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THE CURSE OF UNINFORMED VOTING: AN EXPERIMENTAL STUDY

JENS GROßER
MICHAEL SEEBAUER

Department of Economics
University of Cologne
Albertus-Magnus-Platz
D-50923 Köln
Germany

http://www.wiso.uni-koeln.de

The curse of uninformed voting: An experimental study

Jens Großer (Florida State University and Institute for Advanced Study, Princeton)

Michael Seebauer (University of Erlangen-Nuremberg)

ABSTRACT

We study majority voting over two alternatives in small groups. Individuals have identical preferences but are uncertain about which alternative can better achieve their common interest. Before voting, each individual can get informed, to wit, buy a valuable but imperfect signal about the better alternative. Voting is either voluntary or compulsory. In the compulsory mode, each individual can vote for either of the two alternatives, while in the voluntary mode they can also abstain. An uninformed random vote generates negative externalities, as it may override informative group decisions in pivotal events. In our experiment, participants in groups of three or seven get informed more often with compulsory than voluntary voting, and in this way partly counteract the curse of uninformed voting when they cannot avoid it by abstaining. Surprisingly, uninformed voting is a common phenomenon even in the voluntary mode! A consequence of substantial uninformed voting is poor group efficiency in all treatments, indicating the need to reconsider current practices of jury and committee voting.

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Jens Großer is Assistant Professor at the Departments of Political Science and Economics, Florida State University and Experimental Social Science at Florida State, 531 Bellamy Hall, Tallahassee, FL 32306-2230, and a member of the Institute for Advanced Study, School of Social Science, Princeton in the academic year 2012-13. (jgrosser@fsu.edu). Michael Seebauer is PhD Candidate at the Department of Economics, University of Erlangen-Nuremberg, Lange Gasse 20, 90403 Nuremberg, Germany (michael.seebauer@fau.de).

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1 Introduction

Groups of individuals make decisions in almost every realm of life. An important rationale for this phenomenon is their potential to aggregate information that would otherwise lie dispersed and dormant among the individuals. Accordingly, it is widely argued that more heads have, or can generate, more knowledge than fewer heads, and therefore, larger groups tend to make better decisions than smaller groups. The importance of knowledge accumulation and aggregation in groups is evident in the following examples: juries consider evidence to acquit or convict the accused; legislative committees gather know-how of experts and special interests groups in hearings; hiring committees evaluate documents of applicants; and editors ask referees for their opinions about research papers. But do larger groups really perform better than smaller groups in the presence of free rider incentives (e.g., when gathering information is time-consuming and costly)? And how does the answer depend on the specific information aggregation mechanism (e.g., the communication or voting procedure)? Do individuals get informed more often with compulsory than voluntary voting? At first glance, banning abstention, such as for jurors in criminal trials, seems to be a practical solution to improve group decision-making, but the impact on informational efforts and thus performance is virtually unknown. We tackle these and similar questions using game theory and a laboratory experiment by studying knowledge accumulation and aggregation in different sized groups where individuals have identical preferences, information acquisition is costly, and consensus is obtained by voluntary or compulsory majoritarian voting.

The aggregation of private information via voting is a key function of democratic decision-making.[1] When individuals have identical preferences but different opinions because they are uncertain about which of several alternatives can best achieve the common interest, then pooling their private information leads to a mutual agreement about the *correct* alternative (suppose only one is best). The important Condorcet Jury Theorem (1785) uses statistical inference to show that majority voting can assume this pooling function, and therefore, the group's decision is more likely correct than any individual's decision and almost surely correct in very large groups. In the most basic version of the

[1] More generally, Piketty (1999) puts the importance of information aggregation in elections on a level with the importance of information aggregation in markets.

model underlying this theorem, a group chooses between two alternatives via costless majority voting and uncertainty is given by a common prior probability of one-half, indicating that each alternative has the same chance of being the better one. Moreover, each individual gets a costless private signal, to wit, an independent Bernoulli trial showing the correct alternative with probability $p \in \left(\frac{1}{2}, 1\right)$ and the incorrect alternative with probability $1 - p$. Thus, signals are valuable but imperfect and hence may induce conflicting opinions. Using this simple model, the intuition of Condorcet's Jury Theorem is as follows: the pool of private information grows with each sincere vote (i.e., it mirrors the signal) and, since $p > \frac{1}{2}$, the expected difference in votes grows in favor of the correct alternative so that the probability of a correct group decision weakly increases in the group size.[2] And, by the law of large numbers, in very large groups the fraction of correct signals approaches p with probability one, so that the vote outcome almost surely matches the correct alternative.

The very promising results of the theorem rely on several assumptions, chief among which are that information via private signals is costless and that voting is sincere and costless. But it ignores the free rider incentives that are generated if for example, more realistically, costs of signal acquisition are involved (Downs 1957; Olson 1965). When the incentive to rely on informational efforts of others is strong enough, the result can be "rational ignorance" where the endogenous information pool shrinks rather than increases in the group size, say, if the size is doubled but average effort drops by more than half due to stronger free riding in the larger group (Martinelli 2006; Mukhopadhaya 2003). In other words, Condorcet's Jury Theorem need not hold in the presence of free rider incentives.

In the present paper, we examine how costly information acquisition depends on the group size (three and seven in our experiment) and if compulsory voting induces individuals to get informed more often than voluntary voting.[3] In our game, they first decide independently and simultaneously on whether to buy a private signal and thereafter vote, at no cost, independently and simultaneously over two alternatives using majority rule with random tie-breaking (in the voluntary mode, they can also

[2] According to Austen-Smith and Banks (1996), an "informative" vote mirrors the signal and a "sincere" vote maximizes expected payoffs and may oppose the signal. For our parameters, the two kinds of votes always coincide so we can use both terms synonymously. And, an extra sincere vote *weakly* increases the probability of a correct group decision, because it yields an increase if an odd number of votes is reached but does not change the probability if an even number is reached.

[3] For a more general discussion of voluntary versus compulsory voting and the incentive effects, see for example Abraham (1955), Birch (2009), and Lijphart (1997). Moreover, Börgers (2004) and Großer and Giertz (2009), among others, compare voluntary and compulsory costly voting with private preferences.

abstain). Hence, we depart from Condorcet's basic model in two important ways, to wit, by using endogenous costly signals and by comparing situations where individuals—informed and uninformed—are either free or obliged to vote (in contrast, in the basic model everyone is assigned a costless signal and thus prefers to vote anyway). Individuals base their decisions only on group events that are both pivotal and informative, the latter meaning that the combined signals in the group conveyed by sincere votes favor one of the alternatives. In the one extreme, if everyone is uninformed and votes randomly or abstains, then no signal costs accrue and the group decision is correct half of the time. In the other extreme, if everyone is informed and votes sincerely, then it is correct with maximum possible probability, but the total signal costs may outweigh the higher expected benefits. We utilize *quantal response equilibrium* (QRE; McKelvey and Palfrey 1995), which generalizes Bayesian Nash equilibrium (BNE) by allowing for decision-making errors, in order to derive individual signal acquisition probabilities in between these two extremes, including for large groups. We also derive the effects of these probabilities on correct group decisions and efficiency, using cost-benefit analysis, and test the (comparative statics) predictions for our experimental parameters against the data.

When voting is voluntary, in theory, uninformed individuals rationally abstain—as their random vote may override an informative group decision in pivotal events—and let the informed decide, whose sincere votes increase the probability of a correct group decision and thus expected benefits. This form of delegation is named the "swing voter's curse" (Feddersen and Pesendorfer 1996).[4] By contrast, with compulsory voting the curse of uninformed voting is tolerated. If it prevails, the expected net benefits (i.e., the increase in benefits) of voting informatively are too small compared to the costs and fewer individuals get informed vis-à-vis voluntary voting. However, the anticipation of the curse can also boost signal acquisition as the net benefits are augmented by the value of "curse avoidance," and this happens more likely in smaller groups where free rider incentives are weaker. Such endogeneity effects are very different from the situation with fixed information levels, where expected efficiency is greater with the opportunity to abstain (e.g., Bhattacharya, Duffy, and Kim 2013; Krishna and Morgan 2011, 2012) but

[4] The intuition of the curse is as follows: suppose that individual i is uninformed, and informed (uninformed) others vote sincerely (abstain). In pivotal events where one alternative leads by one vote of others, if i *abstains*, then the probability of a correct group decision is $p > \frac{1}{2}$. However, if i *votes randomly*, then with probability one-half her vote turns a win of the more promising alternative into a tie (which is decided by a coin flip) and with probability one-half her vote only raises its winning margin, so the group decision is correct with probability $\frac{p}{4} + \frac{p}{2} = \frac{3}{4}p$, which is smaller than the p for abstaining.

might be further improved, for example, by a turnout-enhancing lottery prize for a random voter (Gerardi et al. 2009). Another important difference with endogenous costly signals is that observing someone's voluntary or compulsory vote does not reveal whether the individual has made informational efforts, but in the voluntary mode a spotted abstainer may be deemed a free-rider. To wit, uninformed abstaining is socially desirable, however, being ignorant in the first place may not be seen like that. By contrast, with exogenous signals only the favorable view of curse avoidance is valid. Hence, with endogenous costly signals, there are incentives for the uninformed to vote due to the public good nature of information and the possibility that others will punish abstainers in one way or another (see also DellaVigna et al. 2013; Funk 2010; and Bernstein, Chadha, and Montjoy 2001 for overreporting voting).

Since the mid-1990s, game theorists have begun to relax the assumptions of Condorcet's Jury Theorem and examined a variety of different changes to the basic model.[5] Austen-Smith and Banks (1996) study the theorem as an incomplete information game and show that BNE generally involves some uninformative voting, noting that rational individuals only care about pivotal events (Downs 1957), infer aggregate information from their own signal and others' votes in pivotal events, and base their vote on this information and the pivot probabilities.[6] However, for our parameters, everyone voting informatively is actually a BNE (Austen-Smith and Banks 1996, p. 38). Feddersen and Pesendorfer (1996) allow for abstention from voting and distinguish between "partisans" who always vote for the same alternative and "independents" who want to select the correct alternative and are either informed or uninformed. They show that uninformed independents have incentives to abstain even if voting is costless (i.e., the swing voter's curse) and to vote in order to counterbalance any partisan bias so as to maximize the vote impact of their informed allies (see also Feddersen and Pesendorfer 1997, 1999). The Feddersen-Pesendorfer model finds support in the laboratory (Battaglini, Morton, and Palfrey 2010; and with qualification, Morton and Tyran 2011) and from observational studies (e.g., Coupé and Noury 2004; Lassen 2005; Matsusaka 1995; McMurray 2010; Palfrey and Poole 1987; Wattenberg, McAllister, and

[5] For surveys, see Gerling et al. (2005) and Piketty (1999). For example, Ladha (1992) studies correlated voting and finds that Condorcet's Jury Theorem still holds under fairly general conditions in large groups (small groups require substantial restrictions), and the probability of a correct group decision is inversely related with vote correlation.

[6] See also McLennan (1998) and Wit (1998). Feddersen and Pesendorfer (1998) show that with unanimity rule the innocent may be convicted more often in larger than smaller juries, and the probability of false verdicts increases compared to other voting rules. In the laboratory, Guarnaschelli, McKelvey, and Palfrey (2000) find fewer incorrect convictions with unanimity than majority voting.

Salvanto 2000). All these studies use exogenous information. By contrast, we examine voluntary and compulsory majoritarian voting when individuals decide on whether or not to get informed. Also, the effects of potential ignorance on efficiency are not easily quantifiable in the field (an exception is the study of Bartels 1996, where uninformed voting leads to biased results in U.S. Presidential Elections). By contrast, our controlled laboratory study allows for a more detailed analysis of the mutual effects of endogenous costly signals and abstention, and their consequences for efficiency. Our findings with regard to these relationships have important implications for the design of juries and committees.

Rational choice scholars (Downs 1957; Olson 1965) have pointed out that, generally, gathering information about policy alternatives is costly. Therefore, individuals have incentives to free ride on others' informational efforts, which can result in rational ignorance. Mukhopadhaya (2003) revisits Condorcet's Jury Theorem by studying endogenous costly signals and finds that in BNE the information pool can shrink in the group size. In the same vein, Martinelli (2005) shows that if the signal quality depends on the amount invested, individual efforts go to zero as the electorate goes to infinity. However, if the marginal costs are near zero for nearly irrelevant information, then the vote outcome is nonetheless representative of the majority. Feddersen and Sandroni (2006) study costly signal acquisition in an ethical voter model and show that a significant fraction of a large electorate gets informed, and successful information aggregation depends on the signal costs and quality. Oliveros (2012) presents a model in which costs are increasing in the signal quality and finds that BNE exist where, for some individuals, abstention is positively related with quality. Moreover, Gerardi and Yariv (2008), Gershkov and Szentes (2009), and Persico (2003), among others, examine costly signal acquisition as a mechanism design problem, where the designer seeks to implement a socially optimal committee size and voting rule in order to overcome the free rider problem. The following recent, independent studies are most closely related to ours. Shineman (2013) experimentally studies the voluntary and compulsory modes as an individual decision-making problem with costly voting and signal acquisition, and Tyson (2013) analyzes this situation as an incomplete information game and allows for partisans and independents. Sastro and Greiner (2010) investigate abstention and vote invalidation with exogenous signals in both voting modes in the laboratory. Finally, Elbittar et al. (2013) experimentally study endogenous signal acquisition with majority and unanimity voting for different group sizes. To our knowledge, we were the first to study the effects of voluntary versus compulsory voting on endogenous signal acquisition and uninformed voting, and ultimately on group efficiency.

