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Abstract

We experimentally investigate information aggregation through majority voting when some voters are biased. In such situations, majority voting can have a "dark side", i.e. result in groups making choices inferior to those made by individuals acting alone. We develop a model to predict how two types of social information shape efficiency in the presence of biased voters and we test these predictions using a novel experimental design. In line with predictions, we find that information on the popularity of policy choices is beneficial when a minority of voters is biased, but harmful when a majority is biased. In theory, information on the success of policy choices elsewhere de-biases voters and alleviates the inefficiency. In the experiment, providing social information on success is ineffective. While voters with higher cognitive abilities are more likely to be de-biased by such information, most voters do not seem to interpret such information rationally.

JEL-codes: C92, D7, D02, D03

I Introduction

One of the benefits of having democratic choice is the ability of voting to aggregate dispersed information in society. The argument, going back to Condorcet (1785), is simple: if each voter's judgment is more likely to be right than wrong, the collective choice in a majority vote is going to be better (more likely to be right) than the average judgment of individuals acting alone. This is what we call the "bright side" of the vote. The argument applies in situations in which a "right" policy exists, voters have a common interest to implement the right policy, but all voters are uncertain about which policy is right. But the argument is based on various simplifying assumptions. We theoretically and experimentally address two key assumptions and what they imply for a "dark side" of the vote to exist.

The first assumption is that all voters are more likely to be right than wrong when judging a particular issue. While the standard approach to information aggregation allows for some voter uncertainty about what is the right policy, it assumes that voters' judgments are not systematically mistaken. Yet, mounting evidence suggests that people may be biased in some instances (e.g. when making judgments about risky prospects), and in some cases a majority of voters may be biased. We provide a simple game-theoretic model in which voters vary in their competence in making inferences as a basis for our experiment. The model predicts both what we call a "bright side" and a "dark side" of the vote. Voting is beneficial when a majority is unbiased, but harmful when not. That is, the decision made by majority rule can be worse than that made by an average individual acting alone when a majority of voters make incorrect inferences.

The second simplifying assumption we address is that voters form their judgments independently. However, voting is often preceded by debate and flows of social information (as in opinion polls, news reports, and surveys) which may affect voters' judgments in similar ways. For example, voters might learn how popular some choices are in other countries, subnational regions, or localities, but not whether the choices are successful or not. Alternatively, voters might learn how happy individuals in other countries, subnational regions, or localities are with their overall collective choices, but not the specifics of the choices that these voters have made. The consequences of such social information are ambivalent in theory and practice. In general, social information may undermine the efficiency of information aggregation or strengthen it.[1]

We study two types of social information: voters either learn about other voters' opinions (i.e. how popular a particular policy is, as in an opinion poll) or they learn about how successful other, very similar, electorates were in making decisions on a particular topic (but not what exact policy they implemented). Our simple model predicts that the effects of such social information depend on whether a majority of voters is biased or not. If a majority makes correct inferences on average, social information tends to be beneficial. Specifically, social information about previous success does no harm, and social information about opinions improves the informational efficiency of voting. However, when a majority of voters makes biased judgments, providing social information may help or harm informational efficiency. In this case, our model predicts that social information on opinions makes matters worse (further reduces informational efficiency) but social information about success improves matters. The reason for this beneficial effect, i.e. for "brightening up the dark side", is that social information on success "de-biases" voters. Intuitively speaking, when a voter learns that other (similar) groups got it all wrong, the voter will (rationally) reconsider his views and vote against his earlier judgment (or prejudice in that case). The reason is that he knows he is most likely similar to these other voters and therefore his original judgment is likely to be wrong, too.

In the experiment, we find support for all of these predictions, with one important exception. We find support for the "bright side" of the vote (i.e. voting is productive when a majority of voters is more likely to be right than wrong), and for a beneficial effect of social information (information on opinions improves efficiency, information on success has no effect). We also find that the "dark side of the vote" is real. When voters are more likely to get it wrong than right,

[1] See for example Bikhchandani, et al. (1998), Estlund (1994), Hung and Plott (2001), Neuman (1986), and Watts and Dodds (2007).

voting is counterproductive (efficiency is on average eight percent lower). And providing social information on the popularity of policies makes matters even worse (efficiency is 24 percent lower than voting without such social information). But, in contrast to theoretical predictions, social information on success has no clear de-biasing effect in our experiment. With reference to a measure of cognitive ability, we discuss to what extent this result is driven by cognitive limitations and the higher level of reasoning required for de-biasing to be successful. We find evidence that cognitive limitations explain the tendency to make incorrect choices and that those with higher cognitive abilities are slightly better able to interpret social information.

Our simple game-theoretic model provides predictions for our experiment as follows. The model allows voters to vary in their competence in making inferences. We assume that some voters are more likely to be right than others, and we allow for the possibility that some voters are biased, i.e. are more likely to be wrong than right. Importantly, we also allow for the possibility that a majority of voters is biased on a particular issue put before them. However, we assume that voters are overall competent in the sense that each voter is assumed to make correct inferences on average across a series of decision-making situations. Therefore, voters rationally believe their inferences to be correct on the "typical" issue put before them despite making wrong judgments in specific cases. The assumption that voters are un-biased on average makes it plausible that voters are not (as we assume) aware that they are biased on any particular issue. The model predicts both a "bright side" and a "dark side" of the vote and allows us to make predictions for the effects of social information on both the "bright" and the "dark" side of majority voting.

We then confront these predictions with experimental data. Our design involves voting across a series of decision problems in which voters are presented with two solutions, one correct and one incorrect. Voters have a common interest in collectively choosing the correct solution and, given our parameters, have an incentive to vote for what they think is the correct solution. The main innovation of our design is that it allows for testing the informational efficiency of voting on problems in which a majority of voters is (or is not) biased. We choose (after pretesting) a combination of "easy" problems (on which a majority is right) and "hard" problems (on which a majority is wrong) such that the average voter is right on the average issue.

Our main contribution to the literature is to study the consequences of incorrect inferences by individuals on informational efficiency in majority voting. While the consequences of biases have been studied extensively for market outcomes (e.g. Ganguly et al. 2000, Gneezy et al. 2003, and Fehr and Tyran 2005), we are, to the best of our knowledge, the first to experimentally investigate the consequences of incorrect inferences for information aggregation in majority voting (see Kerr et al. 1996 for a general discussion). Our paper is related to a long stream, starting with Shaw (1932), of experimental studies investigating the ability of individuals vs. groups in making correct choices (e.g. Blinder and Morgan 2005 and Slembeck and Tyran 2004) but these studies do not focus on majority voting.

Section II of the paper presents the model and section III explains how experimental design tests the predictions of the model. Section IV presents the experimental results and section V provides some concluding remarks.

II A Model of Voting with Incorrect Inferences and Social Information

II.1 Basic Setup

Our model and experiment build on existing work on information aggregation through voting.[2] We consider a voting game with an odd number of participants, $n \geq 3$. The number of participants is common knowledge. Participants choose whether to vote for one of two options, a or b (abstention is not allowed) in a majority rule election j. The option that receives a majority of the votes in election j is declared the winner in that election with ties broken randomly. There are two states of the world A and B for each election, which occur with equal

[2] For game theoretic studies of the Condorcet Jury problem see Austen-Smith and Banks (1996), Wit (1996), McLennan (1998), Feddersen and Pesendorfer (1998), and Coughlan (2000). Experimental studies include Ladha et al. (1996), Guarnaschelli et al. (2000), Bottom et al. (2002), and Ali et al. (2008).

probability and are independent of the state of the world in other possible elections. In each election voters have homogenous preferences. That is, all voters have the same utility function. We normalize voters' utility from election j to equal 1 if either option a is selected in state of the world A or b is chosen in state of the world B, and 0 otherwise.[3]

Before election j occurs, voter i receives an imperfect signal of the world, $\sigma_{ij} \in \{a, b\}$. Define $p_{ij} \in [0, 1]$ as the probability that voter i in election j receives an a signal when the state of the world is A and a b signal when the state of the world is B. We call p_{ij} voter i's signal quality in election j. Voters do not know their true signal quality for election j when they vote or the true signal qualities of other voters in election j. Importantly, we assume that signal qualities can be incorrect; that is, we allow for $0 \leq p_{ij} < 0.5$, such that an a signal implies that it is more likely that the state of the world is B than it is A. This assumption has not received much attention in the theoretical or experimental literature so far (see Bottom 2002 for an exception). The reason might be that (in a context with 2 alternatives) voters need to be both biased and not aware of their bias for voters' biases to be consequential (otherwise they would just vote counter to their signal). Interestingly, this possibility has been considered by Condorcet:

> "In effect, when the probability of the truth of a voter's opinion falls below $\frac{1}{2}$, there must be a reason why he decides less well than one would at random. The reason can only be found in the prejudices to which this voter is subject."[4]

Define p_i as the mean signal quality of voter i across elections, i.e. the expected value of p_{ij} holding i constant, but varying j; p_j as the mean signal quality across voters in a single election j, i.e. the expected value of p_{ij}, holding j constant and varying i; and p as the mean signal quality across voters and elections (varying both i and j). We assume that the p_{ij} are drawn from voter-specific distributions with constant variances such that for all i, $p_i > 0.5$. Hence,

[3] We might think of these voters as swing voters, whose votes depend on factors that are unknown, while other voters, who are partisans, have known preferences. In our formulation with partisan preferences, the number of partisans favoring option a are equivalent to the number of partisans favoring option b, and thus the votes of the swing voters are decisive.

[4] See Condorcet (1785), cited after Baker (1976), p. 62.

voters may vary in the distribution of their signal qualities such that some may have greater mean signal qualities across elections than others, but all on average expect that most inferences are correct across elections. Furthermore, $p > 0.5$, as well. As a consquence, then, voters who do not have any social information (described below) prior to voting expect that on average their signals are informative such that their inferences are correct and that other voters' signals are informative such that their inferences are correct.

The predictions for the voting game without social information in a particular election j are straightforward. Voters sincerely vote their signals. We provide a detailed derivation of this result in Auxillary Materials Appendix A. There we restrict our analysis to pure-strategy symmetric equilibria, in which all voters who receive the same signal use the same strategy. In solving for the voting equilibria, we assume that voters condition their vote choice on being pivotal. We demonstrate that, assuming voters do not use weakly dominated strategies, a unique equilibrium exists in which all voters vote their signals.

II.2 Equilibrium Behavior with Social Information

II.2.1 Social Information about Opinions

The information we study is "public" in the sense that everyone obtains it, it is free in the sense that voters don't have to pay or search for it. It is "social" in the sense that it refers to what other people think or have done (rather than to the physical environment etc.). Social information about opinions is often provided to voters when they observe other voters choosing in similar elections, public opinion polls, or surveys. We model a voting situation in which voters receive social information about opinions of other voters in a similar situation. That is, assume that there are now two groups of voters, group 1 and group 2, who independently vote over the exact same election j, a and b, with the same consequences for each group. To clearly pin down the effects of informational spillovers, we assume that the realized state of the world is the same; that is, if the state of the world is A in group 1, it is also A in group 2, and vice-versa. The two groups are the same size, n. Voters' preferences are exactly the same in both groups and the realized signal qualities are the same. However, the choices of one group have no effect on the utility of members of the other group except through the information link. Group 1 voters choose first and make their choices exactly as we assume in the previous subsection, with no social information. Then group 2 voters choose, but they are given information about the distribution of choices of group 1 voters (i.e., how popular the options are in group 1) before they choose to vote. Specifically, define n_k as the total number of votes for option k in group 1 and $q = n_a/n$, that is, the proportion of votes in group 1 for option a.[5] Voters in group 2 are told q and $(1-q)$ before they choose. Note that group 2 voters do not learn whether group 1 voters' choices were "correct" in the sense that the voters' choices maximized their utility by choosing the option that matched the state of the world but the proportions that have chosen a and b. Hence, if for the majority of voters $p_{ij} < 0.5$, then it is likely that group 1 members voted a majority for the option that did not match the state of the world.

