Jury Voting without Objective Probability *

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Abstract

Unlike in the standard jury voting experiment, the voting environment in practice has no explicit signal structure. Voters then need to conceptualize the information structure in order to update their beliefs based on "pivotal reasoning." This paper investigates whether voters can play a strategic voting under a "detail-free" environment. We obtain non-parametric predictions in terms of the differences in voting behaviors under majority and unanimity rule. Our experimental results suggest that voters can still play the strategic voting as in the existing experiments.

Keywords. Common value voting game, Majority vs. Unanimity rules, Experiment

JEL Code: D71, D72, C92

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1 Introduction

Since Condorcet (1785), a common value voting model has been studied as an institution to aggregate opinions. In the 90s, the model was extended to a game theoretical framework in order to incorporate a strategic voting. A strategic voter knows that each voter can affect the voting outcome only if her vote is pivotal. Thus, each voter updates her belief about an unobservable state to be consistent with a voting strategy profile conditional on being pivotal. Since the statistical implication of being pivotal is different between voting rules, whether an equilibrium voting strategy reflects each voter's opinion depends on a voting rule. For example, Feddersen and Pesendorfer (1998) show that unanimity rule induces more approval votes compared to majority rule in equilibrium. Such a strategic voting under different voting rules was supported by laboratory experiments, e.g., Guarnaschelli et al. (2000) and Goeree and Yariv (2011).[1]

The existing experiments in the literature often use a stylized setting to ensure the basic assumption of the model. Specifically, they use a jar that consists of two types of colored balls, say, blue and red. There are two types of a jar based on the proportion of blue balls in the jar. The state is then defined by the jar's type. Each voter, who does not know the jar's type, draws a ball from the jar and form her "opinion" about the jar's type. That is, if she draws a blue (red) ball, she infers that the jar's type is more likely to be the one that has a higher proportion of blue (red) balls. While this is a convenient way to ensure the common knowledge of the information structure, there is one concern about the experimental setting: there is often no explicit information structure in practice. For example, in a trial, each juror forms an opinion based on available evidence, but each juror rarely knows the probability that other voter's opinion is correct. In an executive meeting, when board members vote for the future project, each member hardly knows that the probability that other member's opinion is logically consistent with the available information. When there is no explicit information structure, voters need to conceptualize the information structure of the game in order to update one's belief based on the pivotal reasoning. Hence, whether voters can still play the strategic voting becomes a non-trivial question. The purpose of this paper is testing the robustness of strategic voting under such a "detail-free" environment.

[1]Battaglini et al. (2010) also tested another type of pivotal voting model called "swing voter's curse" and confirmed their predictions.

There might be several reasons why the information structure of a practical voting game is implicit and unknown to voters. One of the reasons is that voters could form opinions based on an incorrect reasoning, and the probability of reasoning errors is hardly known in practice. For example, a juror might think that a prosecutor's claim is based on an incorrect reasoning. However, the voter might not know the probability that other voters are also aware of it. In the executive meeting example, an executive might think that a new project is worth launching given the available data, but she does not know whether other executives also know the logical implication of the available data.

In order to analyze a jury voting in which the uncertainty of the game arises from the possibility of reasoning/computational errors, this paper introduces a new experimental design. A proposer solves a logic or math problem and proposes an answer to voters. Each voter evaluates the proposal and then votes for either "approve" or "reject." Then, a voting rule, which is either unanimity or majority rule, determines the voting outcome and each voter is rewarded if and only if the voting rule accepts (rejects) a correct (incorrect) proposal. Since there is no objective uncertainty about the answer to the math/logic problem, the uncertainty of the game arises only from voters' reasoning-errors whose probabilities are unknown to voters.

Unlike in the existing jury voting experiments, there is no explicit signal in our experiment; instead, each voter forms her belief about the state based on one's reasoning. In order to accommodate a whole range of beliefs that can be induced by voters' reasoning, we generalize the jury voting game of Feddersen and Pesendorfer (1998). Since there is no explicit signal, our model cannot obtain point predictions for the experiment. Our approach is to analyze the general properties of equilibria that do not depend on parameter values. We then provide predictions based on the differences in the general properties under two voting rules.

Our model has two predictions. The first prediction is that, as the standard common value voting models, the proportion of approval vote is higher under unanimity rule compared to that under majority rule. Intuitively, since unanimity rule requires more approval votes when a vote is pivotal, the voter needs to have a stronger confidence to reject the proposal under unanimity. The second prediction is that if voters' confidence reflects their cognitive ability sufficiently well, the proportion of "correct rejection votes" under unanimity rule is higher than that under majority rule. On the other hand, if their confidence does not reflect their cognitive ability well, there should be no significant difference in the proportion of correct rejection votes.

In our experiment, unanimity rule induced more approval votes than majority rule confirming our main prediction. This suggests that in spite of the lack of explicit information structure, the subjects could follow the pivotal reasoning. The second prediction was also supported: in the math treatment where voters' confidence reflected their cognitive ability well, the proportion of correct rejection votes was significantly higher. On the other hand, in the logic treatment where voters' confidence did not reflect their cognitive ability, there was no significant difference in the proportion of correct rejection vote.

The rest of our paper is organized as follows. Section 2 describes the experimental design. Section 3 provides predictions based on the model. In Section 4, we report experimental results and discuss them. Section 5 provides the response-time analysis to investigate an alternative interpretation of the experiment. Finally, Section 6 concludes the paper.

