the weighted sum of the immediately prior judgments, with a 50% weight on the immediately prior judgment, and the remaining 50% partitioned equally among the three informants. Hence, each individual in this specification is influenced directly by her own prior judgment, as well as the judgment of three other participants. Each column corresponds to the contemporaneous, single period effect of a particular individual's judgment on each of the other individuals' judgments. For example, the fifth column characterizes the very limited short term effect of the individual who holds preference 5 in Part A of Figure 1. Only the individual with preference 2 requests information.

These short-term direct effects are not, however, simply additive across time. Instead, the information provided by preference holder 5 to preference holder 2 produces indirect effects on all 6 individuals (including preference holder 5) who request information from preference holder 2 at the subsequent time period. Hence, the short-term contemporaneous effects ignore much of the cumulative dynamic underlying communication and persuasion. In this experiment, we do not require individuals to maintain the same contacts across all the experimental sessions, and thus we do not empirically trace effects across the entire session. Rather, our intent is to consider the long term implications of the short term contacts that are established by the participants in the experiment, in an effort to consider both the direct and indirect effects of experts and information in political communication.

Long Term Dynamics of Political Communication

The process described in Equation 1 is recursive, and hence

$$\begin{aligned} p_1 &= Tp_0 \\ p_2 &= Tp_1 = T^2p_0 \\ &. \\ &. \\ &. \\ p_t &= T^tp_0 \end{aligned} \qquad (3)$$

This is a particularly helpful formulation, because it suggests that each entry in T^t provides the long term effect of the jth individual in moving the ith individual from p_0 to pt. If at any value of t, some column of T includes all nonzero elements, it suggests that every individual in the entire population is affected, either directly or indirectly, by every other individual in the entire population, and thus the process leads to convergent beliefs. We are thus assured that the T matrix for round 6 of session 5 leads to convergent beliefs because, in the first order matrix, the column for preference holder 5 contains all nonzero elements, and T raised to successively higher powers converges on the following set of identical row vectors.

$$T^* = \begin{matrix} .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \\ .096 & .250 & .205 & .093 & .084 & .091 & .181 \end{matrix} \qquad (4)$$

Hence we can identify an equilibrium vector for participants' judgments, which is simply the judgmental priors of the participants weighted by T*.

$$p^* = T^*p_0 \qquad (5)$$

Assume for the moment that p_0 provides the set of initial probabilities that each participant favors Candidate B, specified as (.2,.3,.4,.5,.6,.7,.8). This leads to an equilibrium vector of (.481, .481, .481, .481, .481, .481, .481). If we reversed the order of priors in p_0, p* would become an equilibrium vector with all values equal to .519. In short, these alternative outcomes reflect the greater influence of those individuals with preferences 1 through 3 relative to preferences 5 through 7.

A row of T* becomes the unit eigenvector for T,[8] and it provides a relative measure of each participant's influence, capturing both their direct and indirect effects within the network. By comparison to Figure 1A, we see that the individuals who purchased the most information become the opinion leaders in the process. Indeed, the participants in columns 2, 3 and 7 combine for 64 percent of the total network influence.

The network in Part B of Figure 1 produces a similar outcome. Part A of Table 3 shows the unit eigenvectors for both networks. In each instance, the individuals who purchased the most information demonstrate the strongest relative effects. Indeed, the three highest consumers of information account for 64 and 59 percent of opinion leadership.

These networks are inherently stochastic. Individuals need not purchase information, and even individuals who can obtain it for free do not necessarily obtain the full amount that is available. The relationship between information costs and preference is the same in both experimental periods, yet we see variation between the rounds in information purchases. No one in Part A obtained four pieces of private information, but two individuals in Part B purchased the maximum. In short, information costs and preference proximity generate important effects on network structure, but these effects are certainly not deterministic, and we see pronounced differences in networks between the two experimental periods.

Finally, it is important to recognize that the empirical model of opinion leadership in Part A of Table 1 is wholly due to the specification of network selection. That is, we are assuming network effects which are wholly mediated by an individual's choice of discussion partners, without any effects due to the inherent effects of information abundance and scarcity on the processing of either private information or socially communicated information. We turn to the consequences of information and expertise for the behavior of individuals, both with respect to the confidence they place in their own priors, as well as the extent to which they update their priors based on socially communicated information.

Information, Expertise, and Opinion Leadership

As Part B and C of Table 2 suggest, information consumption has important effects on the extent to which individuals depend on their own priors versus depend on messages received from other individuals. That is, individuals who purchase more information reveal more confidence in their own prior judgments, as well as relatively less confidence in the judgments of others. This moves us beyond a strictly sociological view of the problem based on the structure of the relationships among participants, introducing a psychological perspective toward the cognitive processing of new information and the decision-making process whereby individuals update their own preconceived judgments, in a highly uncertain environment, with information provided by others.

Unfortunately, major advances in the cognitive processing of information are rarely considered among network scientists, and major advances in network science appear to be unknown among students of

[8]A row vector in T* (t) provides the unit eigenvector of T – the row vector that, when multiplied times T, returns the same row vector, or tT=t.

cognition. It is as if network scientists ignore the nodes, and cognitive scientists ignore the edges! [9] The reality is that, as Parts B through D of Table 2 show, it is not simply the result of the communication pathways among actors that are important, but also the relative efficacy of those pathways, as well as the relative openness to communication. Indeed, these results reinforce the work of Lodge and Taber (2000) – those who know the most are the least willing to be moved by new information.