2 The game and predictions

The game

An odd-sized group of $2n + 1$ individuals, labeled $i = 1, \dots, 2n + 1$, is choosing between two alternatives, A and B, through majority voting (a coin flip breaks a tie). We assume that each individual is risk neutral and maximizes her expected own payoffs. Moreover, they all have a common interest to align the group decision with an unobservable "true state" of the world, which is also either A or B, with equal common prior probability for each state. For example, a jury wants to acquit the innocent and convict the guilty. Due to the uncertainty about the truth, however, individuals may have different opinions about which alternative is correct in this regard. Formally, their payoffs are identical ex post and given by $U(A, A) = U(B, B) = 1$ and $U(A, B) = U(B, A) = 0$, where the first argument of U denotes the group decision and the second argument denotes the true state. Thus, everyone prefers A (B) if the true state is A (B). Each individual i can either stay uninformed (i.e., continue to know no more than the common prior), $d_i = 0$, or get informed (i.e., learn more than the prior), $d_i = 1$, by acquiring a private signal, $s_i \in \{a, b\}$ at a cost $c_i = c > 0, \forall i$. A signal is an independent Bernoulli trial from a state-dependent distribution with $\Pr(s_i = a|A) = \Pr(s_i = b|B) = p \in \left(\frac{1}{2}, 1\right)$ and $\Pr(s_i = b|A) = \Pr(s_i = a|B) = 1 - p$. Thus, a signal is noisy but informative because the probability that it correctly indicates the true state exceeds the prior, or $p > \frac{1}{2}$. (In the experiment, we focus on $p = \frac{3}{4}$.)

The game has two stages. In the first stage (*Information*), individuals independently and simultaneously decide on whether or not to get informed. In the second stage (*Voting*), either voluntary or compulsory independent and simultaneous costless voting takes place (henceforth also labeled $m = V, C$). With voluntary voting, each individual can vote for alternative A or alternative B, or abstain from voting. By contrast, with compulsory voting the option to abstain is not available. Note that everyone—informed and uninformed—makes a decision in this stage, and thereafter learns the vote outcome but not whether others were informed. In the following, we analyze equilibrium behavior in the *Voting* and *Information* stages in turn, using backward induction.

Voting

In the *Voting* stage, we focus on the following symmetric BNE, which have been shown to predict costless voting quite well in many experiments (e.g., Battaglini, Morton, and Palfrey 2010; McKelvey and Ordeshook 1990), though uninformed compulsory voting has not been studied previously:

Proposition 1 (Voting): *In symmetric BNE, informed individuals vote sincerely in both voting modes, while the uninformed abstain with voluntary voting, and vote randomly with equal probability for each alternative with compulsory voting.*

Proof: See appendix.

Signal acquisition

In the *Information* stage, we derive individual signal acquisition decisions using quantal response equilibrium (QRE; McKelvey and Palfrey 1995), which has been shown to predict binary choices in games similar to ours much better than BNE (e.g., Goeree and Holt 2005; Großer and Schram 2010). QRE generalizes BNE by including stochastic decision-making errors that are systematic in the sense that more lucrative decisions are made more often than less lucrative decisions (i.e., best responses are smooth, not sharp as in BNE). A parameter $\mu \geq 0$ controls the degree of noise. We focus on symmetric QRE where everyone has the same probability of getting informed, $\gamma_i = \gamma, \forall i$. Using the logit specification of Goeree and Holt (2005; henceforth logit equilibrium), in the one extreme without noise, $\mu = 0$ and QRE turns into BNE, while in the other extreme with pure noise, $\mu = \infty$ and decisions are entirely random, or $\gamma = \frac{1}{2}$. We mainly focus on $\mu > 0$, implying that $\gamma \in (0,1)$.

The condition for a logit equilibrium γ_m^* to exist is derived in the appendix and given by $\mu\left[-\ln(\frac{1-\gamma_m}{\gamma_m})\right] = \Pi_{i,m}^e(\gamma_m, \vartheta_m^*, p, n, c)$, where superscript e denotes the expectation operator. The left-hand side (henceforth LHS) is identical in both voting modes and deals with the errors. For $\mu > 0$, it strictly increases in γ, approaches $-\infty$ $(+\infty)$ if γ approaches 0 (1), and always equals zero at $\gamma = \frac{1}{2}$. Given that everyone votes à la Proposition 1 (denoted by the vector ϑ_m^*), the right-hand side (henceforth RHS) gives individual i's expected *net payoffs*, or increase in payoffs, of getting informed if everyone else gets informed with probability γ_m, which depends on the voting mode as specified next.

With *voluntary voting*, the informed vote sincerely and the uninformed abstain (Proposition 1). The condition for a symmetric γ_V^* to exist in this mode, assuming without loss of generality that individual i receives an a-signal when getting informed, is then given by:

$$\mu\left[-ln\left(\frac{1-\gamma_V}{\gamma_V}\right)\right]=\sum_{k=0}^{n}\binom{2n}{2k}{\gamma_V}^{2k}(1-\gamma_V)^{2n-2k}\binom{2k}{k}[p(1-p)]^k\left[p-\tfrac{1}{2}\right]-c. \quad (1)$$

$LHS(1)$ is described above, and $RHS(1)$ gives individual i's expected net payoffs of getting informed, $\Pi_{i,V}^{e}(\gamma_V,\vartheta_V^*,p,n,c)$, which considers that each $-i\neq i$ gets informed with probability γ_V. Hence, each $-i$ votes sincerely for the correct [incorrect] alternative with probability $\gamma_V p$ $[\gamma_V(1-p)]$, and stays uninformed and abstains with probability $1-\gamma_V$. $RHS(1)$ includes i's expected *net benefits* of getting informed (i.e., the sum term) minus the signal cost, c, where the sum over $k=0,\dots,n$ contains: (i) the probability of an even number $2k$ of others being informed, $P_{V,k}(\gamma_V,n,k)\equiv\binom{2n}{2k}{\gamma_V}^{2k}(1-\gamma_V)^{2n-2k}$; (ii) given $2k$, the probability of i being pivotal, $P_{V,piv}(\vartheta_V^*,p,k)\equiv\binom{2k}{k}p^k(1-p)^k$ (i.e., each alternative has k votes, so that her A-vote turns a tie into a win for A);[7] and (iii) her expected net gains in these pivotal events, $W_V^e(\vartheta_V^*,p)=pU(A,A)+(1-p)U(A,B)-\tfrac{1}{2}[U(A,A)+U(A,B)]=p-\tfrac{1}{2}$, which considers that, if she gets informed and uses Bayesian updating, her sincere A-vote yields a correct [incorrect] group decision with probability p $[1-p]$, and she only knows the prior if uninformed.

With *compulsory voting*, the informed vote sincerely and the uninformed vote randomly (Proposition 1). The condition for a symmetric γ_C^* to exist in this mode, assuming without loss of generality that individual i receives an a-signal when getting informed, is then given by:

$$\mu\left[-ln\left(\frac{1-\gamma_C}{\gamma_C}\right)\right]=\binom{2n}{n}\sum_{k_A=0}^{n}\sum_{k_B=0}^{n}\binom{n}{k_A}\binom{n}{k_B}{\gamma_C}^{k_A+k_B}(1-\gamma_C)^{2n-k_A-k_B}p^{k_A}(1-p)^{k_B}\left(\tfrac{1}{2}\right)^{2n-k_A-k_B}$$
$$\times\left[\frac{p^{k_A+1}(1-p)^{k_B}}{p^{k_A+1}(1-p)^{k_B}+(1-p)^{k_A+1}p^{k_B}}-\tfrac{1}{2}\right]-c. \quad (2)$$

$LHS(2)$ is described above, and $RHS(2)$ gives individual i's expected net payoffs of getting informed, $\Pi_{i,C}^{e}(\gamma_C,\vartheta_C^*,p,n,c)$. Note that with compulsory voting the only pivotal events are with n votes of others —informed or uninformed—for each alternative (i.e., her A-vote turns a tie into a win for A). If B is

[7] Individual i is also pivotal if A is short of one vote of others (i.e., when her A-vote turns a loss into a tie). However, in these events opposing signals (including her a-signal) even each other out, so that she knows no more than the prior. Hence, her informed vote would only replace the coin flip and the signal cost be wasted.

correct, then her pivotal A-vote results in an incorrect group decision, which yields $U(A,B)=0$ so that this event is ignored (as in $RHS(1)$). If A is correct, $RHS(2)$ considers that each $-i\neq i$ gets informed with probability γ_C and receives an a [b]-signal with probability p [$1-p$], and stays uninformed with probability $1-\gamma_C$. Hence, each $-i$ votes sincerely for A [B] with probability $\gamma_C p$ [$\gamma_C(1-p)$] and votes randomly with probability $(1-\gamma_C)\frac{1}{2}$ for each alternative. $RHS(2)$ contains i's expected *net benefits* of getting informed (i.e., the sum term) minus the signal cost, c. In pivotal events, for any $k_j=0,\dots,n$ informative votes for $j=A,B$, there must be $n-k_j$ uninformed random j-votes, and for a given pair (k_A,k_B) the pivot probability is $P_{C,piv}(\vartheta_C^*,p,n,k_A,k_B)\equiv\binom{2n}{n}\binom{n}{k_A}\binom{n}{k_B}p^{k_A}(1-p)^{k_B}\left(\frac{1}{2}\right)^{2n-k_A-k_B}$. Since pivotal events also involve uninformed random votes, individual i's expected net gains from voting informatively in these events vary and are equal to $W_C^e(\vartheta_C^*,p,k_A,k_B)\equiv\frac{p^{k_A+1}(1-p)^{k_B}}{p^{k_A+1}(1-p)^{k_B}+(1-p)^{k_A+1}p^{k_B}}-\frac{1}{2}$, namely, her Bayesian updated probability that A is correct given (k_A+1,k_B), including her own A-vote, times $U(A,A)=1$ and minus $\frac{1}{2}U(A,A)=\frac{1}{2}$ if she votes uninformed.[8]

Proposition 2 (Information acquisition): *In symmetric logit equilibrium, for* $\mu>0$ *individuals get informed with probability* $\gamma_m^*(\vartheta_m^*,p,n,c,\mu>0)\in(0,1)$*,* $m=V,C$*. For large enough degrees of noise,* $\mu\geq\underline{\mu}_m>0$*, this probability is unique and decreasing in the odd group size,* $2n+1$*, decreasing in the signal cost, c, and it moves closer to one-half when μ increases.*

Proof: See appendix.

The uniqueness requirement that μ is large enough is due to convex and concave properties of $RHS(1)$ and $RHS(2)$, respectively. Moreover, the proposition does not give comparative statics results for the effects of the voting mode, which depend on n and μ. It also ignores changes in the probability of a correct signal, since while raising $p\in(\frac{1}{2},1)$ usually increases γ_m^*, there is a region of the parameter space where the reverse holds. The reason is that raising p has two opposite effects, to wit, it decreases the pivot probability, $P_{m,piv}(.)$, and increases the expected net gains from voting informatively, $W_m^e(.)$. Finally, BNE ($\mu=0$) is discussed in footnote 30 in the appendix.

[8] Note that in events with more b- than a-signals in the group, individual i prefers to vote against her a-signal. But, ex ante, she expects others to have on average more a- than b-signals so voting informatively is her unique best response.

Efficiency and social optimum

In order to compare ex ante group efficiency—defined by the group's expected total benefits minus expected total signal costs—across voting modes and group sizes, we must derive the probability of a correct group decision, $P_{m,cor}(j|j|\, \gamma_m, \vartheta_m^*, p, n)$ for $m = V, C$ and $j = A, B$, where $j|j$ denotes the event that j is chosen conditional on j being the true state. This probability uses γ_m and is described in the appendix. Given ϑ_m^*, note that increasing γ_m increases $P_{m,cor}(.)$. Moreover, expected total signal costs equal $(2n+1)\gamma_m c$ in both voting modes, so ex ante expected efficiency is given by $(2n+1)[P_{m,cor}(.)U(j,j) - \gamma_m c] = (2n+1)[P_{m,cor}(.) - \gamma_m c]$, $m = V, C$. Finally, in the social optimum with noise-free decision-making, maximization with respect to γ_m yields the implicit solution of γ_m^o: $\partial P_{m,cor}[.]/\partial \gamma_m^o = c$, where superscript o denotes the optimum.

Below, we derive γ_m^*, γ_m^o, and the respective $P_{m,cor}(.)$ for varying μ for our experimental treatments and parameters (see also Figures A2.1-3 in the appendix), and additional predictions for $\mu = 0$ and 0.06 and various group sizes are given in Tables A1 and A2 in the appendix.

Large groups

Although we focus on small groups, our game has also interesting implications for large electorates:

Proposition 3 (Large groups): *As the group size,* $2n+1$*, goes to infinity, if* $\mu > 0$ *and* $p \in (\frac{1}{2}, 1)$*, then the unique limiting symmetric logit equilibrium individuals get informed with probability*

$$\tilde{\gamma}_m(\vartheta_m^*, c, \mu > 0) = \frac{1}{1 + e^{c/\mu}} \in (0,1)$$

for $m = V, C$ *and the group decisions is almost surely correct. If* $\mu = 0$*, then in the limit* $\tilde{\gamma}_m(\vartheta_m^*, c, \mu = 0) = 0$ *for* $m = V, C$ *and the group decision is correct half of the time.*

Proof: See appendix.