As we show in Appendix A, group 1 members sincerely vote their signals. But what about group 2 voters? We also show in the Appendix A that voting decisions of group 2 voters should depend on their signals and the size of q. Specifically, we show that voter i who has received an a signal and knows q, will prefer to vote as follows:

$$\begin{array}{ll} \text{If } 1 > n(1-2q) & \text{Vote for } a \\ \text{If } 1 < n(1-2q) & \text{Vote for } b \\ \text{If } 1 = n(1-2q) & \text{Indifferent} \end{array}$$

Hence, when the size of the majority voting in favor of option b is large in group 1 (in our experiment greater than 60%), then voters in group 2 who have received an a signal should ignore their signals and vote for b. Note that in the limit as n increases, ignoring one's signal becomes optimal if the previous majority is for the other option by just one vote or more. Our result is an extension of the literature on herding and information cascades in independent individual choices (see Bikhchandani, et al. 1998) to sequential independent collective choices.[6]

[5] To simplify notation we drop the subscript j from our variables.

[6] Others have considered whether similar herding and information cascades can occur when voting is sequential within a given election (for experimental studies, see Morton and Williams 1999, Hung and Plott 2002, Battaglini et al. 2007).

II.2.2 Social Information About Success

In contrast to receiving information about opinions and voting choices, a different type of social information is provided when voters learn about whether previous groups' collective choices are successful but not particular information about the choices made by these groups. Voters might receive this information by observing the degree to which other voting groups are pleased or not with governmental decisions. For example, voters in one state in the U.S. may observe the economic well-being of voters in another state or their degree of satisfaction with their government officials. Such information may be provided by surveys or news reports. However, they may not know the specifics of the policies that led to these consequences. The idea here is that voters learn whether other groups made smart (successful) choices in deciding on a particular issue, but not what they chose.

In analyzing social information about success, we make the same simplifying assumptions as in the discussion of social information about opinions in the previous sections. But now, voters in group 2 are given information about the distribution of correct choices of group 1 voters before they choose to vote. Specifically, define n_c as the total number of *correct* votes in group 1 and $c = n_c/n$, the proportion of votes in group 1 voting for the option that matched the state of the world, provided voters with the highest utility. Voters in group 2 are told c and $(1 - c)$ before they choose. Note that group 2 voters do not learn the proportions that have chosen a and b, i.e. how they voted, but simply whether the outcome of the voting was utility maximizing. Again, we expect that group 1 voters should sincerely vote their signals (see Appendix A). We continue to assume that group 2 voters condition their vote choices on the event that they are pivotal and focus on pure-strategy symmetric equilibria in which voters who receive the same signal choose the same strategy.

The crucial effect of providing social information about success is that voters obtain new information on the realized value of the p_j in group 1, not available in the other cases. In the other cases, a voter's best guess as to the probability that his or her signal is correct is given by the parameter p_i, the expected value of her true signal quality. However, in the situation in which voters receive social information on the success of group 1, that is, c, they have additional information about the distribution of p_j that is unavailable to voters without social information or voters with social information on opinions only. Given that all voters in group 1 vote according to their signals, then c is a sample expected value of the mean of true signal qualities across voters in election j, p_j.

Assuming that group 2 voters are Bayesian updaters, voter i will use a weighted average of his or her prior (p_i) and the social information (c) received. In particular, we predict that voter i in group 2's expectation of p_j, which we designate $\widehat{p}_j$, is a weighted average of p_i and c, as follows (where α is the weight placed on the new social information, $0 \leq \alpha \leq 1$):

$$\widehat{p}_j = \alpha c + (1 - \alpha) p_i \tag{1}$$

Suppose now that instead of there being just one group that votes prior to group 2, there are many such groups without social information choosing simultaneously and group 2 voters are told the average of the observed correct rates across these groups. It is well known that the mean of these sample proportions approaches the true value of p_j. In our experiment we provide subjects with the mean proportions across multiple groups and thus one might conjecture that the weight α placed on this average value of c, which we call $\overline{c}$ would approach 1. In the analysis that follows we make the strong assumption that $\alpha = 1$. We show in Appendix A that rational voters will vote their signals when $\overline{c} > 0.5$, vote contrary to their signals when $\overline{c} < 0.5$, and are indifferent between options when $\overline{c} = 0.5$.

Intuitively, voters learn the share of voters in other groups who made the correct choice (but not what it was). A rational voter who learns that a majority of voters in other groups got it right ($\overline{c} > 0.5$), votes according to his or her own signal. That is, the social information has no value in this case. But when a majority of voters got it wrong ($\overline{c} < 0.5$), the voter will vote counter to his or her private signal because he or she infers that voters in other groups got signals drawn with the same expected value, p_j, and since these signals resulted in the wrong choice, he or she infers that his or her signal must have been misleading.

II.3 Efficiency of Voting Choices

What do these theoretical results imply about the efficiency of information aggregation in the groups? First, consider the situation in which no social information exists. How efficient is voting one's signal in this case? We define Informational Efficiency of Majority Voting as the equilibrium probability with which a group makes the correct decision through majority voting. Label the probability of choosing the optimal option under majority voting absent social information as $P_U(p_j)$. For a group of five voters as in our experiment, P_U is given by:

$$P_U(p_j) = p_j^5 + 5p_j^4(1 - p_j) + 10p_j^3(1 - p_j)^2 \tag{2}$$

In a typical election, voting leads to more efficient outcomes than individual choice alone because voters make correct inferences on average. Specifically, when $p_j > 0.5$, $P_U(p_j)$ is greater than p_j. However, when $p_j < 0.5$, i.e., voters make incorrect inferences on a particular issue, voting will result in less efficient information aggregation as the probability of making the correct choice will be less than p_j. Given that for all i, $p_i > 0.5$, then in expectation, inferences will be correct most of the time, and voting leads to more efficient outcomes than if an individual decided alone based on his or her signal.

Now consider voting behavior when voters have social information on opinions. The probability of choosing the utility maximizing option in this case, which we label $P_O(p_j)$, is equal to the probability that the correct option won with more than a one-vote margin of victory in group 1 plus the probability of voting correctly when everyone votes their signals in group 2 times the probability that the margin of victory in the previous group was no more than one vote. This probability can be shown to be equal to the following in the case of five voters:

$$
\begin{aligned}
P_O(p_j) &= (p_j^5 + 5p_j^4(1-p_j)) && (3)\\
&+10\left(p_j^3(1-p_j)^2 + (1-p_j)^3 p_j^2\right)\left(p_j^5 + 5p_j^4(1-p_j) + 10p_j^3(1-p_j)^2\right)
\end{aligned}
$$

As in the case where no social information exists, when $p_j > 0.5$, then $P_O(p_j) > p_j$ and vice-versa when $p_j < 0$. Therefore, information aggregation through voting with social information on opinions is on average more efficient than an individual voting alone. Furthermore, when $p_j > 0.5$, then $P_O(p_j) > P_U(p_j)$, but when $p_j < 0.5$, then $P_O(p_j) < P_U(p_j)$. Thus, voting with social information on opinions is more efficient than voting without social information when inferences are on average correct but more inefficient than voting without social information when inferences are on average incorrect. However, on average, voting with social information on opinions is more efficient than voting without social information, since it is more likely that inferences are on average correct.

When voters have social information on success the probability of choosing the utility maximizing option, which we label $P_C(p_j)$, depends on whether p_j is greater or less than 0.5. When $p_j > 0.5$, $P_C(p_j) = P_U(p_j)$. But when $p_j < 0.5$, then $P_C(p_j) = P_U(1-p_j)$. Thus, for the case of five voters we have:

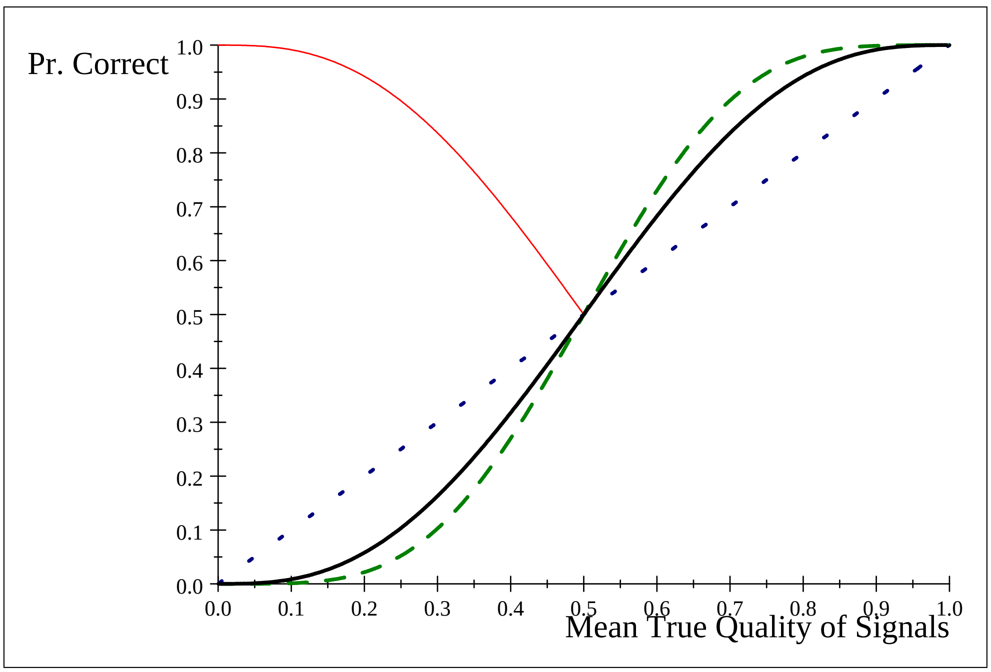
$$
\begin{array}{cl}
P_C(p_j) = p_j^5 + 5p_j^4(1-p_j) + 10p_j^3(1-p_j)^2 & \text{If } p_j > 0.5 \\
P_C(p_j) = (1-p_j)^5 + 5(1-p_j)^4 p_j + 10(1-p_j)^3 p_j^2 & \text{If } p_j < 0.5 \\
P_C(p_j) = 0.5 & \text{If } p_j = 0.5
\end{array} \qquad (4)
$$

Hence, we find that social information about success is equivalent in efficiency to no social information when $p_j > 0.5$, but is more efficient than either the case of no social information and social information on opinions when $p_j < 0.5$. Social information on success is clearly superior in efficiency to voting without social information and individual choice. However, social information on success is not necessarily more efficient than social information on opinions. The greater the variance in p_j and the more likely it is that inferences are on average incorrect, the more likely social information on success is superior to social information on opinions.