We build on these results by constructing T matrices that take account of these contingent effects for both network graphs in Figure 1. The matrix for Figure 1A is shown here:

$$T = \begin{matrix} .350 & .217 & .217 & .216 & .000 & .000 & .000 \\ .000 & .670 & .110 & .000 & .110 & .000 & .110 \\ .110 & .110 & .670 & .000 & .000 & .000 & .110 \\ .000 & .217 & .217 & .350 & .000 & .216 & .000 \\ .217 & .217 & .216 & .000 & .350 & .000 & .000 \\ .000 & .217 & .217 & .000 & .000 & .350 & .216 \\ .000 & .110 & .000 & .110 & .000 & .110 & .670 \end{matrix} \qquad (6)$$

Reflecting the results of Parts C and D of Table 2, the better informed rely more heavily on their priors and less heavily on social communication than the less informed. This produces, in turn, the unit eigenvector in Part B of Table 3, which displays an enhanced level of influence for the informed relative to the uninformed.

In summary, opinion leadership is both a sociological as well as a psychological phenomenon. Not only is the influence of opinion leaders related to their centrality within communication networks and the frequency with which they engage in political communication, but it is also due to the resilience and durability of their judgments. Experts are resistant to persuasion and committed to their own prior judgments, thereby giving them a persuasive advantage in the collective deliberations of democratic discussion.

The Decisive Effects of Slowly Decaying Priors

Finally, advances in cognitive research encourage us to take the mechanics of memory seriously in the analysis of political communication. Working memory is dramatically limited in its capacity, and objects in working memory can be lost after they are passed to long term memory. Hence, memory decay plays a role in the duration of even the strongest beliefs and judgments.

Analyses of these same experimental results support even short term effects on memory decay (Huckfeldt, Pietryka and Reilly 2011). That is, participants in the experiment update their prior judgments three times during a round, and during that short period of time we see a rate of decay in the priors that is especially precipitous among the least informed. At the same time, even the priors of most informed show the short-term consequences of memory decay.

Our goal is to consider the implications that arise due to differential rates of decay among experts and non-experts, and we modify the general model accordingly (see Friedkin and Johnsen 1990; Jackson 2008). Suppose that an individual's prior judgment competes directly with the updating process, but that the importance of the prior declines in time as a consequence of memory decay. We incorporate this idea into a revised model,

$$p_{t+1} = D^{t+1}p_0 + (I-D^{t+1})Tp_t \qquad (7)$$

[9] For particularly notable exceptions see Levitan and Visser (2009) and Lazer et al. (2010).

where the T matrix is taken from (6); D is a diagonal matrix with the rates (defined on a 0,1 interval) at which individuals' prior judgments survive in a single period of time; I is the identity matrix ; and I-D is a diagonal matrix with the rates at which individuals base their judgments on the messages received from informants ***as well as*** their own immediately prior judgments.

Hence, the importance of an individual's prior declines both in time and across individuals. For purposes of illustration, we set the rate of decay to .2 for individuals who purchased 2 or more pieces of information, and to .6 for individuals who purchased 0 or 1 piece of information. (These rates of decay are compatible with our earlier analyses showing rates of decay, structured by private investments in information.)

First, the impact of memory decay declines over time in this formulation. That is, D^{t+k} converges to zero as k increases, but it converges more rapidly among the least informed. Second, and in a similar fashion, $I\text{-}D^{t+k}$ converges on I (the identity matrix), as k increases. And hence, in the long run, the effect of memory decay disappears and we are left with the process described in the basic model (see equation 1). The end result is the same unit eigenvector that is displayed in Table 3B for Group 5, Session 6. The difference is that the system takes much longer to converge on the same equilibrium vector of shared judgments, and during that slow path to equilibrium, the judgments of the opinion leaders are more influential.

The question that arises is whether the long term makes much difference in the deliberations of democratic societies, and the answer is a resounding "sometimes"! Many issues play out on a short time scale, and in these instances opinion leaders are likely to be particularly influential because their priors decay so slowly. Other issues are of longer duration, and we should expect an inevitable convergence toward a long term equilibrium which serves to diminish priors even among opinion leaders.

A Simple Model of the Process

While memory constraints certainly operate on prior judgments, they also operate on the updates to these priors, as well as the messages that are communicated by others. Memory decay can be portrayed at the individual level by expressing the updating process for the subjects' judgments as a function of three factors: (1) decay in the most recently updated judgment, (2) decay in the initial (prior) judgment based on individually purchased private information, and (3) new incoming social information that is communicated by other subjects.

The effect of the prior. The model assumes that the initial (or prior) judgment, formed on the basis of privately purchased information, has an enduring effect that declines at a compound fixed rate between judgments. At the first update, the effect of the prior is wP_0, where w is defined as (1-rate of decay) and at the nth update, its effect is thus w^nP_0.

The effect of updated judgments. Updated judgments generate first order effects that also decline at a fixed rate. At the nth update, the effect of the previous update is αJ_{n-1}, where α is the survival of the previous judgment.

Incoming Information. At the same time that the prior and the previously updated judgments are subject to decay, the subject is responding to an ongoing stream of social information communicated by other subjects.

Hence the current judgment arises as a consequence of the rate of decay in an immediately prior judgment update, the rate of decay in an initial prior judgment, and the effect of contemporaneous social information.

$$\Delta J_t = -dJ_{t-1} + w^t P_0 + eI_t \quad (8)$$

where $\Delta J_t = J_t - J_{t-1}$; d = the rate of decay in the previous judgment, with d expected to lie between zero and 1; P_0=the prior judgment based on privately purchased information; w^t= the effect of the prior at J_t, with w expected to lie between 0 and 1; I_t = incoming social information received at t; and e = the educative impact of the new social information.