The proposition states that in both voting modes, Condorcet's Jury Theorem also holds for large groups with endogenous costly signals if there is some decision-making noise, $\mu > 0$, but not in BNE without any noise. To see the intuition, first note that since $\tilde{\gamma}_m(\mu > 0) \in (0,1)$, in large groups the respective numbers of informed and uninformed individuals are large too. Then, by the law of large numbers, with compulsory voting an even (odd) number of uninformed individuals almost surely cast equally many votes for each alternative (one more vote for either alternative), and with voluntary voting the uninformed abstain. But since $p > 1 - p \Leftrightarrow 2p > 1$, in the limit, noting that $p > \frac{1}{2}$ and $\mu > 0$, the informed individuals' fraction of correct votes exceeds their fraction of incorrect votes by an infinite margin, that is $\lim_{n\to\infty}(2n+1)\tilde{\gamma}(2p-1) = \infty > 1$ for $\tilde{\gamma} \in (0,1)$, so uninformed votes are irrelevant and the group decision is almost surely correct. Finally, since the pivot probability is nil in large groups, a noise-free voter chooses not to buy a signal, $\tilde{\gamma}_m(\mu = 0) = 0$.

3 Experimental design and predictions

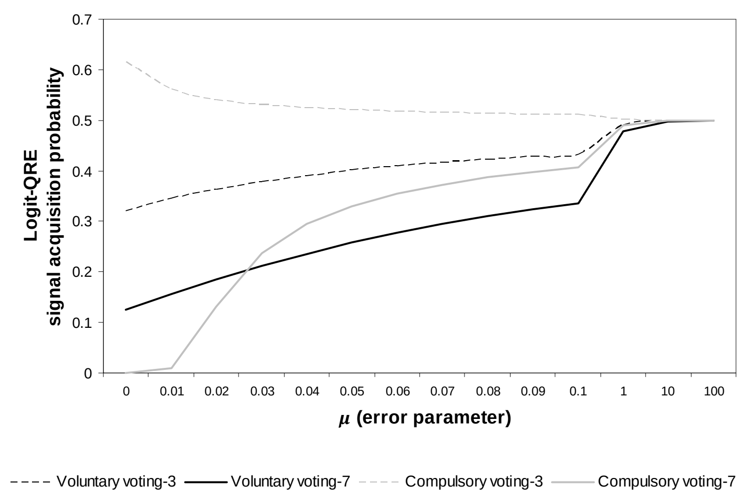
The computer experiment was run at the University of Cologne's Laboratory for Economic Research.[9] In total, 220 students attended eight sessions of 27 or 28 participants that lasted about 1.5 hours. Earnings were expressed in points and exchanged for cash for €1 per 800 points. Participants earned an average of €11.79, including €2.50 for showing up. Instructions are in our online appendix.[10]

We employed a 2×2 treatment design, varying the *voting mode* (voluntary and compulsory) within-subjects in one dimension, and *group size* (three and seven) between-subjects in the other dimension. Treatments are labeled *Voluntary voting-3*, *Voluntary voting-7*, *Compulsory voting-3,* and *Compulsory voting-7*. Each session had two parts of 30 decision periods each, where each part used a different voting mode and the order was changed across sessions. At the beginning of a session, unknown to the participants, subject pools of 27 (28) were randomly divided into three (two) separate matching groups of nine (fourteen). The composition of matching groups was fixed during the entire session, and there was no interaction between them. We used a random matching protocol: within a matching group, participants were randomly put into groups of three (seven) at the beginning of each period. All our statistical tests are run at the matching group level, for which we have twelve (eight) independent observations for groups of three (seven), half of them per each order of the voting modes.[11]

[9] We used z-Tree (Fischbacher 2007) to program the experiment and ORSEE (Greiner 2004) to recruit participants.
[10] The online appendix is available at https://sites.google.com/site/jwghome/research.
[11] Observed average rates of acquired signals are higher in the first than second part in *Voluntary voting-3*, and vice versa in *Compulsory voting-3* ($p \leq 0.021$, Wilcoxon-Mann-Whitney tests, one-tailed), but no difference is found for the larger groups ($p = 0.343$ and 0.557). Note that the six matching groups that first faced the voluntary mode have statistically significantly higher rates averaged over both parts than the other six matching groups, but no difference is found for the larger groups ($p = 0.008$ and 0.557, same tests). As a result, in the smaller groups average rates are not different between voting modes in the first part, and higher with compulsory voting in the second part ($p = 0.120$ and 0.004, same tests). In larger groups, average rates are higher with compulsory than voluntary voting in both parts ($p = 0.014$ and 0.014, same tests). Importantly, the level effect of rates for the smaller groups does not affect our analysis and main results.

Each period consisted of two stages. At the beginning of each period, the true state, A or B, was selected with probability one-half for each but not revealed to the group. In all treatments, in the first stage, participants independently and simultaneously decided on whether to acquire a private signal about the true state and pay $c = 25$ points, or stay uninformed and bear no cost. A signal indicated the true (false) state with probability $p = \frac{3}{4}$ $(1 - p = \frac{1}{4})$. In the second stage, voluntary or compulsory majoritarian voting with random tie-breaking took place, where all participants—informed and uninformed—independently and simultaneously voted, at no cost, for alternative A or B or, if feasible, abstained.[12] After voting, the true state, group decision, and number of votes for each alternative were announced. Each participant's period earnings were determined as follows: she or he received 200 points if the group decision matched the true state and 0 points otherwise, independent of the own signal acquisition and vote decisions, minus 25 points if she or he bought a signal. For more details of the procedures, see the instructions in the online appendix.

Figure 1: Symmetric logit equilibrium signal acquisition probabilities



Note: The figure shows, for our experimental treatments and parameters, symmetric logit equilibrium signal acquisition probabilities for $\mu \in [0,0.1]$ and $\mu \in \{1,10,100\}$. Though not shown (but see Table A1), *Compulsory voting-3* has an additional BNE where no one gets informed.

Figure 1 shows, for our experimental treatments and parameters, symmetric logit equilibrium signal acquisition probabilities per treatment for $\mu \in [0,0.1]$ and the discrete cases $\mu \in \{1,10,100\}$.

[12] In the experiment, these options were labeled *Yellow*, *Blue*, and *No Color* instead of *A*, *B*, and *abstain*, respectively. Note that due to odd group sizes, ties were not possible in the compulsory mode.

Though not shown in the figure (but see Table A1 in the appendix), *Compulsory voting-3* has an additional BNE ($\mu = 0$) with universal rational ignorance. As can be seen, predictions vary markedly in BNE, and move closer to each other towards one-half when μ increases. With compulsory voting, for both group sizes there is a BNE where cursed voting prevails (i.e., nobody buys a signal), and in groups of three there is another BNE where it is counteracted by the highest predicted $\gamma^*(\mu)$. In this voting mode, $\mu > 0$ has the effect of promoting signal acquisition in the former two equilibria (i.e., universal rational ignorance is overcome)[13] and oppressing it in the latter equilibrium. Moreover, given the voting mode, individuals are always more likely to get informed in smaller than larger groups (see Proposition 2). And, given the group size, compulsory voting always triggers higher $\gamma^*(\mu)$ than voluntary voting in groups of three, but in larger groups this only holds for about $\mu \geq 0.025$ while the reverse holds for degrees of noise below this value. Using our $\gamma^*(\mu)$, we can derive the groups‘ expected number of acquired signals (or, information pool), probability of a correct decision, and expected efficiency, which are shown in Figures A2.1 to A2.3 in the appendix. Their comparative statics depend on μ and are therefore discussed further after estimating the degrees of noise for our data.

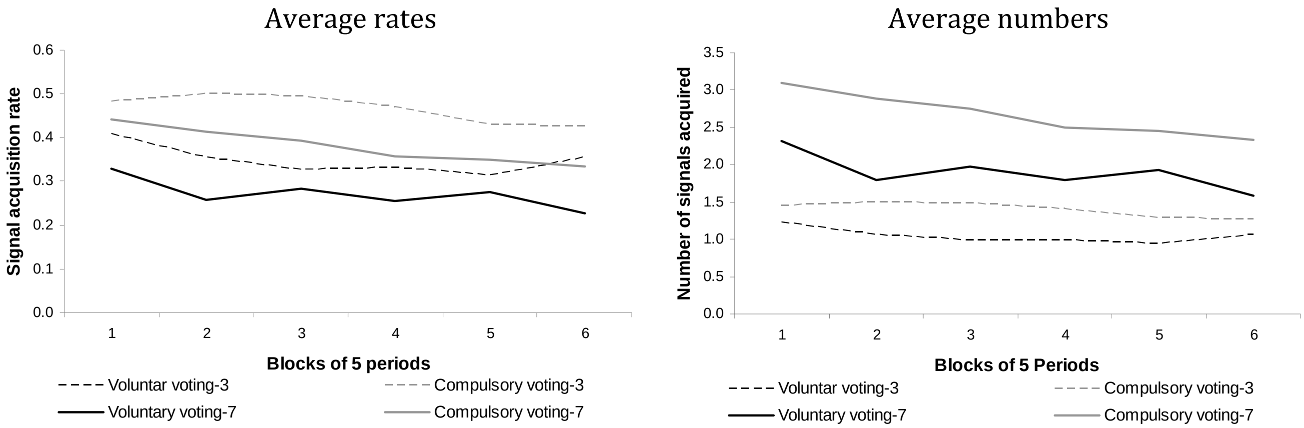
Besides comparing group performances to universal ignorance, $\gamma = 0$, it is also interesting to confront them with the social optimum, which is $\gamma^o = 1$ in all treatments (i.e., a corner solution where the marginal total costs do not exceed the marginal total benefits even if everyone gets informed), and with a single delegate, D, who makes a non-noisy group decision (henceforth noise-free delegate), also always $\gamma^D = 1$. These three benchmark performances are compared to our logit predictions in the experimental results section (see also Figures A2.1 to A2.3). Moreover, since $\gamma^*(\mu) < \gamma^o = 1$ in all treatments, any signal acquisition probability greater than the logit prediction is efficiency enhancing. Thus, raising $\mu > 0$ strictly increases expected efficiency in all treatments but *Compulsory voting-3*, where it decreases efficiency. We can use this exception to test whether deviations from BNE are consistent either with logit equilibrium or implicit cooperation towards higher payoffs.

[13] In *Compulsory voting-3*, the BNE with universal ignorance is not robust to even the smallest noise, so increasing μ leads to a jump to the equilibrium path with high signal acquisition probabilities.

4 Experimental results

In this section, we present and analyze our experimental results. We discuss in turn signal acquisition, correct group decisions, efficiency, uniformed voting, and learning about close vote outcomes.

Figure 2: Signal acquisition



Signal acquisition

Figure 2 shows observed average rates (left panel) and average numbers (right panel) of acquired signals per five-period block per treatment. The overall rate is higher in *Compulsory voting-3* and *-7* than in *Voluntary voting-3* and *-7* (0.47 and 0.38 versus 0.35 and 0.27). By contrast, the overal number is higher in *Compulsory voting-7* and *Voluntary voting-7* than in the respective smaller groups (2.67 and 1.90 versus 1.40 and 1.05). With only one exception, the same orders of rates and numbers of acquired signals also hold per five-period block. Finally, signal acquisiton tends to decline over time in all treatments.[14]

Experimental result 1 (Signal acquisition): *Larger groups acquire almost twice as many signals as smaller groups (81.3% and 90.7% more with voluntary and compulsory voting, respectively), but individuals get informed at the same rates. For both group sizes, compulsory voting induces more signal acquisitions than voluntary voting (33.8% and 40.7% more, respectively).*

[14] Average rates and numbers of acquired signals are higher in periods 1-15 than periods 16-30 in all treatments ($p \leq 0.059$, Wilcoxon signed ranks tests, one-tailed). Moreover, using probit regressions with random effects at the matching group level with signal acquisition as dummy dependent variable and periods 1-30 or periods 1-60 (i.e., over both parts) as independent variable, we find negative and statistically significant coefficients of the period in all treatments ($p \leq 0.048$, two-tailed), except in *Voluntary voting-7* for periods 1-60 ($p = 0.206$).

Support: The null hypothesis of no difference in average acquired signals between groups of seven and three is rejected in favor of greater *numbers* in larger groups with voluntary and compulsory voting (p = 0.0003 and 0.0002, Wilcoxon-Mann-Whitney tests, one-tailed), but not for *rates* for both voting modes (p = 0.140 and 0.409). And, the null of no difference in average acquired signals between the two voting modes is rejected in favor of greater rates and thus numbers with compulsory voting for groups of seven and three (p = 0.001 and 0.004, Wilcoxon signed ranks tests, one-tailed). For completeness, the null is not rejected for rates for *Voluntary voting-3* versus *Compulsory voting-7* (p =0.109, Wilcoxon-Mann-Whitney test, one-tailed), but it is rejected in favor of greater rates in *Compulsory voting-3* versus *Voluntary voting-7* and greater numbers for both comparisons ($p \leq 0.032$, same tests).