Figure 1 below summarizes these efficiency results for the case of five voters.[7] The vertical axis measures the probability of choosing the best option as a function of p_j, the average true quality of signals, measured along the horizontal axis. The dotted line represents the case where this probability equals p_j as in individual choice where individuals follow their signals; $P_U(p_j)$ is given by the solid black line; $P_O(p_j)$ is given by the dashed line; and $P_C(p_j)$ when $p_j < 0.5$ is given the solid red line (and by the solid black line when $p_j > 0.5$). These theoretical results are also summarized below as Predictions 1, 2, and 3 below.

Figure 1: Probability of Optimal Choice as a Function of p_j

(Dotted line represents individual choice = p_j; solid black line = $P_U(p_j)$ & $P_C(p_j)$ when $p_j > 0.5$; dashed line = $P_O(p_j)$; solid red line = $P_C(p_j)$ when $p_j < 0.5$.)



Prediction 1 (Efficiency of Majority Voting without Social Information) *When inferences are on average correct, then majority voting is more efficient at information aggregation*

[7] Obviously, as n increases the probability of making correct choices through majority voting when $p_j > 0.5$ converges to one both with and without social information. When $p_j < 0.5$, this probability converges to zero without social information and with social information on opinions, but convergest to one with social information on successes.

than individual decision-making, but when inferences are on average incorrect, majority voting is less efficient.

Prediction 2 (Efficiency of Majority Voting with Social Information on Opinions) *When inferences are on average correct, then majority voting with social information on opinions is more efficient at information aggregation than both majority voting without social information and individual decision-making, but when inferences are on average incorrect, majority voting is less efficient than both.*

Prediction 3 (Efficiency of Majority Voting with Social Information on Success) *When signals are on average correct, then majority voting with social information on success is more efficient at information aggregation than individual decision-making and equivalent in efficiency to majority voting without social information, but less efficient than majority voting with social information on opinions. When inferences are on average incorrect majority voting with social information on success is more efficient than the other three cases.*

III Experimental Design

III.1 General Procedures

The experiment took place at the Laboratory for Experimental Economics (LEE) of the University of Copenhagen (Denmark). The experiment consisted of a total of 6 sessions: 2 sessions for each of 3 treatments, described below. In each session, 15 to 25 subjects participated. Subjects were recruited using the online system Orsee (Greiner, 2004) and all participants were undergraduate students of the University of Copenhagen. No subject had previous experience with similar experiments and each subject could participate only at one session. The experiment was programmed using the software z-Tree (Fischbacher 2007). At the beginning of each session, subjects received a copy of the instructions available in the Auxiliary Materials Appendix B. We followed the experimental procedures of anonymity, incentivized payments, and neutrally worded instructions that are typically used in such experiments. Overall, 125 subjects participated and earned, on average, 190 Danish Krone (DKK, approx. 25 Euro). Each session lasted approximately 1-2 hours.

III.2 Creating Situations Where Inferences Can be Incorrect

Our theoretical formulation makes precise predictions about how subjects should vote and the efficiency of information aggregation through voting in situations in which the true quality of signals given to voters is uncertain and subjects may make incorrect inferences. We are most interested in the "dark side" of the vote, i.e., the effects incorrect inferences may have on the extent that majority voting can effectively aggregate information. We also wish to discover how social information may hinder or help the ability of voters to aggregate information through voting, particularly when inferences are on average incorrect.

Previous experiments on information aggregation through voting typically make the inference problem for voters exceedingly easy. In a typical such experiment, subjects are told there are two jars, one red and one blue. Each jar has, say, 8 balls. In the red jar there are 6 red balls and 2 blue balls and in the blue jar there are 6 blue balls and 2 red balls. A jar is randomly chosen from a known probability distribution but subjects are not told the identity of the true jar. Each subject then randomly chooses a ball from the unknown jar (with replacement). In expectation, then, subjects should conclude that the true color of the jar has a higher probability of matching the ball each has drawn. Evidence suggests that almost all subjects are able to make the correct inference; that is, in these experiments subjects generally vote the color of the ball they receive as a signal in situations in which sincere voting is predicted such as under majority rule voting. Not surprisingly, typically experimentalists find that majority voting leads to more informed choices than the individuals would reach acting alone.[8]

In our experiment we wished to use decision problems which vary in difficulty, including situations in which it is possible that a majority will make incorrect inferences. Therefore, in

[8] For example, in Guarnaschelli, McKelvey, and Palfrey (2000) the probability that an individual voter acting alone was correct was 70% when voting his or her signal (which voters did 94% of the time under majority rule) but groups deciding by majority rule were correct more than 70% of the time on average, depending on the size of the group and the true jar chosen.

our experiment subjects were presented with a series of quiz questions with two answers, labeled A or B. After extensive pre-testing, 30 questions were chosen. The majority of the questions, although they ranged in difficulty, were on average answered correctly in our pre-testing. But we also included a minority of questions in which most people display cognitive biases and make systematic incorrect inferences as shown in several previous studies (see, for instance, Hoorens, 1993) and in our pre-testing.

Subjects answered the questions sequentially, but were not told the answers to any questions until all had been completed. Between-subject communication was not allowed. The correct answer to a question, then, is the true "state of the world" in our theoretical setup. Subjects were told simply that the answer could be either A or B before reading a question. Hence, before reading a question, subjects should have on average expected either answer was equally likely (in fact they were equally likely). Subjects received their individual signals when they read the questions. Our experimental environment was therefore in some ways more parallel to the target environment of much of the theory of information aggregation in voting (like jury decision-making) than previous experiments as in actual juries individuals are all given common information either verbally or in a written transcript but each individual's understanding of that information is supposedly subject to independent random shocks and their own abilities or competence.

Nevertheless, our laboratory experimental manipulation has the same advantages over field studies of voting groups that exist in previous laboratory experiments in that we controlled the choices before the subjects and could randomize the type of social information received. Moreover, we knew the answers to the questions and thus had an objective measure of the true state of the world. We describe the questions used in the next subsection.

III.3 Questions Used and Cognitive Reflection Test

The easiest question, which received nearly 93% correct responses in pre-testing is question number 11 – "Which country has not adopted the Euro as its standard currency? A. United

Kingdom B. Luxembourg." In contrast, the most difficult question, which received just over 12% correct answers in pre-testing was question 8 – "Consider a room of 24 people. What is the probability that at least two of them have the same birthday (that is, the same day and month, not necessarily same year)? A. It is below 50% B. It is above 50%." In this question, clearly many subjects felt they knew the answer (or otherwise they would have guessed). However, clearly they were making incorrect inferences.

Question 13, "Consider a room with ten people. Suppose they have to form groups. Can they form more different groups with 2 members or with 7 members (a person can be a member in more than one group)? A. 2 members B. 7 members," received the median number of correct responses (B is correct) in pre-testing, almost 58%. Note that not all of the more difficult questions were mathematical in basis. For example, question 3 asked: "In which city did Sigmund Freud die? A. Vienna B. London," which only 44% of subjects answered correctly (answer B) in the pre-testing. A full list of the questions asked and their corresponding correct answers are presented in the Auxiliary Materials. Subjects were given as much time as they wished to answer each question.[9]

In addition to the questions in the experiment, at the end of the experiment subjects completed a simple Cognitive Relfection Test (CRT), reported on in Frederick (2005). In the CRT subjects were asked three questions (which were not incentivized and subjects were given as long as they wished to answer the questions). These questions are also listed in Appendix C. Each of these questions has an intuitive response that is wrong, yet the questions themselves are relatively easy once the answer is explained. As Frederick (2005) demonstrates the CRT test has high predictive validity in measuring cognitive abilities comparable to other measures used in the literature that involve much more extensive questions and longer completion times. As

[9]These questions have been chosen not for their practical relevance but for their quality of having clear-cut right and wrong answers, and we can credibly communicate to subjects that they do. The advantage of our design is that we have (by virtue of pretesting) quite precise knowledge about the accuracy with which subjects answer these questions. We are thus able to compose the questions with $p_j > 0.5$ and $p_j < 0.5$ such that we know p_i (> 0.5) with high confidence. However, the technique does not allow us to know or control p_{ij}.

Also note that we are not interested as such in how subjects vote on these particular questions. In fact, these are issues on which a group would ideally ask a trusted expert (or consult a lexikon).

we expect our subjects to vary in their abilities to make correct inferences, we use the CRT test as a measure of these differences in our empirical analysis of individual behavior.

III.4 Treatments

We conducted three treatments: Baseline (BT), Opinions (OT), and Success (ST). In all the treatments, each question involved two stages: 1) Subjects indicated which answer they thought was correct ("Choice Stage") and 2) Subjects had the possibility to confirm (or switch) their answer ("Confirmation Stage"). Before each question, subjects were randomly re-matched in anonymous groups of 5. Therefore, if there were 25 subjects in a session, for each question there were 5 groups of 5, which were randomly drawn for each question. Simple majority voting was used to determine a group's decision. As the number of voters was odd and abstention was not allowed, we had no tie elections. Each subject received 10 DKK (approx. 1.4 Euro) for every correct group decision independently of how they individually voted. For each treatment we conducted two separate sessions.

The treatments differed only in the information provided to the subjects between the "Choice Stage" and the "Confirmation Stage." In BT we do not provide any information between the two stages. In OT, subjects were told how popular the alternatives (A and B) were among voters in the two previous sessions of BT (q in section II.2.1), while in ST, subjects were told the percentage of individuals who provided the correct answer in BT ($\bar{c}$ in section II.2.2). In addition, in both stages in all treatments, subjects were asked to indicate how certain they were about their answer in a scale from 1 (not certain) to 5 (certain). The measure of certainty was not incentivized. Table 1 summarizes the relevant information and the main characteristics of each treatment.

Table 1: Treatment Description

All Voters and Groups Answered 30 Questions			
Treatment	**Subjects**	**Groups**	**Information**
Baseline (BT)	45	9	None
Opinions (OT)	35	7	q in BT
Success (ST)	45	9	$\bar{c}$ in BT

IV Experimental Results

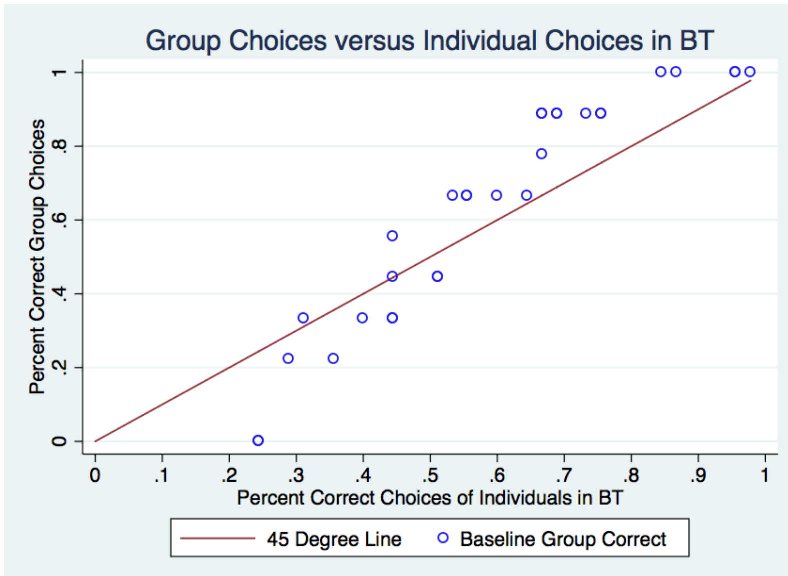
IV.1 Is Majority Voting More Informationally Efficient than Individual Choice?

