TRANSPARENCY'S TWIST: IMPACT OF INFORMATION ACQUISITION ON VOTING

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Abstract

Majority voting is considered an efficient information aggregation mechanism in committee decision-making. But what if voters first need to acquire information from sources of varied quality and cost? Here, efficiency may hinge on free-riding incentives and the 'transparency' regime - the knowledge voters have about others' acquired information. Intuitively, more transparent regimes should improve efficiency. Our theoretical model instead demonstrates that less transparent regimes can match the rate of efficient information aggregation in more transparent regimes. This does not hold generally, however. A Pareto inferior swing voter's curse (*SVC*) equilibrium arises if less informed members abstain, instead of casting a vote based on the information they hold. We test this proposition in a lab experiment, randomly assigning participants to different transparency regimes. Results in less transparent regimes align with the *SVC* equilibrium, leading to less favourable outcomes than in more transparent regimes. We offer the first experimental evidence on the effects of transparency regimes on information acquisition, voting, and overall efficiency.

Keywords: Information acquisition, Voting, Transparency, Swing voter's curse

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1 Introduction

Majority voting is considered one of the most efficient ways of aggregating decentrally held information (Ladha et al. [1996], Piketty [1994], Heese and Lauermann [2021]). It is therefore commonly used in various institutional settings where small groups or committees have to make a decision. Examples include legislative committees gathering expertise of individuals in hearings, hiring committees evaluating applicants or editors basing their decisions on recommendations made in referee reports.

However, efficient information aggregation typically requires that group members are sufficiently well informed, for instance about the qualities of a candidate or the specifics of a policy proposal. In many situations, this implies that group members first need to acquire some new information on which they base their vote. If information acquisition is costly, some group members may free-ride in the hope that other group members will invest more effort into gathering information. When they do acquire some information they may opt for less costly sources of lower quality. In addition, the incentives to acquire information and therefore the overall efficiency of majority voting may also hinge on voters' awareness of the amount and quality of information held by others. This concept, which we term the 'second-order transparency' of the information environment, is an area that has largely been overlooked in studies to date. Intuitively, different levels of second-order transparency could change an individual's incentive to get informed and, ultimately, whether and how they vote.

When committee members interact frequently, there may be high transparency regarding the effort that other committee members invest in information acquisition, or the acquired information may even become common knowledge through private conversations before the vote. In ad-hoc committees, on the other hand, transparency may be relatively low. But does a less transparent environment necessarily imply poorer information aggregation through majority voting? We answer this question through a theoretically informed laboratory experiment which examines the endogenous information acquisition and voting decisions of members of small and large groups. Across different treatment conditions, we vary the transparency of information environments in multiple steps from no to full transparency. Our theoretical model shows that in less transparent environments there exist multiple conceivable pure strategy equilibria that vary in their efficiency, while in fully transparent environments there is only a single equilibrium. We use a laboratory experiment to understand which equilibria are commonly selected under different transparency regimes.

The theoretical framework we use to inform our experimental design studies individuals in an abstract group decision-making task. All group members receive a reward for selecting the option that matches an unknown true binary state of the world via majority voting. Prior to casting their vote, each group member decides on investing in a private and imperfectly informative signal regarding this unknown state.

This theoretical framework mirrors the basic decision environment of the Condorcet Jury Theorem (De Condorcet [1785]), but we add a private information acquisition stage. In its basic form, when group members already hold all relevant information (exogenously), the theorem would state that majority voting can pool individuals' private information into a group agreement about the most plausible alternative, and therefore, the group's decision has a higher probability of being correct than any individual's decision. In very large groups, the probability of being correct approaches to one. This well-known theoretical result on the "wisdom of crowds" relies on the assumption that information via private signals is costless and is provided exogenously, thereby ignoring the free-riding incentives that result when signal acquisition becomes costly and endogenous (Downs [1957], Olson Jr [1971]).[1]

In our game, individuals acquire information by choosing between a high-quality signal or a low-quality signal. The low-quality signal is cheaper in terms of opportunity cost that high-quality signal consumers have to incur. Both signals are noisy, but informative. After receiving their signal and (depending on the information environment) learning about the acquired information of others, group members need to decide whether and how they wish to vote. Alternatively, they can abstain from voting. Most formal models of voting abstract from the possibility of abstention. However, although juries do not allow for abstentions, many other situations, such as legislatures, elections, city councils and department meetings, do. Furthermore, empirical evidence suggests that individuals tend to strategically abstain from voting in these situations by delegating decisions to those better informed or the 'experts' (Morton and Tyran [2011]).

Our paper speaks to several strands in the literature. First, our theory extends on previous work on endogenous information acquisition in the Condorcet jury model (Persico [2004] and Martinelli [2006]). Persico [2004] observes that given a sufficiently high turnout by other voters, there exist significant free-riding incentives and thus individuals rationally choose to stay ignorant if a sufficient number of others do acquire information. Martinelli [2006] and Martinelli [2007] study endogenous, costly and noisy information acquisition in a setting where voters choose between signals of varying accuracy, with more accurate signals being more expensive. Martinelli shows that if the marginal cost of signal accuracy is zero at the lowest accuracy level, then even large electorates see voters acquiring information, and that the voting outcome can potentially be asymptotically efficient. Oliveros [2013] introduces voluntary voting and heterogeneous preferences to this paradigm and finds that those acquiring higher quality information

[1]Whether or not free-riding is common in such environments is an open empirical question with some recent studies suggesting that individuals over-acquire information relative to equilibrium predictions (Bhattacharya et al. [2017]).

do not necessarily abstain less frequently. Gerardi and Yariv [2007] and Gerardi and Yariv [2008] also analyse committee decision-making models of costly information acquisition and show how the aggregation process introduces free-riding incentives in those settings. The study by Eilat and Eliaz [2022] is also relevant in this literature, as they examine the problem of bargaining over information acquisition by a group of players before they decide on a collective action.

Second, our paper speaks to a literature in experimental economics concerned with how individuals collect and process information.[2] A recent study by Reshidi et al. [2021] conducts lab experiments involving costly information-collection processes, in which they compare static versus dynamic information collection, as well as how voting rules affect outcomes. The focus of their work is to see how sequential hypothesis testing, where information is collected in increments, and classical/static hypothesis testing, where information is collected in one shot, perform in practice. On the other hand, the settings in our work combine static information collection with varying transparency of the environment. Unlike our work also, several previous papers examine information acquisition in the presence of non-instrumental motives, such as confirmation seeking behaviour in Fischer et al. [2005] and Charness et al. [2021], or the acquisition of ego-boosting information in Eil and Rao [2011]. There has been relatively small experimental literature looking at the precision versus cost of information trade-offs, which is a major element of our paper. Ambuehl and Li [2018] show that there is an under-reaction of valuation of (payoff-relevant) information to increased informativeness, but information that has a possibility of fully resolving uncertainty is valued quite highly by individuals. In a field experiment, Hoffman [2016] studies business experts who are remunerated for their guess about the price and quality of real websites. They can acquire a costly signal before making their decision. Their findings also provide evidence of individuals overpaying(underpaying) for weak(strong) signals.

Third, our paper contributes to the theoretical and experimental literature examining abstention decisions in committee voting.[3] When voting is voluntary, this literature shows that uninformed individuals should rationally abstain in theory as their random vote may harm their group's decision (Feddersen and Pesendorfer [1996]). The intuition behind this result is that an individual's choice matters only if it is pivotal. But an uninformed individual being pivotal implies that they may overwrite a more informed individual's vote. Thus, this individual rationally abstains as voting is 'cursed' for them. This phenomenon is known as the 'swing voter's curse' (*SVC*). Empirical support for this comes from studies on delegation behavior by uninformed voters (Battaglini et al. [2008], Battaglini et al. [2010]). While compulsory voting reduces the severity of this curse (Grosser and Seebauer [2016]), voluntary voting contradicts

[2] See Martinelli and Palfrey [2020] for a review of experimental results involving information in games of collective decision.

[3] See Palfrey [2009] for a review of the voting experimental literature.

the *SVC* prediction. A related issue of voter motivation to get informed rather than staying ignorant and delegating decision making to an expert has also been studied and it has been found that voters are more motivated to cast informed votes than predicted by theory, which results in more efficient choices through information aggregation (Mechtenberg and Tyran [2019]). Our study provides evidence of *SVC* using endogenous information acquisition in voluntary voting, complementing observational studies with exogenous information (Coupé and Noury [2004]; Lassen [2005]; Palfrey and Poole [1987]; Wattenberg et al. [2000]). Models in Feddersen et al. [2006] and Myerson [1998] also make *SVC* predictions despite costless voting.[4]

In sum, the contributions of our study are threefold. First, we extend a common model of committee decision-making by making information acquisition endogenous and by varying knowledge about other group members' state of information. Second, we design an experiment to test the model predictions in the economic laboratory. Third, we compare the overall efficiency of different information environments providing insights into the optimal design of committee decision-making.

We contribute to the literature by examining the impact of transparency in environment on the information aggregation efficiency of majority voting. We expect majority voting to work well in environments of greater transparency. These environments allow individuals to effectively free-ride by learning from their group-members' information. Even if everyone in the group consumes low-quality information, combined this still lends great informativeness to each individual's vote. It can be expected that less transparent environments might display poorer information aggregation as low-quality information consumers might choose to abstain under the *SVC* eqilibrium. However, we predict that less transparent environments can also aggregate information through majority voting equally well, if individuals follow the *All Vote* equilibrium, that is just vote their information irrespective of the quality.

While voting with and without information acquisition has been studied extensively in the literature (see summary above), the transparency of the voting environment has only received limited attention so far. This is where the main novelty of this paper lies, as we look at the role of the closely related transparency in information environment. The impact of transparency in voting has been explored in few studies. Mattozzi and Nakaguma [2016] examine public vs. secret voting effects on committee decisions, revealing better outcomes for public voting when member bias is substantial, and for secret voting otherwise. Fehrler and Hughes [2018] experimentally assesses transparency's influence on deliberation and committee decisions, not-

[4]Elbittar et al. [2020] investigate the extent to which the voting rule - majority or unanimity, matters for endogenous information acquisition and eventual voting decisions. In contrast, we focus only on the majority rule with voluntary voting and two signal types[5] framework, where we vary the transparency in environment of individuals before they make their voting decision. Guarnaschelli et al. [2000] also use the majority voting rule and predict that voters should always vote according to their signal. This is similar to what we predict under the *All Vote* equilibria in our less transparent environments.

ing negative effects on information aggregation. Morton and Ou [2019] find that secret voting reduces prosocial behavior compared to public voting. Conversely, some research highlights drawbacks of transparency, as seen in public voting, suggesting it incentivises behavior distortion for type signaling. Models by Gersbach and Hahn [2008] and Levy [2007] support secret voting for improved decisions. Public voting, as per Dal Bó [2007] and Felgenhauer and Peter Grüner [2008], may expose committees to undue pressure from interest groups.

While our study has many elements in common with all the papers mentioned, we take a more comprehensive approach as our framework allows us to compare environments of different transparency. Knowing nothing about one's group-members' acquired information, or knowing only the quality of their consumed information, versus endogenously or exogenously knowing the quality and realisation of their information - how do these differing levels of transparency, impact signal choice, informational efficiency, abstention rates and payoffs of individuals? We answer this question through a theoretically informed laboratory experiment. Our results find evidence of less transparency pushing low-quality information consumers to abstain in a Pareto sub-optimal fashion. If these results were found to generalise to larger group settings, it might be fruitful to highlight to (minimally informed) voters that their abstention is potentially harmful to outcomes of group votes and referenda.

In alignment with *SVC* equilibria, while group members consume high-quality information more often in less transparent environments, they cast fewer correct votes due to abstentions - both these components thus contribute to lower earnings as well. This is a striking result as it points to the scope of potentially improving voting outcomes by actively encouraging voters to participate. To our knowledge, we are the first to provide evidence of how the transparency of environment in group decision-making, interacts with the voting mechanism, and if lower transparency in-fact impedes efficient information aggregation through majority voting.

Our results are consistent with the comparative predictions of Bayesian Nash equilibrium (BNE) in our model. Behavioural predictions derived from quantal response equilibrium (QRE) improve on the BNE point predictions. QRE generalises BNE by permitting errors in decision-making (McKelvey and Palfrey [1995]), indicating that individuals do exhibit some systematic decision-making errors in our experiment, due to which our data shows a closer fit to QRE point predictions than to BNE.

The rest of the paper is structured as follows. Section 2 outlines the game and predictions of our model, Section 3 describes our experimental design and procedures, Section 4 provides an account of our results, Section 5 details some behavioural predictions, and Section 6 concludes.

2 The game and predictions

2.1 The game

An odd number of individuals, who are labelled as $i = 1, ..., 2n + 1$, face a choice between two alternatives, R (Red) and B (Blue). These choices are aggregated by majority voting with ties broken by a fair coin toss. It is assumed that individuals are risk-neutral and expected payoff maximisers. All individuals have the same common prior that the state is either R or B with an equal probability. There is a common interest in choosing the (unobservable) correct state, e.g. every member of a jury wishes to acquit when the defendant is innocent and convict when they are guilty. In formal terms, ex post their identical payoffs are given by $U(R, R) = U(B, B) = M > 0$ and $U(R, B) = U(B, R) = 0$, where the group decision is denoted by the first argument and the true state is denoted by the second argument of U. Thus, alternative R (B) is preferred by all individuals if the true state is R (B). Additionally, before making their voting decision, each individual i can choose to become a bit more informed ($d_i = 1$) or a lot more informed ($d_i = 2$) about the likely true state, by acquiring either signal-Y or signal-X, respectively, ${s_i}^S \in \{r, b\}, \forall i$, where $S = \{X, Y\}$. Signal-X is more accurate than signal-Y, however, signal-X consumers incur an opportunity cost by forsaking $c > 0$ that they would have received had they chosen signal-Y. A signal is an independent Bernoulli trial from a state-dependent distribution with $Pr({s_i}^S = r|R) = Pr({s_i}^S = b|B) = p_S \in (\frac{1}{2}, 1)$ and $Pr({s_i}^S = b|R) = Pr({s_i}^S = r|B) = 1 - p_S$, where $p_X > p_Y$. So, both signals are noisy but they are informative, as the probability that it correctly indicates the true state exceeds the prior, or $p_S > \frac{1}{2}$ (note that $p_X = 0.9$ throughout the experiment and p_Y varies between 0.51, 0.60 or 0.80). We also refer to p_S as the signal-S's 'precision'.

The game has two stages. In stage one (*Information*), individuals independently and simultaneously decide on which signal to acquire. In stage two (*Voting*), voluntary and costless voting takes place. Individuals can vote for alternative R or alternative B, or abstain from voting.

Each individual is part of a group and for our treatments, we vary the amount of group-feedback we provide to the individuals in between the above mentioned two stages. More precisely, we vary how much the individuals know about their group-members' chosen signal, prior to determining their own voting decision. In the baseline (*T0*), individuals know nothing about the signal-choices and signal-realisations of their group members. In the treatments *T1* - *T3*, we vary this information. In *T1*, the individuals can observe their group-members' signal-choices; in *T2*, the individuals can observe their group-members' signal-choices, as well as, their respective signal-realisations; and lastly, in *T3*, this information is not automatically transmitted, but instead, each group member decides which information, if any, to reveal to their peers – they can choose to either convey the truth, lie or refrain from passing on any information about their signal-choice, and independent of this decision, they can also choose to either convey the truth, lie or refrain from passing on information about their signal-realisation. Thus, in *T2* group-members' signal-choices and their realisations are exogenously shown to individuals, but in *T3* this information revelation is an endogenous choice by group-members.

Next, we use backward induction to analyse in turn equilibrium behavior in the *Voting* and *Information* stages. We present the case of three players in Appendix A, and the general case below.

2.2 Symmetric equilibrium predictions: Voting

In the *Voting* stage, our focus is on the following symmetric BNE.