Figure 3 confronts our logit predictions with the data. We compute best predictors of the degree of noise, $\hat{\mu}^*$, using maximum likelihood estimations.[15] This is done for the pooled data of all treatments, each weighted by one-fourth, for all thirty periods (large symbols) and for the first and second half of periods only (small symbols), which yields $\hat{\mu}^*_{all} = 0.06$ respectively $\hat{\mu}^*_{1-15} = 0.07$ and $\hat{\mu}^*_{16-30} = 0.05$. The drop in the best predictor from the first to the second half of periods hints to learning towards BNE (see also Goeree and Holt 2005; McKelvey and Palfrey 1995).[16] As seen in Figure 3, observed rates of signal acquisition are predicted poorly for about $\mu < 0.025$ (BNE predicts worst) and much better for $\mu \in [0.025, 0.1]$.[17] For the latter interval, we not only predict greater information pools with compulsory than voluntary voting per group size, but also in larger than smaller groups per voting mode (see Figure A2.1). Overall, our estimates correctly predict five out of six (six out of six) possible comparative statics of observed average rates (numbers) of acquired signals.[18] By contrast, BNE only predicts four out of six (three out of six) comparative statics. Notably, it overrates free-riding and thus fails to predict greater information pools in larger groups (Experimental result 1). Finally, observed average rates are greater

[15] Denote by γ_μ the logit equilibria for μ. Let γ_{obs} be the observed signal acquisition rate for N observations. The Log-likelihood that γ_μ yields γ_{obs} is $\ln(L) = ln\binom{N}{\gamma_{obs}N} + \gamma_{obs}N \ln \gamma_{obs} + (1-\gamma_{obs})N \ln(1-\gamma_{obs})$, which is maximized for $\gamma_\mu = \gamma_{obs}$ if such μ exists, otherwise a corner solution maximizes the Log-likelihood.

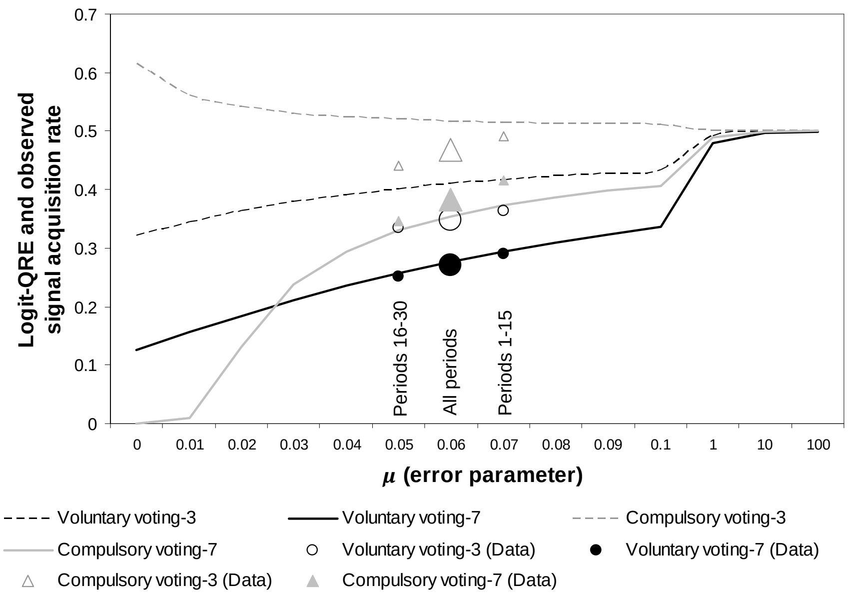
[16] We also find a drop from the first to the second part ($\hat{\mu}^*_{Part\ 1} = 0.07$ and $\hat{\mu}^*_{Part\ 2} = 0.06$, respectively). Note that the observed average signal acquisition rate in *Compulsory voting-3* is in between the treatment's two BNE, so learning is towards the BNE with universal ignorance. While this may reflect the tension between the two BNE, notice that although the rate per matching group varies more in *Compulsory voting-3* than the other treatments, only one of its matching groups is among the six with a lowest rate of about 0.2 (*Voluntary voting-3* and *Compulsory voting-7* have three and two, respectively).

[17] This also holds per treatment, except for *Voluntary voting-3* where the rates are better predicted by low μ. To find a $\hat{\mu}^*$ per treatment, simply move the data points in Figure 3 horizontally until they lie on the respective prediction line.

[18] The only exception is an unpredicted, slightly higher average rate found in *Compulsory voting-7* than in *Voluntary voting-3*. However, these treatments are not directly comparable, and the one exception in the order of observed rates reported earlier occurs in the last block of five periods (left panel of Figure 1), in line with our best predictors.

than BNE in all treatments but *Compulsory voting-3* (i.e., the higher, robust BNE), which is more in line with logit equilibrium than implicit cooperation towards the social optimum.

Figure 3: Signal acquisition and estimated degrees of noise in logit equilibrium



Note: The figure shows maximum likelihood estimations of the degree of noise, $\hat{\mu}^*$, for the pooled data of all treatments, each weighted by one-fourth, for all thirty periods (large symbols) and for the first and second half of periods only (small symbols).

Correct group decisions

Next, we examine how voting translates acquired signals into group decisions. On average, groups choose the correct alternative 62.0% and 66.0% (68.8% and 69.0%) of the time in *Voluntary voting-3* and *-7* (*Compulsory voting-3* and *-7*), respectively.

Experimental result 2 (Correct group decisions): *On average, 62.0% to 69.0% of the group decisions are correct, where smaller groups with voluntary voting do worst.*

Support: The null hypothesis of no difference in average correct group decisions between voluntary and compulsory voting is rejected in favor of greater averages for groups of three with compulsory voting, but not for groups of seven ($p = 0.006$ and 0.237, Wilcoxon signed ranks tests, one-tailed). And, the null of no difference is not rejected for group size comparisons in both the voluntary and compulsory mode ($p = 0.472$ and 0.179, Wilcoxon-Mann-Whitney tests, one-tailed). For comparison, it is also not rejected for *Compulsory voting-3* versus *Voluntary voting-7*, but rejected in favor of greater averages for *Compulsory voting-7* than *Voluntary voting-3* (p =0.372 and 0.042, Wilcoxon-Mann-Whitney tests, one-tailed).

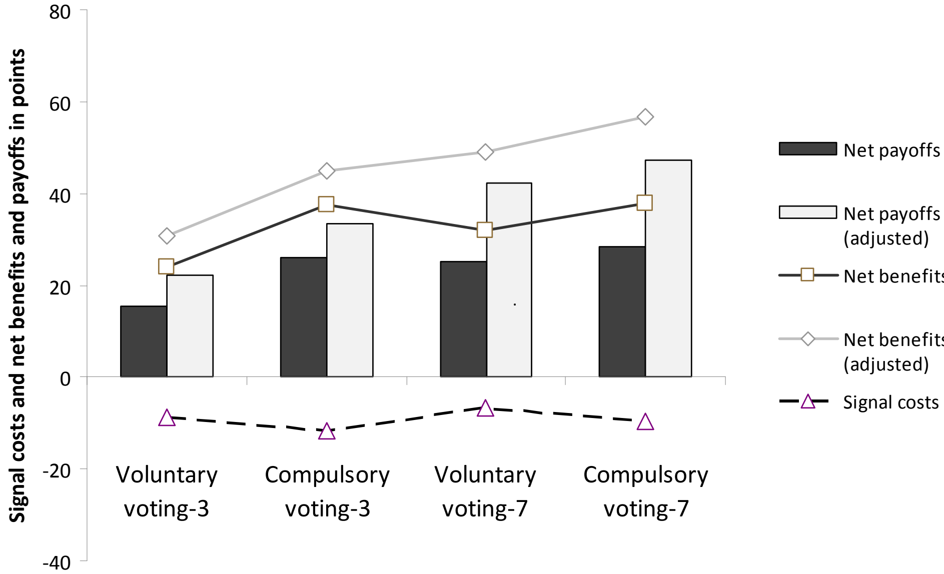
Typically, in all treatments average correct group decisions per matching group are in between the 50% achieved with universal ignorance and the 75% achieved by a single noise-free delegate,[19] and hence lie markedly below the social optimum of 84.4% in groups of three and 92.9% in groups of seven (see Figure A2-2 in the appendix). These relative performances are predicted for $\mu \in [0.025,0.1]$, albeit a delegate in *Voluntary voting-7* should do worse than the group for about $\mu > 0.05$. With regard to comparative statics between treatments for $\mu \in [0.025,0.1]$ shown in Figure A2-2, we should see on average fewer correct group decisions in *Voluntary voting-3* than *-7* (which we do, but not statistically significantly) and about the same averages in *Compulsory voting-3* and *-7* (which we do). Also, there should be more correct group decisions with voluntary than compulsory voting for both group sizes, which we reject. Overall, while in the compulsory voting treatments average correct group decisions are similar to those predicted for $\mu \in [0.025,0.1]$, in the voluntary voting treatments they are markedly smaller than predicted. Against Proposition 1, this hints to cursed uninformed voluntary voting! For another hint, group decisions are not more often correct in *Voluntary voting-7* than *Compulsory voting-3*, even though in the former treatment the information pool was greater on average and participants could abstain. We further discuss uninformed voting, below.

Efficiency

Figure 4 depicts per treatment, averaged over individuals, the observed signal costs (dashed line); net benefits (dark solid line), which equal 200 points times the average fraction of correct group decisions minus 100 points from a random group decision with universal ignorance; and net payoffs (dark bars), which are equal to the net benefits minus the costs. (The light line and bars are discussed below.) As can be seen, individual net payoffs are smallest in *Voluntary voting-3* (15.3 points), and about equal in *Voluntary voting-7* and *Compulsory voting-3* and *-7* (25.3, 25.9, and 28.4 points; note that net benefits and costs are somewhat smaller in *Voluntary voting-7* than in the two other treatments).

[19] 1 (0) out of 12 matching groups had ≤ 50% (≥ 75%) correct group decisions in *Voluntary voting-3*, and these numbers are 0 (3) out of 12 in *Compulsory voting-3*, 1 (1) out of 8 in *Voluntary voting-7*, and 0 (1) out of 8 in *Compulsory voting-7*.

Figure 4: Efficiency



Note: The figure shows per treatment, averaged over individuals, observed signal costs (dashed line), net benefits (solid lines), and net payoffs (bars). The net values are departing from universal ignorance, where each individual has expected benefits and payoffs of 100 points. For adjusted values, all realized uninformed votes are replaced by hypothetical abstentions (if this creates a tie, net values are set to zero points).

Experimental result 3 (Efficiency): *In all treatments, average individual net payoffs are in between the benchmarks of 0 points with universal ignorance and 41.7 and 46.4 points with a single noise-free delegate in groups of three and seven, respectively. Individuals in smaller groups with voluntary voting earn 10.0 to 13.0 points less than those in the other treatments.*

Support: The null hypothesis of no difference in average efficiency between voluntary and compulsory voting is rejected in favor of greater averages for compulsory voting in groups of three, but not for groups of seven ($p = 0.026$ and 0.320, Wilcoxon signed ranks tests, one-tailed). And, the null hypothesis of no difference for group size comparisons is rejected in favor of greater averages for *Voluntary voting-7* than *-3*, but not in the compulsory mode ($p = 0.084$ and 0.472, Wilcoxon-Mann-Whitney tests, one-tailed). For comparison, it is rejected in favor of larger averages for *Compulsory voting-7* than *Voluntary voting-3*, but not for *Compulsory voting-3* versus *Voluntary voting-7* ($p = 0.062$ and 0.472, same tests).

Note that almost always do groups of three and seven achieve lower average net payoffs than in social optimum (43.8 and 60.9 points) and with a single noise-free delegate (41.7 and 46.4 points, i.e. 50 minus 25/group size),[20] and recall that net payoffs are equal to zero with universal ignorance (see also

[20] 1 (0; 0) out of 12 matching groups in *Voluntary voting-3* earned on average less than with universal ignorance (more than with a single noise-free delegate; more than in social optimum), and these numbers are 0 (1; 1) out of 12 in *Compulsory voting-3*, 1 (1; 0) out of 8 in *Voluntary voting-7*, and 0 (1; 0) out of 8 in *Compulsory voting-7*.

Figure A2.3 in the appendix). Finally, as a consequence of smaller average correct group decisions than predicted in the voluntary voting treatments, observed net payoffs are also smaller than predicted. By contrast, predicted and realized net payoffs are similar in the compulsory voting treatments.

Uninformed voting

Here, we investigate uninformed voting in more detail. Table 1 shows per treatment average fractions of sincere voting, insincere voting, and abstention of the informed, and voting and abstention of the uninformed (note that we cannot distinguish between sincere and insincere uninformed voting).