The model is rewritten as:

$$J_t = \alpha J_{t-1} + w^t P_0 + eI_t \quad , \quad (9)$$

where α = 1-d = the memory or survival of the previous judgment.

Employing recursion to push the model beyond the reach of our experimental observations yields

$$J_n = (w^n P_0 + \alpha w^{n-1} P_0 + \alpha^2 w^{n-2} P_0 + \ldots + \alpha^{n-1} w P_0) + eI_n + \alpha eI_{n-1} + \ldots + \alpha^{n-1} eI_1 \quad . \quad (10)$$

To consider the long term dynamic logic, we take the equation to its limit. For n sufficiently large, the equilibrium is

$$J_n = (w^n P_0 - \alpha^n w^0 P_0)/(1 - \alpha/w) + eI_n + \alpha eI_{n-1} + \ldots + \alpha^{n-1} eI_1 \quad . \quad (11)$$

Assuming that both α and w are bounded by 0 and 1, the effect of the prior converges on zero and the summary judgments inevitably depend on the continuing stream of incoming information, where the stream of information is weighted to favor the most recent information.

In short, the past is attenuated because this system of behavior forgets past events and past judgments rather than accumulating them – as any stable system must. How fast does the memory of this behavioral system decay? The key lies in the behavior of w^n and α^n. As α increases – as the immediately past updated judgment looms larger in the formulation of the current judgment – the importance of information received earlier maintains its effect longer.
Since the updated judgment is the mechanism whereby the prior is modified by new information, $\boldsymbol{\alpha}$ also provides an index on the temporal durability of effects due to messages from other participants. As $\boldsymbol{w}$ increases, the importance of the prior takes longer to disappear. In this context, it is important to consider the dynamic implications in the short-term as well as the long-term, and hence to obtain estimates for the model parameters.

Estimating the Model

For purposes of estimation, we multiply both sides of equation 4 by α before subtracting the corresponding sides of the equations from equation 5. Upon rearrangement this yields,

$$J_3 = \alpha J_2 + w^3 P_0 + eI_3 \quad (12)$$

Hence, regressing the final updated judgment regarding a candidate's position on the previous judgment, the prior, and the incoming social information, provides statistical estimates for the model parameters – α, w, and e.

Part A of Table 4 displays the results of estimating the model in equation 8 for high information subjects, defined as subjects who purchased more than 1 piece of information. For both candidate judgments, the final updated judgment (J_3) is regressed on the immediately preceding updated judgment (J_2), the initial prior judgment (P_0), and the immediately preceding (third) piece of communicated information (I_3). Part B of Table 4 carries out this procedure for low information subjects, defined as those who purchased less than 2 pieces of information.

First, the table shows that the effect of the initial (prior) judgment has an effect that is dramatically dependent on the amount of information purchased by a subject. That is, the prior only matters among those participants who invest in private information. Second, as would be expected, the table shows a substantial effect due to the immediately preceding update that is comparable among high and low information individuals. Third, the model shows a substantial effect due to the final (third) message that is attenuated by the amount of private information purchased by the participant.

Returning to the modified DeGroot model in equation 7, not only can we specify the rates of memory decay in the priors, but we can also take account of memory decay with respect to the social communication process that is captured in the T matrix. First, the effect of the immediately preceding judgment can be taken directly from the regression, as well as the effect that is due to the most recent socially communicated information. As the model in equation 6 suggests, earlier messages are subject to decay. The most recent message effect is ***"e",*** and earlier messages are discounted by raising α^{n-1} to successively higher powers. All the model parameters must be represented in the T matrix as summing to unity across the rows. This involves adjusting the parameter magnitudes so that their relative magnitudes relative to one another are maintained.

The model assumes that each individual has three informants, and that each individual cycles through the informants in the order in which they were initially chosen, receiving and responding to each message in the order in which it is received. Hence, the first informant sends messages at t=1, 4, 7, etc. The second informant sends messages at t=2, 5, 8, etc. And the third informant sends messages at t=3, 6, 9, etc. Hence we construct three T matrices, corresponding to the subjects first, second, and third choices of informants from the other subjects.

Hence the T_1 matrix becomes:

		Informant Preference						
		1	***2***	***3***	4	5	6	***7***
	1	.79	***.00***	***.21***	.00	.00	.00	***.00***
	2	***.00***	***.84***	***.00***	***.00***	***.00***	***.00***	***.16***
Requestor	***3***	***.00***	***.16***	***.84***	***.00***	***.00***	***.00***	***.00***
Preference	4	.00	***.00***	***.21***	.79	.00	.00	***.00***
	5	.00	***.00***	***.21***	.00	.79	.00	***.00***
	6	.00	***.21***	***.00***	.00	.00	.79	***.00***
	7	***.00***	***.00***	***.00***	***.00***	***.00***	***.16***	***.84***

The T2 matrix becomes:

		Informant Preference						
		1	***2***	***3***	4	5	6	***7***
	1	.79	***.00***	***.00***	.21	.00	.00	***.00***
	2	***.00***	***.84***	***.16***	***.00***	***.00***	***.00***	***.00***
Requestor	***3***	***.00***	***.00***	***.84***	***.00***	***.00***	***.00***	***.16***
Preference	4	.00	***.21***	***.00***	.79	.00	.00	***.00***
	5	.00	***.21***	***.00***	.00	.79	.00	***.00***
	6	.00	***.00***	***.00***	.00	.00	.79	***.21***
	7	***.00***	***.16***	***.00***	***.00***	***.00***	***.00***	***.84***