Prediction 1 concerns information aggregation in our Baseline Treatment (BT). Specifically, we expect that when individuals largely make correct inferences, group choices are better than individual choices and when individuals largely make incorrect inferences, group choices are inferior to individual choices.

Figure 2 graphs the percentage of correct group choices in BT versus the percentage of correct individual choices. Recall that under majority voting in the BT treatment, subjects should vote their signals or own inferences about the likely answer to a question. Hence the incentives in the BT treatment were specifically designed to elicit sincere responses on the part of subjects and we can use the individual choices in BT as an estimate of the choices that the subjects would have made if answering the questions individually. Therefore, we use the individual choices in the BT treatment as our estimates of the percent of correct responses by question when individuals are acting alone.[10] We find that indeed as expected, when the percentage of individuals who answer correctly is greater than 50% (which hereafter we label as an "easy" question and which occurs in 2/3 of the questions), almost always the percentage of correct group choices is higher (above the 45 degree line), but that when the percentage of individuals who answer incorrectly is less than 50% (which hereafter we label as a "hard" question and which occurs in 1/3 of the questions), most of the time the percentage of correct group choices is lower (below the 45 degree line).

[10] Note that the individualized choices are not incentivized separately from group voting choices because if we had done so then subjects would have had an incentive to "hedge" when uncertain, behaving in a strategic manner either in their individual or voting choice. See Blanco, et al. (2010). However, there may be a free-rider problem for voters to the extent that they see cognitive effort as costly and thus may choose to vote randomly, letting the outcome be decided by those supposedly with greater cognitive skills. However, we find little evidence of such free riding as we find that the individual choices in the pre-testing are highly correlated with the individual choices in BT and when we use the individual choices from the pre-testing to classify questions instead of the individual choices in BT, our results are qualitatively the same.

Figure 2



Are these differences statistically significant? When questions are easy, the mean proportion of correct responses by individuals is 71%, while the mean proportion of correct group responses is 81%, which is significantly different with a p-value of 0.00, $z = 2.86$.[11] When questions are hard, the mean proportion of correct responses by individuals is 36%, while the mean proportion of correct group resonses is 28%, which is significantly different with a p-value of 0.06 in a one-tailed test, $z = 1.54$. We thus find support for both parts of Prediction 1, that majority voting results in more informationally efficient choices when individuals on average make correct inferences and that majority voting results in less informationally efficient choices when individuals on average make incorrect inferences, which is summarized in Result 1 below.

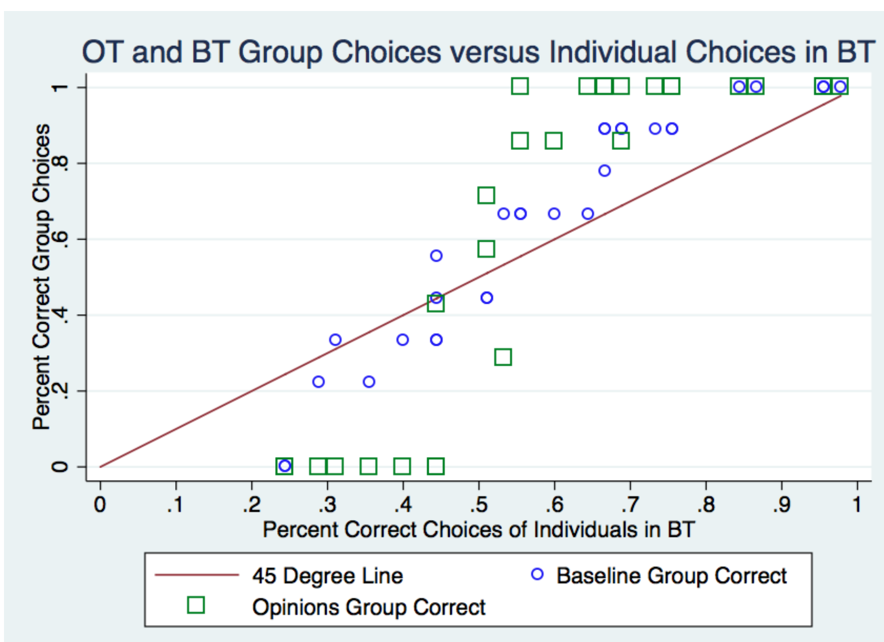
Result 1 (Group Choices with No Social Information) *As expected, majority voting results in more informationally efficient choices when individuals on average make correct inferences, but less informationally efficient choices when individuals on average make incorrect inferences.*

[11] As we are testing differences in proportions, a t test or Mann Whitney test of means is not appropriate. The tests of proportions presented here follow Wang (2000).

IV.2 Does Social Information on Opinions Improve Information Efficiency?

Prediction 2 states that social information on opinions induces groups to make better decisions than absent such social information when inferences are on average correct, but worse decisions when inferences are on average incorrect. In Figure 3 below, we graph percent correct group choices in OT and BT versus the percent correct by individuals in BT. We do not use the unconfirmed choices in OT as subjects may choose to "free ride" on the social information they expect to receive, expending little cognitive effort on making their unconfirmed choices and we do not use the confirmed choices in OT as we expect subjects to follow the social information on opinions when that information conflicts with their first response and thus the confirmed choices are not an accurate measure of their signals. Figure 3 shows that social information on opinions improves group choices when questions are easy, but has a negative effect on group choices when questions are hard. Social information drives groups to be either largely 100% correct or 100% incorrect, having a particularly strong effect on group choices when questions are hard.

Figure 3



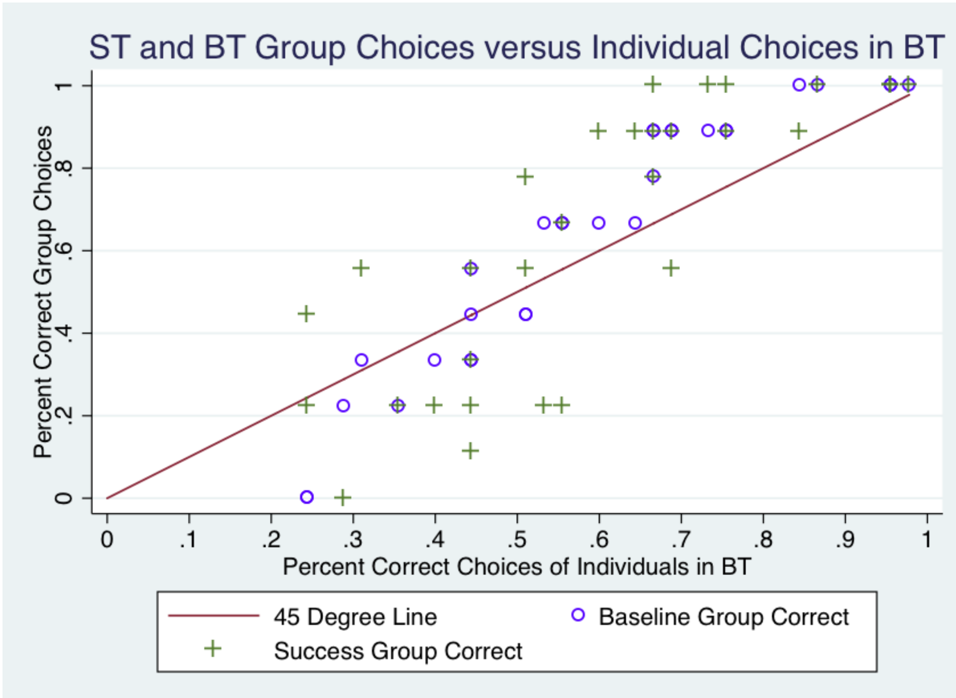
These differences are strongly significant. That is, we find that in OT groups make correct decisions 91% of the time when questions are easy, which is significantly greater than the proportion in BT (81%), with a p-value of 0.02, $z = 2.41$. When questions are hard, OT groups make correct decisions only 4% of the time, which is significantly less than the proportion in BT (28%), with a p-value of 0.00, $z = 3.88$. Hence we find strong support for Prediction 2, which is summarized in Result 2 below.

Result 2 (Group Choices with Social Information on Opinions) *Social information on opinions leads to more informationally efficient group choices by majority voting than without such information when individuals on average make correct inferences, but less efficient group choices by majority voting than without such information when individuals on average make incorrect inferences.*

Does Social Information on Success Improve Information Efficiency?

Figure 4 presents the effects of social information on success versus our baseline treatment; that is we graph percent correct group choices in ST and BT versus percent correct individual choices in BT. In line with Prediction 3 we find no effect of information on successes on the percentage of group choices when questions are easy. The proportion of groups making correct choices is the same (81%) in both ST and BT. However, in contrast to Prediction 3, when questions are hard, the proportion of groups making correct choices is similar in ST (29%) and BT (28%). Surprisingly, voters appear little influenced by learning the success of earlier voter decisions, which is summarized in Result 3 below.

Figure 4



Result 3 (Group Choices with Social Information on Success) *We find no evidence that social information on success mitigates the effects of incorrect inferences on group choices through majority voting.*

IV.3 Voter Responses to Social Information

IV.3.1 Do Voters Switch Answers in Response to Social Information?

Our group-level analysis suggests that voters strongly respond to social information on opinions but not to information on successes. We now explore individual voter behavior. In our design, we first elicit initial answers and then ask for confirmed answers after receiving the social information. Table 2 shows the extent that voters change their answers between initial and confirmed responses by treatment and by question type.

Table 2: Percent Switching by Treatment & Question Type						
	Hard Questions*			Easy Questions**		
	BT	OT	ST	BT	OT	ST
No Switch, Incorrect	58.4	70.3	53.6	27.1	13.9	26.8
Switch from Incorrect to Correct	4.0	2.0	13.8	3.3	18.3	4.4
Switch from Correct to Incorrect	5.3	13.1	6.9	2.2	0.6	1.4
No Switch, Correct	32.2	14.6	25.8	67.3	67.3	67.3
Observations	450	350	450	900	700	900
*< 50% Individual Choices Correct in BT						
**> 50% Individual Choices Correct in BT						

We find significant differences in switching behavior across treatments.[12] When questions are easy, there is a strong effect of OT: about 3 times as many switch in OT as in BT (18.9% vs. 5.5%), and they are about 30 times more likely to switch the right way (from incorrect to correct) than the wrong way (18.3% vs. 0.6%). But the "dark side of the social information on opinions in voting is also clear. With hard questions, switching is also more likely in OT (15.1% vs. 9.3%) but now voters are more than 6 times as likely to switch the wrong way than the right way (13.1% vs. 2.0%).