Proposition 1 (*Voting*).

1. *In 'All Vote' equilibria, individuals vote according to the information they hold in all treatments.*
2. *In 'Swing Voter's Curse' equilibria for T0 and T1, signal-X choosers vote according to the information they hold, while signal-Y choosers abstain.*

Proof. See Appendix A. □

2.2.1 Symmetric equilibrium predictions: Signal-choice in *All Vote* equilibria

For *T0* and *T1*, and by default for the individual settings of *T2* and *T3* (as our treatments make no actual difference in the individual settings), in the *Information* stage, we derive individual signal choice probabilities using BNE, under *All Vote* equilibria. We focus on symmetric BNE where everyone chooses signal-*X* with equal probability $\sigma_i = \sigma, \forall\, i$. In special cases, this probability may be 0 or 1, i.e., we may have a pure strategy equilibrium. We will sometimes denote the pure action of choosing signal-*X* ($\sigma = 1$) by σ_1 and the pure action of not choosing signal-*X* ($\sigma = 0$) by σ_0. Without loss of generality, we assume that individual i receives an *r*-signal.

Given voting according to signal, the expected utility from choosing signal-*X* is given by

$$U(\sigma_1) = MPr[R|s_i^X = r, PIV]P_{piv}, \tag{1}$$

and the expected utility from choosing signal-*Y* is given by

$$U(\sigma_0) = MPr[R|s_i^Y = r, PIV]P_{piv} + c, \tag{2}$$

where P_{piv} is the probability a vote is pivotal.

Suppose the probability of choosing signal-*X* is $\sigma \in [0, 1]$. Then, the ex-ante likelihood of an individual voting for the correct alternative is

$$z_\sigma = p_X\sigma + p_Y(1 - \sigma). \tag{3}$$

Now, we have[6]

$$\left.\begin{array}{l} U(\sigma_1) = Mp_X P_{piv} \\ U(\sigma_0) = Mp_Y P_{piv} + c \end{array}\right\} \text{where}$$

$$P_{piv} = \binom{2n}{n}[z_\sigma(1 - z_\sigma)]^n. \tag{4}$$

The signal-*X* choice probability σ depends on the sign of $U(\sigma_1) - U(\sigma_0)$, which turns out to be a comparison of the net benefit of choosing signal-*X* over signal-*Y*, conditional on being pivotal, with the normalised cost. In particular, $\sigma^* \geq 0$ if and only if

$$(p_X - p_Y)P_{piv} \geq \frac{c}{M} \tag{5}$$

and $\sigma^* = 1$ if the inequality is strict. Notice that the net benefit of choosing signal-*X* instead of signal-*Y* is itself a function of σ.

Then, the solution value σ^* is used to compute informational efficiency. It is given by

$$W = \sum_{k=n+1}^{2n+1} \binom{2n+1}{k} z_\sigma^k(1 - z_\sigma)^{2n+1-k}. \tag{6}$$

In the group-settings of *T2* and *T3*, since individuals are in non-pivotal events (Proposition 1), therefore, they find no reason to invest in the more costly signal-*X*. Thus, they always choose signal-*Y*, i.e. $\sigma^* = 0$, and the informational efficiency here is calculated as below

$$W = \sum_{k=n+1}^{2n+1} \binom{2n+1}{k} p_Y^k(1 - p_Y)^{2n+1-k}. \tag{7}$$

[6]We show through the three-member group example presented in Appendix A that in *All Vote* equilibria, $Pr[R|s_i^X = r, PIV]$ is always equal to p_X and $Pr[R|s_i^Y = r, PIV]$ is always equal to p_Y.

2.2.2 Symmetric equilibrium predictions: Signal-choice in *SVC* equilibria

For *T0* and *T1*, in the *Information* stage, we derive individual signal choice probabilities using BNE, under *SVC* equilibria. We focus on symmetric BNE where everyone chooses signal-*X* with equal probability γ. In special cases, this probability may be 0 or 1, i.e., we may have a pure strategy equilibrium. We will sometimes denote the pure action of choosing signal-*X* ($\gamma = 1$) by γ_1 and the pure action of not choosing signal-*X* ($\gamma = 0$) by γ_0. Without loss of generality, we assume that individual *i* receives an *r*-signal.

Given voting according to signal, if one is a signal-*X* chooser, and abstaining if one is a signal-*Y* chooser, the expected utility from choosing signal-*X* is given by[7]

$$U(\gamma_1) = Mp_X P_{piv}, \tag{8}$$

and the expected utility from choosing signal-*Y* is given by

$$U(\gamma_0) = \frac{M}{2} P_{piv} + c, \tag{9}$$

where P_{piv} is the probability a vote is pivotal.

Suppose the probability of choosing signal-*X* is $\gamma \in [0, 1]$. Then, we have

$$P_{piv} = \sum_{k=0}^{n} \binom{2n}{2k} \gamma^{2k} (1-\gamma)^{2n-2k} \binom{2k}{k} [p_X(1-p_X)]^k, \tag{10}$$

where the sum over $k = 0, ..., n$ contains: (i) the probability of an even number $2k$ of others choosing signal-*X*, i.e. $\binom{2n}{2k}\gamma^{2k}(1-\gamma)^{2n-2k}$; (ii) given $2k$, the probability of individual i being pivotal, i.e. $\binom{2k}{k} p_X^k (1-p_X)^k$ (each alternative has *k* votes so her own *R*-vote turns a tie into a win for *R*).

The signal-*X* choice probability γ depends on the sign of $U(\gamma_1) - U(\gamma_0)$, which turns out to be a comparison of the net benefit of choosing signal-*X* over signal-*Y*, conditional on being pivotal, with the normalised cost. In particular, $\gamma^* \geq 0$ if and only if

$$\left(p_X - \frac{1}{2}\right) P_{piv} \geq \frac{c}{M} \tag{11}$$

and $\gamma^* = 1$ if the inequality is strict. Notice that the net benefit of choosing signal-*X* instead of signal-*Y* is itself a function of γ.

[7] We show in the three-member group example presented in Appendix A, that for *SVC* equilibria, being in a pivotal event implies that leaving individual i aside: there are an equal number of voting (according to signal) signal-*X* choosers with conflicting signals (and/or an even number of signal-*Y* choosers who are abstaining), which would result in a tie election.

The solution value γ^* is then used for the calculation of informational efficiency. If the true state is j, then each individual has more likely a j- than $-j$-signal, where $j = R, B$ and $j \neq -j$. Thus, the probability of a correct group decision is given by the formula

$$W = \sum_{k=1}^{2n+1} \sum_{k_j=\lfloor \frac{k+1}{2} \rfloor}^{k} \binom{2n+1}{k} \gamma^k (1-\gamma)^{2n+1-k} \binom{k}{k_j} p_X^{k_j} (1-p_X)^{k-k_j} + \frac{1}{2} \sum_{k=0}^{n} \binom{2n+1}{2k} \gamma^{2k} (1-\gamma)^{2n+1-2k} \binom{2k}{k} [p_X(1-p_X)]^k. \quad (12)$$

Outright wins of alternative j are accounted for in the first term (i.e., there are more votes for j than $-j$ out of k signal-*X* informed (according to signal) votes, $k_j \geq \lfloor \frac{k+1}{2} \rfloor$, and the remaining $2n + 1 - k$ individuals abstain), and ties are accounted for in the second term (i.e., there are k signal-*X* informed (according to signal) votes for each alternative, and $2n + 1 - 2k$ abstaining), which are broken by the flip of a coin.

2.3 Group payoff

We would need to compare ex ante group payoffs (defined by total expected "benefits from a group decision minus opportunity costs") across our main treatments (transparency in information environments), precisions of signal-*Y* and group sizes, using the different probabilities of a correct group decision that we have derived. Now, the total expected opportunity costs equal $(2n + 1)\sigma c$ [σ or γ], so, in the event where j is chosen and j is the true state, for $j = R, B$, the ex ante expected group payoff is $(2n + 1)[WU(j, j) - \sigma c]$, where $U(j, j) = M$.

We now proceed to discussing the details of our experiment. Specific predictions for our experimental treatments will be delivered at the end of the following section.

3 Experiment

3.1 Design

Our experiment is designed to study the impact of varying the transparency of the decision environment on information acquisition and voting behaviour. We define transparency as the extent to which participants know about the information acquired by their group members.

In decision environments where individuals have complete knowledge of their group members' acquired information, this highest level of transparency can improve efficiency as all voting decisions are relatively well-informed. However, this statement is not true in general, when information needs to first be acquired, since transparent environments are also conducive to free-riding: a majority of group members may choose the less accurate signal as it is costless, in the hope that the other group members invest in more accurate signals. Intuitively, if most group members end up choosing the less accurate signal, then the eventual voting decisions might be of poor quality, thereby harming payoffs. Which of these two effects prevail is an empirical question that we aim to answer through our experiment.[8]

In the remainder of the design section we will first explain the decision tasks. We will then discuss the details of the rounds. We move on to describe the different treatments that we include in our study. Finally, we end with presenting the logistics and the procedures.

3.1.1 Decision Tasks

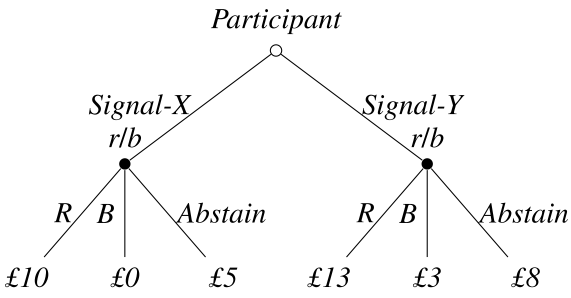
Participants make a total of 18 decisions over the course of 9 rounds. Each round follows the same structure. First, there is an information acquisition stage, in which participants choose between two types of signals. In the second stage, participants have the option to vote or abstain. Before a round, a draw of nature determines a random state of nature - represented in the experiment as drawing a ball from an urn with an equal number of *(R)ed* or *(B)lue* balls. Participants are asked to guess as a group (or individually) the colour of this ball. Figure 1 illustrates a round where a Red ball has been drawn and the participant is not part of a group. The participant first chooses to acquire signal-*X* or signal-*Y*. After observing their signal-realisation of *red* or *blue*, they then choose to vote for either alternatives: *Red* or *Blue*, or, choose to abstain, in which case, a fair coin-toss determines their guess. The possible scenarios and their respective outcomes are as follows.

Consider a case where the participant chooses signal-*X* and guesses *Red*. In this case, since the guess matches the true colour for the round, the participant receives a bonus-payment of **£10** for being correct. On the other hand, if the participant chooses signal-*X* and guesses *Blue*, then they receive **£0** for being incorrect since the guess does not match the true colour. If instead, they choose to abstain, then the guess is delegated to a coin-toss: it is equally likely that *Red* or *Blue* guess is placed, and therefore here the expected payment is **£5**.

If the participant chooses signal-*Y* and guesses *Red*, then, since the guess matches the true colour for this round, they receive the bonus-payment of £10 for being correct. In addition, they save £3 by choosing signal-*Y*, and forsaking this opportunity cost that they would have incurred had they had chosen signal-*X* instead. This totals to **£13**. On the other hand, if the participant

[8]Our theoretical predictions show that despite of excessive free-riding, efficiency is not harmed as these environments enable the group members to cast highly informed votes.

Figure 1: Basic Structure of the Game



The above figure shows decision-tasks in the simple scenario of group-size = 1 member setting and random draw of the true colour for this round being Red. The outcomes are presented in terms of expected payment.

chooses signal-*Y* and guesses *Blue*, then, since the guess does not match the true colour, they receive £0 for being incorrect. However, they do gain £3 as cost-saving by choosing signal-*Y*. So, in total, they earn **£3**. If instead, they choose to abstain, then the guess is delegated to a coin-toss: it is equally likely that *Red* or *Blue* guess is placed, and therefore here the expected payment is £5 for a correct guess, in addition to £3 as cost-saving for choosing signal-*Y*, totaling to **£8**.

3.1.2 Rounds and Order

In this subsection, we detail the design that we have outlined previously. The experiment consists of three parts, which correspond to different group sizes. Part 1 has a group-size of one member, Part 2 has a group-size of three members and Part 3 has a group-size of nine members. Thus, each participant acts alone in Part 1, is grouped with two other participants in Part 2, and is grouped with eight other participants in Part 3. We are mostly interested in studying groups of three and groups of nine members. Groups of one member were included to test subjects' understanding of the decision tasks. Therefore, we exclude observations related to the group-size of one from our main analysis, and present them in Appendix A.

Each of the three parts constitute of three rounds, in which the precision of signal-*Y* varies, keeping the signal-*X* precision fixed at 0.90. We vary the probability distribution according to which a signal-*Y* reveals the true colour [Small (S): 51/100, Medium (M): 60/100 and Large (L): 80/100 in each Part]. Between sessions, we vary the order in which different precisions of signal-*Y* occur. One of the following orders is adopted in each session: [S, M, L], [S, L, M], [M, S, L], or [L, M, S] as shown in Table 3.1.[9]

[9]For all parts within a session there is the same precision ordering. For each order, there was a total of 4 sessions.

Table 3.1: Experimental details.

Signal-Y precision ordering	Group-size	Group-size	Group-size	Number of sessions
S $\rightarrow$ M $\rightarrow$ L	1	3	9	4
S $\rightarrow$ L $\rightarrow$ M	1	3	9	4
M $\rightarrow$ S $\rightarrow$ L	1	3	9	4
L $\rightarrow$ M $\rightarrow$ S	1	3	9	4

Notes: One of the above signal-Y precision orderings is adopted and remains unchanged throughout the session as we vary the group-size. Each ordering is repeated for 4 sessions.

The idea behind varying the signal-Y precision and the group-size is to vary the free-riding incentives, and observe the impact on information acquisition and voting behaviour of individuals. Increasing signal-Y precision increases free-riding incentives as there is then less to gain informationally by investing in the costly, slightly more accurate signal-X. Increasing group-size reduces the pivotality of an individual, thereby again increasing their incentive to choose the costless and less accurate signal-Y.

In general, we also select our parameters so that they allow for Pareto dominance of *All Vote* over *SVC* equilibria. This enables us to empirically derive insight from equilibrium selection by participants.

3.1.3 Treatments

Four between-subjects **treatments** are used to study the main question of the paper, i.e. how transparency affects information acquisition and voting. Transparency is varied between treatments by changing the amount of feedback we provide to participants in every round before they submit their vote. Across treatments we vary how much participants know about their group-members' signal choices and realizations, prior to submitting their guess. We summarise the resulting treatments and corresponding sample size in Table 3.2.

Before voting, in **T1**, participants observe their group-members' signal-choices; in **T2**, participants observe their group-members' signal-choices, as well as, their respective signal-realisations; and lastly, in **T3**, group-members' information is not automatically transmitted, but instead, participants themselves get to decide which, if any, information to reveal to their group members – they can choose to either convey the truth (whole or in part), or to lie (whole or in part), or refrain from passing on information (whole or in part), regarding their signal-choice and realisation. By adding these layers one at a time and progressing through the various treatments that we have, we arrive at T3, which is closest to many real-world information environments, where members decide for themselves what to share with others.

Table 3.2: Details of treatments

Main treatments	Group-members' signal-choice	Group-members' signal-realisation
T0	Not observable	Not observable
T1	Observable	Not observable
T2	Observable	Observable
T3	Observable endogenously	Observable endogenously

Notes: We vary the observability of signal-choice and realisation in increments across treatments.