And the T3 matrix becomes:

		Informant Preference						
		1	***2***	***3***	4	5	6	***7***
	1	.79	***.21***	***.00***	.00	.00	.00	***.00***
	2	***.00***	***.84***	***.00***	***.00***	***.16***	***.00***	***.00***
Requestor	***3***	***.16***	***.00***	***.84***	***.00***	***.00***	***.00***	***.00***
Preference	4	.00	***.00***	***.00***	.79	.00	.21	***.00***
	5	.21	***.00***	***.00***	.00	.79	.00	***.00***
	6	.00	***.00***	***.21***	.00	.00	.79	***.00***
	7	***.00***	***.00***	***.00***	***.16***	***.00***	***.00***	***.84***

where the preferences for well informed subjects are shown in bold parentheses.

In a similar fashion, we can estimate the weights that subjects place on their own priors, and on this basis construct the D matrix in equation 7. The coefficients on the priors in Table 4 provide an estimate of ***w*** (the rate of decay in the prior) raise to the third power. Hence, the cube root provides an estimate for the prior's time variant rate of decay rate -- .57 among the more informed and .27 among the less informed. As we will see, this dramatic difference carries enormous consequences for the social dynamic, and it produces the following D matrix.

$$D = \begin{matrix} .27 & .00 & .00 & .00 & .00 & .00 & .00 \\ .00 & .57 & .00 & .00 & .00 & .00 & .00 \\ .00 & .00 & .57 & .00 & .00 & .00 & .00 \\ .00 & .00 & .00 & .27 & .00 & .00 & .00 \\ .00 & .00 & .00 & .00 & .27 & .00 & .00 \\ .00 & .00 & .00 & .00 & .00 & .27 & .00 \\ .00 & .00 & .00 & .00 & .00 & .00 & .57 \end{matrix}$$

Based on the D and T matrices, as well Equation 7, as we can iteratively estimate convergence paths for the individual requestors. Figure 2a displays the DeGroot estimates of the requestors' candidate estimates across time. Highly informed individuals (2, 3, and 7) are shown with a solid red line, whereas low-information individuals are shown with dashed black lines. A few things are particularly notable about this graph. The highly informed individuals, most of whom begin estimating Candidate A's position at the high end of the scale, appear to be much more influential to the final equilibrium than low-information individuals. The three high-information subjects estimated Candidate A's position as a 6 on average, while the low-information subject averaged a 3. However, the final equilibrium value estimated by our modified DeGroot model (5.30) is far closer to the estimates of the high information, rather than

the low-information, voters.

The influence of the experts arises as a consequence of two factors. First, high-information voters have a much stronger attachment to their priors than low-information voters. Second, high-information voters are asked for information more often than low-information voters, so their viewpoints are more influential throughout the network. As can be seen in Figure 2a, high-information voters also tend to be slower to converge to equilibrium – especially early on – as their attachment to their prior makes them much more resistant to change.

Figure 2b displays the convergence towards equilibrium as a proportion of the distance between the subject's initial prior judgment and the final equilibrium.

$$\frac{P_t - P^*}{P_0 - P^*}$$

By definition, every subject starts off at a "1," and values greater than 1 indicate that the subject has diverged from the eventual equilibrium.[10] Like before, solid red lines indicate high-information individuals, whereas dashed black lines indicate low-information individuals. Equilibrium is represented by a solid horizontal line at zero. Hence the criterion variable standardizes a subject's distance from equilibrium at any point in time relative to the initial distance from equilibrium at the beginning of the process. This serves to enhance the observed magnitude of change among those individuals who begin the process near to the ultimate equilibrium.

In this graph, we see that most individuals behave roughly as expected: three low-information individuals, relatively unattached to their priors, converge to equilibrium more rapidly on average than the high-information subjects. The high-information subjects also converge to equilibrium, but the slow decay in their priors delays the convergence.

The seeming exception is the low-information individual whose behavior is characterized by a few wild swings before she or he also begins to converge. This path to equilibrium is explained by the particular patterns of interaction within the communication process – the subject requested information from particular individuals who provide divergent signals, pushing the subject farther away from the ultimate equilibrium. (While the swings are not as pronounced, substantial shifts can also be seen in two of the high-information subjects.) While this initial advice was eventually attenuated, the impact of that information persisted due to the subject's reliance on his or her own immediately prior judgments.

Hence Figure 2 serves to illustrate the noisy nature of the communication process. While strong pressures toward equilibrium tend to filter and dampen aberrant messages, particular time paths are highly dependent on particular communication patterns and events, as well as the order in which information is received, leading to highly diverse and variable dynamics across individuals and groups.

Implications and Conclusions

While information costs constitute an impediment to participation for many individuals, these costs are highly variable across individuals. As Wolfinger and Rosenstone (1980) suggest, information

[10] In theory, values under zero indicate that the subject, after having prematurely converging rapidly upon equilibrium, has overshot and diverged away from equilibrium to the other side. However, there are no cases of this in our currently selected round.

costs are lower among those individuals for whom the acquisition and processing of information is easier – typically individuals with higher levels of education. And as Fiorina (1990) argues, many individuals may find information about politics to be intrinsically rewarding – they read about the Democrats and Republicans with the enthusiasm of a basketball fan reading about the Dallas Mavericks. For these people, information costs are in fact negative, and staying informed thus becomes a self-reinforcing behavior.