When questions are easy, as expected, switching behavior in ST is virtually identical to switching behavior in BT. That is, we expect that when questions are easy, social information on success should only reinforce subjects' own inferences and not lead to any switching, unlike social information on opinions. In contrast, when questions are hard, we expect that social information on success will de-bias voters, i.e. will lead subjects whose initial choices are incorrect to switch to correct choices. We find that 20.7% switch answers in ST when questions are hard (compared to 9.3% in BT). Furthermore, almost 2/3 of the switches are from incorrect to correct choices (13.8% vs. 6.9%). Thus, when we examine individual voting behavior, we find some evidence that social information on successes is influencing voters. However, there is also more switching by subjects whose initial responses were correct to wrong when questions are hard in ST as compared to BT. Thus, on net the beneficial influence of social information on successes is not

[12] The χ^2 statistic comparing treatments when questions are easy and the initial answer is correct is 7.11, Pr = 0.03; when questions are easy and the initial answer is incorrect it is 166.49, Pr = 0.00; when questions are hard and the initial answer is correct it is 38.22, Pr = 0.00; and when questions are hard and the initial answer is incorrect it is 53.58, Pr = 0.00.

strong enough to lead to significantly better group outcomes under ST as compared to BT when questions are hard. These results are summarized below:

Result 4 (Voter Switching in Response to Social Information on Opinions) *Social information on opinions leads to signficantly more switching in initial responses than without such information. When questions are easy, this switching leads to more efficient information aggregation, but when questions are hard, this switching leads to less efficient information aggregation.*

Result 5 (Voter Switching in Response to Social Information on Success) *Social information on success has little effect on switching in initial responses when questions are easy, but does lead to significantly more switching in inital incorrect to correct responses when questions are hard. However, this switching is not on net large enough to lead to higher information efficiency under social information on successes.*

IV.3.2 Does Social Information Affect Voter Certainty?

We also asked subjects to provide an estimate of how certain they were about their choices, both their initial choices and their confirmed choices on a scale of 1 to 5, where 5 represents most certainty. We find significant differences in voter certainty across treatments.[13] In Table 3 we summarize how certainty changes between initial and confirmed choices by treatment and by question type.

[13] For the comparison of the difference in certainty by treatments when questions are easy (more than 50% of individuals gave correct responses in BT), the χ^2 statistic = 146.09, Pr = 0.00 and for when questions are hard (less than 50% of individuals gave correct responses in BT), it is 80.22, Pr = 0.00.

Table 3: **Percent Responses to Information**						
	Hard Questions*			Easy Questions**		
Difference	BT	OT	ST	BT	OT	ST
-4	0.0	0.9	0.9	0.0	0.7	0.0
-3	0.7	0.0	2.2	0.3	0.6	0.4
-2	1.6	2.9	6.2	1.1	3.7	2.2
-1	6.9	9.1	14.9	4.8	8.9	4.7
0	78.2	65.4	64.2	84.9	62.7	80.1
1	8.2	16.3	7.8	6.1	17.7	8.6
2	2.4	5.1	3.1	1.0	4.4	2.4
3	1.3	0.0	0.2	0.8	0.9	1.2
4	0.7	0.0	0.4	1.0	0.4	0.3
Observations	450	350	450	900	700	900
*< 50% Individual Choices Correct in BT						
**> 50% Individual Choices Correct in BT						

When we compare OT with BT in Table 3, we find that social information on opinions affects voter certainty in both hard and easy questions, leading to both increases and decreases in certainty. But a comparison of mean differences in uncertainty between the two treatments does not show a significant effect overall, suggesting that increases in uncertainty offset increases in certainty.[14] Evidence suggests that the changes in uncertainty in easy questions may reflect unconscious recognition when a subject is making a wrong or right choice. That is, when questions are easy and the subject's confirmed response is wrong, certainty decreases significantly more in OT than in BT but when the subject's confirmed response is right, certainty increases significantly more in OT than in BT.[15] We find no significant differences at conventional levels that depend on correctness of a subject's confirmed response when questions are hard, however, suggesting that when questions are hard social information on opinions does not affect unconscious recognition of the correctness of an answer.[16] This result again supports the previous evidence that social information on opinions does not help individuals make more correct decisions when questions are hard.

[14] The t-statistic comparing mean differences in certainty between BT and OT for hard questions is 0.28, Pr = 0.78 and for easy questions is 0.84, Pr = 0.40.

[15] The t-statistic comparing mean differences in certainty between BT and OT for easy questions when the confirmed response is wrong is 4.90, Pr = 0.00 and for when the confirmed response is correct is 2.51, Pr = 0.01.

[16] The t-statistic comparing mean differences in certainty between BT and OT for hard questions when the confirmed response is wrong is 0.90, Pr = 0.37 and for when the confirmed response is correct is 1.69, Pr = 0.09.

In contrast, when we compare ST with BT, we find that social information on successes has little effect on certainty when questions are easy but a significant overall negative effect on certainty when questions are hard.[17] This effect when questions are hard is significant whether subjects confirmed responses are both incorrect and correct.[18] Hence, social information on successes does appear to have an unconscious effect on subjects' views of the correctness of their answers when questions are hard and we find further evidence that on average subjects do respond to social information on successes as predicted when questions are hard, although not enough to affect the efficiency of voting. We summarize these results below:

Result 6 (Voter Certainty and Social Information on Opinions) *Social information on opinions affects voter certainty in their answers when questions are easy. Certainty increases when confirmed responses are correct, but decreases when they are not.*

Result 7 (Voter Certainty and Social Information on Success) *Social information on success affects voter certainty in their answers when questions are hard. Certainty decreases regardless of whether confirmed responses are correct or incorrect.*

IV.3.3 Do Cognitive Reflection Tendencies Explain Voter Behavior?

CRT and Voter Choices As described above, we also included in our experiment a three-question measure of Cognitive Reflection, CRT. Our theory assumes that voters vary in their abilities to make correct inferences and this test may approximate such abilities. In Table 4 below we summarize the extent that voters make confirmed correct choices by total CRT score (3 implies correct on all three 3 CRT questions, etc.) by treatment and question type.

[17] The t-statistic comparing mean differences in certainty between BT and ST for hard questions is 4.87, Pr = 0.00 and for easy questions is 0.47, Pr = 0.64.

[18] The t-statistic comparing mean differences in certainty between BT and ST for hard questions and confirmed responses are incorrect is 4.89, Pr = 0.00 and for when confirmed responses are correct is 1.95, Pr = 0.05. The statistics for the comparisons for easy questions are 0.13, Pr = 0.89 and 0.47, Pr = 0.64, respectively.

Table 4: Correct Votes by CRT, Treatment, & Question Type							
		Hard Questions*			Easy Questions**		
CRT Score		BT	OT	ST	BT	OT	ST
0	Percent Correct	34.4	17.3	32.0	66.1	81.4	69.0
	Correct Obs.	31	19	32	119	179	138
	Total Obs.	90	110	100	180	220	200
1	Percent Correct	33.0	11.7	33.3	64.0	89.2	68.3
	Correct Obs.	33	7	30	128	107	123
	Total Obs.	100	60	90	200	120	180
2	Percent Correct	41.3	15.6	46.8	74.4	86.1	74.7
	Correct Obs.	66	14	89	238	155	284
	Total Obs.	160	90	190	320	180	380
3	Percent Correct	33.0	20.0	38.6	75.5	87.8	72.1
	Correct Obs.	33	18	27	151	158	101
	Total Obs.	100	90	100	200	180	140
* < 50% Individual Responses Correct in BT							
**>50% Individual Responses Correct in BT							

First, we consider whether an individual's CRT score is a significant predictor of whether he or she makes a correct confirmed response in BT, without any social information. We find evidence that individuals who have higher CRT scores are significantly more likely to make confirmed correct responses in BT.[19] In a simple probit regression with probability of making a confirmed correct response as the dependent variable, a one unit change in CRT score leads to an appoximately 3% increase in the probability of making a correct confirmed response in BT.[20] Yet, a closer look at the data reveals that somewhat surprisingly the effect is primarily for easy questions, a probit estimation for hard questions reveals no significant influence of CRT score but that a one unit change in CRT score leads to an approximately 4% increase in the probability of making a correct confirmed response in BT when questions are easy.[21]

Second, CRT scores do not predict correct confirmed choices under social information on opinions, OT. We find that with social information on opinions, the effect of CRT scores on the probability of making a correct confirmed choice is insignificant overall and separately for

[19] The χ^2 statistic for the comparison of correct responses by CRT score in BT is 9.25, Pr = 0.03.

[20] The z statistic in the probit estimation = 2.02, Pr = 0.04, Pseudo $R^2 = 0.003$.

[21] The z statistic in the probit estimation for hard questions = 0.28, Pr = 0.78, Pseudo $R^2 = 0.0002$ and for easy questions = 2.23, Pr = 0.03, Pseudo $R^2 = 0.007$.

both easy and hard questions.[22] This makes sense if having a higher CRT score is primarily a predictor of behavior on easy questions, since social information on opinions is an effective method by which voters with lower cognitive abilities can make inferences about correct responses when questions are easy.

Third, CRT scores predict correct confirmed choices in ST for hard choices. We find that indeed, with social information on success a one-unit increase in CRT score significantly increases the probability of a confirmed correct answer of a hard question by 4% but has no significant effect on the probability of a confirmed correct answer of an easy question.[23] The effect for hard questions is strongest for those with higher CRT scores. The last point coupled with the data from BT appears to suggest that CRT scores predict not so much how well an individual can answer a hard question, but whether the individual responds rationally to information on success. We summarize our analysis in the following results:

Result 8 (CRT and Voting) *We find that higher CRT scores are associated with significantly higher probability of making a correct confirmed response in majority voting without social information, but the effect seems to be present only when questions are easy. We find no relationship between CRT scores and the correctness of confirmed responses in majority voting with social information on opinions. We find that higher CRT scores are associated with a significantly higher probability of making a correct confirmed response in majority voting with social information on successes when questions are hard only; suggesting that individuals with higher CRT scores are more responsive to such information.*

CRT, Switching, and Certainty Recall that our analysis of individual voting behavior has shown that although we do not find much evidence that social information on success

[22] The z statistic in the probit estimation for both types of questions combined = 1.41, Pr = 0.16, Pseudo $R^2 = 0.001$; for hard questions only = 0.38, Pr = 0.71, Pseudo $R^2 = 0.001$; and for easy questions only = 1.37, Pr = 0.17, Pseudo $R^2 = 0.005$. We estimate using robust standard errors clustered by subject id.

[23] The z statistic in the probit estimation for hard questions only = 1.99, Pr = 0.05, Pseudo $R^2 = 0.005$; and for easy questions only = 1.19, Pr = 0.23, Pseudo $R^2 = 0.002$. We estimate robust standard errors clustered by subject id.

alleviates the problems that occur in majority decision-making when questions are hard, we do find evidence that voters respond to the information on success when questions are hard by both changing their responses and by decreased certainty in their confirmed responses. If CRT scores measure whether individuals respond in this fashion then we should find an effect of CRT scores on switching behavior and changes in certainty of responses.