3.2 Procedures and implementation

The experiment and all instructions were fully computerised using z-Tree (Fischbacher [2007]). In the spring of 2020, we recruited 315 student participants to participate in one of 19 sessions (some sessions could not be run to full capacity, so we had to run extra sessions in order to complete data-collection for roughly 72 participants in each main treatment).[10] Each session consisting of 18 or 9 participants, lasted for about one hour. Participants were recruited from the regular subject pool at the Behavioural, Experimental & Data Science Network (BEADS) Laboratory of the University of Birmingham, using Sona System (`https://radboud.sona-systems.com`). Detailed instructions of the experiment are presented in Appendix B. Our sampling, hypotheses, and subsequent analyses follow a pre-registered plan that can be found at `https://osf.io/2v6j5/`.

Between rounds, the colour of the ball is drawn at random, based on the stated probability distribution of the chosen signal. Participants were also instructed that we would randomly select a part and round for payment. After the experiment, participants were asked to complete a short questionnaire and received their earnings in cash. The mean take-home payment was £12.82 (min. £3.00; max. £16.00), including a £3.00 show-up fee.

3.3 BNE predictions

In BNE, under *All Vote* equilibria for all the treatments, individuals always vote according to the information they hold. Under *SVC* equilibria, on the other hand, for *T0* and *T1*, signal-X choosers vote according to the information they hold (i.e. their signal in these treatments), and signal-Y choosers abstain.

We derive qualitative and point predictions for the chosen experimental parameters (assuming risk neutrality).[11] We have symmetric pure strategy BNE in all scenarios, which arise if ev-

[10] All sessions were completed before any Covid lockdown or social distancing measures were implemented in the UK.

[11] Point-predictions are presented in Table xxx of Appendix A.

eryone votes without choosing signal-*X*, except when functioning in a 'group' of 1-member (individual setting) and signal-*Y* precision equals 0.51 or 0.60. On the other hand, in the group-settings of *T2* and *T3*, individuals are non-pivotal and therefore always choose signal-*Y*. The following comparative statics hypotheses are derived from pure strategy BNE, by averaging across the group-settings (i.e. individual-settings are excluded).

H1 (*Signal-X acquisitions and treatment*): The average rate of signal-*X* acquisitions in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3*.
The average rate of signal-*X* acquisitions in *T0* and *T1* under *SVC* equilibria, is greater than that in *T2* and *T3*.

H2 (*Accuracy of group decisions*): The average rate of correct group decisions in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3*.
The average rate of correct group decisions in *T0* and *T1* under *SVC* equilibria, is lower than that in *T2* and *T3*.

H3 (*Payoffs*): The average payoff per person in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3*.
The average payoff per person in *T0* and *T1* under *SVC* equilibria, is lower than that in *T2* and *T3*.

3.4 Pareto optimality

On comparing the average rate of correct group decisions in *T0* and *T1* under *All Vote* equilibria with that under *SVC* equilibria, we find that *All Vote* fares better[12], and is therefore Pareto optimal. As a result, individuals in these treatments would be better off by following the *All Vote* equilibria rather than the *SVC* equilibria. Moreover, if we do find results to be consistent with *SVC* equilibrium predictions in our experiment, then we could deduce that the desire to delegate to others who might be better informed leads individuals to make Pareto sub-optimal decisions.

4 Experimental Results

We begin by examining average payoff patterns between treatments. To gain a better understanding of these results, we then delve into the mechanisms shaping these patterns by studying

[12]Derived above in H2 as accuracy of group decisions.

factors such as the rate of correct guessing, information acquisition, and abstentions. These additional analyses also allow us to determine which equilibria participants select.

4.1 Average payoffs and Rates of correct guessing

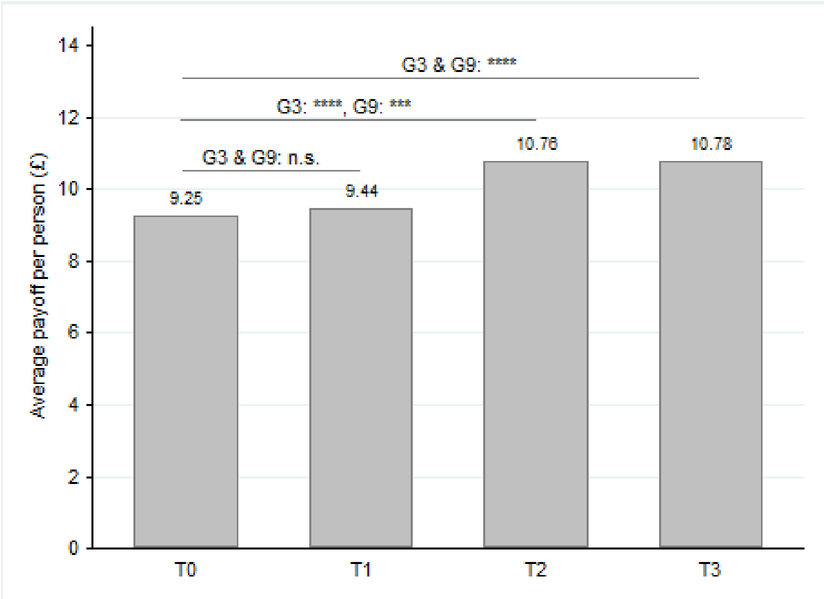
Figure 2 displays the average realised payoff per person earned in each of the treatments, for 9-member groups as the unit of observation. The major component of payoff is the bonus that a participant earns if a majority of their group members correctly guess the true colour of the ball. Figure 3 compares the rate of correct guessing that determines this bonus, across treatments. The natural baseline to compare the treatments against, is T0. So, comparing T0, in which no other information apart from one's own is observable, to T1, in which the signal-choices of one's group-members are observable, we find that there is no significant effect on the average payoff per person (Rank Sum tests, Group level of 3 members: $p = 0.6353$ and Group level of 9 members: 0.1889) [13]. Similarly, we find no significant impact on the rate of correct guessing, between these two treatments (Rank Sum tests, $p = 0.5289$ and 0.3431, for 3-member groups and 9-member groups as unit of observation, respectively). Intuitively speaking, making the other group-members' signal type choices observable does not help inform one's guess of the 'true' colour. As a result, on average, individuals in T1 earning the same and guessing correctly at a rate the same as those in T0, conforms to what we also expect to occur.

In T2, the participants can observe their group-members' signal-choices and their respective signal-realisations, whereas, in T3, the participants can observe whatever signal-choice and/or signal-realisation information that their group-members have chosen to convey. Average payoffs in both T2 and T3 exhibit highly significant differences, when compared to the average payoff in T0 (Rank Sum tests, $p < 0.001$ for both when unit of observation is 3-member groups, while $p < 0.01$ for T2 versus T0, and $p < 0.001$ for T3 versus T0, when unit of observation is 9-member groups). Further, average payoffs in T2/T3 are 16-17% higher than in T0.[14] We also find that the rate of correct guessing in T2 is significantly higher than that in T0 (Rank Sum tests, $p < 0.05$ for both the group-levels of 3 and 9 members). Similarly, participants in T3 guess correctly at a rate that is significantly higher than that of participants in T0 (Rank Sum

[13]We conduct our analysis of average payoff per person and a few other aspects by aggregating (averaging) at the group-level. The figure presents our results using 9-member groups as the unit of observation, although, we state p-values for both the group levels.
Note that for T0, using individual observations would have sufficed as there does not exist any group feedback there, however, for T1, T2 and T3, this is not the case, as past feedback about one's group-members' signals might affect one's own choices here, and as a result, the payoff. The 9-member group approach is obviously more conservative than the 3-member group one.

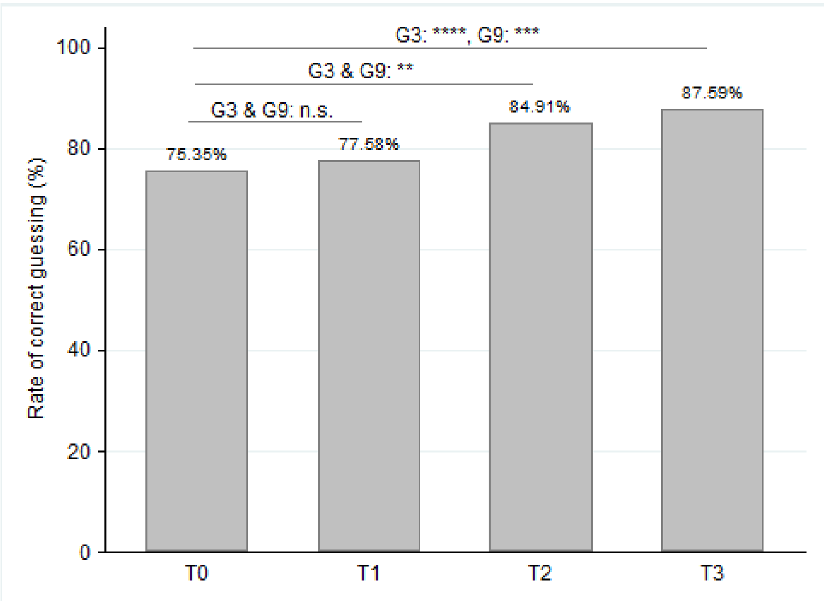
[14]This finding was ex-ante not obvious because in theory it is possible for individuals in less transparent environments to earn as much as those in more transparent environments.

Figure 2: Average payoff per person (Unit of observation: 9-member group)



The above figure shows the average payoff per person, for each treatment, exclusive of the show-up fee of £3. p-values for both, group levels of 3-members (G3), as well as, 9-members (G9), are indicated. Observations related to the individual setting, that is, when group-size = 1, have been excluded.

Figure 3: Rate of correct guessing (Unit of observation: 9-member group)



The above figure shows the rate of correct guessing in each treatment. p-values for both group levels of 3-members, as well as, 9-members, are indicated. Observations related to the individual setting have been excluded.

tests, $p < 0.001$ and $p < 0.01$, for 3-member groups and 9-member groups as unit of observation, respectively).

T2 creates one of the most transparent environments in our framework. It provides additional information, over what participants receive in T0. Using information on signal realisations offers them a chance to learn from their group-members' signals, and eventually place a guess that is much more informed than that of the participants' in T0. Therefore, it is expected that we observe participants in T2 exhibiting a significantly higher rate of correct guessing, as a result, earning more as compared to those in T0.

Theoretically it is not clear whether there should be a difference between T2, where information is automatically revealed and T3, where information revelation is due to the endogenous choices of group members. If members misrepresent information then this is a less transparent information environment. Whether misrepresentation occurs depends on preferences for truth-telling. There is no monetary incentive to misrepresent signal acquisition choices. Moreover, as ample evidence on lying aversion shows (Abeler et al. [2019], Dufwenberg and Dufwenberg [2018], Gneezy et al. [2018]), most decision makers are generally reluctant to mislead others – especially if there is no monetary gain from it. On the other hand, if they care about their social image, decision makers who consume information from less accurate sources may wish to hide this from their group-members.[15] We observe a highly significant impact on the average payoff earned in T3 as well when compared to that earned in T0. This suggests that in T3, like in T2, participants are able to more effectively aggregate their group-members' information.[16] This is corroborated by the finding that participants in T3 also guess correctly at a rate that is significantly higher than that of participants in T0 (Rank Sum tests, $p < 0.001$ and $p < 0.01$, for 3-member groups and 9-member groups as unit of observation, respectively). This tells us that participants in T3 are largely trusting of the information that they receive from their group-members, plausibly because they believe that their incentives to lie are low.[17]

In sum, we find that more transparent treatments of T2 and T3 generate higher payoffs and

[15] We in fact find minimal amount of lying in the experiment, e.g. there were only 7 instances in total where a participant conveyed their information acquisition choice as signal-X to their group-members, when it actually was signal-Y.

[16] By design, this possibility does not exist in T0 and T1.

[17] We also compare T2 to T1 and T3 to T2 as the level of transparency rises successively. We have already examined the non-significant impact on average payoff and rate of correct guessing when T1 is compared to T0. Further along, moving from an information environment where only group-members' signal-choices are observable to one where both the signal-choices, as well as, the respective signal-realisations are observable, that is, on comparing T2 with T1, we find that it is the observability of signal-realisations that explains most of the treatment effect (Rank Sum tests, average payoffs: $p < 0.001$ and $p < 0.05$, rate of correct guessing: $p < 0.05$ and $p < 0.10$, for 3-member groups and 9-member groups as unit of observation, respectively). A comparison between T2 and T3 shows that automatic revelation and endogenous revelation look very similar behaviourally (Rank Sum tests, average payoffs: $p = 0.8934$ and 0.7527, rate of correct guessing: $p = 0.8113$ and $p = 0.7525$, for 3-member groups and 9-member groups as unit of observation, respectively). There is hence high trust in what people reveal and information is mostly truthful.

rates of correct guessing than less transparent treatments of T0 and T1. This is in line with our theoretical predictions under *SVC* equlibrium. It indicates that less transparency is harmful. In Table xxx of the Appendix, we provide regression-based tests that further corroborate this core finding. We next turn our attention to the second component of average payoff: information acquisition cost, which relates to the cost savings if choosing the cheaper signal-*Y*.

4.2 Information acquisition

Free-riding i.e. choosing the less accurate signal that yields cost-savings, and then abstaining, is the central reason why less transparent environments could theoretically perform worse than more transparent ones. In subsection 4.1 we have shown that less transparent environments do perform worse. Is this because there is free-riding or do they perform worse despite of no free-riding? To understand this, we compare information acquisition choices between less transparent (T0, T1) and more transparent (T2, T3) environments.

The signal acquisition patterns are clearly impacted by the transparency of the decision environment, as is evident from the graphical presentation in Figure 4.[18] Comparing T1 to T0, there is no significant difference in acquiring the more precision signal-*X* between the two treatments (Chi Square test, $p = 0.675$). In the more transparent environments T2 and T3, the rate of acquiring more precise signals falls significantly relative to T0 (Chi Square test, $p < 0.05$ for both). There is thus less free-riding in less transparent information environments.

Recall that the second component of the average payoff per person relates to cost savings of choosing the cheaper signal-*Y*. We can observe that participants choose signal-*Y* significantly more frequently in T2 and T3, as compared to T0, and they also guess correctly more often. They also earn more on average. This straightaway tells us that the saved opportunity cost gained by the participants from choosing signal-Y more often in T2 and T3, is also reflected in them earning higher average payoffs. Whereas, the percentage of participants choosing signal-*X* in T1 is not significantly different from that in T0, which would reflect in similar second components of cost savings in average payoffs. Thus, this contributes to understanding why we also observe no significant difference in the average payoffs between these two treatments.[19]

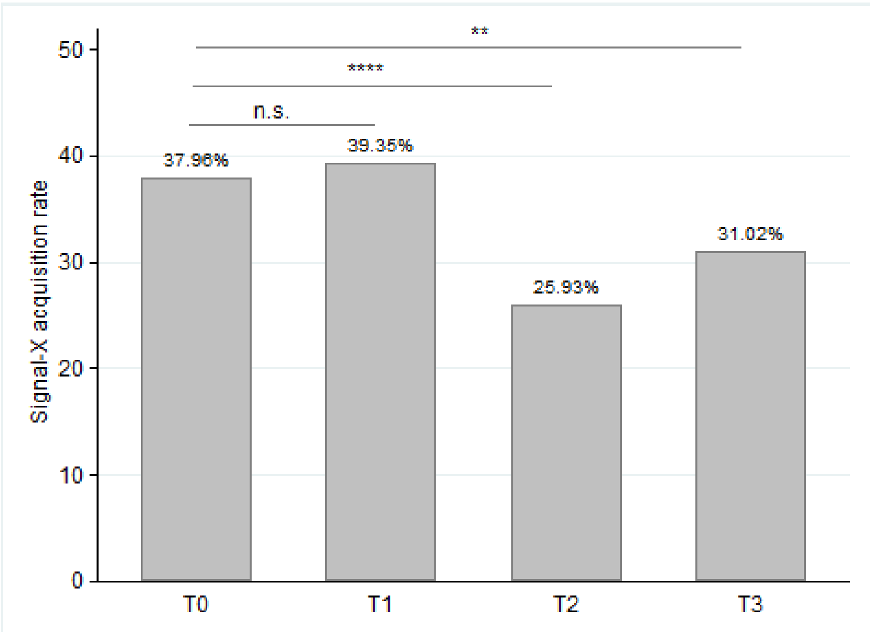
[18] In this analysis, the unit of observation that we use is individual, and not at the group-level. This is because signal-choices are made by participants before group-feedback is provided to them. Therefore, it is safe to consider signal-choices as independent observations. Of-course, in the later rounds of T1, T2 and T3, participants can form beliefs about how much information their group-members will obtain - we address this concern at the end of this subsection.