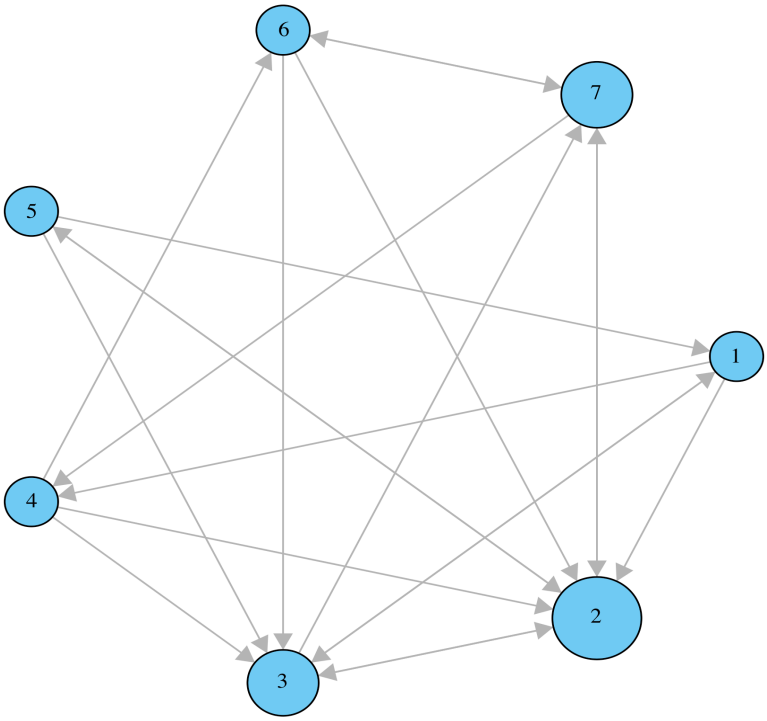
Hence, we should not be surprised to see the division of labor in the communication of political information suggested by Berelson and his colleagues (1954). Individuals with high information costs will intentionally or unintentionally rely on individuals with minimal (or negative) information costs. The resulting patterns of communication may indeed produce an electorate that makes surprisingly expert choices – at least relative to the low mean levels of political awareness among individuals within the electorate (Converse 1964; Zaller 1992; Delli Carpini and Keeter 1996; Page and Shapiro 1992; Erikson, MacKuen, and Stimson 2002). In this way, civic capacity in the aggregate benefits from the diffusion of expert opinion within and throughout networks of political communication.

At the same time, political communication is not an antiseptic exercise in civic education. It involves people with opinions and interests who are not only learning from one another but also persuading one another. The accumulated record, based on surveys and experiments, suggests that the process tends to be driven by knowledge and expertise. That is, the process is skewed in favor of politically engaged participants with more information – the very individuals identified by Lodge and Taber (2000) as being most opinionated and most likely to demonstrate motivated reasoning. Moreover, because the experts are often activists within their own closely held networks of communication, they have the potential to mislead as well as to inform. That is, the information being communicated is typically biased, reflecting the interests of the informant, and thus we cannot assume that all crowds are wise crowds. Not only does information diffuse through communication networks, but misinformation as well.

Finally, this paper bumps up against an inherent limitation of the DeGroot model in its basic form. That is, the model predicts that self contained groups – groups that are tied together by direct and indirect ties – will inevitably converge on an equilibrium of shared beliefs. At the same time, the empirical record demonstrates the survival of heterogeneous opinions within self contained populations. Not only do the friends of your friends hold views with which you disagree, but you probably have at least a few friends with whom you are not in perfect harmony. Portraying the dynamic that yields a stable, heterogeneous equilibrium is an ongoing challenge in the study of communication networks (Huckfeldt, Johnson, and Sprague 2004) .

Figure 1. Directed graphs for randomly chosen rounds. Size of node indexes amount of information purchased. Direction of edge signifies the participant from whom information is being requested.