Table 5 summarizes switching behavior by treatment, question type, and CRT score. We do not find significant variations in switching behavior that is explained by CRT scores in BT or in OT.[24] However, we do find that CRT scores significantly explain switching behavior in two cases in ST: 1) when questions are hard and initial responses are correct, subjects with higher CRT scores switch significantly less to incorrect responses than subjects with lower CRT scores and 2) when questions are easy and initial responses are incorrect, subjects with higher CRT scores switch significantly more to correct responses than subjects with lower CRT scores.[25] Hence, there is evidence that subjects with higher CRT scores are better able to make inferences from the social information on success in ST.

[24]The χ^2 statistic for BT, hard questions, and initially incorrect responses = 6.03, Pr = 0.11 and for initially correct responses =4.76, Pr = 0.19; for easy questions the values are 3.80, Pr = 0.28 and 1.19, Pr = 0.76, respectively. For OT, hard questions an initially incorrect responses the statistic = 0.86, Pr = 0.84 and for initially correct responses = 5.36, Pr = 0.15; for easy questions the values are 4.65, Pr = 0.20 and 1.43, Pr = 0.70.

[25]The χ^2 statistic for ST, hard questions, and initially incorrect responses = 4.48, Pr = 0.21 and for initially correct responses = 11.20, Pr = 0.01; for easy questions the values are 9.51, Pr = 0.02 and 2.90, Pr = 0.41, respectively.

Table 5: Percent Switching by Treatment, Question Type, & CRT Score								
	Hard Questions*				Easy Questions**			
CRT Score	0	1	2	3	0	1	2	3
Baseline Treatment (BT)								
No Switch, Incorrect	58.9	59.0	55.0	63.0	32.2	33.0	23.4	22.5
Switch from Incorrect to Correct	3.3	8.0	3.8	1.0	6.7	3.0	2.5	2.0
Switch from Correct to Incorrect	6.7	8.0	3.8	4.0	1.7	3.0	2.2	2.0
No Switch, Correct	31.1	25.0	37.5	32.0	59.4	61.0	71.9	73.5
Observations	90	100	160	100	180	200	320	200
Opinions Treatment (OT)								
No Switch, Incorrect	65.5	71.7	73.3	72.2	18.2	10.8	13.3	11.1
Switch from Incorrect to Correct	2.7	1.7	2.2	1.1	23.2	23.3	11.1	16.1
Switch from Correct to Incorrect	17.3	16.7	11.1	7.8	0.5	0.00	0.6	1.1
No Switch, Correct	14.6	10.0	13.3	18.9	58.2	65.8	75.0	71.7
Observations	110	60	90	90	220	120	180	180
Success Treatment (ST)								
No Switch, Incorrect	56.0	57.8	50.0	54.3	29.5	31.1	24.0	25.0
Switch from Incorrect to Correct	13.0	8.9	17.4	11.4	1.5	3.3	6.0	5.7
Switch from Correct to Incorrect	12.0	8.9	3.2	7.1	1.5	0.6	1.3	2.9
No Switch, Correct	19.0	24.4	29.5	27.1	67.5	65.0	68.7	66.4
Observations	100	90	190	70	200	180	380	140
*$<$ 50% Individual Choices Correct in BT								
**$>$ 50% Individual Choices Correct in BT								

Do we find that CRT scores explain changes in voter certainty? Table 6 summarizes how voter certainty changes by treatment, question type, and CRT score. To make the table easier to interpret, we use a simplified measure of changes in voter certainty; that is whether voter certainty decreases, stays the same, or increases between initial responses and confirmed responses. Although there are clear variations within treatments that appear to be related to CRT scores, the relationships do not appear to be monotonic as one would expect if certainty or uncertainty increases with cognitive abilities. When we estimate regressions with raw certainty differences as dependent variables and CRT score as our explanatory variable for each treatment and question type, we find that CRT score can only significantly explain certainty changes in BT with hard questions, with subjects with higher CRT scores displaying more certainty in their confirmed responses than their initial ones, which might reflect additional attention paid by these subjects to the questions.[26] These results are summarized below.

[26] The t statistic in the regression = 2.14, with Pr = 0.4, $R^2 = 0.01$. We use robust standard errors clustered by subject id. The results are qualitatively the same if we use ordered probit for the analysis.

Table 6: Percent Certainty Differences by CRT Score								
	CRT Scores							
	Hard Questions*				Easy Questions**			
	0	1	2	3	0	1	2	3
Certainty Changes	Baseline Treatment (BT)							
Decrease	10.0	6.0	10.0	10.0	7.2	7.0	4.7	7.0
No Change	81.1	87.0	75.6	71.0	84.4	84.0	88.4	80.5
Increase	8.9	7.0	14.4	19.0	8.3	9.0	6.9	12.5
Observations	90	100	160	100	180	200	320	200
	Opinions Treatment (OT)							
Decrease	13.6	23.3	5.6	12.2	18.2	16.7	9.4	11.1
No Change	61.8	50.0	73.3	72.2	61.4	55.0	69.4	62.8
Increase	24.6	26.7	21.1	15.6	20.5	28.3	21.1	26.1
Observations	110	60	90	90	220	120	180	180
	Success Treatment (ST)							
Decrease	13.0	21.1	32.1	22.9	6.5	7.2	6.8	10.0
No Change	75.0	72.2	54.7	64.3	81.5	84.4	77.4	80.0
Increase	12.0	6.7	13.2	12.9	12.0	8.3	15.8	10.0
Observations	100	90	190	70	200	180	380	140
*< 50% Individual Choices Correct in BT								
**> 50% Individual Choices Correct in BT								

Result 9 (CRT Scores and Switching) *Higher CRT scores are associated with switching behavior when voters have social information on success. Specifically, when the majority of voters make incorrect inferences, and subjects have initial correct responses, those with higher CRT scores are less likely to switch to the incorrect choice and when the majority of voters make correct inferences, and subjects have initial incorrect responses, those with higher CRT scores are more likely to switch to the correct choice.*

Result 10 (CRT Scores and Certainty) *CRT scores have very little relationship with changes in voter certainty in response to social information.*

IV.4 Cognitive Abilities and Understanding the Impact of Social Information on Voting

We find that on average voters are much less influenced by social information on success than they are on opinions. Why might voters find social information on opinions more persuasive than social information on success? The finding that cognitive abilities are predictors of which types of voters are influenced by social information on success and under what conditions suggests a possible answer.

Consider the situation in which a voter receives social information on opinions. The voter learns either that the majority of previous voters agrees with his or her choice or does not agree with his or her choice. If the majority agrees, then it is easy to keep his or her choice the same, if the voter learns that the majority doesn't agree, then it is relatively easy to say, well maybe I'm wrong because the majority is so consistently thinking this way. The voter does not have to think about why it is that maybe the majority disagrees, it is a relatively simple calculus. According to this logic, it makes sense that we see little evidence that cognitive abilities explain switching behavior in OT.

Now consider the situation in which a voter receives social information on success. The voter either learns that the majority of previous voters was correct or that the majority was incorrect. If he or she learns that the majority was correct in the past it is easy to reason, well, probably the majority will be correct again, and I don't need to do anything. The voter does not need to take the additional step to think about what this means about the voter's own inferences. But if the voter learns that on average the majority was incorrect the voter has to first figure out that this means that most people make incorrect inferences and that he or she is probably like most people and is also making an incorrect inference. The voter has to think through the implications for inferences of others and his or her own inference. So the level of reasoning for social information on success to influence voter choices is higher for this case. Again, according to this logic, it makes sense that we see significant evidence of cognitive abilities explaining voter switching in ST when questions are hard, but not when questions are easy.

Our analysis suggests, then, that social information on opinions is more problematic for majority voting outcomes when voters on average make incorrect inferences in particular because the reasoning required of voters is not difficult in order to use such information, but that social information on success does not help alleviate the problems with majority voting when voters on average make incorrect inferences precisely for the same reason that voters often make incorrect inferences in the first place, because the reasoning required for such information to be influential is more cognitively taxing.

V Concluding Remarks

To err is human. In a democracy, voters will often be uncertain about what is the right course of action, and be more or less prone to erroneously support inefficient policies. But the existence of such uncertainty and error does not imply that democracy is necessarily doomed to systematically select inefficient policies. This paper shows experimentally that majority voting is beneficial (has a "bright side") in the sense that democratic choice can be superior to the average voter's opinion if it aggregates information effectively. Majority voting has a "bright side" even when almost all voters are uncertain and when many err, as long as a majority of voters is more likely to be right than wrong about what policy to choose. Social information on opinions (the popularity of alternatives in the electorate) and on how successful democratic choice tends to be makes the "bright side" shine even brighter, i.e. further improves efficiency, or does at least not harm.

Yet, our experiment also shows that the "dark side" of the vote is looming. We find that voting is counterproductive when the average voter is biased (is more likely to be wrong than right), and that social information on opinions further exacerbates the perverse effect of majority voting. Counter to theoretical predictions, we find that voters are not enlightened (i.e. do not make clearly better choices) when they learn about how bad choices in other electorates on the same issue were. Thus, we find that voters are not effectively de-biased by such information, probably because voters are not aware of their biases and de-biasing requires substantial cognitive skills.

We were able to produce these findings by virtue of a novel experimental design. Previous experimental studies of information aggregation in voting had designs that were chosen to minimize the possibility of incorrect inferences and have therefore not been able to study the dark side of the vote or how it is shaped by social information. In contrast, our design allows us to bring a series of issues before voters which all have a clear correct answer and we know (but voters do not know) for which of these issues most individuals tend to make correct inferences or systematically biased judgments.

We think our results should be read as a warning against the belief that majority voting will in all cases be beneficial in that it yields superior choices due to efficient information aggregation. Such a belief may be nurtured by theoretical accounts (based on the Condorcet Jury Theorem), but they often use psychologically unrealistic assumptions.[27] But our results should not be read as saying that democratic (majoritarian) choice is necessarily doomed (it is not, there is a "bright side") nor that majoritarian choice should be rejected in cases where it is likely to aggregate information inefficiently.

Caution in interpretation is warranted on at least two grounds. First, our paper focuses on the ability of majority voting to select the best solution when one exists (the "epistemic" quality of democracy). This issue seems relevant in situations such as when the board of a company decides on investing in product A or B, or a jury decides on whether a defendant is guilty or not. Clearly, majoritarian choice has other benefits than aggregating information,[28] and has other drawbacks than failure to aggregate information inefficiently in specific circumstances (like the exploitation of minorities by majorities, see for example Gerber et al. 1998). Thus, our results provide just one – we think an important one – aspect in the debate on the pros and cons of majoritarian choice. Second, when evaluating majoritarian choice, it needs to be compared to other (realistic) alternatives, which also have their pros and cons.

[27] We do not know to what extent such theoretical accounts shape the faith of politicians and lay people in the ability of majoritarian choice. Casual observation suggests that perceptions are rather mixed. Winston Churchill seems not to have had much faith in that ability, judging from his quip that "The best argument against democracy is a five-minute conversation with the average voter."

[28] For example, it may help to hold self-interested elites in check, allow voters to participate in decision making and to express their preferences, or increase compliance by improving the legitimacy of policy choices (see e.g. Dal Bo et al. 2010, Markussen et al. 2011 for experimental studies).