[19] We can also examine the impact of transitioning to successive treatments on signal choices. We have already observed no significant difference between T0 and T1. Comparing T2 to T1, we find a highly significant drop in signal-*X* acquisition (Chi-squared test, $p < 0.001$). This decrease may be attributed to the increased free-riding incentives in T2, leading participants to invest less in signal-*X*. Comparing T3 and T2, a small but statistically significant difference in signal-*X* acquisition rate is found (Chi-squared test, $p < 0.10$). This might be due to the scope of misrepresentation of information that exists in T3 (but not in T2), which encourages participants to rely

In sum, these findings are consistent with the *SVC* equilibrium predictions we have outlined in 3.3). In this equilibrium, we expected to observe a greater consumption of high-quality information in less transparent environments as compared to the more transparent ones.

We note in passing that these results occur for both group sizes and for different precision levels of the y-signal. In line with our theoretical considerations, informational free-riding is more common in larger groups (Figure A1). Similarly, and also in line with our theoretical considerations, increasing the precision of the cheaper signal has the expected effect of increasing informational free-riding (Figure A2).[20]

Figure 4: Signal-*X* acquisition rate (Unit of observation: Individual)



The above figure shows the signal-X acquisition rate in each treatment. Observations related to the group-size = 1 setting have been excluded.

more on their own signal, resulting in a relatively higher signal-*X* acquisition rate. In summary, participants in T2 choose signal-*X* the least, followed by those in T3, due to transparency leading to greater free-riding incentives in these treatments. These findings are supported by the first stage regression in Table 6.6 of Appendix A.

[20] In the appendix, we also address potential concerns regarding the independence of signal acquisition choices, especially in treatments T1, T2, and T3 where participants remain in their initial groups. Given the potential for non-independence due to feedback on group members' signal acquisition choices, our analysis focuses on the first-round decisions, deemed uncontaminated. Results in Figure xxx of Appendix A corroborate our primary conclusions.

4.3 Abstentions

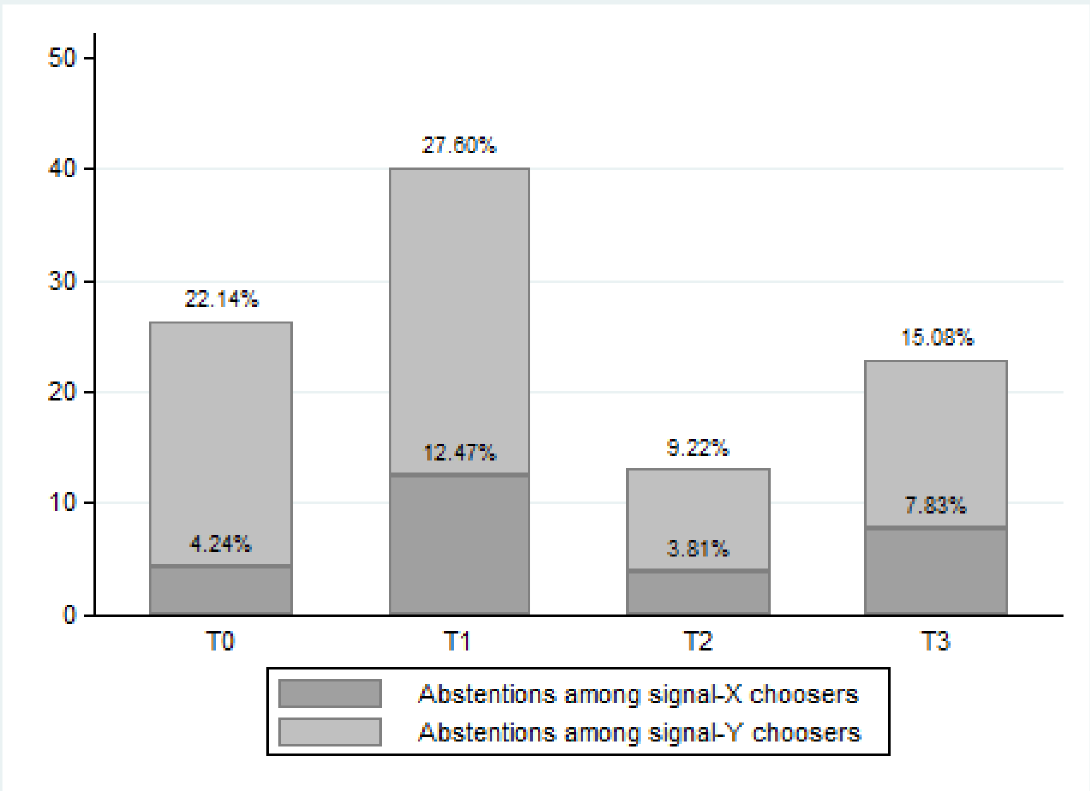
We have laid out theoretical reasons for why low transparency environments may perform worse in information aggregation when abstentions are possible in section 2. However, low transparency environments need not necessarily perform worse though, if individuals do not abstain and just vote their information. Even low-quality signals are informative and hence even those who consume a low-quality signal should not abstain. In other words, abstaining is not Pareto optimal. Conversely, if fewer abstain in more transparent environments because they free-ride but still learn from the information they receive from others, this is another reason why more transparent environments may be performing better.

We look at the abstention rates in our different treatments, and present these results in Figure 5, dis-aggregated by signal-*X* and signal-*Y* choosers. The patterns we observe are consistent with *SVC* equilibria. Consumers of low-quality information abstain to a much larger degree in less transparent environments as compared to more transparent ones.

In T0, the abstention rate of signal-*Y* choosers at 22.14% is approximately 18 percentage points higher than that of signal-*X* choosers at 4.24%. This pattern is consistent with the *SVC* equilibrium predictions. Less informed participants delegate a decision to more informed participants, ignoring the fact that their consumed signal is still informative. A similar pattern with more abstentions arises in T1, where participants can observe exactly how many of their fellow group-members are more informed. This induces the less informed signal-*Y* choosers to abstain the most among all the treatments, at a rate of 27.60%. On the other hand, signal-*Y* choosers abstain the least in T2, at a rate of 9.22%. Furthermore, this abstention rate of signal-*Y* choosers is only 5% higher than that of signal-*X* choosers, who abstain at a rate of 3.81%. Similar low rates of abstention are observed in T3.[21] These two treatments provide the opportunity to their participants to observe and learn from their group-members' signal-realisations. As a result, the incentives to abstain are at a minimum in these treatments, as the participants can effectively aggregate information from all their group-members, instead of relying solely on their own information. This leads to all the participants in these treatments getting informed to a high degree, even if they personally have chosen signal-*Y*.

[21] Abstention rates among signal-*Y* choosers:
- no significant difference between T0 and T1 (Rank Sum tests, $p = 0.3689$ and 0.3994, for 3-member groups and 9-member groups as unit of observation, respectively); significant difference between T0 and T2 (Rank Sum tests, $p < 0.01$ and $p < 0.05$, for 3-member groups and 9-member groups as unit of observation, respectively); no significant difference between T0 and T3 (Rank Sum tests, $p = 0.0818$ and 0.2473, for 3-member groups and 9-member groups as unit of observation, respectively).
- significant difference between T1 and T2 (Rank Sum tests, $p < 0.001$ and $p < 0.01$, for 3-member groups and 9-member groups as unit of observation, respectively); significant difference between T1 and T3 (Rank Sum tests, $p < 0.01$ and $p < 0.05$, for 3-member groups and 9-member groups as unit of observation, respectively).
- no significant difference between T2 and T3 (Rank Sum tests, $p = 0.1034$ and 0.0927, for 3-member groups and 9-member groups as unit of observation, respectively).

Figure 5: Abstention rates (Unit of observation: 9-member group)



The above figure shows the abstention rate among signal-X and signal-Y choosers in each treatment. Observations related to the individual setting have been excluded.

4.4 How well is the information available used?

We next investigate whether and how participants make use of the information they receive before voting. A Bayesian updater would take all signals (if known) and their quality into account to update their prior into the direction of the most likely (posterior) state of the world. But participants may also follow simpler or mentally less taxing behavioural rules such as following the most common realisation i.e. ignoring signal quality, or following only their own signal.[22]

We find that in T2, in 88.66% of total instances, participants vote for the majority realisation, while in 87.91% of total instances, they vote for the Bayesian majority. In T3, in 90.40% of

[22] In T0 and T1, participants have access to only their own signal, so the analysis looking at majority realisation or Bayesian updating makes sense only for T2 and T3.

Table 4.1: Use of available information

T2	Majority follow
Aligned (303 instances)	90.43%
Not aligned (94 instances)	82.98%

T2	Bayesian majority follow
Aligned (294 instances)	91.16%
Not aligned (103 instances)	78.64%

T3	Majority follow
Aligned (305 instances)	93.12%
Not aligned (70 instances)	78.57%

T3	Bayesian majority follow
Aligned (249 instances)	93.57%
Not aligned (126 instances)	42.86%

Notes: For T2 and T3, out of all instances where own signal is aligned/not aligned with the majority or the Bayesian majority colour in the group, we determine the proportion of such instances where participants vote for the majority colour, and those where they vote for the Bayesian majority colour. Observations related to the individual setting have been excluded.

total instances, participants vote for the majority realisation, while in 76.53% of total instances, they vote for the Bayesian majority. So in general, participants tend to follow the majority realisation more often than the Bayesian majority.[23] This is plausibly because Bayesian updating is cognitively more difficult than just quickly deducing the majority realisation in the group. We also observe that following the (Bayesian) majority is seen slightly (less) more strongly in T3 as compared to T2, perhaps owing to the scope of misrepresentation possible in T3 but not in T2, especially considering the behavioural reasons that might induce lying about one's signal-choice which could in-turn harm accurate Bayesian updating.

Table 4.1 presents the proportions of instances where participants follow the majority colour, and where they follow the Bayesian majority colour, dis-aggregated by whether their own signal aligns with the majority or the Bayesian majority. In T2, out of all instances where a participant's signal aligns with the (Bayesian) majority colour, in (91.16%) 90.43% of such instances, the participant follows the (Bayesian) majority colour. On the other hand, out of all instances where a participant's signal does not align with the (Bayesian) majority colour, in (78.64%) 82.98% of such instances, the participant still follows the (Bayesian) majority colour. Similarly, in T3, out of all instances where a participant's signal aligns with the (Bayesian) majority colour, in (93.57%) 93.12% of such instances, the participant follows the (Bayesian) majority colour. On the other hand, out of all instances where a participant's signal does not align with the (Bayesian) majority colour, in (42.86%) 78.57% of such instances, the participant still follows the (Bayesian) majority colour.

[23]However, there is still a large proportion of instances where participants vote for the Bayesian majority.

Following the (Bayesian) majority colour when it aligns with own signal is expected. Interestingly, even in a large chunk of instances where own signal is not aligned, participants still choose to go against their own signal and vote for the (Bayesian) majority. This suggests that the participants try to make good use of all the information available to them. The most stark difference between T2 and T3 comes through when comparing the proportion of instances where own signal does not align, and yet participants vote for the Bayesian majority. This proportion falls by a great extent in T3. This again points to a level of mistrust that participants in T3 might have about potentially free-riding group-members choosing to deceive about their signal-choice.

5 BNE versus Quantal Response equlibrium

We have used BNE equilibrium to derive the theoretical predictions summarised in our set of hypotheses. Our results are consistent with the qualitative predictions arising from *SVC* BNE. Still, BNE makes some strong assumptions about participants' rationality and computational abilities. Here we contrast the predictions from BNE to quantal response equilibrium (QRE), which allows for some stochastic errors in decision-making.[24]

For T0 and T1, and by default for the individual settings of T2 and T3 (as our treatments make no actual difference in the individual settings), in the *Information* stage, we derive individual signal choice probabilities using QRE, which generalises BNE by including stochastic decision-making errors that are systematic in the sense that more lucrative decisions are made more often than less lucrative decisions, so best responses are smooth rather than sharp as in BNE. A parameter $\mu \geq 0$ denotes the degree of noise. We focus on symmetric QRE where everyone chooses signal-*X* with equal probability $\lambda_i = \lambda, \forall i$. Using logit specification, in the one extreme without noise, $\mu = 0$ and QRE (henceforth also termed logit equilibrium) turns into BNE, while in the other extreme with pure noise, $\mu = \infty$ and decisions are entirely random, or $\lambda = \frac{1}{2}$.

The condition for a logit equilibrium λ^* to exist is $\mu[-ln(\frac{1-\lambda}{\lambda})] = \Pi_i^e(\lambda, \nu^*, p_X, p_Y, n, M, c)$, as derived in Appendix A, where superscript *e* denotes the expectation operator. The left-hand side (*LHS*) is identical in all treatments and deals with the errors in signal choice decisions. If $\mu > 0$, *LHS* strictly increases in λ, approaches $-\infty$ $(+\infty)$ if λ approaches 0 (1), and always equals zero at $\lambda = \frac{1}{2}$. Given that everyone votes à la Proposition 1, denoted by the vector ν^*, the right-hand side (*RHS*) represents individual *i*'s expected *net payoff* (or, payoff increase) of choosing signal-*X* if everyone else chooses signal-*X* with probability λ.

[24] According to Hypothesis 1, the average rate of signal-*X* acquisitions in T0 and T1 is predicted to be 8.60%, while Figure 4 shows that it is actually 37.96% in T0 and 39.35% in T1.