2 Jury voting experiment without "jar"

In order to analyze a strategic voting without any explicit information structure, we introduce an experimental design in which a state is solely determined by the solution of a logic/math problem. Since the uncertainty of the game arises only from the possibility of reasoning errors, voters need to conceptualize the information structure in order to play a strategic voting.

2.1 Design of experiment

We have four treatments: T1, T2, T3, and T4. In each treatment, subjects were randomly matched to form a group of 6. Each group consists of one proposer and five voters who were randomly assigned. The proposer proposes an answer to a logic or math problem and each voter votes for either "approve" or "reject." There are four treatments based on the type of a question (math or logic) and the type of a voting rule (majority rule or unanimity rule). The following table summarizes all treatments:

	Math	Logic
Majority rule	T1	T3
Unanimity rule	T2	T4

The experiment is one shot, and each voter makes a decision only once. The timeline of the each treatment is as follows.

- **Stage 1.** A question is provided to the proposer.
- **Stage 2.** After 5 minutes, the question and the proposed answer are provided to each voter. Voters are not allowed to communicate with other voters.
- **Stage 3.** After 5 minutes, each voter chooses whether to approve or reject the proposal.
- **Stage 4.** Given votes, a voting outcome is determined by a voting rule. Under majority rule, the voting outcome is "approve" ("reject") if votes for "approve" ("reject") is the majority of votes. Under unanimity rule, the voting outcome is "approve" if all voters approve. Otherwise, the voting outcome is "reject."

The payoff of each player is as follows:

- Proposer: For all treatments, if the proposed answer is correct, the proposer receives 5 euro; otherwise he/she receives 2 euro. Since the payoff is independent of the voting outcome, the incentive to answer correctly is exactly the same in all treatments.
- Voters: For all treatments, if the voting outcome is consistent with the truth-value of the proposal, i.e., the group approves a correct proposal or rejects an incorrect proposal, each voter receives 5 euro, otherwise each voter receives 2 euro. Thus, the payoff depends only on whether a voting outcome is correct or not.

In total, 228 subjects participated in the experiment. There were 9 or 10 groups per treatment. The subjects were students studying at German universities and were randomly recruited from a subject pool of approximately 3100 subjects using an email recruitment system. Each subject participated only in one treatment. The experiments were conducted in a laboratory where subjects were randomly seated in partitioned cubicles. In addition to earnings from the experiment, each subject received a show up fee of 2.5 euro. They were informed that their votes will be anonymous and that they will be paid privately.

2.2 Math and logic problems

2.2.1 Math problem

In the math treatment, each player solves the following problem.

> "Adam's income is the solution of 85877×97879. You can get Adam's age by adding each digit of his income, e.g., if his income is 5466, then his age is $5+4+6+6$. What is his age?"

Observe that the math problem does not require any sophisticated reasoning but a reasonable computational skill. Thus, when a subject can finish the computation in time, her answer might have a good chance to be correct, while her answer might have a low chance to be correct when she fails to obtain an answer in time. In other words, a voter could have a good sense to assess the probability of having a correct opinion.

2.2.2 Logic problem

In the logic treatment, each player solves the following problem.

> There are four countries, A,B,C, and D. In the last year, countries A and B had their unemployment rate 5% and 10% respectively. On the other hand, in the last year, countries C and D had their economic growth rate 2% and 5% respectively. We want to test the following statement about the economy of the four countries.
>
> "In the last year, if the unemployment rate of a country is higher than 6%, the economic growth rate of the country was less than 3%."
>
> Suppose you can access to the following reports: (i) country C's unemployment rate, (ii) country D's unemployment rate, (iii) country A's growth rate, (iv) country B's growth rate. Which report(s) MUST you check to test the truth of the statement?

This problem is a modified version of Wason selection task (1966). The original Wason selection task is more abstract and notorious for its difficulty. Thus, we put an economic context to make the problem intuitive and induce more correct proposals.

Most people usually notice (iv) needs to be checked. On the other hand, people often choose (i) mistakenly. This is a wrong choice since any level of country C's unemployment rate cannot refute the statement: if the rate is lower than 6%, the statement is silent about the growth rate, while if it is higher than 6%, the growth rate, 2%, satisfies the statement. (ii) is another information to be checked. This is because if the unemployment of country D is higher than 6%, it refutes the statement.

2.2.3 Discussion about the cognitive tasks

The math and logic tasks are different in two dimensions: the math question is more time-demanding than the logic question while the logic question requires more sophisticated reasoning. It would be difficult for some subjects to complete the computation within 5 minutes while 5 minutes might be enough for most subjects to get their own answers in the logic question.

When a subject fails to complete her computation in time, she would have low confidence in her evaluation of a proposal. In other words, whether a subject could compete her computation in time or not would play a role of feedback that helps her to form reasonable confidence about her evaluation. On the other hand, the feedback might not be available in the logic treatment since most subjects would obtain their own solutions in time. Thus, it might be difficult to be aware of one's reasoning error in the logic treatment and, consequently, some subjects could be overconfident in their opinions.

In fact, in psychology, Kruger and Dunning (1999) found that, in logical reasoning, the subjects with low cognitive ability tended to be not only mistaken but also unaware of their poor reasoning ability. In other words, the subjects with low cognitive ability were overconfident. Moreover, they argue that overconfidence could be attributed to lack of feedback in logical reasoning; that is, it is difficult to be aware of one's mistake in logical reasoning without any feedback.

3 Theoretical analysis

This section provides theoretical predictions. Unlike in the standard jury experiment, there is neither an explicit signal nor a prior probability in our experiment. Thus, we need to employ a more general model to describe the experimental setting and obtain predictions.