Our design to study the effects of biased choices can be used to study further aspects of the dark side of the vote or information aggregation more generally. We think interesting avenues for further research on information aggregation in majority voting are selective participation, other forms of social communication preceding voting, and other voting rules.

Selective participation and abstention are important aspects of many democratic choices, and may shape the quality of democratic choice in important ways (e.g. Bhattacharya et al. 2012). In our experiment, voting was compulsory and therefore biased and non-biased voters were equally likely to participate. Suppose that participation and voter competence is correlated. For example, biased voters may be somehow aware that they are biased and abstain while non-biased voters may participate at higher rates. If so, the dark side documented here may be mitigated. But our data suggests that is no likely to happen. Those who got it wrong were not much less confident.

Other forms of social information may reduce or even eliminate the dark side of the vote. Suppose we had informed voters in our experiment about what policies other groups had chosen and how successful these policies were. We think it is quite likely that voters would have made near-perfect choices in this case. Such an effect is likely in our design because the groups and issues were identical, but is not guaranteed to obtain in more complicated settings, e.g. when experience with a particular policy in state may only be a noisy predictor of success of the same policy elsewhere because states differ (see Sausgruber and Tyran 2005 for an experimental investigation of policy emulation). Other forms of communication may or may not be helpful (Goeree and Yariv 2010). Deliberation among non-experts or when experts cannot persuade others of their superior knowledge is not necessarily a remedy and may result in group think, i.e. on agreeing on an arbitrary policy, not necessarily the correct one (see Sausgruber and Tyran 2011 for an experiment with free communication preceding voting on taxes in a market). However, credible experts may be game-changers. One way to become credible is to establish a proven track record of superior judgment (see Penczynski 2012).

Alternative voting rules may mitigate the dark side of the vote. For example, point voting may restore informational efficiency if voters assign points (out of a budget of 100, say) to alternatives according to how certain they are to be right. This would be the case if the certainty correlates well with competence and voting is non-strategic (but it is well-known that voters are insincere with point voting, e.g. Nitzan et al. 1980).[29] Markets may fare better than voting in aggregating information, because the marginal rather than the median person drives the outcome. But biases also seem to beset such markets at least in some instances (e.g. Ganguly et al. 2000, Snowberg and Wolfers 2010).

Our experiments suggest that models of information aggregation through majority voting and associated experimental work should take the effects of biased voters on the efficiency of group choices more seriously. Our findings suggest that the dark side of the vote is real, and social information can play an important, and surprising, role in shaping it.

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Auxillary Materials to be Published Online

Appendix A: Derivation of Equilibria

Voting Without Social Information

First, we examine voting equilibria without social information in a particular election j. To simplify the notation, we drop the subscript j from the variables. Can we rule out equilibria in which everyone votes contrary to his or her signal? It is straightforward to see that we can. Since we have an odd number of voters and no abstention, then there is only one pivotal event for a particular voter, a tie, in which the voters excluding i are exactly splitting their votes between a and b. Assuming these voters are choosing contrary to their signals, then this means that exactly half have received a signals and half have received b signals. Label this event PIV. Assume that voter i has received an a signal. Voter i compares his or her utility from voting for a versus b conditioned on this pivotal event. Label $EU_i(a|\sigma_i = a, PIV)$ as voter i's expected utility of voting for a given an a signal and that he or she is pivotal. This utility is a function of the likelihood that A is the true state of the world conditioned on i's signal and the voter is pivotal as follows:

$$EU_i(a|\sigma_i = a, PIV) = \Pr(A|\sigma_i = a, PIV) * 1 + \Pr(B|\sigma_i = a, PIV) * 0 \tag{5}$$

$EU_i(b|\sigma_i = a, PIV)$ can be similarly derived.

Simplifying, $EU_i(a|\sigma_i = a, PIV)$ is equal to the probability that A is the true state of the world given that voter i receives an a signal and the voter is pivotal. As events A and B are a priori equally likely, then $EU_i(a|\sigma_i = a, PIV)$ can be shown to equal p_i (the expected signal quality for voter i):

$$
\begin{aligned}
EU_i(a|\sigma_i &= a, PIV) = \Pr(A|\sigma_i = a, PIV) \qquad (6)\\
&= \frac{\Pr(\sigma_i = a, PIV|A)0.5}{\Pr(\sigma_i = a, PIV|A)0.5 + \Pr(\sigma_i = a, PIV|B)0.5}\\
&= \frac{(n-1)0.5p_i^n\,(1-p_i)^{n-1}}{(n-1)0.5p_i^n\,(1-p)^{n-1} + (n-1)\,0.5p_i^{n-1}\,(1-p_i)^n}\\
&= p_i
\end{aligned}
$$

Similarly, the $EU_i(b|\sigma_i = a, PIV) = 1 - p_i$. Given that $p_i > 0.5$, option a will therefore maximize voter i's expected utility. Hence, voter i will choose to vote his or her signal and it is not an equilibrium for all voters to vote contrary to their signals.

Given that for all voters, voting contrary to their signals is not an equilibrium, does an equilibrium exist in which all voters vote their signals? Again, assuming that voters condition their vote on being pivotal, then given that in the event voter i is pivotal, he or she expects that all other voters are voting their signals and the logic discussed above, it is straightforward to demonstrate that under our assumptions voting one's signal is optimal when other voters are also voting their signals and that an equilibrium exists in which all voters vote their signals sincerely.

Finally, as in all voting games, there are trivial equilibria in which all voters vote for either a or b, regardless of their signals since in such a case no vote is pivotal and any voting choice is an optimal response. To rule out such equilibria, we assume that voters do not use weakly dominated strategies. That is, as we have shown, the strategy of voting one's signal yields greater expected utility when the probability of being pivotal is positive and is equivalent to the expected utility when the probability of being pivotal equals zero. Thus, the strategy of voting one's signal weakly dominates voting the same option regardless of one's signal.

Voting with Social Information on Opinions

As previously, we assume that voters condition their vote choices on the event that they are pivotal. We also continue to focus on pure strategy symmetric equilibria in which voters who receive the same signal choose the same strategy. Furthermore, since we have assumed that both voting groups have an odd number of voters, then group 2 voters either learn that the majority of group 1 voted for a or that the majority voted for b (and the relative size of that majority).

Voting Contrary to Signals First, consider whether an equilibrium exists in which all voters in group 2 vote contrary to their signals. Assume that voter i has received an a signal and learns q, the proportion of group 1 voted for a. As above, in the event that he or she is pivotal then exactly half of the remaining group 2 voters are voting for a and the other half are voting for b, event PIV. As in the case without social information, it is straightforward to show that $EU_i(a|\sigma_i = a, q, PIV)$ is given by:

$$\begin{aligned} EU_i(a|\sigma_i &= a, q, PIV) = \Pr(A|\sigma_i = a, q, PIV) \\ &= \frac{\Pr(\sigma_i = a, q, PIV|A)0.5}{\Pr(\sigma_i = a, q, PIV|A)0.5 + \Pr(\sigma_i = a, q, PIV|B)0.5} \\ &= \frac{(n-1)0.5p_i^n (1-p_i)^{n-1} \Pr(q|A)}{(n-1)0.5p_i^n (1-p_i)^{n-1} \Pr(q|A) + (n-1)\,0.5p_i^{n-1} (1-p_i)^n \Pr(q|B)} \\ &= \frac{p_i \Pr(q|A)}{p_i \Pr(q|A) + (1-p_i) \Pr(q|B)} \end{aligned} \tag{7}$$

Similarly, $EU_i(b|\sigma_i = a, q, PIV) = \frac{(1-p_i)\Pr(q|B)}{p_i \Pr(q|A)+(1-p_i)\Pr(q|B)}$. The difference in expected utility from voting for a instead of b is then given by:

$$EU_i(a|\sigma_i = a, q, PIV) - EU_i(b|\sigma_i = a, q, PIV) = \frac{p_i \Pr(q|A) - (1-p_i)\Pr(q|B)}{p_i \Pr(q|A) + (1-p_i)\Pr(q|B)} \tag{8}$$

Since the denominator of the righthandside of equation (4) is always positive, then voter i should vote for a if $p_i \Pr(q|A) > (1-p_i)\Pr(q|B)$, or if $\frac{p_i}{1-p_i} > \frac{\Pr(q|B)}{\Pr(q|A)}$. From the binomial distribution, it is straightforward to show that $\frac{\Pr(q|B)}{\Pr(q|A)} = \left(\frac{p_i}{1-p_i}\right)^{n(1-2q)}$. Voter i then will receive higher expected utility for voting for a given he or she has received an a signal if $\frac{p_i}{1-p_i} > \left(\frac{p_i}{1-p_i}\right)^{n(1-2q)}$.

Recall that $p_i > 0.5$ by assumption, so $\frac{p_i}{1-p_i} > \frac{1-p_i}{p_i}$. Therefore, voter i who has received an a signal and knows q, will prefer to vote as follows:

$$\begin{array}{ll} \text{If } 1 > n(1-2q) & \text{Vote for } a \\ \text{If } 1 < n(1-2q) & \text{Vote for } b \\ \text{If } 1 = n(1-2q) & \text{Indifferent} \end{array} \tag{9}$$

Intuitively, this voting calculus makes sense; if a voter has received an a signal and is conditioning on the pivotal event in which all other voters in group 2 are voting their signals, then he or she should vote for a as long as b has received no more than one vote more than a in group 1. If $n = 5$, as in our experiment, then for values of $q > 0.4$, voter i should vote for a. If b has received two or more votes than a in group 1 (in our experiment less than 40% of the vote in group 1), voter i should vote for b even though he or she has received an a signal, and if a has received exactly two votes less than b (in our experiment 40% of the vote in group 1), voter i should be indifferent between voting for a and b.

Hence in our experiment for values of $q > 0.4$, it is not an optimal response for a voter who has received an a signal to vote contrary to his or her signal. Using the same logic, the converse holds for voters who have received b signals – for values of $q < 0.6$, it is not an optimal response for them to vote contrary to their signals. Thus, no value of q exists in which both types of voters will find it optimal to vote contrary to their signals and such an equilibrium in which all vote contrary to their signals does not exist.

Voting Signals Now consider whether an equilibrium exists in which all voters in group 2 vote their signals. As the pivotal event is the same in this case as in the case in which all voters vote contrary to their signals, the calculus of voting derived above is exactly the same. In our experiment, therefore, if $q \geq 0.4$, it is an optimal response for a voter who has received an a signal to vote his or her signal and if $q \leq 0.6$, it is an optimal response for a voter who has received a b signal to vote his or her signal. We can conclude that an equilibrium exists in which all voters in group 2 vote their signals when $0.6 \geq q \geq 0.4$.

Ignoring Signals The analysis above demonstrates that when q is low (high), voters who receive an a (b) signal have an incentive to vote contrary to their signals if other voters are voting their signals. Is it an equilibrium for low (high) values of q, for all voters to vote for b (a)? Of course, as noted previously, all voters voting for one option is always an equilibrium even in the voting game without social information given our assumption that $n \geq 3$, since changing one's vote cannot change the outcome. However, we ruled such equilibria out by assuming that voters do not use weakly dominated strategies when social information did not exist. But with social information, such equilibria no longer involve voters using weakly dominated strategies when q is either low or high, since this is the optimal strategy in such cases when all other voters are voting their signals as shown above. Thus, when q is low (in our experiment below 40%), we expect all voters to vote for b (including those with a signals) and when q is high (in our experiment greater than 60%), we expect all voters to vote for a (including those with b signals).