Lets consider the *All Vote* equilibria where everyone votes according to the information they hold and no-one abstains (Proposition 1). Here, the condition for a symmetric λ^* to exist, assuming without loss of generality that individual *i* receives an *r*-signal, is given by:

$$\mu\Big[-ln\Big(\frac{1-\lambda}{\lambda}\Big)\Big] = \binom{2n}{n}\sum_{k_R=0}^{n}\sum_{k_B=0}^{n}\binom{n}{k_R}\binom{n}{k_B}\lambda^{k_R+k_B}(1-\lambda)^{2n-k_R-k_B}p_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R}$$
$$\times(1-p_Y)^{n-k_B}Mp_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R}(1-p_Y)^{n-k_B}$$
$$\times\Bigg[\frac{p_X}{p_X^{k_R+1}(1-p_X)^{k_B}p_Y^{n-k_R}(1-p_Y)^{n-k_B}+(1-p_X)^{k_R+1}p_X^{k_B}(1-p_Y)^{n-k_R}p_Y^{n-k_B}}$$
$$-\frac{p_Y}{p_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R+1}(1-p_Y)^{n-k_B}+(1-p_X)^{k_R}p_X^{k_B}(1-p_Y)^{n-k_R+1}p_Y^{n-k_B}}\Bigg]-c. \quad (13)$$

LHS(1) is described above, and *RHS*(1) gives individual *i*'s expected net payoff of choosing signal-*X*, $\Pi_i^e(\lambda,\nu^*,p_X,p_Y,n,M,c)$. Given our result from Proposition 1: we know that no-one abstains under *All Vote* equilibria, and so, the only pivotal events are with *n* votes of others, from signal-*X* and/or signal-*Y* choosers, for each alternative (i.e., her *R*-vote turns a tie into a win for *R*). If *B* is correct, then her pivotal *R*-vote results in an incorrect group decision, which yields $U(R,B)=0$ so this event is ignored. If *R* is correct, *RHS*(1) considers that each $-i$ chooses signal-*X* with probability λ and receives an *r* [*b*]-signal with probability $p_X[1-p_X]$, and chooses signal-*Y* with probability $1-\lambda$ and receives an *r* [*b*]-signal with probability $p_Y[1-p_Y]$. So, each $-i$ votes (according to the information they hold) for *R* [*B*], with probability λp_X $[\lambda(1-p_X)]$ when choosing signal-*X*, and with probability $(1-\lambda)p_Y$ $[(1-\lambda)(1-p_Y)]$ when choosing signal-*Y*. *RHS*(1) is decomposed into individual *i*'s expected net benefit of choosing signal-*X* (i.e., the sum term) minus the opportunity cost, *c*. In pivotal events, for any number $k_j=0,...,n$ of signal-*X* informed votes for alternative $j=R,B$, there must be $n-k_j$ signal-*Y* informed *j*-votes, and for a given pair (k_R,k_B), $(n-k_R,n-k_B)$, the pivot probability is $P_{piv}(\nu^*,p_X,p_Y,n,k_R,k_B)\equiv\binom{2n}{n}\binom{n}{k_R}\binom{n}{k_B}p_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R}(1-p_Y)^{n-k_B}$. The expected net gain of individual *i* from voting more informatively in pivotal events is $W^e(\nu^*,p_X,p_Y,n,k_R,k_B,M)\equiv$

$$Mp_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R}(1-p_Y)^{n-k_B}$$
$$\times\Bigg[\frac{p_X}{p_X^{k_R+1}(1-p_X)^{k_B}p_Y^{n-k_R}(1-p_Y)^{n-k_B}+(1-p_X)^{k_R+1}p_X^{k_B}(1-p_Y)^{n-k_R}p_Y^{n-k_B}}$$
$$-\frac{p_Y}{p_X^{k_R}(1-p_X)^{k_B}p_Y^{n-k_R+1}(1-p_Y)^{n-k_B}+(1-p_X)^{k_R}p_X^{k_B}(1-p_Y)^{n-k_R+1}p_Y^{n-k_B}}\Bigg].$$

In words, this is her Bayesian updated probability that *R* is correct given (k_R+1,k_B) signal-*X* informed votes, including her own *R*-vote, and $(n-k_R,n-k_B)$ signal-*Y* informed votes, times

$U(R,R) = M$ and minus her Bayesian updated probability that *R* is correct given (k_R, k_B) signal-*X* informed votes and ($n - k_R + 1$, $n - k_B$) signal-*Y* informed votes, including her own *R*-vote, times $U(R,R) = M$, if she casts a signal-*Y* informed vote.[25] Let's now focus on $\mu > 0$, so that $\lambda \in (0,1)$.

In symmetric logit equilibrium of T0, T1, and of the individual settings in T2 and T3, for $\mu > 0$ individuals choose signal-*X* with probability λ^* (ν^*, p_X, p_Y, n, M, c, $\mu > 0$) $\in (0,1)$. For our experimental parameters and taking $\mu = 0.70$, we derive our λ^* for each setting in Appendix A, and find the average to be 5.27% signal-*X* acquisition rate in group-settings of T0 and T1. This is already an increase from the BNE prediction of 0.00% as per H1. We note here that this *All Vote* QRE prediction with a small μ is a lower bound of sorts. As can be observed from H1, the *SVC* equilibrium which explains our results, will have a higher signal-*X* acquisition rate QRE prediction. Moreover, the error term μ can also be adjusted to a higher degree, in order to get closer to the absolute numbers we see in our results.

6 Discussion

In this paper, we have examined information acquisition and subsequent voting decisions in committees under different levels of transparency. When transparency is low and voters can't observe their group-members' acquired information, or can only observe the quality of their information sources, there exist multiple pure-strategy equilibria. In the Pareto optimal *All Vote* equilibria, all individuals vote according to their signal realisations, while in *SVC* equilibria, individuals with low (high)-quality information abstain (vote according to their signal realizations). We compare these less transparent environments with more transparent ones, where individuals can observe their group-members' signal quality and realisation, as revealed to them either exogenously or endogenously by their group-members. We predict that the less transparent environments can perform (in terms of average payoffs) as well as the more transparent and informative environments, if individuals in the less transparent environments follow the *All Vote* equilibria. That is, individuals in less transparent environments can compensate for lower transparency by just voting according to their own signal realisation.

Behaviour in the less transparent environments of our experiment is consistent with *SVC* equilibria. Participants consume high quality information more often compared to participants in more transparent environments, yet make fewer correct decisions and abstain more often, both of which lead them to earning less. This suggests that it is not the lower transparency that

[25] Note that in pivotal events with signals-profile such that alternative *B* is more likely than *R* in the group, individual *i* prefers to vote against her *r*-signal. But, ex ante, she expects others to have on average signals such that *R* is at-least as likely as *B*, so voting as informed by her signal is her unique best response.

is intrinsically harmful, but instead it is the less informed individuals' sub-optimal abstention decisions that do the harm in these less transparent environments, where all signals still are informative.

Our results indicate that transparency is an important determinant of the performance of majority voting in committee decision-making. In less transparent environments voters tend to mistakenly believe that refraining from contributing their less-informed guess to the majority vote would be more advantageous for their group. Essentially, they misjudge the optimality of delegating their group's vote to the more informed group members or the perceived 'experts.' Conversely, we observe significantly lower rates of abstention among less informed individuals in more transparent environments. The increased transparency in these environments enables individuals to engage in free-riding behavior more effectively while still benefiting from their group members' signals. This ultimately leads to higher levels of informational efficiency and, consequently, greater payoffs.

Our research yields novel evidence for selection of *SVC* equilibrium when operating in less transparent environments. This allows us to uncover the underlying mechanism explaining why majority voting may exhibit reduced effectiveness when aggregating information in such environments. In environments with lower transparency, individuals abstain from casting their votes when they are less informed. Consequently, this reluctance to participate ultimately harms payoffs, even when others in their group invest in the more accurate signal more often. Hence, our study carries further implications for comprehending the interplay between transparency of information environments, occurrence of free-riding, and participation within committees in a general sense.

Since we study committee decision-making, an important question is the extent that our results hold when preferences are made heterogeneous, instead of homogeneous as they are in our current framework. This would have real-world applicability, for instance in the context of say voting in a department of a firm with members having different career concerns. Another fruitful avenue for future research would be to investigate whether employing another voting rule such as the unanimity rule, generates different results.

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Appendix A: Proofs, and further Results and Tables

Voting equilibria in the three voter game of T0 and T1

All Vote equilibria

While solving for the voting equilibria, we focus on equilibria where individuals vote their signals if they do decide to vote. Now, provided that all individuals are voting their signals if they vote, and since we are considering the case of three (odd number) voters, along-with $1 > p_X > p_Y > \frac{1}{2}$, implies that there always exists a positive probability that a voter is pivotal in determining the election result. Since an individual's voting versus abstaining decision is irrelevant if they are non-pivotal, therefore we analyse an individual's decision to participate or not, by examining the expected utility they receive from participation, in the event they are pivotal.

Under this pivotality assumption, we solve for the pure-strategy Bayesian–Nash equilibria of our game. First, we look at whether no-one voting can exist as an equilibrium. Here, any voter can determine the outcome and each individual's vote is potentially pivotal. Given that others are abstaining, an individual's expected utility from also abstaining equals $\frac{M}{2}$ if they are a signal-*X* chooser, and $\frac{M}{2} + c$ if they are a signal-*Y* chooser, as the election would result in a tie. On the other hand, an individual's expected utility from voting in this situation equals Mp_X if they are a signal-*X* chooser, and $Mp_Y + c$ if they are a signal-*Y* chooser. Since $p_X, p_Y > \frac{1}{2}$, therefore, all individuals abstaining as a pure strategy cannot exist as an equilibrium.

Second, we examine whether all individuals voting can exist as an equilibrium. Since the number of voters is odd, therefore, the sole pivotal event that can exist in this scenario in the absence of one's vote, is a tie. Thus, the voting versus abstaining decision by individuals is conditioned on there being a tie vote if they decide to abstain. That is, in the event of a tie, given that an individual's signal is informative, their voting decision will improve the group's probability of choosing the true state of the world.

The interesting case to consider is where one group-member chooses signal-*X* and the other two group-members choose signal-*Y*. Without loss of generality, let's assume that the signal-*X* choosing individual 1 receives an *r*-signal. Individual 1's vote only matters if the other group-members' votes are tied which would occur if one gets an *r*-signal and the other has a *b*-signal. Label this event PIV^1. Individual 1 compares her utility from abstaining to voting conditioned on this pivotal event. If individual 1 abstains, in the pivotal event she receives an expected utility of $\frac{M}{2}$, since the outcome of the election would be a tie and *r* and *b* are equally likely to win.

Label $EU_1(\textit{All Vote}|s_1^X = r, PIV^1)$ individual 1's expected utility of voting when the other two signal-*Y* choosing group-members participate given the pivotal event. $EU_1(\textit{All Vote}|s_1^X = r, PIV^1)$ is a function then of the likelihood that *R* is the true state of the world conditioned on individual 1's signal and the pivotal event as follows:

$$EU_1(\textit{All Vote}|s_1^X = r, PIV^1) = [Pr(R|s_1^X = r, PIV^1) * M] + [Pr(B|s_1^X = r, PIV^1) * 0] \tag{14}$$

From Bayes Rule, the expected utility then is equal to the probability that *R* is the true state of the world given that individual 1 gets an *r*-signal and the other two group-members' signals-*Y* are split, times the bonus-payment from a correct group decision. Furthermore, this expected utility can be shown to simply equal $p_X M$:

$$\begin{aligned} EU_1(\textit{All Vote}|s_1^X = r, PIV^1) &= Pr(R|s_1^X = r, PIV^1)M \\ &= \frac{Pr(s_1^X = r, PIV^1|R)0.5}{[Pr(s_1^X = r, PIV^1|R)0.5] + [Pr(s_1^X = r, PIV^1|B)0.5]}M \\ &= \frac{2p_X p_Y(1-p_Y)}{[2p_X p_Y(1-p_Y)] + [2(1-p_X)p_Y(1-p_Y)]}M \\ &= p_X M \end{aligned} \tag{15}$$

Since $Mp_X > \frac{M}{2}$, therefore, individual 1 should participate and vote for *r*. Similarly, if individual 1 receives a *b* signal, she should vote for *b*.

Now consider the other two group-members who happen to be signal-*Y* choosers. Take one of these signal-*Y* choosers and assume she has received an *r*-signal. Her vote only matters if the election is a tie without her vote, so either individual 1 has an *r*-signal and the other signal-*Y* choosing group-member has a *b*-signal or vice-versa.

Call this pivotal event PIV^2. Now, if the signal-*Y* choosing individual 2 abstains, in the pivotal event the election is a tie and her expected utility is $\frac{M}{2} + c$. On the other hand, her expected utility if she votes as per her *r*-signal in the pivotal event is given by the probability that the true state of the world equals *R* in the pivotal event times the bonus-payment and additionally the saved opportunity cost from choosing signal-*Y*. Furthermore, from Bayes' Rule this expected utility can be shown to equal $p_Y M + c$:

$$
\begin{aligned}
EU_2(\textit{All Vote}|s_2^Y = r, PIV^2) &= Pr(R|s_2^Y = r, PIV^2)M + c \\
&= \frac{Pr(s_2^Y = r, PIV^2|R)0.5}{[Pr(s_2^Y = r, PIV^2|R)0.5] + [Pr(s_2^Y = r, PIV^2|B)0.5]}M + c \\
&= \frac{[p_X p_Y(1-p_Y) + (1-p_X)p_Y^2]0.5}{[p_X p_Y(1-p_Y) + (1-p_X)p_Y^2]0.5 + [(1-p_X)p_Y(1-p_Y) + p_X(1-p_Y)^2]0.5}M + c \\
&= p_Y M + c
\end{aligned}
$$

Since $p_Y M + c > \frac{M}{2} + c$, individual 2 should vote for *r*. Similarly, if individual 2 receives a *b*-signal, she should vote for *b*. The case of the signal-*Y* choosing individual 3 is analogous. Thus, we have shown the existence of an equilibrium where all voters vote their signals in this case. It is also straightforward to show that no equilibrium exists in which only the signal-*Y* choosing individuals participate since in that case the signal-*X* chooser, individual 1, has an incentive to vote as we have seen above. It is also easy to see that in all other cases of all three group-members choosing signal-*X*, all choosing signal-*Y*, or two choosing signal-*X* and one choosing signal-*Y*, individuals will always prefer to vote for their signals.

Swing voter's curse equilibria

Continuing with the same setting as above of one signal-*X* chooser and two signal-*Y* choosers in the three-member group, we now investigate whether equilibria exists in which only the signal-*X* chooser, individual 1, participates. In other words, we examine whether a swing voter's curse equilibrium (labelled as *SVC*) exists in which the more informed individual votes, but the less informed individuals abstain. We know from the analysis above that if the two signal-*Y* choosers are abstaining, the optimal response for signal-*X* chooser is to vote her signal. We now analyse if it is optimal for the two signal-*Y* choosers to abstain given that the signal-*X* chooser is participating.

Suppose signal-*Y* choosing individual 2 receives an *r*-signal. Since only signal-*X* choosing individual 1 is participating, individual 2's vote is pivotal only if that vote is different from individual 1's, in which case individual 2 will force a tie election and individual 2's utility is equal to $\frac{M}{2} + c$. What happens if individual 2 abstains? In the pivotal event when individual 2's signal differs from individual 1's, individual 1 will decide the election. So individual 2's expected utility in the pivotal event is the probability that individual 1's signal is correct in the pivotal event, times the bonus-payment, and additionally the saved opportunity cost from choosing signal-*Y*. Given that individual 2 has received an *r*-signal, the pivotal event is that individual 1 has received a *b*-signal.

$$EU_2(SVC|s_1^X = b, s_2^Y = r) = Pr(B|s_1^X = b, s_2^Y = r)M + c$$
$$= \frac{p_X(1-p_Y)}{p_X(1-p_Y)+(1-p_X)p_Y}M + c \quad (16)$$

It is straightforward to show that $EU_2(SVC|s_1^X = b, s_2^Y = r) > \frac{M}{2} + c$ since $p_X > p_Y$. Thus, it is an optimal response for individual 2 to abstain if individual 1 is voting her signal and signal-*Y* choosing individual 3 is abstaining since individual 1 has better quality information. Similarly, we can show that it is optimal for individual 3 to abstain as well. Thus a swing voter's curse equilibrium exists.

Finally, we note that there don't exist any asymmetric pure-strategy equilibria in which the two signal-*Y* choosers go for different pure strategies. As we have seen individual 1 always votes. And, given that individual 1 is voting, if one signal-*Y* chooser has an optimal response to vote, so does the other signal-*Y* chooser. Thus, we always have the existence of such an *All Vote* equilibrium. Furthermore, in the *SVC* equilibrium, both signal-*Y* choosers optimally abstain.