3.1 Model

Let $\Omega = \{0,1\}$ be the set of states. If the proposal is correct, $\omega = 1$, whereas $\omega = 0$ if the proposal is incorrect. Since both math and logic questions have the correct answer, ω is always well-defined given a proposal. However, since voters have to evaluate the non-trivial proposal under a time constraint, most of the voters would be not entirely sure about their evaluation of the proposal. Then, let $p_i \in [0,1] = P$ denote voter i's belief about $\omega = 1$ after the voter evaluates the proposal. If voter i thinks that the proposal is more likely to be correct, p_i is higher. In other words, p_i is essentially voter i's confidence about $\omega = 1$. Since voters could make mistakes in their reasoning/computation when evaluating the proposal, p_i can be heterogeneous across voters. Then, assume that, given ω, p_i is independently drawn from a continuous distribution $F(p|\omega)$ for each i.[2] We also assume that each voter's opinion is more informative than a pure noise: if p_i is higher, the proposal is more likely to be correct. Formally, we assume $\frac{f(p|1)}{f(p|0)}$ is increasing in p, that is, it satisfies the monotone likelihood ratio property. p_i could be partly determined by voter i's cognitive ability. However, there is a caveat: even if a voter has low cognitive ability, it is possible that the voter is as confident as a voter with higher cognitive ability, i.e., the voter with low cognitive ability can be "overconfident." In this case, higher p_i does not reflect her cognitive ability well.

Remark 1. While there is neither an explicit signal nor a prior probability in our setting, the model of Feddersen and Pesendorfer (1998) is "embedded" in our model.[3] Note that p can be any value $[0,1]$ in our setting whereas p is determined by a binary signal given a prior probability in their model. That is, p takes only two possible values in their model. Thus, we can always construct $f(p|\omega)$ to be consistent with the binary signal structure and the prior probability of their model.

A voting rule determines a voting outcome given a voting profile $(a_1, a_2, .., a_5)$. Specifically, a voting rule is characterized by the minimum number of approval votes in order to pass the

[2] Voter i's cognitive ability should be a major determinant of p_i, while voter i's cognitive ability is determined before the experiment. Thus, the assumption that p_i is drawn from a distribution might not be very natural if i is interpreted as a subject's identity. However, if i is interpreted as a seat number in the session, the assumption is natural as the subjects were randomly assigned to seats.

[3] For more detail, see Appendix.

proposal, which is denoted by $k \in \{3, 5\}$. Thus, in our experiment, a voting rule is **majority** if $k = 3$, whereas a voting rule is **unanimity** if $k = 5$.

Turning to a voter's payoff function, each voter gets higher payoff when voting outcome $x \in \{A, R\}$ is consistent with state $\omega \in \{0, 1\}$. By normalizing the payoff in the experiment, voter i's payoff function can be written as follows.

$$u_i(x, \omega) = \begin{cases} -\frac{1}{2} & \text{if} \quad (x, \omega) = (A, 0) \\ 0 & \text{if} \quad (x, \omega) = (R, 0) \\ -\frac{1}{2} & \text{if} \quad (x, \omega) = (R, 1) \\ 0 & \text{if} \quad (x, \omega) = (A, 1) \end{cases}$$

for all i.

Given p_i, each voter simultaneously chooses either "approve" A or "reject" R. Formally, voter i's strategy is defined as a mapping $\sigma_i : P \to \{R, A\}$. We focus on pure strategies since, in any equilibrium with a mixed strategy, the set of p who uses a mixed strategy has measure zero.

Voter i's decision affects her payoff only when her vote is pivotal. Given a strategy profile σ, let $\psi_\sigma(k, p_i)$ be voter i's belief about $\omega = 1$ conditional on being pivotal and p_i under voting rule k. That is,

$$\psi_\sigma(k, p_i) := \frac{\Pr(piv|\omega = 1; k, \sigma)p_i}{\Pr(piv|\omega = 1; k, \sigma)p_i + \Pr(piv|\omega = 0; k, \sigma)(1 - p_i)}.$$

Voter i's expected payoff from a_i given σ and p_i is then

$$E[U(a_i, \sigma_{-i}(p_{-i}))|p_i] = \begin{cases} -\frac{1}{2}(1 - \psi_\sigma(k, p_i)) & \text{if } a_i = A \\ -\frac{1}{2}\psi_\sigma(k, p_i) & \text{if } a_i = R \end{cases}.$$

σ^* is an **equilibrium** if, for all i,

$$E[U(\sigma_i^*(p_i), \sigma_{-i}^*(p_{-i}))|p_i] \geq E[U(a_i, \sigma_{-i}^*(p_{-i}))|p_i]$$

for any a_i.

3.2 Analysis and Predictions

A voting strategy is a **cutoff strategy** if there exists $\hat{p}_i \in P$ such that

$$\sigma_i(p_i) = \begin{cases} A & \text{if } p_i > \hat{p}_i \\ R & \text{if } p_i < \hat{p}_i \end{cases}$$

for each i.

Lemma 1. *Any equilibrium strategy is a cutoff strategy.*

Proof. See Appendix. □

To obtain predictions that are comparable to the existing literature, we focus on **symmetric equilibria**, i.e., if $\sigma_i(p_i) = a'$ and $p_j = p_i$, then $\sigma_j(p_j) = a'$. In short, if two voters have exactly the same belief about ω, they choose the same action.[4]

The next proposition states that the equilibrium cutoff under unanimity rule is always lower than that under majority rule. Let $\hat{p}(k)$ be the cutoff p of a symmetric equilibrium given k.