In summary, when q is low (below 40% in our experiment), we expect all voters, regardless of signals, to vote for b. When q is high (above 60% in our experiment), we expect all voters, regardless of signals, to vote for a. And when q is in a middle range (between 40 and 60% in our experiment), we expect all voters to vote their signals.

Voting with Social Information on Success

As in the previous analysis, we begin with an investigation of whether an equilibrium exists in which all voters in group 2 vote contrary to their signals. The analysis is similar to the case where voters have no social information with $\overline{c}$ now the voters' expectation about the quality of their signals. Assume that voter i receives an a signal. Following the logic above then $EU_i(a|\sigma_i = a, c, PIV) = \overline{c}$ and $EU_i(b|\sigma_i = a, c, PIV) = 1 - \overline{c}$. If $\overline{c} < 0.5$, then it is optimal for voter i to vote contrary to his or her signal, voting for b and voting contrary to one's signal is the only equilibrium (again ruling out equilibria with weakly dominated strategies and asymmetric equilibria). Conversely, if $\overline{c} > 0.5$, then it is optimal for voter i to vote his or her signal, voting for a. It follows directly then that when $\overline{c} > 0.5$, voting one's signal is the only equilibrium in such a case. Given that all groups have odd numbers of voters, then $\overline{c} \neq 0.5$, and we expect that voters will vote their signals when $\overline{c} > 0.5$ or vote contrary to their signals when $\overline{c} < 0.5$.

Appendix B: Instructions

Welcome to the experiment. Please do not communicate with other participants during the experiment. If you have any questions please raise your hand. You can earn money in this experiment. The amount of money you earn depends on your decisions and the decisions of other participants. All earnings will be paid out at the end of the experiment.

During the experiment, your income will be calculated in points. These points are converted into Danish kroner (DKK) according to the following exchange rate:

$$1 \text{ point} = 1 \text{ DKK}$$

The experiment has 30 periods in total. At the beginning of each period, all participants are randomly sorted into groups of 5. The group composition does not remain constant throughout the experiment but is reshuffled after each period. That is, the members of your group will change in every period. Decisions are anonymous; no participant is told during or after the experiment which other participants are in their group.

Your task in each period

In each period, all members of the group are asked the same question and given two possible answers. One of the answers is correct, the other is wrong. In each period you are asked to:

1. Indicate which of the two answers you think is correct.
2. Indicate how certain you are that your answer is correct. This is done on a scale from 1 to 5, where 1 is "not certain" and 5 is "very certain".
3. Indicate your final answer (= your vote).
4. Indicate your final certainty that your vote is correct.

The group decides on one of the two answers by **majority voting**. The answer which gets more votes is the group's decision. For example, if 3 group members vote for answer A and 2 for B, the group's decision is A.

Each member of the group earns points as follows:

- 10 points for each group member if the group answer is correct
- 0 points for each group member if the group answer is wrong

Your earnings are determined exclusively by the group decision. If the group answers the question correctly, all group members earn 10 points. If the group answer is wrong, all group members earn 0 points.

For example, if you vote for the correct answer, and the other four members vote for the wrong answer, the group's decision is for the wrong answer and all group members, including you, will earn 0 points. Conversely, if you vote for the wrong answer and the other four members vote for the correct answer, all group members, including you, earn 10 points.

In Opinions Treatment

Important: Before indicating your final answer (= your vote), we will inform you about the percentage of votes for A and B in a previous session of the same experiment. In this previous session, participants were not informed about the voting in other experiments. This information will be communicated in each period.

In Success Treatment

Important: Before indicating your final answer (= your vote), we will inform you about the percentage of votes for the correct answer we got in a previous session of the same experiment. In this previous session, participants were not informed about the voting in other experiments. This information will be communicated in each period

In All Treatments

At the end of the experiment you will be given feedback about the number of correct group decisions and your earnings.

The timing

There are 30 questions in total. Please answer each question within the time limit (will be indicated in the upper right corner of the decision screens). Each period is structured as follows:

All group members are asked the same question

■

Each group member indicates what he or she believes to be the correct answer

■

Each group member indicates how certain he or she is that this answer is correct

■

We inform you about

In Opinions Treatment: the percentage of votes for A and B in a previous session

In Success Treatment: the percentage of votes for the correct answer in a previous session

■

Each group member indicates his or her answer (= your vote)

■

Each group member can change or confirm his or her level of certainty

■

Group decision (majority vote)

Do you have any questions?

If so, please raise your hand.

Appendix C: Questions (Correct answers in bold)

Question 1: Consider a fair coin being tossed 8 times. The coin can either turn out to be heads (H) or the tails (T). Compare the two possible outcomes: 1. H T H T H T H 2. H T T T H T H H

Which of the following two statements are right? **A. The two outcomes are equally likely** B. 1 is more likely than 2

Question 2: What name comes next in the following sequence: Alan Alda, Chevy Chase, Fred Flintstone, John Johnson, Oscar Oman? **A. Ursula Upson** B. Vera Vermont

Question 3: In which city did Sigmund Freud die? A. Vienna **B. London**

Question 4: Consider participating in a game show: There are 3 doors to choose from. Behind one of the doors, a prize is hidden. The other 2 doors do not contain a prize. You have to choose a door first, but this door is not opened. Instead, the host opens one of the other doors which does not contain the prize. Then, you can 'switch' or 'remain' with your initial choice. This choice determines whether you will win the prize. Will you be more likely to find the prize if you switch? **A. Yes** B. No

Question 5: Suppose Shelly is getting ready for bed, when the weatherman reports that there is a 40 % chance of rain tomorrow. As she lies down she is thinking 'Is it Ben or Donna who is picking me up tomorrow? Ben is late half the time so I might get caught in the rain waiting for him'. Then she remembers that Donna is always on time. 'I hope I will not get caught in the rain waiting for my ride'. However, she decides not to call anyone at this late hour and just take her chances instead. What is the probability that she will get caught in the rain as she feared? **A. There is less than 15 % chance that she will get caught in the rain** B. There is more than 15 % chance that she will get caught in the rain

Question 6: How long does it approximately take Uranus to complete one round around the sun? A. 8 years **B. 84 years**

Question 7: Which country is the Canary Islands part of? A. Portugal **B. Spain**

Question 8: Consider a room of 24 people. What is the probability that at least two of them have the same birthday (that is, the same day and month, not necessarily same year)? A. It is below 50 % **B. It is above 50 %**

Question 9: Which country is larger (covers the largest area)? A. Germany **B. Sweden**

Question 10: What is the value of 4^{16} or 4x4x4x4x4x4x4x4x4x4x4x4x4x4x4x4 equal to? A. Approximately 17.200.000.000 **B. Approximately 4.300.000.000**

Question 11: Which country has not adopted the Euro as its standard currency? **A. United Kingdom** B. Luxembourg

Question 12: A card is drawn at random from an ordinary deck of playing cards. What is the probability that it is neither a face card (Jack, Queen or King) nor a black card? **A. 20/52** B. 14/52

Question 13: Consider a room with ten people. Suppose they have to form groups. Can they form more different groups with 2 members or with 7 members (a person can be a member in more than one group)? A. 2 members **B. 7 members**

Question 14: Which planet is larger (equatorial diameter)? **A. Jupiter** B. Saturn

Question 15: The United States of America consists of how many states? **A. 50** B. 52

Question 16: Suppose rolling four fair six-sided dice. What is the probability that at least one of them will be a 6? A. Approximately 2/3 **B. Approximately 1/2**

Question 17: Imagine an urn filled with balls. 2/3 of the balls are of one color and 1/3 is of another color. Jean has drawn 5 balls from the urn and found that 4 were red and 1 was white. Robert has drawn 20 balls and found that 12 were red and 8 were white. Which of the two individuals should feel more confident that the urn they are drawing from contains 2/3 red balls and 1/3 white balls, rather than the opposite? A. Jean **B. Robert**

Question 18: In what year did Israel become a state? A. 1950 **B. 1948**

Question 19: A cab was involved in a hit-and-run accident at night. Two cab companies, the Green and the Blue (according to the color of the cab they run), operate in the city. 85 %

of the cabs in the city are green and 15 % are blue. The police found one witness saying that the hit-and-run car was blue. Since the accident happened at night time the court decided to test the reliability of the witness under similar conditions. The test concluded that the witness correctly identified the witness under similar conditions. The test concluded that the witness correctly identified the color of the car 80 % of the times, but misjudged it 20 % of the times. What is the probability that the witness was right and the hit-and-run car was blue? **A. Approximately 41%** B. Approximately 75%

Question 20: What is the name of the capital of Australia? **A. Canberra** B. Sydney

Question 21: What is the value of $\sqrt{64}$? **A. 8** B. 128

Question 22: What is the name of the capital of the Netherlands? **A. Amsterdam** B. The Hague (Den Haag)

Question 23: Suppose that in the male population 1 out of 250 has HIV. A man with normal risk behavior towards HIV / AIDS decides to test himself for HIV. The test has a 4 % rate of false positives, that is, it sometimes comes out positive even if the test person does not have HIV. But the test has 0 % false negatives, that is, the test only comes out negative if the test person does have HIV. The result of the test comes out positive. What is the probability that the man has HIV? A. Approximately 90 % **B. Approximately 9 %**

Question 24: In which country was the battle of Waterloo fought? A. The Netherlands **B. Belgium**

Question 25: You are shown a set of 4 cards below. Each card has a letter (vowel or consonant) on one side and a number (even or odd) on the other side. You are asked to verify the rule: 'if there is a vowel on one side of the card, there is an even number on the other side' by selecting two cards that must be turned to decide whether the rule is true or false. The cards show 'E', 'K', '2', '7'. Which cards do you turn? A. 'E' and '2' **B. 'E' and '7'**

Question 26: Which continent is larger (covers the largest area)? **A. Africa** B. North America

Question 27: Which Shakespear play features the line: “A plague on both your houses”? **A. Romeo and Juliet** B. Macbeth

Question 28: Planet Earth has an equatorial circumference of approximately 40.000 kilometers. How much will Earth's circumference increase if its radius is increased by 1 meter? A. Approximately 60 kilometers **B. Approximately 6 meters**

Question 29: The year 2005 was the H.C. Andersen year in Denmark. Why? **A. Because H.C. Andersen was born 200 years earlier** B. Because H.C. Andersen died 200 years earlier

Question 30: Consider two lotteries, A and B. It costs 100 DKK to participate in each lottery. Lottery A. You win 200 DKK with 80 % probability and you win 60 DKK with 20 % probability Lottery B. You win 300 DKK with 60 % probability and you win 20 DKK with 40 % probability. Which lottery gives the highest average payoff? A. Lottery A **B. Lottery B**

Questions Used in Cognitive Reflexion Test:

1. A bat and a ball cost $1.10. the bat costs $1.00 more than the ball. how much does the ball cost?

2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?