Also note that this *SVC* equilibrium only exists for this specific case of one signal-*X* and two signal-*Y* choosers in the group. While the group-members' signal-choices are observable in *T1*, on the other hand in *T0*, signal-*Y* choosing individuals will need to have such beliefs about the signal-choices and voting behaviour of their group-members in order to sustain this equilibrium. Let's take the case where there is only one signal-*Y* chooser but two signal-*X* choosers in the three-member group, as an example to demonstrate this. Without loss of generality we label the two signal-*X* choosers individual 1 and individual 2 respectively, and the signal-*Y* chooser, individual 3. Consider the choice of individual 3. Assume that both individual 1 and individual 2 are voting their signals. The pivotal event for individual 3 will be when individual 1 and individual 2's signals conflict. In which case, individual 3, would break a tie. If individual 3 chooses not to vote in this case, her expected utility is equal to $\frac{M}{2} + c$. If she chooses to vote, her expected utility is simply equal to her information quality, p_Y, times the bonus-payment and the additional saved opportunity cost from choosing signal-*Y*:

$$EU_3(s_3^Y = r, PIV^3) = \frac{p_Y p_X(1-p_X)}{p_Y p_X(1-p_X)+(1-p_Y)p_X(1-p_X)}M + c = p_Y M + c \quad (17)$$

Since $p_Y M + c > \frac{M}{2} + c$, the signal-*Y* chooser should always participate when the two signal-*X* choosers are participating. Is it optimal for both signal-*X* choosers to participate? Suppose both signal-*Y* choosing individual 3 and signal-*X* choosing individual 1 are voting. Should the signal-*X* choosing individual 2 then vote? In the pivotal event, individual 3 and individual 1 have conflicting signals. If individual 2 abstains, then her expected utility is $\frac{M}{2}$. But following the analysis above, if individual 2 votes, her expected utility from voting is $p_X M$. Thus, given that individual 3 is voting, both individual 1 and individual 2 should vote. Hence, a traditional *SVC* equilibrium in which *all* signal-*X* choosers vote and the signal-*Y* chooser abstains does not exist for any values of p_X and p_Y.

Note that in the above case, though, *SVC* like equilibria exist in which only one signal-*X* chooser participates. To see this, suppose that signal-*X* choosing individual 1 is voting and signal-*Y* choosing individual 3 is abstaining. Should signal-*X* choosing individual 2 vote? In the pivotal event, individual 2 has received a different signal from individual 1 and voting will result in a tie election. The expected utility for individual 2 from voting is thus equal to $\frac{M}{2}$. However, the expected utility for individual 2 from abstaining in the pivotal event is also equal to $\frac{M}{2}$, because with conflicting signals both states of the world are equally likely, and so, individual 2 is indifferent between voting or not. Therefore, abstention is a rational response of individual 2 in this case. Individual 3 should also abstain if individual 1 is voting but individual 2 is not, since the expected utility to individual 3 from voting is equal to $\frac{M}{2} + c$, but the expected utility of abstaining is given by equation (4) and since $p_X > p_Y$, individual 3's expected utility from abstaining, delegating her vote to individual 1 is higher than $\frac{M}{2} + c$. Thus, here two *SVC* equilibria exist – one in which only individual 1 participates and one in which only individual 2 participates. However, these *SVC* equilibria involve using weakly dominated strategies and significant coordination among signal-*X* choosers on who votes and who abstains, and of-course such beliefs about one's group-members' signal-choices (in *T0*) and voting behaviour in order to sustain this equilibrium.

No interior symmetric mixed-strategy equilibrium exist here though. Intuitively, individual 3 always prefers to vote if the probability that both individuals 1 and 2 vote is positive. Given that individual 3 always prefers to vote in this situation, then individuals 1 and 2 optimally choose to vote when there is a positive probability that the other will vote. Similarly, there is no interior asymmetric mixed-strategy equilibrium where one signal-*X* choosing individual votes and the other signal-*X* choosing individual and signal-*Y* choosing individual randomise.

Let's now also consider the case of all three group-members choosing signal-*Y*, and the case of all three group-members choosing signal-*X* will follow analogously. Here, an *All Vote* equilibrium exists, following the reasoning used before. Since all individuals posses the same quality of information, therefore perhaps it cannot technically be called *SVC* equilibria here, however, such equilibria do exist in which only one individual votes. To see how this might be true, let's look at these three voters whose information quality is given by p_Y, whom we call individual 1, individual 2, and individual 3. Assume that individual 1 is voting and individual 2 is abstaining. Should individual 3 vote? Individual 3's vote will be pivotal if her signal differs from individual 1's, in which case she will cause a tie election and receive an expected utility of $\frac{M}{2} + c$. But if she chooses abstention, then her expected utility (in the pivotal event) is also equal to $\frac{M}{2} + c$ because with opposing signals both states of the world are equally likely. As a result, individual 3 is indifferent between voting and abstaining. Similarly, it is rational for only individual 2 or only individual 3 to participate. Thus, three *SVC* equilibria are possible here. Of course, these *SVC* equilibria involve choosing the weakly dominated strategy of abstaining and significant coordination issues, in addition to having such beliefs about one's group-members' signal-choices (in *T0*) and voting behaviour.

There do not exist any interior symmetric mixed-strategy equilibria in this case. Intuitively, if one individual thinks that both of the other individuals will vote, then she would optimally choose to vote as well. Following the same reasoning, no interior mixed-strategy equilibrium exists in which one individual always votes and the other two randomise.

Mixed-strategy equilibria

We return to the case of one signal-*X* chooser and two signal-*Y* choosers, and study whether the voting game of this setting also has a symmetric mixed-strategy equilibrium in which the signal-*Y* choosers randomise between voting and abstaining. As noted before in this case, we have our refinement that signal-*X* choosing individual 1 has a dominant strategy of voting her signal irrespective of the strategies chosen by signal-*Y* choosing individuals 2 and 3. Define a as the symmetric mixed-strategy equilibrium probability that a signal-*Y* chooser abstains. By definition, this value is such that each signal-*Y* chooser is indifferent between abstaining and voting given that the signal-*X* chooser is voting her signal and the other signal-*Y* chooser is abstaining with probability a. It is given by the following:

$$a = \frac{4p_X p_Y + 2p_Y^2 - p_X - p_Y - 4p_X p_Y^2}{2p_X p_Y} \tag{18}$$

This probability increases with values of p_Y, decreases with values of p_X, and increases as the difference between p_X and p_Y reduces. That is, if the difference between p_X and p_Y is big, then abstaining by both signal-*Y* choosing individuals is more likely to result in the correct choice. Thus, for say signal-*Y* choosing individual 2 to be indifferent between abstaining and voting, then there must be a high voting probability for signal-*Y* choosing individual 3, because otherwise individual 2 would prefer the pure strategy of abstaining.

For our subsequent analysis, we focus only on pure-strategy symmetric overall and symmetric in signal-choice[26] equilibria.

[26]i.e. all individuals of the same signal type play the same strategies

Signal choice equilibria in the three voter game of *T0* and *T1*

Signal choice BNE in *All Vote* equilibria

1. *Both group-members choose signal-X*

   In this case, an individual being pivotal implies that the other two signal-*X* choosing group-members receive opposing signals. Now, given voting according to information held (i.e. according to own signal in these treatments), and assuming without loss of generality that individual *i* receives an *r*-signal, her expected utility from choosing signal-*X* is given by

   $$U(d_i = 2) = MPr[R|s_i^X = r, PIV]P_{piv}, \tag{19}$$

   and her expected utility from choosing signal-*Y* (i.e., not choosing signal-*X*) is given by

   $$U(d_i = 1) = MPr[R|s_i^Y = r, PIV]P_{piv} + c, \tag{20}$$

   where P_{piv} is the probability a vote is pivotal.

   Notice that the other two group-members' opposing signals cancel each other out as they are of equal strength here. Therefore, individual i essentially updates her belief based solely on her own signal, and the probability of a signal-*X* (*Y*) choosing individual voting for the correct alternative being p_X (p_Y), we have

   $$\left.\begin{array}{l} U(d_i = 2) = Mp_X P_{piv} \\ U(d_i = 1) = Mp_Y P_{piv} + c \end{array}\right\} \text{where}$$

   $$P_{piv} = \binom{2}{1} p_X(1 - p_X). \tag{21}$$

   The signal-choice depends on the sign of $U(d_i = 2) - U(d_i = 1)$, which turns out to be a comparison of the net benefit of choosing signal-*X* over signal-*Y*, conditional on being pivotal, with the normalised cost. In particular, individual i chooses signal-*X* if and only if

   $$(p_X - p_Y)P_{piv} \geq \frac{c}{M} \tag{22}$$

2. *One group-member chooses signal-X and the other chooses signal-Y*

   Being pivotal implies that the other two group-members receive opposing signals, but their signals don't cancel each other out here as they are of unequal strength. Therefore, while updating her belief, individual i along-with her own signal-realisation, takes into account possible signals of her group-members. We have:

$$
\begin{aligned}
&U(d_i = 2) \\
&= M\left[\frac{p_X^2(1-p_Y) + p_X(1-p_X)p_Y}{((p_X^2(1-p_Y)) + (p_X(1-p_X)p_Y)) + (((1-p_X)^2 p_Y) + ((1-p_X)p_X(1-p_Y)))}\right] P_{piv} \\
&= M p_X P_{piv},
\end{aligned}
$$

$$
\begin{aligned}
&U(d_i = 1) \\
&= M\left[\frac{p_Y p_X(1-p_Y) + p_Y^2(1-p_X)}{((p_Y p_X(1-p_Y)) + (p_Y^2(1-p_X))) + (((1-p_Y)(1-p_X)p_Y) + ((1-p_Y)^2 p_X))}\right] P_{piv} \\
&\quad + c \\
&= M p_Y P_{piv} + c,
\end{aligned}
\tag{23}
$$

where

$$
P_{piv} = p_X(1-p_Y) + (1-p_X)p_Y. \tag{24}
$$

3. *Both group-members choose signal-Y*

   This translates to being identical to case 1, except now

$$
P_{piv} = \binom{2}{1} p_Y(1-p_Y). \tag{25}
$$

For our experimental parameters, we find that none of the conditions listed above for choosing signal-*X* are satisfied. As a result, individual i always chooses signal-*Y* in our three-member group settings.

Signal choice BNE in *SVC* equilibria

As we have seen in our voting equilibrium analysis earlier, there exists an *SVC* equilibrium when there is one signal-*X* chooser and two signal-*Y* choosers in a three-member group. Therefore, the only pivotal event here is of the signal-*X* chooser's both group-members choosing signal-*Y*, and we examine below whether this signal-choice equilibrium indeed holds under *SVC*, or whether the signal-*X* chooser has an incentive to deviate to choosing signal-*Y* instead.

Given voting according to own signal by signal-*X* choosers and abstaining by signal-*Y* choosers, and assuming without loss of generality that individual i receives an *r*-signal, her expected utility from choosing signal-*X* is given by

$$
U(d_i = 2) = MPr[R|s_i^X = r, PIV]P_{piv}, \tag{26}
$$

and her expected utility from deviating and choosing signal-*Y* (i.e., not choosing signal-*X*) is given by

$$U(d_i = 1) = MPr[R|s_i^Y = r, PIV]P_{piv} + c. \tag{27}$$

Being pivotal in this scenario implies that if individual i chooses signal-*Y*, then she forces a tie election, whereas, if she chooses signal-*X*, then she updates her belief based on her signal, and with the probability of a signal-*X* choosing individual voting for the correct alternative being p_X, we have

$$\left.\begin{array}{l} U(d_i = 2) = Mp_X P_{piv} \\ U(d_i = 1) = \frac{M}{2} P_{piv} + c \end{array}\right\} \text{where}$$

$$P_{piv} = 1. \tag{28}$$

The signal-choice depends on the sign of $U(d_i = 2) - U(d_i = 1)$, which turns out to be a comparison of the net benefit of choosing signal-*X* conditional on being pivotal, with the normalised cost. In particular, individual *i* chooses signal-*X* if and only if

$$\left(p_X - \frac{1}{2}\right) P_{piv} \geq \frac{c}{M} \tag{29}$$

For our experimental parameters, we find that this condition is always satisfied.

Probability of correct decisions and Pareto optimality

Returning to the case of one signal-*X* chooser and two signal-*Y* choosers in a three-member group, in order to determine the relative informational efficiency of the different equilibria we identify here, we compute the probability of the majority voting correctly in each. Let us assume that the true state of the world is *R*. This then means that the probability of the majority voting correctly in the *All Vote* equilibrium, is equal to the probability of at least two out of the three voters receiving an *r* signal. Now, since everyone is voting, therefore, there can be no ties, and so, this probability is given by:

$$\textit{Pr(Majority Correct in All Vote Eq.)} = 2p_X p_Y(1 - p_Y) + p_Y^2 \tag{30}$$

On the other hand, in the *SVC* equilibrium, the probability of the majority voting correctly is simply equal to the probability that the signal-*X* chooser has received a correct signal, which is p_X.

On comparing these two equilibria, when $\frac{p_Y^2}{(1-2p_Y(1-p_Y))} > p_X$, the Pareto optimal equilibrium is the *All Vote* equilibrium and when $\frac{p_Y^2}{(1-2p_Y(1-p_Y))} < p_X$ the Pareto optimal equilibrium is the *SVC* case. The equilibria are equivalent in optimality when $\frac{p_Y^2}{(1-2p_Y(1-p_Y))} = p_X$. For our experimental parameters, we find that the *SVC* equilibrium is Pareto optimal when $p_Y = 0.51, 0.60$, while the *All Vote* equilibrium is Pareto optimal when $p_Y = 0.80$. Thus, we observe that when there is a big difference between p_X and p_Y, then the *SVC* equilibrium in which the group vote depends on the more informed signal-*X* chooser's accuracy, is more efficient than the *All Vote* equilibrium. However, when the difference is small, then the *All Vote equilibrium* in which the group vote is dependant on the accuracy of all voters' signals is more efficient. The *All Vote* equilibrium ranks higher than *SVC* when the signal-*X* chooser is correct and the signal-*Y* choosers are incorrect, but ranks lower than *SVC* when the signal-*X* chooser is correct and the signal-*Y* choosers are incorrect. The latter situation is more likely when there exists a big difference between p_X and p_Y.

Proof of Proposition 1

In the 'individual' setting across all the treatments, i is always pivotal and votes according to own signal.
Below, we consider the group-settings of each treatment in turn. In the *Voting* stage, an individual i is pivotal if other individuals $-i$ cast (i) equally many votes for each alternative; (ii) one more vote for *R*; or (iii) one more vote for *B*; and she is not pivotal in all other events. We say that *i* "strictly prefers" a decision to another one if, in pivotal events, it selects the alternative indicated by strictly higher likelihood in the group (including her own signal). And, we say *i* is "indifferent" in non-pivotal events or if, in pivotal events, the two alternatives are indicated by equal likelihood in the group. We now analyse the voting behaviour.

In *T0* and *T1*, we must show that there exists a symmetric overall *All Vote* equilibrium where each individual votes according to the information they hold (i.e. according to signal in these treatments). Suppose each other individual $-i$ votes according to signal. Since everyone else is voting and the group size is odd, $2n + 1$, an individual i is only pivotal if other individuals $-i$ cast n votes for each alternative (pivotal events (i)), and she is not pivotal in all other events. Assuming without loss of generality that she has an *r*-signal, then voting for either alternative or abstaining do not dominate each other because: in non-pivotal events and in pivotal events with *R* and *B* indicated equally by all the group-members' signals (including hers) - she is indifferent, and in pivotal events where *R* is indicated as strictly more likely than *B* - with her signal being responsible for tipping the scale in favour of *R*, [*B* is indicated as strictly more likely than *R*] in the group, she prefers to vote according to information held [against her *r*-signal]. But, using her own *r*-signal, she expects that others have on average signals such that *R* is at-least as likely as *B*, so her unique best response is to vote according to her signal. Thus, given that others vote according to information held, it is a best response of individual i to use the same strategy as everyone else, which shows existence of our symmetric overall *All Vote* equilibrium in *T0* and *T1*.