Proposition 1. *Given any symmetric equilibrium under each voting rule,* $\hat{p}(5) < \hat{p}(3)$.

Proof. See Appendix. □

To provide the intuition for Proposition 1, note that a voter can affect the voting outcome only if her vote is pivotal. If a voter is pivotal under unanimity rule, all other voters approve a proposal. On the other hand, if a voter is pivotal under majority rule, half of the other voters choose "reject," whereas the other half of them choose "approve." Thus, when a voter rejects a proposal in unanimity rule, she requires a higher level of confidence compared to under majority rule.

Unlike in our model, voters play a mixed strategy equilibrium under unanimity rule in Feddersen and Pesendorfer (1998). Specifically, when a voter observes a signal that supports the prosecutor's claim, the voter chooses "approve" whereas she randomizes her votes over "reject" and "approve" when the voter observes a signal that does not support the prosecutor's claim. The reason their model has the mixed strategy equilibrium under unanimity rule is as follows. Suppose that voters follow a symmetric pure strategy profile under unanimity rule. It implies that when a voter is pivotal, all other voters observe the signal that supports the prosecutor's claim. Then, even if the voter observes the opposite signal, she has an incentive to follow the other voters, that is, there is no sincere voting equilibrium.

[4] Since the subjects have different cognitive abilities, one might think that it is unnatural to consider an equilibrium in which the strategy profile is independent of i. However, as we mentioned in the earlier footnote, if i is interpreted as a seat number in the session instead of a subject's identity, it is natural to consider an equilibrium in which two voters in seat i and j choose the same action if $p_i = p_j$ as the subjects were randomly assigned to seats.

On the other hand, in our setting, there is no need to randomize their votes since the type space is continuous, i.e., $P = [0, 1]$. That is, instead of choosing the probability of voting for rejection, the cutoff level $\hat{p}$, which controls the ex ante probability of rejection vote, is determined so that it balances the expected payoffs from two votes. In fact, from the ex ante perspective, our pure strategy equilibrium is analogous to their mixed strategy equilibrium: the ex ante probability that a voter votes for rejection is higher under unanimity rule compared to under majority rule.

Given a symmetric equilibrium with cutoff $\hat{p}(k)$, the ex ante probability of $a_i = R$ conditional on ω is $\Pr(a_i = R|\omega, k) = F(\hat{p}(k)|\omega)$. Thus, Proposition 1 implies that the ex ante probability of $a_i = R$ under unanimity rule is lower than that under majority rule. Assuming that $f(p|\omega)$ is independent of voting rules, we obtain our main prediction.[5]

Prediction 1. *The proportion of rejection votes under majority rule is larger than that under unanimity rule.*

This is the key implication of "strategic voting" in common value voting games. Note that if many voters are naive in the sense that they do not update their beliefs according to the pivotal reasoning, a voting rule should not affect voting behaviors.

The next prediction is about **correct votes**: rejection votes when the proposal is wrong. Let $\Pi_R(k)$ be the probability of $\omega = 0$ conditional on $a_i = R$. The next proposition states that the probability of correct-reject votes is higher under unanimity rule.

Proposition 2. *Given any symmetric equilibrium under each voting rule,* $\Pi_R(5) > \Pi_R(3)$.

Proof. See Appendix. □

The idea of Proposition 2 is the following. From Proposition 1, the minimum level of confidence that induces rejection vote is higher under unanimity rule, i.e., $\hat{p}(5) < \hat{p}(3)$. Note that voters with $p \in [0, \hat{p}(k))$ vote for rejection under voting rule k. Thus, voters who strongly believe that the proposal is wrong, i.e., $p \in [0, \hat{p}(5))$, vote for rejections under both voting rules, while voters who believe that the proposal is wrong but with less confidence, i.e., $p \in (\hat{p}(5), \hat{p}(3))$ vote for rejection

[5] Since the proposer's payoff is independent of a group decision, there is no reason that the quality of proposals depends on a voting rule. Then, since the subjects were assigned to four treatments randomly, $f(p|\omega)$ should be independent of voting rules.

only under majority rule. Since only voters who are strongly confident vote for rejection under unanimity rule, the proportion of correct rejection vote should be higher under unanimity rule.

As we mentioned in Section 2-2-3, even if a voter has a low cognitive ability, it is possible that the voter is as confident as a voter with a higher cognitive ability. If there are many voters who are overconfident, a large proportion of voters with $p \in [0, \hat{p}(5))$ could have almost the same cognitive ability as voters with $p \in (\hat{p}(5), \hat{p}(3))$. Consequently, there should be an only negligible difference in the rate of correct rejection votes under two voting rules. From this observation, we can obtain the following prediction: Proposition 2 should be empirically pronounced only if voters' confidence reflects their cognitive ability well. To state this formally, consider voters who think that a proposed answer is wrong. Suppose we ask each of these voters to choose his/her confidence level c from $\{1, 2, 3, 4\}$ where higher c refers to higher confidence. If the rate of correct rejection votes conditional on c is not significantly increasing in c given a cognitive task, we can interpret that voters' confidence does not reflect their cognitive ability well. Thus, there should be almost no difference in the rate of correct rejection votes under two voting rules. On the other hand, if the rate of correct rejection votes conditional on c is significantly increasing in c given a cognitive task, we can interpret that voters' confidence reflects their cognitive ability. In this case, the difference in the rate of correct rejection votes should be pronounced as in Proposition 2.