A. Session 5, Round 6:



B. Session 8, Round 3:

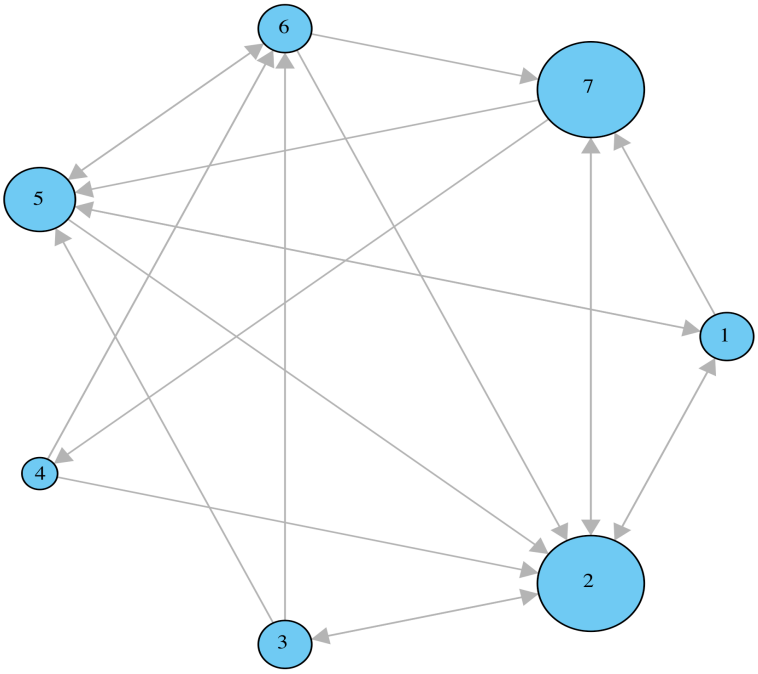


Figure 2a. Estimated convergence to equilibrium among subjects by expertise

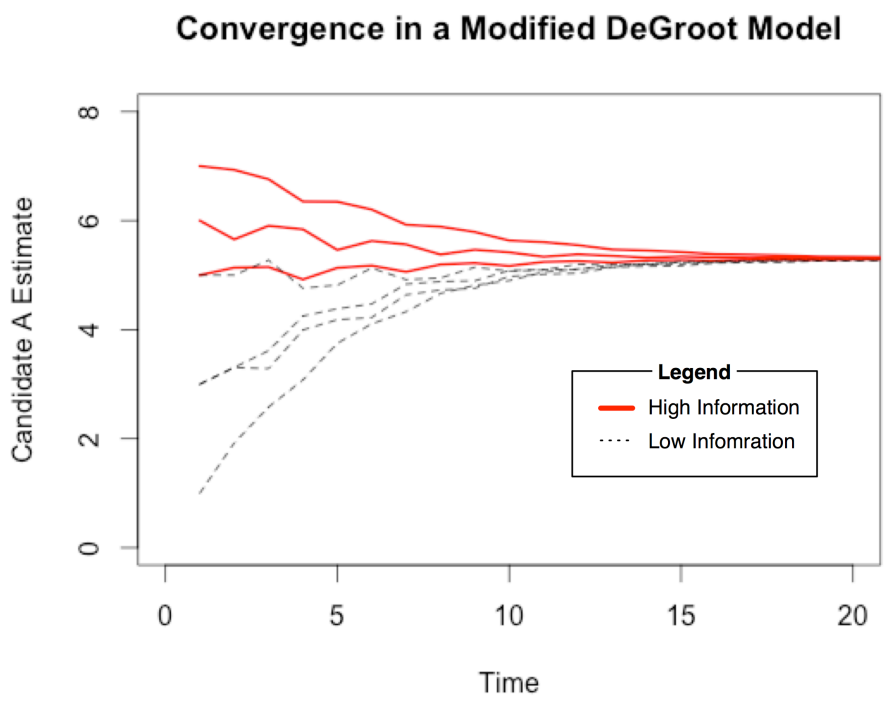


Figure 2b. Estimated proportional convergence to equilibrium among subjects by expertise

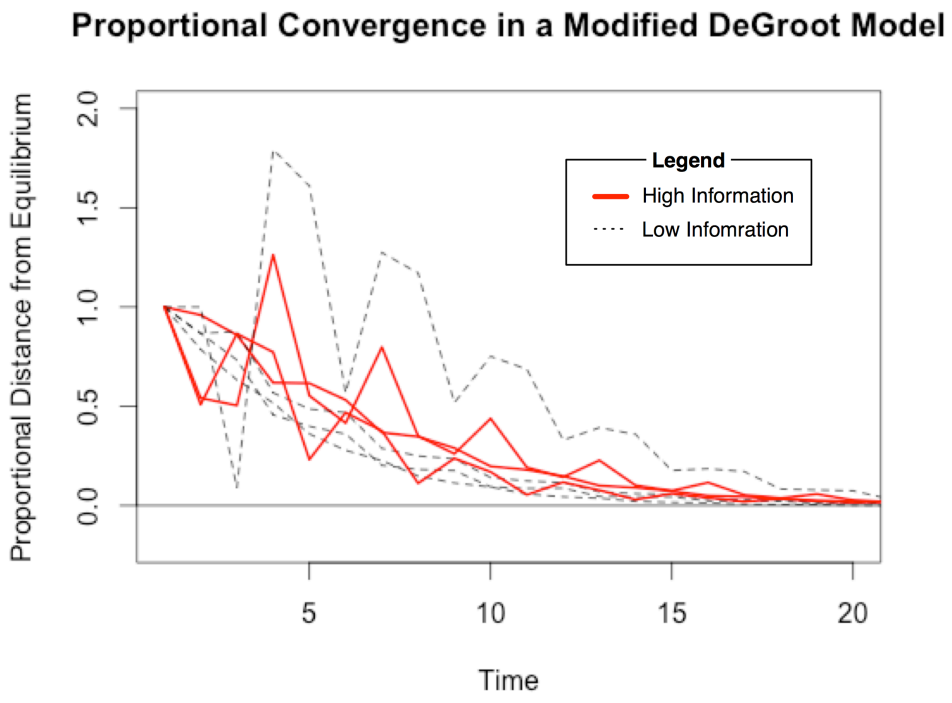


Table 1. Network formation in experiment.

A. Subject's selection of informants at each round by the distance in preferences between the subject and each potential informant, and the amount of information purchased by the potential informant . (Logit model. Adjusted for clustering on subjects.)

	Coefficient	s.e.	t-value
Distance between preferences	-.14	.04	3.65
Amount of information purchased	.19	.04	4.61
constant	.74	.13	5.62

N = 4494 (84 subjects)
$\chi 2$,df,p = 34, 2, .00

B. Predicted probability that a dyad will form based on information purchased by potential informant and distance between preferences of subject and potential informant.

information purchased by informant	Distance between Preferences in Dyad					
	1	2	3	4	5	6
0	.65	.61	.58	.54	.51	.48
1	.69	.66	.62	.59	.56	.52
2	.73	.70	.67	.64	.60	.57
3	.76	.74	.71	.68	.65	.62
4	.80	.77	.75	.72	.69	.66

Table 2. Subject's final judgment regarding the Candidate "A" at each round by their initial (prior) judgment as well as the information conveyed by each of their informants. (Least squares models absent intercepts. Standard errors are adjusted for clustering on subjects.)