Table 1: Fractions of informed and uninformed voting

Treatment	Informed			Uninformed	
	Voting		Abstention	Voting	Abstention
	Sincere	Insincere			
Voluntary voting-3	0.341	0.007	0.001	0.252	0.399
Compulsory voting-3	0.461	0.006	-	0.533	-
Voluntary voting-7	0.268	0.003	0.000	0.293	0.436
Compulsory voting-7	0.377	0.004	-	0.618	-

As seen in the table, observed decisions mainly support Proposition 1, albeit with one important exception. As predicted, the informed almost never abstain in the voluntary mode and almost always vote sincerely in both voting modes.[21] However, as suspected, we find substantial voluntary voting of the uninformed (38.7% and 40.2% of their decisions in *Voluntary voting-3* and *-7*, respectively).[22] Figure 4 also shows *adjusted* net benefits and net payoffs averaged over individuals, for which we replaced each realized uninformed vote with a hypothetical abstention (gray line and bars).[23] The adjustment allows us to evaluate the actual negative impact of the swing voter's curse on group decisions and efficiency, but naturally it cannot capture how decisions in the voluntary mode would have been made absent of uninformed voting. The figure reveals a substantial damage in all treatments: the adjustment raises the

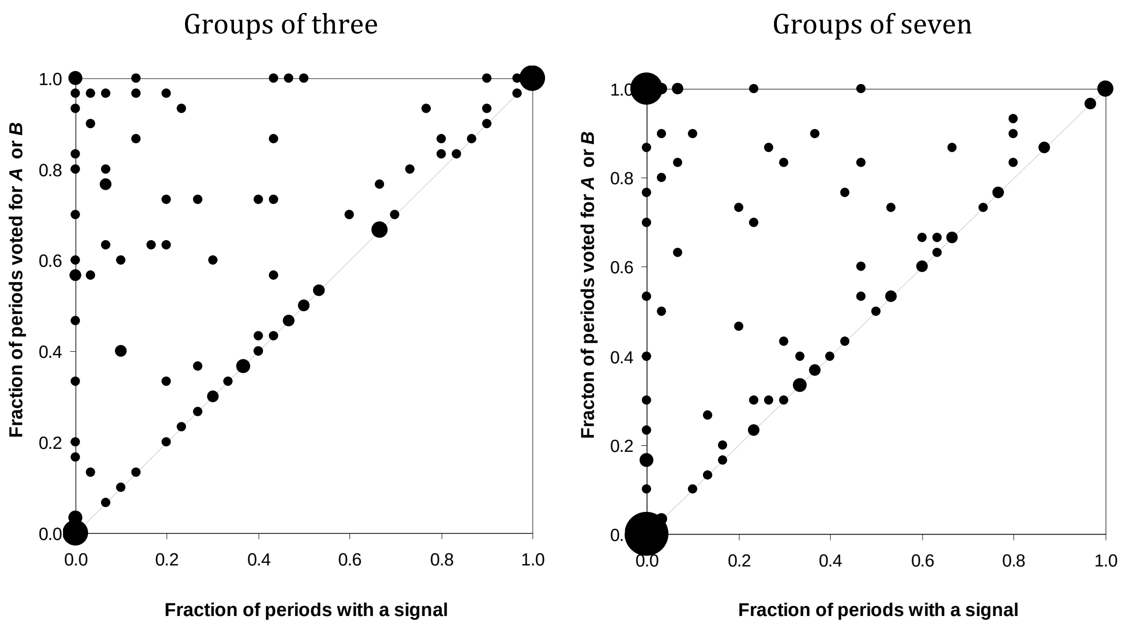
[21] Out of 3,240 (3,360) decisions, we only find 4 (1) informed abstentions by one participant in *Voluntary voting-3* (*-7*), and 22 and 18 (9 and 15) insincere votes in *Voluntary voting-3* and *Compulsory voting-3* (-7 and *-7*), respectively.

[22] Uninformed votes were slightly biased: in each treatment, 54% for *Blue* versus 46% for *Yellow* ($p \leq 0.019$, binomial tests, one-tailed). Moreover, in 40.4% and 21.0% (29.7% and 18.8%) of the elections in *Voluntary voting-3* and *-7* (*Compulsory voting-3* and *-7*), uninformed votes replaced a coin flip for a tie of informed votes, in 4.4% and 12.1% (7.4% and 13.3%) they turned a win of the correct color into a loss, and in 1.5% and 3.3% (1.9% and 3.5%) they turned a loss of the correct color into a win. Finally, between 54.1% and 65.6% (56.3% and 70.6%) of these incorrect (correct) changes were for *Blue*, except for 38.1% correct changes in *Compulsory voting-3*.

[23] When an adjustment creates a tie, we use net benefits of zero points instead of a coin flip. This choice has virtually no effect on the reported averages.

fraction of correct group decisions by 3.4 and 8.4 (3.7 and 9.4) percentage points in *Voluntary voting-3* and *-7* (*Compulsory voting-3* and *-7*), which raises average individual benefits and payoffs by 6.8 and 16.9 (7.4 and 18.8) points. Finally, we can compare adjusted values in the voluntary mode, where the uninformed are predicted to abstain, to the respective realized values in the compulsory mode. In groups of three (seven), adjusted average individual net benefits and net payoffs with voluntary voting are 30.8 and 22.1 (49.0 and 42.2), and the respective realized values with compulsory voting are 37.6 and 25.9 (37.9 and 28.4). These numbers accentuate the generally poor performance in *Voluntary voting-3*, and suggest high forgone gains in *Voluntary voting-7* where, without cursed voting, groups could have done markedly better than in the compulsory mode.

Figure 5: Uninformed voluntary voting per participant



Note: The figure shows for each participant (dot) the fraction of periods in which she or he was informed on the horizontal axis, and the fraction of periods in which she or he voted on the vertical axis. Larger circle sizes indicate larger numbers of participants at the same coordinates.

Next, we examine uninformed voluntary voting at the individual level. Figure 5 shows scatterplots for *Voluntary voting-3* (left panel) and *Voluntary voting-7* (right panel), where each dot represents one participant (the size of their agglomeration at the same coordinates is indicated by the size of larger circles). The horizontal axis shows the fraction of periods in which she or he was informed, and the vertical axis shows the fraction of periods in which she or he voted. Hence, individuals on the diagonal (gray line) never voted uninformed,[24] and those above the diagonal voted uninformed to various extents. Clearly, uninformed voluntary voting is not restricted to just a few individuals: in *Voluntary voting-3* and *-7*, more than half of them voted uninformed to some extent (59 out of 108 and 60 out of 112 participants, respectively).

Experimental result 4 (Uninformed voting): *There is a sizable number of uninformed voluntary votes (25.2% and 29.3% out of all decisions in groups of three and seven), nearly half as many as uninformed compulsory votes (53.3% and 61.8%). Uninformed voluntary voting is common among individuals.*

There are several possible explanations why so many uninformed participants do not abstain when they can. For example, people are boundedly rational in many aspects, and therefore may simply not realize that random voting can negatively affect the group decision—which is less intuitive than the positive effect of informed sincere voting—or ignore pivotal events altogether (e.g., Esponda and Vespa 2012; Martinelli 2011). One would then expect to see some learning of the swing voter's curse in our experiment, to wit, a decline in uninformed voluntary voting. However, our results in this regard are mixed (see Figure A3),[25] which hints to a fraction of participants who were conscious of the curse when casting their uniformed voluntary vote.[26] These people may vote because abstaining basically reveals their ignorance and hence can lead others to reciprocate by getting informed less often in future periods.[27] Finally, in line with overreporting of voting in election surveys (e.g., Bernstein, Chadha, and Montjoy 2001), some people derive pride from signaling to others that they voted and feel embarrassed to admit their failure to do so (DellaVigna et al. 2013), which too may explain uninformed voluntary voting. Our experiment is not designed to find out the exact causes of anomalous uninformed voting, so we leave this task to future research.

[24] The two participants who abstained informed (see footnote 21) virtually always voted uninformed otherwise.
[25] Using probit regressions with random effects at the matching group, in *Voluntary voting-3* we find no statistically significant effect of the period on uninformed voting for both parts together ($p = 0.956$, two-tailed), and negative and positive effects for the first and second part, respectively ($p \leq 0.090$). In *Voluntary voting-7*, we find no significant effect for the first part ($p = 0.490$), but negative effects for the second part and both parts together, respectively ($p \leq 0.070$). Recall that in the two compulsory voting treatments signal acquisition declines over time (footnote 14), so uninformed voting increases over time.
[26] Participants could not directly observe if others voted informed. It is likely that they anticipated some extent of uninformed voluntary voting, especially if they did so too. Though learning this extent is very difficult, they could update their beliefs about uninformed voting after each period, using the numbers of correct and incorrect votes of others. This is what we study below.
[27] In our random matching protocol, participants could infer that they encounter a particular other participant on average 2.31 and 6.67 times per part in groups of three and seven (unknown to them, they met more often due to the matching group procedure described earlier), so abstaining could indeed have direct and indirect effects on relevant future group decisions.

Next, we analyze uninformed voluntary voting using models of bounded rationality. First, applying *individual rational choice* to our situation, noise-free players decide optimally as if they were alone. By ignoring social interaction entirely, they are always pivotal in their limited rational minds. Consequently, for all treatments, they should consistently get informed and vote sincerely (as our noise-free delegate), and off the equilibrium path, the uninformed randomly choose A or B or, if feasible, abstention. By contrast, our participants are often uninformed, and at rates that depend on the treatment which also noisy behavior could not explain (but uninformed decisions in the voting stage appear to be random, as predicted; see Figure 5 and footnote 22). Also, below we show that participants consider closeness of the next vote when making their signal acquisition decisions (see Table 2). Overall, individual "rational" choice is not a plausible explanation of our data. Second, turning to logit equilibrium, it cannot improve on the BNE prediction of sincere voting (Prediction 1), as this is what informed participants virtually always do (Table 1). However, it can capture the observed substantial uninformed voluntary voting, which BNE cannot. To see this, note that the uninformed surely abstain in the noise-free extreme of logit equilibrium, and choose A or B or abstention with probability one-third for each in the other extreme with pure noise. Then, on the logit equilibrium path, raising the degree of noise shifts probability density from uninformed abstention in equal shares to uninformed A- respectively B-votes, which is consistent with the 38.7% and 40.2% of uninformed votes (about half for each A and B; see footnote 22) found in *Voluntary voting-3* and *-7*. If one agrees that sincere voting is much more intuitive than the swing voter's curse, so one can justify decision-making noise only for the uninformed, then logit equilibrium is a plausible explanation of our data (but note that then three different degrees of noise are to be estimated, including for signal acquisition decisions). The notion of intuitive sincere voting is supported by other prominent models of bounded rationality, such as *k–level reasoning* (e.g., Camerer, Ho, and Chong 2004), *cursed equilibrium* (Eyster and Rabin 2005), and *analogy-based expectation equilibrium* (Jehiel 2005). As shown by Battaglini, Morton, and Palfrey (2010), whose analysis also applies to our voting stage, all three models predict that any informed player—even a fully unsophisticated one—votes sincerely (different behavior is predicted for uninformed players: the fully unsophisticated choose randomly, as in the individual choice model off the equilibrium path, and everyone else abstains). As mentioned earlier, our data are also consistent with the notion that some participants consciously take the risk of casting a cursed voluntary vote, which likely includes those who realize that others do so and then reciprocate by doing just the same. At this point, we must leave it to future research to find out the respective fractions of noisy and conscious cursed voting. Knowing these fractions can help to improve predictions, since noisy and conscious types have different expected benefits from voting and thus different signal acquisition probabilities in equilibrium. Ideally, these predictions also take into account imperfect information about the distribution of the various types. The likely result is that logit equilibrium signal acquisition probabilities are in between those derived in this paper, that is, where the uninformed always abstain in the voluntary mode and always vote in the compulsory mode. However, realizing cursed voluntary voting of others might trigger strong negative reciprocity in individuals and drag down information pools below predicted levels, something which may have occurred in *Voluntary voting-3*.

Learning about close votes

Next, we analyze whether participants base their current signal acquisition decisions on closeness of the next vote, which they may project from others' previous voting decisions. We do so by running for each treatment separately probit regressions with random effects at the level of the matching group (mg). The dependent dummy variable, $\gamma_{i,t}$, equals 1 if individual i acquired a signal in period t, and 0 otherwise. As independent variables, we use one dummy variable, two quantitative variables, and various interactions of these variables. First, the lagged dependent dummy variable, $\gamma_{i,t-1}$, separates individuals who were informed in the previous period, $t-1$, from those who were not. This allows us to inspect whether those who tend to be informed and uninformed respond to information in previous voting decisions of others differently. Second, the first quantitative variable, $(\#VOTES/2n)_{\forall-i,t-1}$, is defined as the previous number of—informed and uninformed—votes by all individuals other than i, $\forall - i \neq i$, labeled $\#VOTES_{\forall-i,t-1}$, divided by the number of other individuals, $2n$. Naturally, this variable is only used with voluntary voting. Third, the second quantitative variable, $(\Delta VOTES/\#VOTES)_{\forall-i,t-1}$, is defined as the number of correct votes minus the number of incorrect votes by $\forall - i$ in $t-1$, labeled $\Delta VOTES_{\forall-i,t-1}$, divided by $\#VOTES_{\forall-i,t-1}$. The two quantitative variables are normalized using $2n$ respectively $\#VOTES_{\forall-i,t-1}$ as denominators in order to account for the differences in group size. Fourth, we use a variable that interacts the two quantitative variables, and three variables that interact the lagged dependent variable with each quantitative variable and their interaction variable (again, variables using $(\#VOTES/2n)_{\forall -i,t-1}$ are not applicable in the compulsory mode). Finally, we include two error terms, $\varepsilon_{i,t}$ and ω_{mg}, where the latter is a random effect used to correct for the panel structure in the data. The two quantitative variables were chosen, since in our random matching protocol they reveal basic information that a participant can avail for updating her or his projection of a close vote in the current period. To be precise, for any given, unknown strictly positive probability with which other individuals buy a signal, a greater number of their votes leads to a greater expected margin of victory for the correct alternative (recall that informed participants virtually always voted sincerely). And, given the number of others' votes, a greater margin of victory for the correct alternative means that they have a greater probability of buying a signal, on average. Therefore, if an individual prefers to avoid the signal cost when believing that the next vote outcome might not be close, then both $(\#VOTES/2n)_{\forall -i,t-1}$ and $(\Delta VOTES/\#VOTES)_{\forall -i,t-1}$ should negatively affect her current signal acquisition probability. Moreover, the interaction of both quantitative variables should strengthen the negative effect, since a greater number of others' votes jointly with a greater probability of them getting informed and casting a sincere vote makes a correct group decision even more likely.