Prediction 2: *The proportion of correct rejection votes under unanimity rule is higher than that under majority rule if the rate of correct rejection votes conditional on c is significantly increasing in c given a cognitive task. On the other hand, if the rate of correct rejection votes conditional on c is not significantly increasing in c given a cognitive task, there is no significant difference in the proportion of correct rejection votes under two voting rules.*

Prediction 2 is not a direct implication of Proposition 2; Prediction 2 states that the result of Proposition 2 should be observed if voters are not so "overconfident," while the result of Proposition 2 should be empirically negligible if many voters are "overconfident." Prediction 2 is unique to our experiment since there is no room to have overconfidence in the standard jury experiment where the objective probability is given.

Remark 2. Prediction 1 is not sensitive to the possibility of overconfidence. This is because Prediction 1 is an *immediate* implication of Proposition 1, that is, if $\hat{p}(3) > \hat{p}(5)$, the proportion of voters with $p < \hat{p}(3)$ is always higher than that with $p < \hat{p}(5)$ even if voters are overconfident.

4 Experimental results

This section reports experimental results.

4.1 Strategic voting

Our main question is whether voting rules affect voting behaviors as the model predicts (Prediction 1). Table 1 shows that unanimity rule induced more approval votes compared to majority rule. Under unanimity rule, voters approved the proposed answer 57.8%, while voters approved 37.9 % under majority rule. The difference in proportions was significant at 1% level, and thus Prediction 1 was supported. The result is consistent with the existing literature on common value voting experiments, e.g., Guarnaschelli et al. (2000) and Goeree and Yariv (2011). Hence, our result suggests the strategic voting in common value voting games is a robust phenomenon even under the lack of the explicit information structure.

The voting behavior was similar under both logic and math treatments. In the math treatment, the proportion of approval votes under unanimity rule was 50%, which was higher than 30% observed under majority rule. In the logic treatment, the proportion of voters who approved under unanimity rule was 64%, which was higher than 47 % observed under majority rule.

Since the proportion of approval votes was only 30% under majority rule in the math treatment, our model suggests that the average voter had a low p_i in the math treatment. On the other hand, since the proportion of approval votes was 47% under majority rule in the logic treatment, the average p_i was higher than that in the math treatment.

4.2 Proportion of correct votes

Table 2 compares the proportion of correct votes between voting rules. The proportion of correct rejection votes was 75% under unanimity rule, which was higher than 49% under majority rule. The difference was significant at 6%. On the other hand, for the logic treatment, the proportion of correct rejection votes under unanimity rule was 50%, while it was 63% under majority rule. The difference was not statistically significant.

Prediction 2 states that the proportion of correct rejection votes should depend on a voting rule only if voters' confidence reflects their cognitive ability well. Thus, according to Prediction 2, the voters' confidence should reflect their cognitive ability in the math treatment while it is not the case in the logic treatment.

Note that this hypothesis is also consistent with our observation in Section 2-2-3: in the math treatment, whether a subject could complete her computation in time might play a role of feedback that could help her to form reasonable confidence. On the other hand, "feedback" would not be available in the logic treatment as most subjects could obtain their own solutions in time. Thus, it would be difficult to be aware of one's reasoning error in the logic treatment and, consequently, some subjects could be overconfident in their opinions.

In order to test the difference in the quality of confidence, we collected the data of voters' confidence by using a questionnaire. Specifically, after voting decisions, we asked the subjects two questions: (i) whether the proposal was correct or not; (ii) the level of his/her confidence in four categories: "very confident," "confident," "somewhat confident," and "not confident." The regression in Table 3 presents the marginal effect of the confidence level and the question type on the probability of correct votes under unanimity rule. We found that when the confidence level increases one level, the probability of correct votes in the math treatment increases by 0.15, p-value $= 0.06$. This suggests that the voters' confidence reflected their cognitive ability well in the math treatment. On the other hand, in the logic treatment, when the confidence level increases one level, the probability of correct votes increases only by 0.03, which is not statistically significant. That is, the voters' confidence did not reflect their cognitive ability in the logic treatment, confirming our hypothesis.

4.3 Performance of voting rules

Since the purpose of this paper is to analyze the individual voting behavior in a detail-free environment, the experiment is not designed to test group level decisions. That is, the setting is not specific enough to obtain predictions at the group level.[6] The sample size of group decisions, which is one fifth of the sample size of individual decisions, might not be large enough to draw a

[6] To obtain testable predictions at the group level, we need to specify the parameters of the model, which contradicts the purpose of our experiment, a detail-free experiment.

conclusion about the group performance under different voting rules. However, it might be worth reporting whether unanimity rule induced more approval in voting outcomes as the prediction in Feddersen and Pesendorfer (1998).

Table 4 reports that the proportion of correct voting outcomes between the voting rules. The proportions of correct outcomes were not significantly different across voting rules. In the math treatment, the proportion of correct outcomes was 56% under unanimity rule, while it was 50% under majority rule. On the other hand, in the logic treatment, the proportion of correct outcomes was 40% under unanimity rule, while it was 44% under majority rule.

Not surprisingly, the performance was sensitive to whether the proposal was correct. Under majority rule, 33% of correct proposals in the logic treatment were approved, while 20% of correct proposals in the math treatment were approved. However, under unanimity rule, all correct proposals in both treatments were rejected by the voting rule. Thus, even though unanimity rule induced more approval at the individual level, the voting rule rejected more correct proposals than majority rule. In other words, as in Guarnaschelli et al. (2000) and Goeree and Yariv (2011), unanimity rule was a more "conservative" rule in spite of the strategic voting.