A. All subjects, with no weights for information purchases.

	Coefficient	s.e.	t-value
Prior judgment	.51	.04	12.61
First message	.17	.02	9.46
Second message	.14	.03	5.36
Third message	.17	.03	5.80

N = 749 (84 subjects)
R^2= .92
Root MSE= 1.06

B. All subjects, with priors weighted by information purchases.

	Coefficient	s.e.	t-value
Prior judgment	.44	.05	9.15
Amount of information purchased	-.10	.05	1.90
Prior X info purchased	.05	.02	2.86
First message	.17	.02	9.05
Second message	.15	.03	5.56
Third message	.18	.03	6.19

N = 749 (84 subjects)
R^2= .92
Root MSE= 1.05

C. Subjects who purchased more than 1 piece of information on candidates.

	Coefficient	s.e.	t-value
Prior judgment	.67	.04	15.12
First message	.10	.02	4.90
Second message	.10	.03	3.85
Third message	.14	.03	5.05

N = 454 (74 subjects)
R^2= .95
Root MSE= .86

D. Subjects who purchased less than 2 pieces of information on candidates.

	Coefficient	s.e.	t-value
Prior judgment	.35	.06	5.95
First message	.23	.04	6.39
Second message	.16	.04	3.85
Third message	.21	.06	3.46

N = 295 (59 subjects)
R^2= .89
Root MSE= 1.23

Table 3. Unit eigenvectors for experimental periods. Expert effects in bold italics.

	Participant with Preference: 1	2	3	4	5	6	7	Σ expert
A. Baseline condition.								
Group 5, Period 6:	(.096	***.250***	***.205***	.093	.084	.091	***.181***)	.64
Group 8, Period 3:	(.141	***.250***	.084	.057	***.173***	.123	***.171***)	.59
B. With information weights.								
Group 5, Period 6:	(.059	***.305***	***.249***	.057	.052	.056	***.222***)	.78
Group 8, Period 3:	(.090	***.312***	.053	.036	***.217***	.078	***.214***)	.74

Table 4. Final judgment regarding candidate positions by initial prior judgment, immediately previous judgment, and previous (third) message received from other participants. For high information and low information subjects.

A. High information subjects who purchased more than 1 piece of information.

	Candidate A		Candidate B	
	Coef.	t	Coef.	t
Prior	.19	2.85	.28	4.07
Previous judgment	.65	8.88	.60	7.27
Previous message	.12	5.32	.10	5.09
Constant	.12	1.22	.12	1.05
N=	454		454	
subjects=	74		74	
R2=	.79		.83	
Root MSE=	.67		.62	

parameters

w=.57	w=.65
α=.65	α=.60
e=.12	e=.10

B. Low information subjects who purchased less than 2 pieces of information.

	Candidate A		Candidate B	
	Coef.	t	Coef.	t
Prior	.02	.59	.06	4.07
Previous judgment	.67	9.01	.64	7.27
Previous message	.18	4.15	.20	5.09
Constant	.33	1.98	.41	1.66
N=	295		295	
subjects=	59		59	
R2=	.55		.53	
Root MSE=	.99		1.07	

parameters

w=.27	w=.39
α=.67	α=.64
e=.18	e=.20

References

Ahn, T.K., R. Huckfeldt, and J.B. Ryan. 2010. "Communicaiton, Influence, and Informational Asymmetries among Voters," Political Psychology 31: 763-787.

Ahn, T.K., Robert Huckfeldt, Alexander K. Mayer, and John B. Ryan. 2008 "Political Experts and the Collective Enhancement of Civic Capacity." Paper presented at the annual meeting of the Midwest Political Science Association, Chicago.

Austin-Smith, David. 1990. "Information Transmission in Debate." *American Journal of Political Science* 34: 124—152.

Axelrod, Robert, 1997a . The Dissemination of Culture: A Model with Local Convergence and Global Polarization. *Journal of Conflict Resolution* 41: 203-26.

Barabasi, Albert-Laszlo. 2002. *Linked: The New Science of Networks*. Cambridge, MA: Perseus.

Berelson, Bernard R., Paul F. Lazarsfeld, and William N. McPhee. 1954. *Voting: A Study of Opinion Formation in a Presidential Election*. Chicago: University of Chicago Press.

Boudreau, Cheryl. 2008. "Closing the Gap: When Do Cues Eliminate Differences Between Sophisticated and Unsophisticated Citizens?" Working paper, University of California, Davis

Boyd, Robert and Peter J. Richerson. 1985. *Culture and the Evolutionary Process.* Chicago: The University of Chicago Press.

Calvert, Randall L. 1985.. The Value of Biased Information: A Rational Choice Model of Political Advice. *Journal of Politics* 47: 530-555.

Converse, Philip E. 1964. "The Nature of Belief Systems in Mass Publics." In. D. E. Apter, ed. *Ideology and Discontent*. New York: Free Press, 206-261.

Crawford, Vincent, and John Sobel. 1982. "Strategic information Transmission." Econometrica 50(6): 1431-51.

DeGroot, M.H. 1974. "Reaching a Consensus," Journal of the American Statistical Association 69: 118-121.

xDelli Carpini, Michael X. and Scott Keeter. 1996. *What Americans Know about Politics and Why It Matters*. New Haven, Connecticut: Yale University Press.