Table 2: Probit estimations of signal acquisitions with random effects at the matching group level

Constant and independent variables	**Coefficients**			
	Voluntary voting-3	**Compulsory voting-3**	**Voluntary voting-7**	**Compulsory voting-7**
Constant	**-1.048*****(0.099)	**-1.002*****(0.094)	**-1.000*****(0.119)	**-1.227*****(0.045)
$\left(\frac{\Delta VOTES}{\#VOTES}\right)_{\forall -i,t-1}$	**0.131** (0.151)	**-0.141**** (0.063)	**0.203** (0.155)	**-0.278**** (0.113)
$\left(\frac{\#VOTES}{2n}\right)_{\forall -i,t-1}$	**-0.258**** (0.114)	—	**-0.379*** (0.204)	—
$\left(\frac{\Delta VOTES}{\#VOTES} \times \frac{\#VOTES}{2n}\right)_{\forall -i,t-1}$	**-0.471**** (0.230)	—	**-0.700**** (0.311)	—
$\gamma_{i,t-1}$	**1.962*****(0.119)	**1.983*****(0.067)	**1.472***** (0.186)	**2.182*****(0.067)
$\gamma_{i,t-1} \times \left(\frac{\Delta VOTES}{\#VOTES}\right)_{\forall -i,t-1}$	**0.228** (0.226)	**0.049** (0.091)	**-0.300** (0.261)	**0.173** (0.163)
$\gamma_{i,t-1} \times \left(\frac{\#VOTES}{2n}\right)_{\forall -i,t-1}$	**0.089** (0.179)	—	**0.706**** (0.323)	—
$\gamma_{i,t-1} \times \left(\frac{\Delta VOTES}{\#VOTES} \times \frac{\#VOTES}{2n}\right)_{\forall -i,t-1}$	**-0.099** (0.344)	—	**0.257** (0.511)	—

Note: The dependent variable is the individuals' binary decision on whether to buy a signal (= 1), or not buy (= 0). The independent variables (first column) are defined in the main text. * (**; ***) indicates significance at the 10% (5%; 1%) level, and absolute standard errors are given in parentheses.

Table 2 reveals some interesting learning effects.[28] First, in all treatments, previously informed individuals have a much higher baseline probability of getting informed in the current period than the previously uninformed (all constants are negative and large, and statistically significant, and all coefficients of $\gamma_{i,t-1}$ are positive and large, and significant). Second, focusing first on the previously uninformed, in both compulsory voting treatments they get informed less likely when the value of $(\Delta VOTES/\#VOTES)_{\forall -i,t-1}$ increases (both coefficients are negative and statistically significant). By contrast, in both voluntary voting treatments, they avail the extra information of varying numbers of others' votes by getting informed less likely when the value of $(\#VOTES/2n)_{\forall -i,t-1}$ increases (both coefficients are negative and statistically significant). Moreover, they only respond to $(\Delta VOTES/\#VOTES)_{\forall -i,t-1}$ by getting informed with a much lower probability when the value of the interaction of the two quantitative variables increases (both coefficients of $(\Delta VOTES/\#VOTES)_{\forall -i,t-1}$ are insignificant, and both coefficients of the interaction variable are large and negative, and significant). Third, compared to their uninformed counterparts, the previously informed generally do not respond differently to information in previous voting decisions of others, except that a greater value of $(\#VOTES/2n)_{\forall -i,t-1}$ markedly and statistically significantly raises their probability of getting informed in the current period, which (all other coefficients are insignificant in all treatments). Overall, it seems that apart from the higher baseline signal acquisition probabilities of individuals who tend to be informed, both previously informed and uninformed participants generally respond to voting decisions of others in similar ways. In particular, our probit estimations suggest that many of them avoid the signal cost in anticipation of a close vote.

Experimental result 5 (Learning and close votes): *In all treatments, previously informed participants are more likely to get informed in the current period than those who were not informed. Moreover, independent of their previous signal acquisition decision, participants are generally more (less) likely to get informed when the information in others' previous decisions indicates that the next vote might (not) be close.*

[28] Though not included in the panel models, uninformed votes were slightly biased by the gambler's fallacy. Overall, after the true state was *Yellow*, 55% voted for *Blue* ($p \leq 0.023$ except for $p = 0.352$ in *Voluntary Voting-7*, binomial tests, one-tailed) and after it was *Blue*, 55% voted for *Yellow* ($p \leq 0.036$ except for $p = 0.159$ in *Compulsory Voting-3*, same tests).

5 Conclusions

We study majority voting over two alternatives in small groups. Individuals have identical preferences but are uncertain about which alternative is correct (both are equally likely correct). Prior to voting, each individual can acquire a costly signal that is informative but imperfect. To wit, it shows the correct alternative with probability $p \in (\frac{1}{2}, 1)$, and the incorrect one with probability $1 - p$. We investigate voluntary and compulsory voting. An uninformed vote can negatively impact the group decision as it can override an informative group decision. With voluntary voting, uninformed individuals can avoid this curse by abstaining, which is not a feasible option in the compulsory mode.

In our experiment, we employ groups of three and seven. We find that, on average, larger groups have greater information pools than smaller groups in both voting modes, and that the pools are greater with compulsory than voluntary voting. The results are predicted by logit equilibrium for degrees of decision-making errors commonly observed in related collective action experiments, but not by BNE. Surprisingly, in both voluntary voting treatments there is substantial uninformed voting by many participants, with strong negative consequences for efficiency. Overall, the fraction of correct group decisions and efficiency are in between those predicted for universal ignorance (i.e., the group decision is correct half of the time, at no signal costs) and for a single noise-free delegate who decides for the group and whose expected performance is lower than in social optimum. Moreover, smaller groups with voluntary voting do worst, while groups in all other treatments fare about equally unsatisfactory. While low performances are predicted by logit equilibrium in the compulsory mode where some uniformed voting is tolerated, they are lower than predicted in the voluntary mode due to the swing voter's curse.

Our results are disillusioning and suggest that the curse must be taken very seriously in the current practice of jury and committee voting. For example, in order to prevent uninformed voluntary voting, one might consider introducing some voting costs (see also Tyson 2013) or random monitoring of the knowledge of decision makers. And, an important issues is the robustness of our findings. In this regard, Elbittar et al (2013) and Shineman (2013) provide complementary evidence of uninformed voluntary voting in different setups. Overall, our small group study of majoritarian voting with endogenous costly information hints to severe efficiency losses associated with the curse of uninformed voting. But even without the curse, compared to the social optimum, predicted and observed efficiencies are low due to the collective action problems involved. Therefore, our study suggests that there is room for improving existing designs of jury and committee voting, and hopefully it can inspire further research in this direction.

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Appendix

Proof of Proposition 1

In the *Voting* stage, note that individual i is pivotal if other individuals $-i \neq i$ cast (i) equally many votes for each alternative; (ii) one more vote for A; or (iii) one more vote for B; and she is non-pivotal in all other events. We say that i "strictly prefers" a decision to another one if, in pivotal events, it selects the alternative indicated by strictly more signals in the group (including her own signal), and that she is "indifferent" in non-pivotal events or if, in pivotal events, the two alternatives are indicated by equally many signals in the group. We now analyze voluntary and compulsory voting in turn.

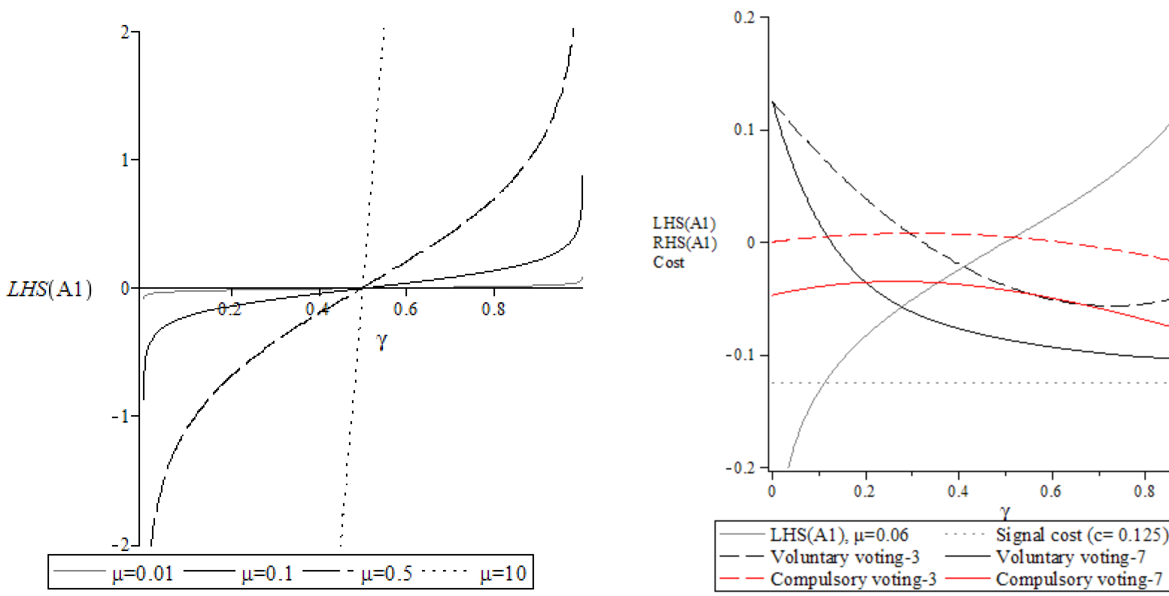
With *voluntary voting*, we must show that there exists a symmetric BNE where each informed individual votes sincerely and each uninformed individual abstains. Suppose that each informed other individual $-i$ votes sincerely and each uninformed $-i$ abstains. *If i is informed*, assuming without loss of generality that she has an a-signal, then sincere voting is her only weakly dominant strategy because: first, it weakly dominates abstaining as in pivotal events (i) it is strictly preferred, and in pivotal events (ii) and (iii) and in non-pivotal events she is indifferent; second, sincere voting weakly dominates voting for B as in pivotal events (i) and (ii) it is strictly preferred, and in pivotal events (iii) and in non-pivotal events she is indifferent. *If i is uninformed*, then abstaining weakly dominates voting for A [B] as in pivotal events (iii) [(ii)] abstaining is strictly preferred, and in pivotal events (i) and (ii) [(i) and (iii)] and in non-pivotal events she is indifferent. Thus, given that others vote sincerely if informed and abstain if uninformed, i's only weakly dominant strategy is to use the same strategy as everyone else. This completes our proof of existence of our symmetric BNE with voluntary voting.

With *compulsory voting*, we must show that there exists a symmetric BNE where each informed individual votes sincerely and each uninformed individual votes randomly with probability one-half for each alternative. As everyone must vote and the group size is odd, $2n + 1$, individual i is only pivotal if other individuals $-i \neq i$ cast n votes for each alternative (see pivotal events (i)), and she is non-pivotal in all other events. Suppose now that each informed $-i$ votes sincerely and each uninformed $-i$ votes with probability one-half for each alternative. *If i is informed*, assuming without loss of generality that she has an a-signal, then neither A nor B dominates the other decision because: in non-pivotal events and in pivotal events with one more B- than A-votes of informed others she is indifferent between voting for A and for B; in pivotal events with at least as many A- than B-votes of informed others she prefers to vote sincerely; and in pivotal events with at least two more B- than A-votes she prefers to vote against her own signal. However, using her own a-signal, she expects that informed others have more a- than b-signals, on average, and thus her unique best response is to vote according to her signal. *If i is* *uninformed*, then there is also no domination because: if she is pivotal, she prefers to vote for A [B] if there are more A- than B-votes [B- than A-votes] of informed others, and she is indifferent if she is non-pivotal and if each alternative has equally many votes of informed others. As i has no signal, she expects that informed others have equally many a- and b-signals, on average, and thus any probability mix of voting for A and for B is a best response, including $(\frac{1}{2}, \frac{1}{2})$. Thus, given that others vote sincerely if informed and vote with probability one-half for each alternative if uninformed, it is a best response of individual i to use the same strategy as everyone else, which shows existence of our symmetric BNE with compulsory voting. ■

Proof of Proposition 2

We first derive the symmetric logit equilibrium conditions (1) and (2) for the signal acquisition probability γ_m^*, $m = V, C$ and thereafter prove our comparative statics results.

Figure A1: Logit equilibrium



Note: The left panel shows $LHS(A1)$ for various degrees of noise. The right panel shows $LHS(A1)$ for $\mu = 0.06$, $RHS(A1)$, and the signal cost (i.e., the lower bound) for our experimental treatments and parameters. In all treatments, both sides of $(A1)$ intersect only once so that each has a unique $\gamma^*(\mu = 0.06)$: 0.409 and 0.277 in *Voluntary voting-3* and *-7*, and 0.517 and 0.355 in *Compulsory voting-3* and *-7*, respectively.