Table 4 shows that majority rule rejected 80% of the correct proposals under the math treatment. This result is consistent with the implication of Table 1. As we mentioned in 4-1, Table 1 suggests that the average voter had a low p_i in the math treatment. Thus, voters frequently rejected proposals believing the proposal is likely to be wrong. In the logic treatment, majority rule rejected 67% of correct proposals which is lower than that in the math treatment. This result is also consistent with the implication of Table 1: as we mentioned in 4-1, the average p_i in the logic treatment was higher than that in the math treatment.

At first glance, the poor information aggregation under "rational voting" seems puzzling. However, this is consistent with the rational voting theory. In fact, Austen-Smith and Banks (1995) showed that if voters' prior is sufficiently high or low given the size of voters, voting rules poorly aggregate private information in the symmetric equilibrium. In the existing experiments, e.g., Guarnaschelli et al. (2000), majority rule effectively aggregated private signals because the prior probability of the state was chosen so that the sincere voting strategy is the symmetric equilibrium strategy.

5 Discussion: Rational inattention and response-time analysis

Our experiment uses rather challenging cognitive tasks so that whether a proposed answer is correct or not is uncertain for some voters. Since voters do not know the probability that each voter makes an error in her reasoning, the experiment creates "natural uncertainty" in the context of jury voting. When each voter's cognitive capacity is considered as a "type" whose distribution is exogenous, our experiment can be interpreted as a class of the standard jury voting games, e.g., Austen-Smith and Banks (1995) and Feddersen and Pesendorfer (1998).

However, this interpretation has a caveat: when each voter chooses whether to be attentive or not given her cognitive cost, a voter's belief could be determined endogenously in our experiment.[7] The experiments in rational inattention tend to use easy cognitive tasks to isolate mistakes caused by inattention from mistakes caused by "limited cognitive capacity."[8] On the other hand, our cognitive tasks are not designed to isolate mistakes caused by "limited cognitive capacity."

Whether rational inattention played a major role in our experiment is an empirical question. To obtain a testable implication of rational inattention, observe that being inattentive is to ignore information whereas being attentive is to process information. Thus, rational inattention is essentially an optimal information acquisition. Our experimental setting is then interpreted as a voting game with costly information acquisition.[9] Note that a voting rule affects the optimal information acquisition decision; since the probability of being pivotal is very low in unanimity rule, the benefit of information acquisition is also low in unanimity rule.[10] Hence, unanimity rule provides less incentive to be attentive compared to majority rule.[11] Since a voter's "cognitive effort" is not

[7]We appreciate one of the referees for pointing out this possibility.

[8]For example, Caplin, Dean and Martin (2011) tested a rational inattention model of individual decision making. In their experiment, the value of each choice is represented by a simple algebraic expression so that the subjects fail to choose the best choice when they are inattentive.

[9]There are some experimental papers that investigate voting games with costly information acquisition, e.g., Grosser and Seebauer (2013) and Elbittar, Gomberg, Martinelli and Palfrey (2014). However, unlike in our experiment, the cost of information acquisition in their experiments is explicit in the sense that it directly reduces the payoff.

[10]We can compute the average probability of being pivotal from the frequency of approval/rejection votes. In the logic treatment, the probability of being pivotal was around 16.78% under unanimity rule while it was 37.23% under majority rule. In the math treatment, it was 6.25% and 26.46% respectively.

[11]For more detail, see Persico (2004) and Elbittar, Gomberg, Martinelli and Palfrey (2014).

directly observable, we use voters' response time, i.e., how long the average voter spent her time before voting, as a proxy for cognitive effort. We then obtain the following testable implication of rational inattention: the average response time of voters in unanimity rule is shorter than that in majority rule.

Table 5 summarizes the voters' response time. The subjects under unanimity rule on average used 229.22 seconds while the subjects under majority rule on average used 220.56 seconds. The two-sample t-test indicates that there is no significant difference in the response time under the two voting rules. Moreover, we compared the distribution of response times under the two voting rules using the Mann-Whitney test. It is found that there is no significant difference in the distributions. Thus, the response time analysis suggests that voting rules did not affect the level of their cognitive effort, unlike the rational inattention model predicts.

As we discussed in Section 2-2-3, the math question seems to demand a higher level of cognitive effort compared to the logic question. Table 6 reports the comparison of the average response time in the math and logic treatments. It is found that under both voting rules, the average response time in the math treatment was longer than that in the logic treatment. The difference is significant at 1 percent level under two-sample t-test. This suggests that the response time is a good proxy for cognitive effort in our experiment.

The result that a voting rule did not affect their response time might not be so surprising if we consider their decision environment: the subjects needed to solve only one question that is rather challenging given the time constraint. It might not be so painful for the subjects to focus on one question for five minutes. Another possibility is that they were absorbed in the challenging task and did not have room to think about the optimization of cognitive effort.

6 Concluding remarks

The standard experiment with a stylized setting can provide a richer set of predictions while it is not obvious whether observed behaviors are induced by the stylized setting. For example, in the standard jury voting experiments, Bayesian reasoning could be induced by the stylized information structure that consists of a jar and colored balls. As Wilson (1987) emphasizes, it is important to analyze the robustness of an institution in a "detail-free environment."[12] In this paper, we introduced a simple experimental setting that can test the robustness of the strategic voting in a detail-free jury voting game. Our result suggests that the existing result in jury voting experiments is robust: voters can play the strategic voting in the detail-free environment. We believe that the detail-free and standard experiments are complements; the standard experiment with a stylized setting can provide a richer set of predictions whereas the detail-free experiment tests the robustness of their results at the cost of fewer predictions.