Downs, Anthony. 1957. *An Economic Theory of Democracy*. New York: Harper and Row.

Druckman, James N. and Kjersten R. Nelson. 2003. Framing and Deliberation: How Citizens' Conversations Limit Elite Influence. *American Journal of Political Science* 47: 728-744.

Erikson, Robert S., Michael B. MacKuen, and James A. Stimson. 2002. *The Macro Polity*. New York: Cambridge University Press.

Farrell, Joseph and Matthew Rabin. 1996. "Cheap Talk," Journal of Economic Perspectives 10: 103-118.

Fehr, Ernst and Simon Gächter. 2002. “Altruistic Punishment in Humans,” Nature 415:137-140.

Festinger, Leon. 1957. *A Theory of Cognitive Dissonance*. Palo Alto, CA: Stanford University Press.

Fiorina, Morris P. 1990. “Information and Rationality in Elections.” In *Information and Democratic Processes*, ed. John A. Ferejohn and James H. Kuklinski. Urbana: University of Illinois Press.

Huckfeldt, Robert. 1983. “Social Contexts, Social Networks, and Urban Neighborhoods: Environmental Constraints on Friendship Choice.” *The American Journal of Sociology*, 89: 651-669.

Huckfeldt, Robert. 2001. The Social Communication of Political Expertise. *American Journal of Political Science* 45: 425-438.

Huckfeldt, Robert, Paul E. Johnson, and John Sprague. 2004. Political Disagreement. Cambridge University Press.

Huckfeldt, Robert, Matthew Pietryka, and Jack Reilly. 2011. “Noise, Bias, and Expertise in Political Communication Networks.” UC Davis: working paper.

Huckfeldt, Robert and John Sprague. 1993. "Citizens, Contexts, and Politics," in A.W. Finifter (ed.), Political Science: The State of the Discipline II. Washington, D.C.: American Political Science Association, 281-303.

Huckfeldt, Robert and John Sprague. 1995. *Citizens, Politics, and Social Communication: Information and Influence in an Election Campaign*. New York: Cambridge University Press.

Johnson, James. 1993. “Is Talk Really Cheap? Prompting Conversation Between Critical Theory and Rational Choice.” American Political Science Review 87: 74-86.

Jackson, Matthew O. 2008. Social and Economic Networks. Princeton University Press.

Katz, Elihu. 1957. “The Two Step Flow of Communication: An Up-to-Date Report on an Hypothesis.” *Public Opinion Quarterly*, 21:67-81.

Katz, Elihu and Paul F. Lazarsfeld 1955. *Personal Influence: The Part Played by People in the Flow of Mass Communications.* New York: Free Press.

Kunda, Ziva (1990). The Case for Motivated Reasoning. *Psychological Bulletin* 108(3): 480- 498.

Lau, Richard R. and David P. Redlawsk. 1997. “Voting Correctly.” *American Political Science Review*, 91: 585-598.

Lazarsfeld, Paul F., Bernard Berelson and Hazel Gaudet. 1948. *The People’s Choice: How a Voter Makes Up His Mind in a Presidential Campaign*. New York: Columbia University Press.

Lazer, David B. Rubineau, N. Katz, C. Chetkovich, and M. Neblo. 2010. The Coevolution of Networks and Political Attitudes, Political Communication 27: 248-274.

Levitan, Lindsey. C., & Visser, Penny S. 2009. “Social Network Composition and Attitude Strength:

Exploring the Dynamics within Newly Formed Social Networks,”. Journal of Experimental Social Psychology, 45: 1057-1067.

Lodge, Milton and Charles Taber. 2000. “Three Steps Toward a Theory of Motivated Political Reasoning.” In Anthony Lupia, Mathew D. McCubbins, and Samuel L. Popkin (eds.) *Elements of Reason: Cognition, Choice, and the Bounds of Rationality*. New York: Cambridge University Press, 183-213.

Lord, Charles G., Lee Ross, and Mark R. Lepper. 1979. “Biased Assimilation and Attitude Polarization: The Effects of Prior Theories on Subsequently Considered Evidence.” *Journal of Personality and Social Psychology*, 37:2098-2109.

Lupia, Arthur and Mathew D. McCubbins. 1998. *The Democratic Dilemma: Can Citizens Learn What They Need To Know?* New York: Cambridge University Press.

Nickerson, David. 2008. "Is Voting Contagious? Evidence from Two Field Experiments," American Political Science Review 102: 49-57.

Page, Benjamin I. and Robert Y. Shapiro. 1992. *The Rational Public: Fifty Years of Trends in Americans' Policy Preferences*. Chicago: University of Chicago Press.

Putnam 1993.

Ryan, John Barry. Forthcoming. “Social Networks as a Shortcut to Correct Voting.” American Journal of Political Science.

Taber, Charles and Milton Lodge. 2006. “Motivated Skepticism in the Evaluation of Political Beliefs.” *American Journal of Political Science*, 50: 755-769.

Verba, Sidney. 1961. *Small Groups and Political Behavior*. Princeton: Princeton University Press.

Weimann, Gabriel. 1982. "On the Importance of Marginality: One More Step into the Two-Step Flow of Communication." *American Sociological Review*, 47 (6): 764-773.

Weimann, Gabriel. 1991. "The Influentials: Back to the Concept of Opinion Leaders?" *Public Opinion Quarterly*, 55: 267-279.

Wolfinger, Raymond E. and Stephen J. Rosenstone. 1980. *Who Votes?* New Haven: Yale University Press.