(*Logit equilibrium condition*) Anticipating equilibrium voting, ϑ_m^* (Proposition 1), individual i's expected payoffs of getting informed and not getting informed, $U_m^e(d_i = 1, \gamma_m, \vartheta_m^*, p, n) - c$ and $U_m^e(d_i = 0, \gamma_m, \vartheta_m^*, p, n)$, are augmented by the stochastic terms $\mu\epsilon_1$ and $\mu\epsilon_0$, respectively, where ϵ_1 and ϵ_0 are iid random variables (recall that the parameter $\mu \geq 0$ controls the degree of noise). To keep things simple, in the following we omit the index m whenever our analysis applies to both voting modes or the mode is obvious. Then, if everyone else buys a signal with probability γ, individual i gets informed if and only if $U^e(d_i = 1) - c + \mu\epsilon_1 \geq U^e(d_i = 0) + \mu\epsilon_0 \Leftrightarrow \Pi_i^e(\gamma, \vartheta^*, p, n, c)/\mu \geq \epsilon_0 - \epsilon_1$,[29] which occurs with probability $\gamma = F[\Pi_i^e(.)/\mu]$, where $\Pi_i^e(.) \equiv U^e(d_i = 1) - U^e(d_i = 0) - c$ denotes her expected *net payoffs* of getting informed and F is the distribution function of the difference $\epsilon_0 - \epsilon_1$. Taking the inverse of $\gamma = F(.)$ and multiplying both sides by μ yields $\mu F^{-1}(\gamma) = \Pi_i^e(.)$. Finally, using the logistic distribution, $F(x) = 1/(1 + e^{-x})$, gives our logit equilibrium condition

$$\mu\left[-ln\left(\frac{1-\gamma}{\gamma}\right)\right] = \Pi_i^e(\gamma, \vartheta^*, p, n, c). \qquad (A1)$$

If $\mu = 0$, then $LHS(A1)|_{\gamma\in[0,1]} = 0$ and $(A1)$ turns into the BNE condition. If $\mu > 0$, then $LHS(A1)$ has the following properties: regarding γ, $\frac{\partial LHS(A1)}{\partial\gamma} = \frac{\mu}{\gamma(1-\gamma)} > 0$ for $\gamma \in (0,1)$, $\lim_{\gamma\to 0} LHS(A1) = -\infty$, $LHS(A1)|_{\gamma=1/2} = 0$, and $\lim_{\gamma\to 1} LHS(A1) = +\infty$; and regarding μ, $\frac{\partial LHS(A1)}{\partial\mu} < 0$ for $\gamma \in (0, \frac{1}{2})$, $\frac{\partial LHS(A1)}{\partial\mu} = 0$ for $\gamma = \frac{1}{2}$, and $\frac{\partial LHS(A1)}{\partial\mu} > 0$ for $\gamma \in (\frac{1}{2}, 1)$. The left panel of Figure A1 illustrates these properties for $\mu \in \{0.01, 0.1, 0.5, 10\}$. It depicts γ on the horizontal axis, and $LHS(A1)$ on the vertical axis. For $RHS(A1)$, the expected net payoffs of getting informed are bounded by $-c < \Pi_i^e(.) \leq \frac{1}{2} - c$, that is, in the lower bound i's pivot probability approaches zero, and in the upper bound it equals one and $p = 1$.

(*Existence*) We use Intermediate Value Theorem to show that $\gamma_m^* \in (0,1)$, $m = V, C$ always exists for $\mu > 0$. Note that $LHS(A1)$ and $RHS(A1)$ are continuous for $\gamma \in (0,1)$. Then, as $\lim_{\gamma\to 0} LHS(A1) = -\infty < RHS(A1) \in \left(-c, \frac{1}{2} - c\right] < \lim_{\gamma\to 1} LHS(A1) = +\infty$, both sides of $(A1)$ and thus both sides of logit equilibrium conditions (1) and (2) intersect at least once, which proves that for $\mu > 0$ there always exists a $\gamma_m^* \in (0,1)$ in both voting modes.[30]

[29] We assume without loss of generality that an indifferent individual i chooses to get informed.

[30] For BNE ($\mu = 0$), it is readily verified that $\gamma^* = 0$ [= 1] if the signal cost is too high [low] so that both sides of $(A1)$ do not intersect or intersect at $\gamma = 1$. Moreover, $\gamma^* \in (0,1)$ for intermediate costs and both sides intersect at least once.

($Uniqueness$) The right panel of Figure A1 shows $LHS(A1)$ for $\mu = 0.06$ and $RHS(A1)$ for our experimental treatments and parameters. As can be seen, $RHS(A1)$ has convex and concave properties with voluntary and compulsory voting, respectively, which for some parameter constellations yields multiple equilibria (though not for our experimental parameters). In particular, multiplicity can arises when $LHS(A1)$ is flat (i.e., μ is small).[31] To keep things simple, we focus on unique equilibria by assuming for both voting modes that the degree of noise is large enough, or $\mu \geq \underline{\mu}_m > 0$, where $\underline{\mu}_m$ gives the respective lower bound that ensures uniqueness. Note that computations show that $\underline{\mu}_m$ falls below the typical estimate of $\hat{\mu}$ in binary choice experiments similar to ours.

Next, we derive comparative statics predictions for unique γ^*.

(*Group size*) We must show that increasing the group size from $2n+1$ to $2n+3$ decreases $\gamma^*(n)$ in the region of the parameter space of *unique* equilibrium. For both voting modes, $LHS(A1)$ is constant in n so that it suffices to prove that $RHS(A1)|_n > RHS(A1)|_{n+1}$ for $\gamma \in (0,1)$. If $RHS(A1)$ strictly decreases with n for all $\gamma \in (0,1)$, then $\gamma^*(n)$ must indeed decrease since $LHS(A1)$ is constant in n and strictly increasing in $\gamma \in (0,1)$.

With *voluntary voting*, $m = V$, the terms $p - \frac{1}{2}$ and c on $RHS(1)$ are constant in both n and γ. Then, to see that $RHS(1)$ decreases with n, it suffices to show for

$$P_V(\gamma_V, \vartheta_V^*, p, n) = \sum_{k=0}^{n} \binom{2n}{2k} {\gamma_V}^{2k} (1-\gamma_V)^{2n-2k} \binom{2k}{k} [p(1-p)]^k \qquad (A2)$$

that $P_V(n) - P_V(n+1) > 0$ for all $\gamma \in (0,1)$. First, for individual i's pivot probability, if $2k$ others are informed, we have $P_{V,piv}(\vartheta_V^*, p, k) = \binom{2k}{k}[p(1-p)]^k > P_{V,piv}(\vartheta_V^*, p, k+1) = \binom{2k+2}{k+1}[p(1-p)]^{k+1} \Leftrightarrow \frac{(k+1)^2}{(2k+1)(2k+2)} > p(1-p)$, since $\frac{1}{4} > p(1-p)$ for $p \in (\frac{1}{2}, 1]$ and $\frac{(k+1)^2}{(2k+1)(2k+2)} > \frac{1}{4} \Leftrightarrow 2k+2 > 0$ for $k = 0, \ldots, n+1$. Second, the *cdf* of $P_{V,k}(\gamma_V, n, k) = \binom{2n}{2k}\gamma^{2k}(1-\gamma)^{2n-2k}$ first-order stochastically dominates the *cdf* of $P_{V,k}(\gamma_V, n+1, k) = \binom{2n+2}{2k}\gamma^{2k}(1-\gamma)^{2n+2-2k}$ for $k = 0 \ldots n+1$ and $\gamma \in (0,1)$. Thus, combing both results, $(A2)$ and hence $RHS(1)$ decrease for $\gamma \in (0,1)$ if the group increases by two individuals, so that $\gamma_V^*(n) > \gamma_V^*(n+1)$ with voluntary voting.

[31] For example, for $\mu = 0.001$ and $p = 0.75$, we compute $\gamma_V^* \in \{0.541, 0.932, 0.99999\}$ for $n = 1$ and $c = 0.08$, and $\gamma_C^* \in \{0.00002, 0.035, 0.225\}$ for $n = 23$ and $c = 0.04$.

With *compulsory voting*, $m = C$, the term c on $RHS(2)$ is constant in n. Then, to see that $RHS(2)$ decreases with n, it suffices to show for

$$P_C(\gamma_C, \vartheta_C^*, p, n) = \binom{2n}{n} \sum_{k_A=0}^{n} \sum_{k_B=0}^{n} \binom{n}{k_A}\binom{n}{k_B} {\gamma_C}^{k_A+k_B}(1-\gamma_C)^{2n-k_A-k_B}\, p^{k_A}(1-p)^{k_B}\left(\tfrac{1}{2}\right)^{2n-k_A-k_B} \times \left[\frac{p^{k_A+1}(1-p)^{k_B}}{p^{k_A+1}(1-p)^{k_B}+(1-p)^{k_A+1}p^{k_B}} - \tfrac{1}{2}\right] \quad (A3)$$

that $P_C(n) - P_C(n+1) > 0$ for all $\gamma \in (0,1)$. First, the fraction of pivotal events out of all possible events decreases with n, that is $\binom{2n}{n}\left(\frac{1}{2}\right)^{2n} > \binom{2n+2}{n+1}\left(\frac{1}{2}\right)^{2n+2}$ for $\gamma \in [0,1]$, which works to decrease $(A3)$. Second, let's denote $Q(\vartheta_C^*, n, p, k_A, k_B) \equiv p^{k_A}(1-p)^{k_B}\left(\frac{1}{2}\right)^{2n-k_A-k_B}$, $x \equiv k_A - k_B$, and rewrite $W_C^e(\vartheta_C^*, p, k_A, k_B) \equiv \frac{p^{k_A+1}(1-p)^{k_B}}{p^{k_A+1}(1-p)^{k_B}+(1-p)^{k_A+1}p^{k_B}} - \frac{1}{2}$ as $W_C^e(\vartheta_C^*, p, x \geq 0) = \frac{p^{x+1}}{p^{x+1}+(1-p)^{x+1}} - \frac{1}{2} > 0$ if $x \geq 0$ and $W_C^e(\vartheta_C^*, p, x < 0) = \frac{p(1-p)^{-x}}{p(1-p)^{-x}+p^{-x}(1-p)} - \frac{1}{2} \leq 0$ if $x < 0$, with $-(n+1) \leq x \leq n+1$ (i.e., the Bayesian updated value depends on x, but not on the particular levels of k_A and k_B that determine x). Then, for $p \in (\frac{1}{2}, 1)$ and all $k_A, k_B = 0, \dots, n$ and $x = -n, \dots, n$ we have

$$Q(n, k_A, k_B)W_C^e(x) > Q(n+1, k_A, k_B)W_C^e(x) = \left(\tfrac{1}{2}\right)^2 Q(n, k_A, k_B)W_C^e(x);$$

$$Q(n, k_A, k_B)W_C^e(x) > Q(n+1, k_A+1, k_B+1)W_C^e(x) = p(1-p)Q(n, k_A, k_B)W_C^e(x);$$

$$Q(n, k_A, k_B)W_C^e(x) > Q(n+1, k_A+1, k_B)W_C^e(x+1) = p\tfrac{1}{2}Q(n, k_A, k_B)W_C^e(x+1);$$

$$Q(n, k_A, k_B)W_C^e(x) > Q(n+1, k_A, k_B+1)W_C^e(x-1) = (1-p)\tfrac{1}{2}Q(n, k_A, k_B)W_C^e(x-1),$$

where the inequalities always hold because $1 > \left(\frac{1}{2}\right)^2$, $1 > p(1-p)$, $2W_C^e(x) > pW_C^e(x+1)$, and $2W_C^e(x) > (1-p)W_C^e(x-1)$, respectively. Third, the *cdf* of $\binom{n}{k_j}\gamma^{k_j}(1-\gamma)^{n-k_j}$ first-order stochastically dominates the *cdf* of $\binom{n+1}{k_j}\gamma^{k_j}(1-\gamma)^{n+1-k_j}$ for $k_j = 0, \dots, n$, with $j = A, B$ and $\gamma \in (0,1)$. Thus, combing all three results, $(A3)$ and hence $RHS(2)$ decrease for $\gamma \in (0,1)$ if the group increases by two individuals, so that $\gamma_C^*(n) > \gamma_C^*(n+1)$ with compulsory voting.

(*Signal cost*) An increase in $c > 0$ decreases the unique $\gamma^*(c)$ by the following argument: $LHS(A1)$ is constant in c, while $\frac{\partial RHS(A1)}{\partial c} = -1 < 0$ for $\gamma \in [0,1]$. Since $LHS(A1)$ strictly increases with $\gamma \in (0,1)$, both sides of $(A1)$ must intersect further to the left if c increases, so that $\gamma^*(c)$ decreases with c.