[12] Wilson (1987) emphasizes the theoretical aspect whereas our paper focuses on the empirical aspect.

Table 1. Proportion of voters voted "approve"

	Unanimity	Majority	Mean Difference	Proportion Test	*p*-value
Logic	0.64	0.47	0.17	1.70*	0.09
	(0.07)	(0.07)			
Math	0.50	0.30	0.10	1.93*	0.053
	(0.08)	(0.06)			
All questions	0.58	0.38	0.20	2.71***	0.01
	(0.05)	(0.05)			

Notes: *,**, and *** represent significance at 10, 5, and 1 percent levels, respectively. Standard errors are presented inside parentheses.

Table 2. Proportion of correct votes

	Unanimity	Majority	Mean Difference	Proportion Test	*p*-value
All questions	0.63	0.54	0.09	0.87	0.38
	(0.08)	(0.06)			
Math	0.75	0.49	0.26	1.91*	0.06
	(0.10)	(0.08)			
Logic	0.50	0.63	-0.13	-0.81	0.42
	(0.12)	(0.10)			

Notes: *,**, and *** represent significance at 10, 5, and 1 percent levels, respectively. Standard errors are presented inside parentheses.

Table 3. Relationship between correctness of voting and confidence level in unanimity voting

Conditional on Logic question

	Dependent variable: Correct voting
Confidence level	0.03
	(0.07)
# of observations	45
Pseudo R^2	0.06

Conditional on Math question

	Dependent variable: Correct voting
Confidence level	0.15^{*}
	(0.06)
# of observations	45
Pseudo R^2	0.06

Notes: This table presents the marginal effect coefficient of the Probit regression on whether the subject vote correctly. Confidence level is the level of self-reported confidence level elicited in the questionnaire on correctness to the answer to the question that whether the voter has found any mistake in the proposed answer.

Table 4. Proportion of correct voting outcomes

	Unanimity	Majority	Mean Difference	Proportion Test	*p*-value
Logic	0.40	0.44	-0.04	-0.20	0.84
Math	0.56	0.50	0.06	0.24	0.81
Conditional on correct proposals					
Logic	0	0.33	-0.33	-1.10	0.27
Math	0	0.20	-0.20	-0.95	0.34
Conditional on wrong proposals					
Logic	0.57	0.50	0.07	0.26	0.80
Math	1	0.80	0.20	1.05	0.29

Table 5. Voters response time (seconds)

	Unanimity Voting	Majority Voting	Mean Difference	t-Test	*p*-value
All questions	229.22	220.56	8.66	0.95	0.34
	(6.44)	(6.49)			
Math	250.68	236.8	13.88	1.12	0.27
	(9.47)	(8.12)			
Logic	212.06	202.51	9.55	0.76	0.45
	(8.06)	(9.71)			

Table 6. Comparison of voters response time (seconds) in Math and Logic Treatments

	Math	Logic	Mean Difference	t-Test	*p*-value
Unanimity Voting	250.68 (9.47)	212.06 (8.06)	38.62	3.12^{***}	0.002
Majority Voting	236.8 (8.12)	202.51 (9.71)	34.29	2.73^{***}	0.01

Notes: *, **, and *** represent significance at 10, 5, and 1 percent levels, respectively.

7 Appendix

7.1 Remark 1

In Feddersen and Pesendorfer (1998), there is a binary signal $s \in \{0, 1\}$ and the probability of $s = \omega$ is $\lambda \in (\frac{1}{2}, 1)$. Let μ be the prior probability of $\omega = 1$. Since the signal is binary, there are only two possible p in their model: one is the probability of $\omega = 1$ conditional on $s = 1$, i.e., $p_1 = \frac{\lambda\mu}{\lambda\mu+(1-\lambda)(1-\mu)}$ and the other is the probability of $\omega = 1$ conditional on $s = 0$, $p_0 = \frac{(1-\lambda)\mu}{(1-\lambda)\mu+\lambda(1-\mu)}$.

Since their model has only two possible values of p, whereas our setting allows any value in $[0, 1]$, discretize $P = [0, 1]$ to $\{p_0, p_1\}$ and let $f(p|\omega)$ be a probability mass function conditional on ω. The degenerated version of our model is then equivalent to their binary signal model if $f(p_1|1) = f(p_0|0) = \lambda$ and $f(p_0|1) = f(p_1|0) = 1 - \lambda$.

7.2 Proof of Lemma 1

Suppose not. Then, there exists voter i such that $a_i = A$ for p_i', while $a_i = R$ for $p_i'' > p_i'$. However, note that

$$\psi_\sigma(k, p_i) = \frac{\Pr(piv|\omega = 1; k, \sigma)p_i}{\Pr(piv|\omega = 1; k, \sigma)p_i + \Pr(piv|\omega = 0; k, \sigma)(1 - p_i)}.$$

Obviously, $\psi_\sigma(k, p_i'') > \psi_\sigma(k, p_i')$ given any strategy profile σ. Note that voter i's expected payoff from a_i given σ and p_i is

$$E[U(a_i, \sigma_{-i}(p_{-i}))|p_i] = \begin{cases} -\frac{1}{2}(1 - \psi_\sigma(k, p_i)) & \text{if } a_i = A \\ -\frac{1}{2}\psi_\sigma(k, p_i) & \text{if } a_i = R \end{cases}.$$

Thus, whenever she prefers A to R given p_i', she also prefers A to R given p_i'', a contradiction.

7.3 Proof of Proposition 1

Let $\psi_{\hat{p}}(k, p_i)$ be $\psi_\sigma(k, p_i)$ in which σ is the symmetric cutoff strategy profile with $\hat{p}$.