In *T0* and *T1*, we must also show that there exists a symmetric in signal-choice *Swing Voter's Curse* equilibrium where each signal-*X* chooser votes according to signal and each signal-*Y* chooser abstains. Note that in our setting, this kind of equilibrium can only occur if individuals in *T0* believe (or they can actually observe in *T1*), that in total there are an even number of signal-*Y* choosers and odd number of signal-*X* choosers in the group. Suppose now, each other individual who is a signal-*X* chooser votes according to signal and each other other individual who is a signal-*Y* chooser abstains. If individual i is a signal-*X* chooser, assuming without loss of generality that she has an *r*-signal, then voting according to signal is her only weakly dominant strategy, because voting according to signal weakly dominates abstaining [voting for

B] as in pivotal events (i) it is strictly preferred, (and pivotal events (ii) and (iii) cannot occur here) and in non-pivotal events she is indifferent. If i is a signal-*Y* chooser, again assuming without loss of generality that she has an *r*-signal, then abstaining weakly dominates voting according to signal [voting for *B*] as in pivotal events (iii) [(ii)] abstaining is strictly preferred, and in pivotal events (ii) [(iii)] and in non-pivotal events she is indifferent ((i) cannot occur here). Thus, given that others vote according to signal if signal-*X* informed and abstain if signal-*Y* informed, i's only weakly dominant strategy is to use the same strategy as everyone else. This completes our proof of existence of our symmetric in signal-choice *Swing Voter's Curse* equilibrium in *T0* and *T1*.

In *T2*, we must show that there exists a symmetric BNE where each individual votes according to the information they hold (i.e. for the most likely state of the world). Suppose each other individual $-i$ votes according to the information available. Then, individual i is not pivotal, and therefore is indifferent. Thus, if we consider a symmetric BNE where everyone votes according to the information available, then this equilibrium indeed holds as no individual has an incentive to deviate. The same analysis follows for *T3* as it is in each individual's interest to truthfully convey her information to her group-members. This completes our proof of existence of our symmetric BNE in *T2* and *T3*. □

Table xxx shows symmetric equilibrium predictions for all combinations of our experimental parameters.[27]

H1 (*Signal-X acquisitions and treatment*): The average rate of signal-*X* acquisitions in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3* (0.000).
The average rate of signal-*X* acquisitions in *T0* and *T1* under *SVC* equilibria, is greater than that in *T2* and *T3* (0.086 versus 0.000).

H2 (*Accuracy of group decisions*): The average rate of correct group decisions in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3* (0.716).
The average rate of correct group decisions in *T0* and *T1* under *SVC* equilibria, is lower than that in *T2* and *T3* (0.613 versus 0.716).

H3 (*Payoffs*): The average payoff per person in *T0* and *T1* under *All Vote* equilibria, is equal to that in *T2* and *T3* (7.16).
The average payoff per person in *T0* and *T1* under *SVC* equilibria, is lower than that in *T2* and *T3* (5.87 versus 7.16).

[27]The signal-*X* acquisition rates are obtained by plugging our experimental parameters in equations (22) and (28). Similarly, the informational efficiency numbers are obtained from equations (23), (24) and (29). The expected group payoffs are then computed using these, according to the formula explained in subsection 2.3.

6.1 Pareto optimality

On comparing the average rate of correct group decisions in *T0* and *T1* under *All Vote* equilibria with that under *SVC* equilibria, we find that *All Vote* fares higher (0.716 versus 0.613)[28], and is therefore Pareto optimal. As a result, individuals in these treatments would be better off by following the *All Vote* equilibria rather than the *SVC* equilibria. Moreover, if we do find results to be consistent with *SVC* equilibrium predictions in our experiment, then we could deduce that the desire to delegate to others who might be better informed leads individuals to make Pareto sub-optimal decisions.

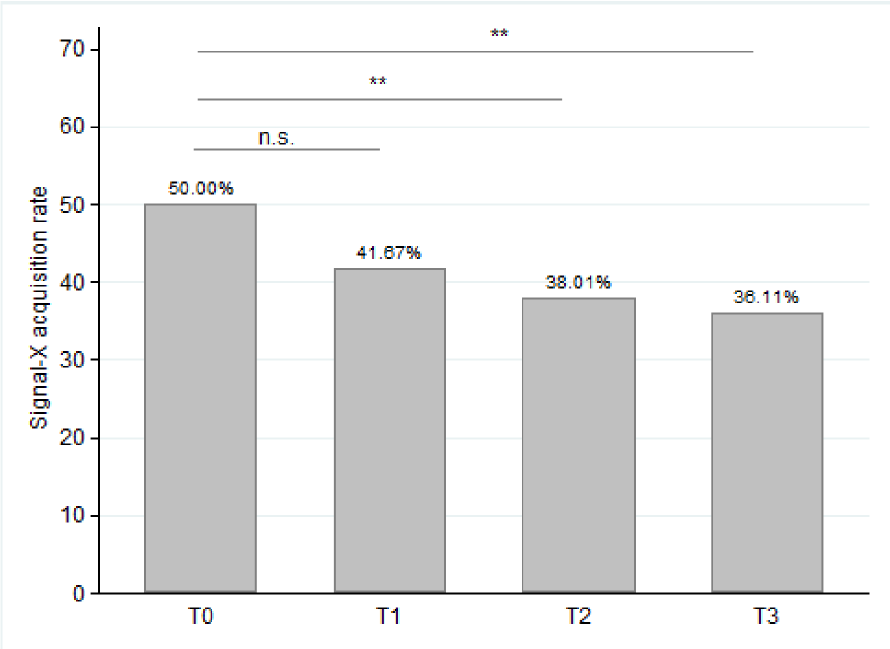
[28]Derived above in H2 as accuracy of group decisions.

Table 6.1: BNE: signal-*X* acquisition rate, group decision accuracy, and group payoffs.

T0, T1, T2 and T3: All Vote		
σ^*	W^*	Expected group payoff
	p_Y = 0.51	
	Individual	
1	0.899	5.99
	Three-member group	
0	0.515	15.45
	Nine-member group	
0	0.525	47.21
	p_Y = 0.60	
	Individual	
0.5	0.750	6
	Three-member group	
0	0.648	19.44
	Nine-member group	
0	0.733	66.01
	p_Y = 0.80	
	Individual	
0	0.8	8
	Three-member group	
0	0.896	26.88
	Nine-member group	
0	0.980	88.24
T0 & T1: SVC		
	Three-member group	
0.136	0.625	17.54
	Nine-member group	
0.036	0.600	53.02

Notes: σ^* denotes the equilibrium rate of signal-*X* acquisition and W^* denotes equilibrium (informational) efficiency. The bonus payment is $M = 10$ and the opportunity cost of choosing signal-*X* is $c = 3$.

Figure 5: Signal-*X* acquisition rate for 'first round' decisions (Unit of observation: Individual)

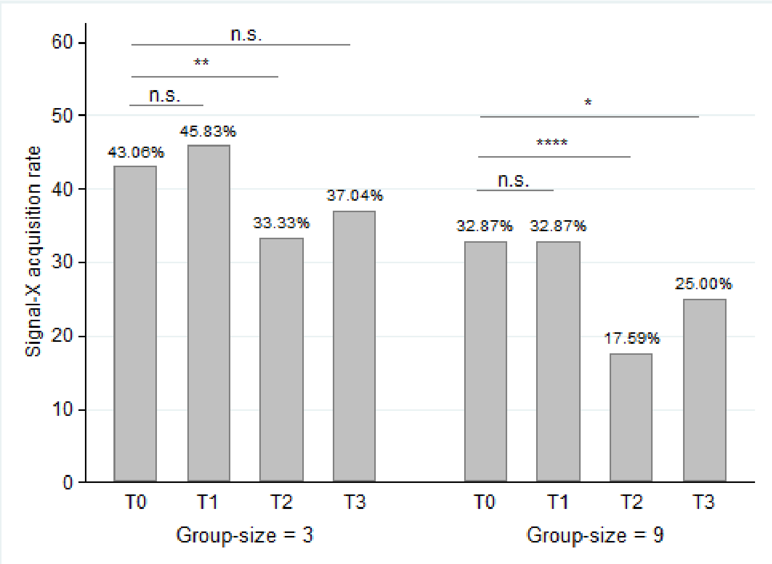


The above figure shows the signal-X acquisition rate in each treatment, for the first decisions in group-settings, which can be considered as truly independent. Observations related to the group-size = 1 setting have been excluded.

Information acquisition

- **Breakdown by group-size**

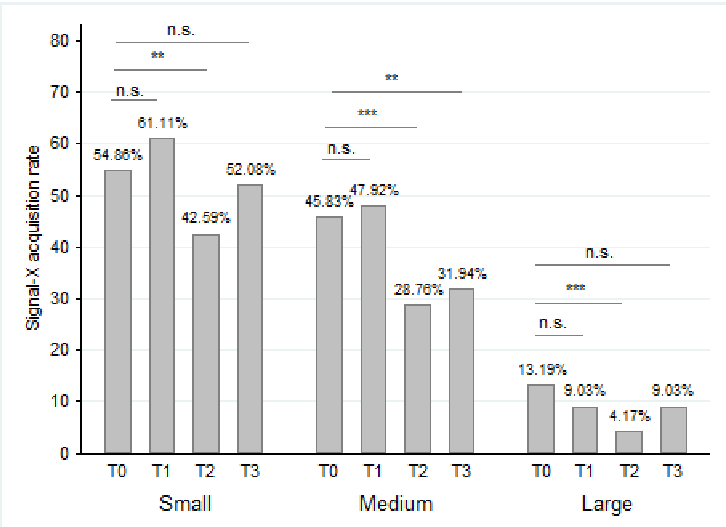
Figure A.1: Signal-*X* acquisition rate (Unit of observation: Individual)



The above figure shows the signal-X acquisition rate in each group-setting, for each treatment.

- **Breakdown by signal-*Y* precision**

Figure A.2: Signal-*X* acquisition rate (Unit of observation: Individual)



The above figure shows the signal-X acquisition rate in each signal-Y accuracy-setting, for each treatment.

Regressions

Table 6.2: Main Treatment Effects

	(1) Net Payoff (Group-size = 3)	(2) Net Payoff (Group-size = 3)	(3) Net Payoff (Group-size = 9)	(4) Net Payoff (Group-size = 9)
T1	-0.194	1.258	0.455	-0.269
	(-0.59)	(0.60)	(1.01)	(-0.20)
T2	1.274**	0.832	1.851****	3.618
	(2.49)	(0.61)	(4.12)	(1.25)
T3	1.246***	-0.611	1.817***	3.065
	(3.24)	(-0.44)	(3.15)	(1.64)
Accuracy	6.553****	6.171****	4.090***	5.077**
	(7.42)	(3.43)	(2.63)	(2.39)
T1 × Accuracy		-2.223		1.094
		(-0.69)		(0.55)
T2 × Accuracy		0.694		-2.745
		(0.31)		(-0.57)
T3 × Accuracy		2.896		-1.938
		(1.36)		(-0.68)
Constant	5.192****	5.435****	6.474****	5.833****
	(8.50)	(5.24)	(6.25)	(4.17)
Observations	753	753	718	718

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Note: Participant and Round have been set as the panel and the decision-order/time variable within the panel, respectively, for all the regressions.

Table 6.3: Treatment Effects

	(1) Signal-X acq (Group-size = 3)	(2) Signal-X acq (Group-size = 3)	(3) Signal-X acq (Group-size = 9)	(4) Signal-X acq (Group-size = 9)
T1	0.137	0.605	0.00379	1.710*
	(0.64)	(0.52)	(0.01)	(1.89)
T2	-0.503*	-0.321	-0.894****	0.278
	(-1.71)	(-0.21)	(-4.07)	(0.19)
T3	-0.282	-0.0748	-0.423**	0.180
	(-0.87)	(-0.06)	(-2.06)	(0.17)
Accuracy	-7.987****	-7.628****	-7.417****	-6.089****
	(-8.74)	(-5.51)	(-8.32)	(-4.71)
T1 $\times$ Accuracy		-0.759		-2.854*
		(-0.37)		(-1.67)
T2 $\times$ Accuracy		-0.291		-1.980
		(-0.12)		(-0.74)
T3 $\times$ Accuracy		-0.336		-0.992
		(-0.18)		(-0.54)
Constant	4.724****	4.503****	3.872****	3.070****
	(8.22)	(5.30)	(8.61)	(4.45)
Observations	891	891	864	864

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6.4: Treatment Effects (Group-size = 3 and Red is most likely signal)

	(1) Blue Guess	(2) Blue Guess	(3) Blue Guess
T1	0.198	0.129	1.658
	(0.44)	(0.33)	(0.95)
T2	0.308	-1.017	0.689
	(0.35)	(-1.17)	(0.32)
T3	1.334	-0.386	1.830
	(1.63)	(-0.49)	(0.77)
Accuracy	-4.062**	-2.884*	-0.484
	(-2.34)	(-1.84)	(-0.19)
Blue Signals = 1		1.578****	1.678*
		(3.81)	(1.65)
Blue Signals = 2		2.205****	2.304**
		(9.65)	(2.25)
T1 × Accuracy			-2.590
			(-0.85)
T2 × Accuracy			-2.399
			(-0.75)
T3 × Accuracy			-3.911
			(-1.28)
Blue Signals=1 × T2			-0.464
			(-0.31)
Blue Signals=2 × T2			-0.483
			(-0.24)
Constant	0.227	-0.415	-1.827
	(0.25)	(-0.52)	(-1.22)
Observations	372	356	356

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6.5: Treatment Effects (Group-size = 9 and Red is most likely signal)

	(1) Blue Guess	(2) Blue Guess	(3) Blue Guess
T1	-0.389	-0.359	-3.664**
	(-1.36)	(-1.30)	(-1.97)
T2	0.109	-0.767	-5.952***
	(0.22)	(-1.34)	(-3.19)
T3	0.785**	-0.944**	-6.620****
	(2.38)	(-2.42)	(-4.22)
Accuracy	0.778	0.580	-5.681**
	(0.61)	(0.47)	(-2.30)
Blue Majority		2.397****	2.874***
		(3.95)	(2.61)
T1 × Accuracy			5.540*
			(1.74)
T2 × Accuracy			8.397***
			(2.73)
T3 × Accuracy			8.655***
			(3.10)
Blue Majority × T2			-0.354
			(-0.25)
Constant	-1.701**	-1.495*	2.134
	(-2.26)	(-1.76)	(1.64)
Observations	364	364	364

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6.6: Treatment Effects

	Correct Guessing
Signal-Choice (1 = Signal-*X*)	-0.172
	(-0.60)
Constant	0.943****
	(8.55)
First Stage	
T1	0.0200
	(0.43)
T2	-0.213****
	(-3.76)
T3	-0.142***
	(-3.04)
Accuracy	-1.730****
	(-14.03)
Group-size = 9	-0.105****
	(-5.46)
Constant	1.611****
	(16.71)
Observations	1471

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6.7: Treatment Effects (Group-size = 3)

	(1) Correct Guessing	(2) Correct Guessing	(3) Correct Guessing
T1	-0.0314	-0.0703	0.675
	(-0.32)	(-0.59)	(0.67)
T2	0.343*	0.179	-0.230
	(1.88)	(0.74)	(-0.23)
T3	0.472***	0.153	-1.937
	(3.20)	(0.66)	(-1.33)
Accuracy	0.273	2.270****	1.958**
	(0.63)	(4.19)	(2.28)
Signals-X = 1		0.798****	1.055****
		(4.51)	(5.77)
Signals-X = 2		1.038***	1.274**
		(3.18)	(2.39)
Signals-X = 3		1.658****	6.017****
		(3.54)	(10.38)
T1 × Accuracy			-1.053
			(-0.72)
T2 × Accuracy			1.000
			(0.85)
T3 × Accuracy			3.473*
			(1.95)
Signals-X=1 × T1			-0.112
			(-0.45)
Signals-X=1 × T2			-0.607
			(-1.35)
Signals-X=1 × T3			-0.476
			(-0.83)
Signals-X=2 × T2			-0.185
			(-0.21)
Signals-X=3 × T2			-5.000****
			(-4.42)
Constant	0.670**	-0.929**	-0.829
	(2.21)	(-2.57)	(-1.50)
Observations	753	739	739

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Table 6.8: Treatment Effects (Group-size = 9)