(*Degree of noise*) An increase in $\mu \geq \underline{\mu}_m > 0, m = V, C$ moves $\gamma^*(\mu) \neq 0.5$ closer to one-half by the following argument: increasing μ yields a steeper $LHS(A1)$, which always goes through $LHS(A1)|_{\gamma=\frac{1}{2}} =$

0 (where it is independent of μ) and $RHS(1)$ is constant μ. This means that both sides of $(A1)$ must intersect at a new equilibrium $\gamma'^{*}(\mu') \in \left(\gamma^{*}(\mu), \frac{1}{2}\right]$ if $\gamma^{*}(\mu) < 0.5$ and $\gamma'^{*}(\mu') \in \left[\frac{1}{2}, \left(\gamma^{*}(\mu)\right)\right.$ if $\gamma^{*}(\mu) > 0.5$. Thus, $\gamma^{*}(\mu) \neq 0.5$ moves closer to one-half if μ increases. ■

Probability of a correct group decision

If the true state is j, then each informed individual has more likely a j- than a $-j$-signal, where $j = A, B$ and $j \neq -j$. With *voluntary voting*, the probability of a correct group decision is then given by:

$$P_{V,cor}\left[j|j|\ \gamma_V, \vartheta_V^*, n, p\right] = \sum_{k=1}^{2n+1} \sum_{k_j=\left\lceil\frac{k+1}{2}\right\rceil}^{k} \binom{2n+1}{k} \gamma_V^k (1-\gamma_V)^{2n+1-k} \binom{k}{k_j} p^{k_j} (1-p)^{k-k_j}$$
$$+\frac{1}{2}\sum_{k=0}^{n} \binom{2n+1}{2k} \gamma_V^{2k} (1-\gamma_V)^{2n+1-2k} \binom{2k}{k} [p(1-p)]^k. \qquad (A4)$$

The first term considers outright wins of alternative j (i.e., there are more votes for j than $-j$ out of k informed sincere votes, $k_j \geq \left\lceil\frac{k+1}{2}\right\rceil$, and the remaining $2n+1-k$ individuals abstain), and the second term considers ties (i.e., there are k informed sincere votes for each alternative, and $2n+1-2k$ abstentions), which are broken by a coin flip. Moreover, with *compulsory voting*, the probability of a correct group decisions is given by:

$$P_{C,cor}\left[j|j|\ \gamma_C, \vartheta_C^*, n, p\right] = \sum_{\kappa_j=n+1}^{2n+1} \sum_{k_j=0}^{\kappa_j} \sum_{k_{-j}=0}^{2n+1-\kappa_j} \binom{2n+1}{\kappa_j} \binom{\kappa_j}{k_j} \binom{2n+1-\kappa_j}{k_{-j}} \qquad (A5)$$
$$\times \gamma_C^{k_j+k_{-j}} (1-\gamma_C)^{2n+1-k_j-k_{-j}} p^{k_j} (1-p)^{k_{-j}} \left(\frac{1}{2}\right)^{2n+1-k_j-k_{-j}},$$

where κ_j denotes the total number of j-votes, and k_j $[k_{-j}]$ the number of informed sincere j $[-j]$-votes. Alternative j wins outright if there are more informed sincere and uninformed random votes for j than $-j$, or $\kappa_j \geq n+1$. Unlike in $(A4)$, there is no second term in $(A5)$ because ties are impossible in odd-sized groups with compulsory voting.

Proof of Proposition 3

If n goes to infinity, the logit equilibrium condition $(A1)$ gets

$$\lim_{n\to\infty} \mu \left[-ln\left(\frac{1-\tilde{\gamma}_m}{\tilde{\gamma}_m}\right)\right] = \lim_{n\to\infty} \Pi_{i,m}^{e}(\tilde{\gamma}_m, \vartheta_m^*, p, n, c), \qquad (A6)$$

$m = V, C$, where $\tilde{\gamma}_m$ denotes the limiting equilibrium signal acquisition probability. First, note that $LHS(A6) = \lim_{n\to\infty} \mu\left[-ln\left(\frac{1-\tilde{\gamma}_m}{\tilde{\gamma}_m}\right)\right] = \mu\left[-ln\left(\frac{1-\tilde{\gamma}_m}{\tilde{\gamma}_m}\right)\right]$ and $\lim_{n\to\infty} c = c > 0$ in $\Pi^e_{i,m}(.)$ on $RHS(A6)$. For $\mu > 0$, which implies $\tilde{\gamma}_m > 0$, if n goes to infinity, then individual i's pivot probability approaches zero, so that $\lim_{n\to\infty} \Pi^e_{i,m}(\tilde{\gamma}_m, \vartheta^*_m, p, n, c) = -c$ for $m = V, C$ (i.e., as $\lim_{n\to\infty} \binom{N}{h} y^h (1-y)^{N-h} = 0$ for $y \in (0,1)$ and $h = 0, \dots, N$ and, for the compulsory mode, $W^e_C(.) < 1$). Therefore, $(A6)$ gets

$$\mu\left[-ln\left(\frac{1-\tilde{\gamma}_m}{\tilde{\gamma}_m}\right)\right] = -c \Leftrightarrow \frac{1-\tilde{\gamma}_m}{\tilde{\gamma}_m} = e^{c/\mu} \Leftrightarrow \tilde{\gamma}_m(\vartheta^*_m, c, \mu > 0) = \frac{1}{1+e^{c/\mu}} > 0 \qquad (A7)$$

for $m = V, C$, as stated in the proposition. Next, for $\mu > 0$ and $p \in (\frac{1}{2}, 1)$, if n increases without bound, then the difference in expected numbers of informed votes for the correct minus the incorrect alternative is $\lim_{n\to\infty}[(2n+1)\tilde{\gamma}_m p - (2n+1)\tilde{\gamma}_m(1-p)] = \lim_{n\to\infty}(2n+1)\tilde{\gamma}_m(2p-1) = \infty$, the expected number of uninformed random votes equals zero with voluntary voting (i.e., the uninformed all abstain), and $\lim_{n\to\infty}(2n+1)(1-\tilde{\gamma}_m) = \infty$ with compulsory voting. Thus, the uninformed by themselves create a sure tie in the voluntary mode and, by the law of large numbers, they almost surely create a tie if their number is even and a one-vote lead for either alternative if their number is odd. But these ties and one-vote leads do not matter, as there are infinitely more votes for the correct than incorrect alternative. Therefore, for $\mu > 0$ and $p \in (\frac{1}{2}, 1)$, large groups make a correct group decision almost surely. Finally, for $\mu = 0$ (i.e., BNE), we have $LHS(A6) = 0$. If $\tilde{\gamma}_m(\mu = 0) > 0$, then $\lim_{n\to\infty} \Pi^e_{i,m}(\tilde{\gamma}_m, \vartheta^*_m, p, n, c) = -c$, which is a contradiction for $c > 0$, since individual i would choose not to buy a signal, $\tilde{\gamma}_m(\mu = 0) = 0$! Therefore, in equilibrium it must be that $\tilde{\gamma}_m(\vartheta^*_m, c, \mu = 0) = 0$ ("universal rational ignorance"), and thus the group decision is correct half of the time, which completes our proof of Proposition 3. ■

Figures A2: Group performances

Figure A2.1: Expected information pool

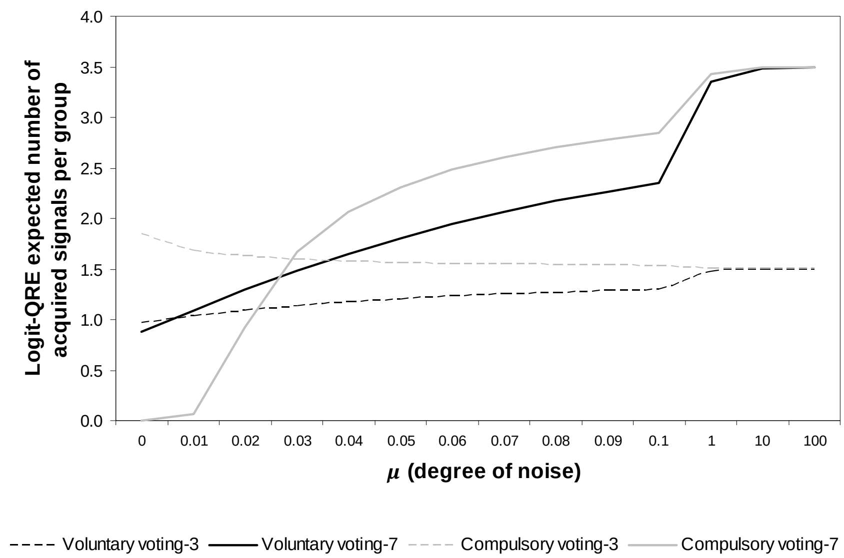


Figure A2.2: Probability of a correct group decision

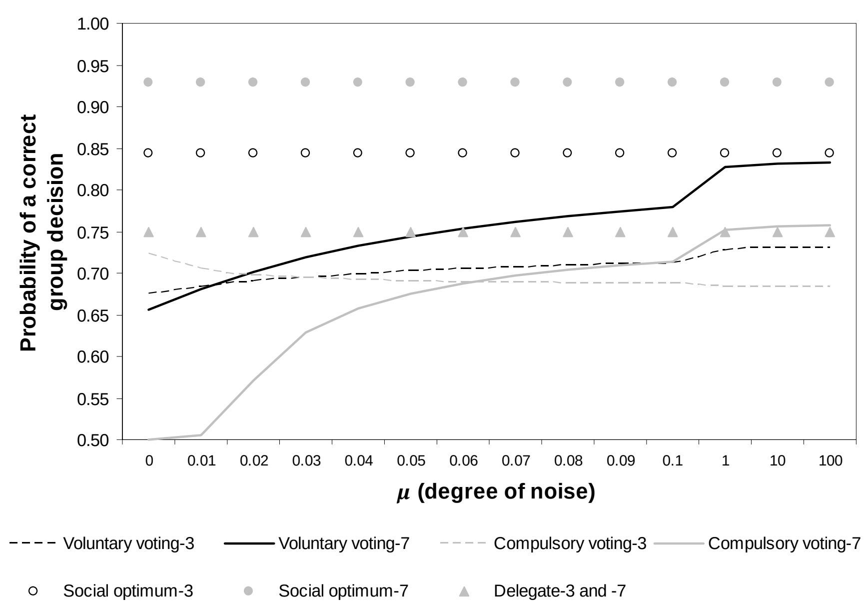
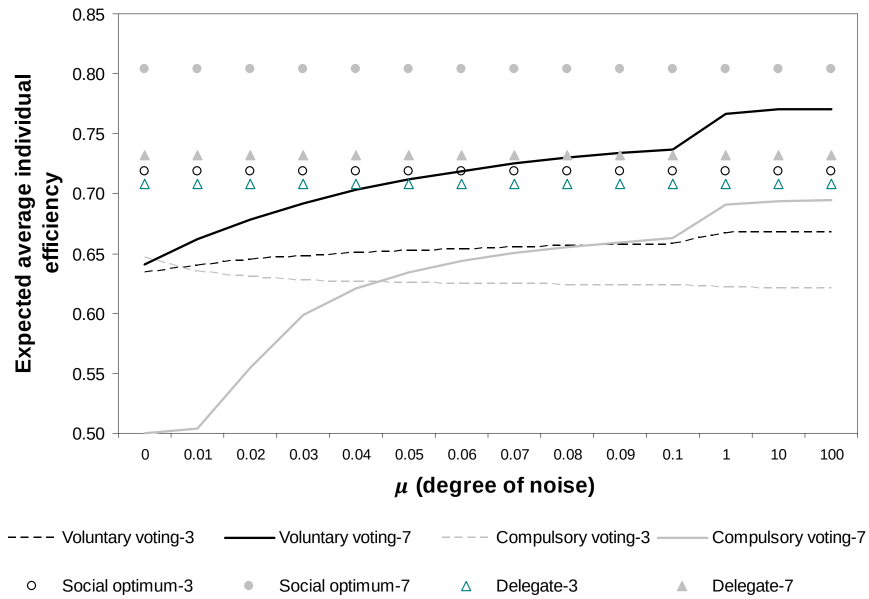


Figure A2.3: Expected efficiency



Note: For our logit equilibrium signal acquisition probabilities (Figure 1), the lines depict per treatment the expected number of acquired signals per group (Figure A2.1), the probability of a correct group decision (A2.2), and expected efficiency per individual (i.e., group efficiency divided by group size; A2.3). In social optimum, as $\gamma^{o} = 1$, the expected number of acquired signals per group equals the respective group size (not shown in A2.1), and with a single noise-free delegate, as $\gamma^{D} = 1$, it equals one (also not shown). The probabilities of a correct group decision and average expected efficiency per individual in social optimum (for a single delegate) are shown as circles (triangles) in A2.2 and A2.3, respectively.

Table A1: Bayesian Nash equilibrium

	BNE predictions ($\mu = 0$)					
	Voluntary voting			Compulsory voting		
Group size	γ^*	$P_{correct}$	*Efficiency*	γ^*	$P_{correct}$	*Efficiency*
1	1	.750	.625	1	.750	.625
3	.321	.675	.635	.615	.723	.647
				0	.500	.500
5	.181	.662	.639	0	.500	.500
7	.125	.657	.641	0	.500	.500
9	.096	.654	.642	0	.500	.500
11	.078	.652	.642	0	.500	.500
13	.065	.651	.642	0	.500	.500
15	.056	.650	.643	0	.500	.500
17	.049	.649	.643	0	.500	.500

Table A2: Logit equilibrium

	Logit predictions ($\mu = 0.06$)					
	Voluntary voting			Compulsory voting		
Group size	γ^*	$P_{correct}$	*Efficiency*	γ^*	$P_{correct}$	*Efficiency*
1	.889	.722	.611	.889	.722	.611
3	.409	.705	.654	.517	.690	.625
5	.322	.732	.692	.408	.686	.635
7	.277	.754	.719	.355	.688	.644
9	.250	.771	.740	.323	.692	.651
11	.230	.786	.757	.301	.696	.658
13	.216	.799	.772	.284	.700	.665
15	.205	.810	.784	.272	.705	.671
51	.140	.914	.896	.193	.756	.732

Figure A3: Fractions of informed voting, abstention, and uninformed voting over periods