First of all, given a strategy profile σ, voter i's belief that voter j chooses A conditional on ω is

$$Q_{j,\omega}(\sigma) = \int_{p_j \in \{p_j : \sigma_j(p_j) = A\}} f(p_j|\omega)dp_j.$$

By the definition of symmetric equilibrium, $Q_{j,\omega}(\sigma)$ does not depend on j. Thus, let $Q_\omega(\sigma) = Q_{j,\omega}(\sigma)$.

Since each group consists of five voters in the experiment, voter i is pivotal when $k-1$ out of four voters choose A. Then, given σ, ω and k, we can compute the probability of being pivotal conditional on ω. That is,

$$\Pr(piv|\omega; k, \sigma) = \binom{4}{k-1} Q_\omega(\sigma)^{k-1}(1 - Q_\omega(\sigma))^{4-(k-1)}.$$

Then, the probability of $\omega = 1$ conditional on being pivotal given p_i is

$$\psi_\sigma(k, p_i) = \frac{\Pr(piv|\omega = 1; k, \sigma)p_i}{\Pr(piv|\omega = 1; k, \sigma)p_i + \Pr(piv|\omega = 0; k, \sigma)(1 - p_i)}.$$

Note that if σ is a symmetric cutoff strategy profile with $\hat{p}$, $Q_\omega(\sigma) = 1 - F(\hat{p}|\omega)$. Since $F(\hat{p}|\omega)$ is continuous in $\hat{p}$, $\psi_{\hat{p}}(k, \hat{p})$ is also continuous in $\hat{p}$. Moreover, $\lim_{\hat{p}\to 1} \psi_{\hat{p}}(k, \hat{p}) = 1$ and $\lim_{\hat{p}\to 0} \psi_{\hat{p}}(k, \hat{p}) = 0$. Then, there exists $\hat{p}(k) \in (0, 1)$ such that $\psi_{\hat{p}(k)}(k, \hat{p}(k)) = \frac{1}{2}$ given k. Since $\psi_{\hat{p}(k)}(k, p)$ is strictly increasing in p, $\psi_{\hat{p}(k)}(k, p) > (<)\frac{1}{2}$ if $p > (<)\hat{p}(k)$. Thus, given voting rule k, there exists a symmetric equilibrium in which each voter uses the cutoff strategy with $\hat{p}(k)$.

Now, we claim that given any symmetric equilibrium under each voting rule, $\hat{p}(3) > \hat{p}(5)$. Note that $\Pr(piv|\omega; 5, p_i) = [1 - F(\hat{p}|\omega)]^4$. The probability of $\omega = 1$ conditional on being pivotal is then

$$\psi_{\hat{p}}(5, p_i) = \frac{[1 - F(\hat{p}|1)]^4 p_i}{[1 - F(\hat{p}|1)]^4 p_i + [1 - F(\hat{p}|0)]^4(1 - p_i)}.$$

By the monotone likelihood ratio property, $f(\hat{p}|0)[1 - F(\hat{p}|1)] \geq f(\hat{p}|1)[1 - F(\hat{p}|0)]$. It follows that $\frac{d\psi_{\hat{p}}(5,\hat{p})}{d\hat{p}} > 0$. Since $\psi_{\hat{p}}(5, \hat{p})$ is strictly increasing in $\hat{p}$, $\hat{p}(5)$, which solves $\psi_{\hat{p}}(5, \hat{p}) = \frac{1}{2}$, is unique. That is, there exists a unique symmetric equilibrium under unanimity rule. On the other hand, since unanimity rule requires a larger number of A when a voter is pivotal, $\psi_{\hat{p}}(3, \hat{p}) < \psi_{\hat{p}}(5, \hat{p})$ given any $\hat{p}$. Then, $\hat{p}(3)$, which solves $\psi_{\hat{p}}(3, \hat{p}) = \frac{1}{2}$, has to be strictly higher than $\hat{p}(5)$.

7.4 Proof of Proposition 2

Let $\mu := \int_{p\in P} f(p, \omega = 1)dp$. Since $\Pr(R|\omega; k) = F(\hat{p}(k)|\omega)$ given equilibrium cutoff $\hat{p}(k)$, the probability of $\omega = 0$ conditional on $a_i = R$ in the symmetric equilibrium is

$$\Pi_R(k) = \frac{F(\hat{p}(k)|0)(1 - \mu)}{F(\hat{p}(k)|0)(1 - \mu) + F(\hat{p}(k)|1)\mu}.$$

From Proposition 1, $\hat{p}(3) > \hat{p}(5)$. Then, by the monotone likelihood property,

$$\frac{F(\hat{p}(5)|0)}{F(\hat{p}(5)|1)} > \frac{F(\hat{p}(3)|0)}{F(\hat{p}(3)|1)}.$$

It follows that

$$\frac{F(\hat{p}(5)|0)}{F(\hat{p}(3)|0)} > \frac{F(\hat{p}(5)|0)(1-\mu) + F(\hat{p}(5)|1)\mu}{F(\hat{p}(3)|0)(1-\mu) + F(\hat{p}(3)|1)\mu}$$

for any $\mu > 0$. Thus,

$$\frac{F(\hat{p}(5)|0)(1-\mu)}{F(\hat{p}(5)|0)(1-\mu) + F(\hat{p}(5)|1)\mu} > \frac{F(\hat{p}(3)|0)(1-\mu)}{F(\hat{p}(3)|0)(1-\mu) + F(\hat{p}(3)|1)\mu}.$$

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