	(1) Correct Guessing	(2) Correct Guessing	(3) Correct Guessing
T1	0.173	0.171	0.336
	(1.07)	(1.05)	(0.66)
T2	0.421**	0.382**	0.193
	(2.39)	(2.08)	(0.16)
T3	0.496*	0.231	-0.345
	(1.71)	(0.68)	(-0.32)
Accuracy	-0.179	0.0976	-0.0587
	(-0.29)	(0.16)	(-0.10)
Signals-*X* Majority		0.974**	0.942**
		(2.57)	(2.01)
T1 × Accuracy			-0.249
			(-0.36)
T2 × Accuracy			0.273
			(0.14)
T3 × Accuracy			0.899
			(0.63)
Signals-*X* Majority × T2			5.055
			(.)
Constant	0.721*	0.541	0.643
	(1.68)	(1.29)	(1.58)
Observations	718	718	718

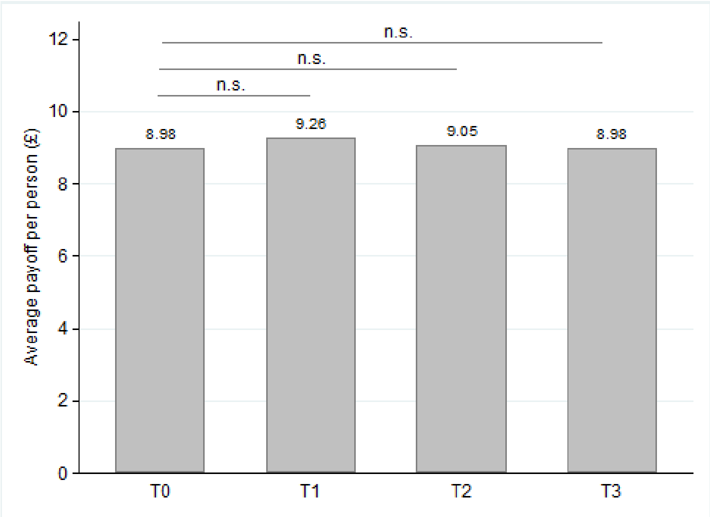
t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

Sanity checks (Group-size = 1)

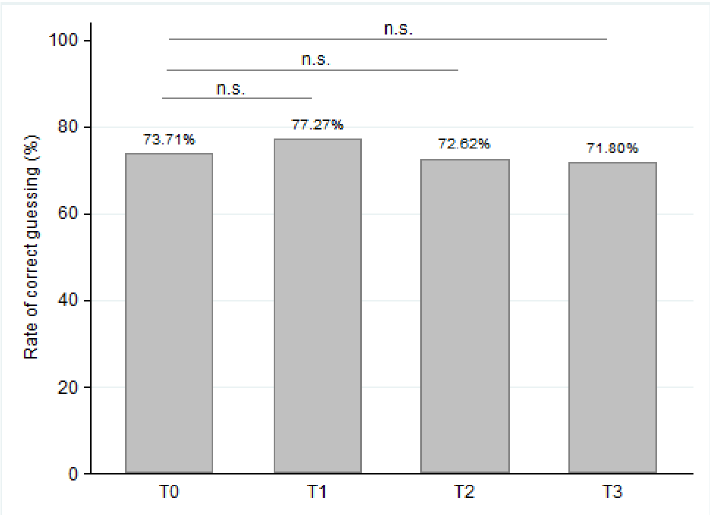
As we would expect to see, there exist no significant differences between treatments in individual settings, as there is no scope for group-feedback here, which forms the basis for differentiating our treatments in various degrees.

Figure A.3: Average payoff per person (Unit of observation: Individual)



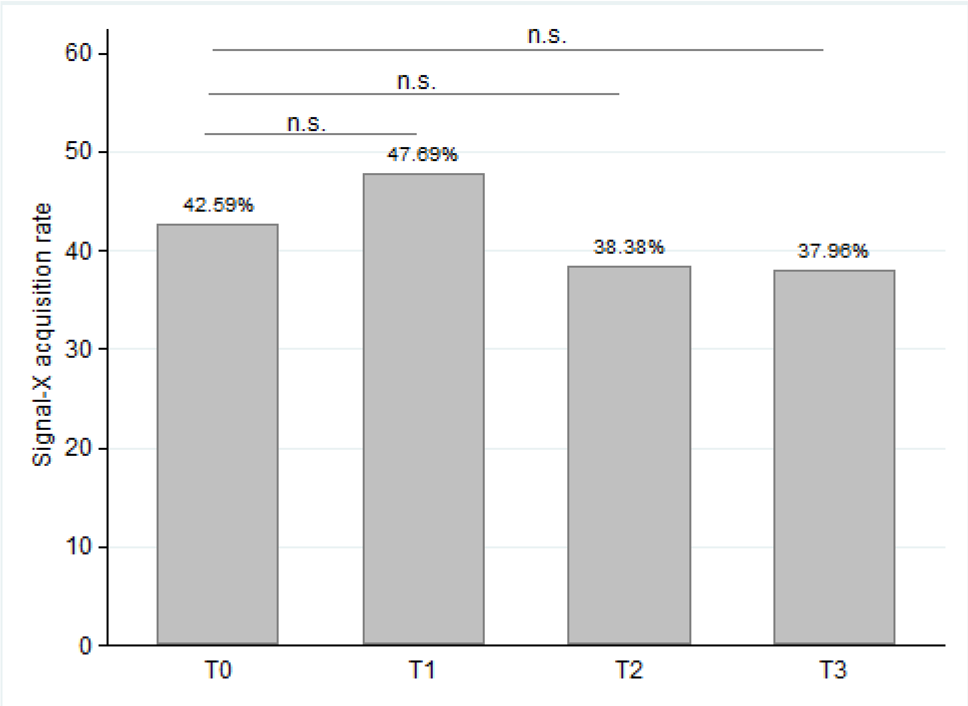
The above figure shows the average payoff per person exclusive of the show-up fee, when group-size = 1.

Figure A.4: Rate of correct guessing (Unit of observation: Individual)



The above figure shows the rates of correct guessing when group-size = 1.

Figure A.5: Signal-X acquisition rate (Unit of observation: Individual)



The above figure shows the signal-X acquisition rates when group-size = 1.

6.2 Setting conducive for free-riding

As group-size increases, a participant's pivotality decreases, and consequently, their free-riding incentive increases. With regard to signal-*Y* precision, as it increases, greater is the return from free-riding on group-members' signals too, plus the gain from going for the more precise signal becomes smaller, both of which in-turn again increase the free-riding incentive of a participant. Therefore, it is worth inspecting the extreme scenario in which free-riding incentives are at their strongest in our framework, in order to find out if our overall results change.

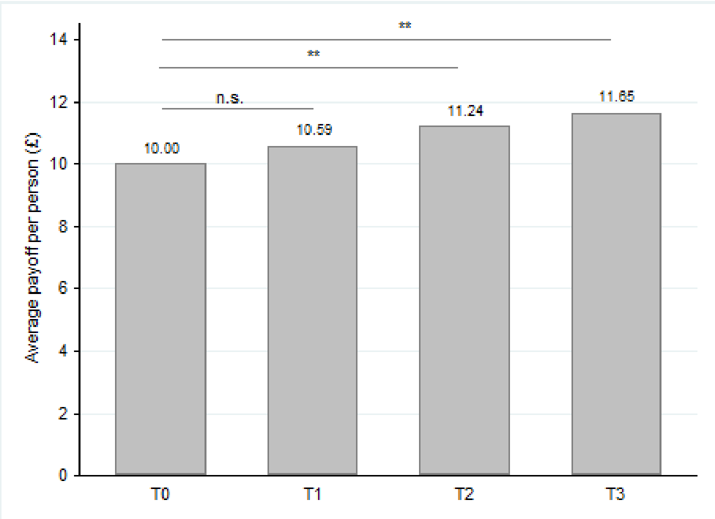
These considerations of free-riding are evidenced by the figures in Appendix A. In Figure A.1, we dis-aggregate the signal-*X* acquisition rate by group-size. Comparing between treatments, we find that there is reduced acquisition of the costly but more accurate signal-*X*, in groups of 9 members, as compared to groups of 3 members. In other words, we observe more free-riding in bigger groups.[29] We also dis-aggregate the signal-*X* acquisition rate by signal-*Y* accuracy level, and present these findings graphically in Figure A.2. We find that free-riding increases as the signal-*Y* accuracy increases. In addition to the explanation behind this discussed above, this also goes to show that higher accuracy signal-*Y* choosers are sufficiently well-informed, and don't find reason to forego the saved opportunity cost by choosing signal-*X* instead, as the gap in returns of informativeness from choosing signal-*X* versus choosing signal-*Y* is little. Taking these factors into account, we select the setting of group-size equal to 9 members and signal-*Y* precision equal to 0.80, to investigate various patterns between treatments in this most extreme case where the temptation to free-ride is the highest.

6.2.1 Average payoffs

Figure 10 presents average payoffs in the setting where conditions are the most conducive for free-riding on group-members in our framework. We observe that our results are robust even in this limiting case, and the combination of informative signals, transparent environments and majority voting, continues to work well here too.

[29] Bhattacharya et al. [2017] provide similar evidence showing the importance of group-size in voting with endogenous information acquisition.

Figure 10: Average payoff per person when group-size = 9 and signal-*Y* precision = 0.80

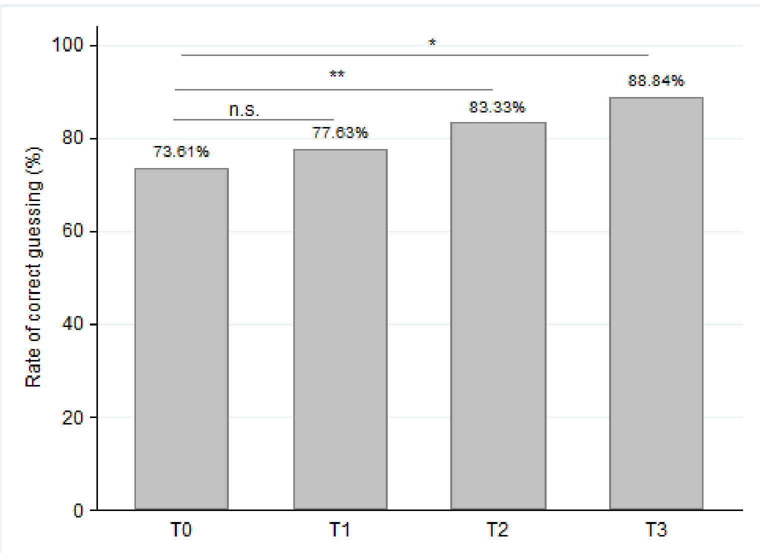


The above figure shows the average payoff per person exclusive of the show-up fee, when group-size = 9 and signal-Y precision = 0.80. The unit of observation is 9-member group.

6.2.2 Rate of correct guessing

Figure 11 below presents the rates of correct guessing in this setting, and again we find that our results between treatments continue to hold here too.

Figure 11: Rate of correct guessing when group-size = 9 and signal-*Y* precision = 0.80

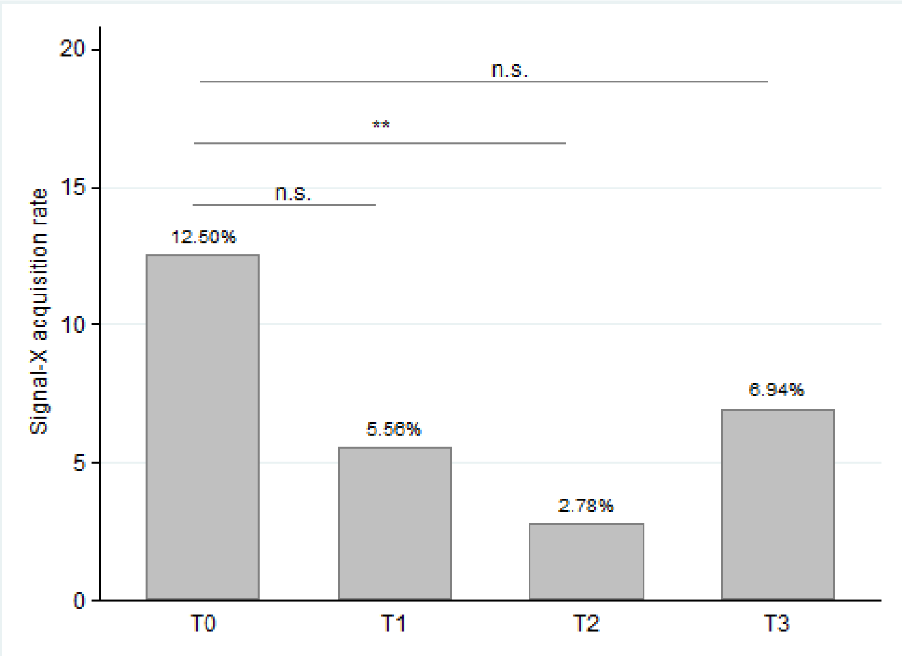


The above figure shows the rate of correct guessing in the setting where group-size = 9 and signal-Y precision = 0.80. The unit of observation is 9-member group.

6.2.3 Information acquisition

Figure 12 graphically presents the signal-*X* acquisition rates in this free-riding friendly setting.

Figure 12: Signal-*X* acquisition rate when group-size = 9 and signal-*Y* precision = 0.80



The above figure shows the signal-X acquisition rate in the setting where group-size = 9 and signal-Y precision = 0.80. The unit of observation is individual.

We observe here that, the signal-*X* acquisition rate in T1 and T3 respectively, are not significantly different from that in T0 (Chi-squared tests, $p = 0.146$ and 0.261, respectively). However, the signal-*X* acquisition rate in T2 is significantly lower than that in T0 (Chi-squared test, $p < 0.05$). Recalling the results from Figure 4, the comparison that shows a change here is that between T0 and T3. In Figure 4, there is a significant difference in the signal-*X* acquisition rates between these two treatments, however, now in the extreme setting of Figure 12, that difference has disappeared. As we have explained earlier, in T3, there is a possibility of misrepresentation of information by group-members. Therefore, there might exist a tendency among the participants, to not completely trust the information that would be conveyed to them, and instead rely on their own signals more. Thus, this slight under-confidence in free-riding and learning from one's group-members' information in T3, comes out starkly in this extreme setting where the conditions are least conducive for acquiring signal-*X*. This leads to the non-significant difference in the signal-*X* acquisition rate between T0 and T3, as in T0, participants only have to rely on their own signal, and that's why invest in signal-*X* more frequently.

Logit equilibrium

Individuals in the group-settings of *T2* and *T3* are indifferent owing to their non-pivotality, therefore, never choose the costly signal-*X*.

For *T0* and *T1* (and for the individual settings of *T2* and *T3*, by default), we derive symmetric logit equilibrium condition (30) for signal-*X* choice probability λ^*.

(*Logit equilibrium condition*) Given equilibrium voting ν^* (Proposition 1), individual *i*'s expected payoff from choosing signal-*X* versus from choosing signal-*Y*, is:
$U^e(d_i = 2, \lambda, \nu^*, p_X, n, M)$ versus $U^e(d_i = 1, \lambda, \nu^*, p_Y, n, M) + c$, which are augmented by the stochastic terms $\mu\epsilon_2$ and $\mu\epsilon_1$, respectively, where ϵ_2 and ϵ_1 are iid random variables (recall that the parameter $\mu \geq 0$ denotes the degree of noise). Then, if everyone else chooses signal-*X* with probability λ, individual *i* chooses signal-*X* if and only if $U^e(d_i = 2) + \mu\epsilon_2 \geq U^e(d_i = 1) + c + \mu\epsilon_1 \Leftrightarrow \Pi_i^e(\lambda, \nu^*, p_X, p_Y, n, M, c)/\mu \geq \epsilon_1 - \epsilon_2$,[30] which occurs with probability $\lambda = F[\Pi_i^e(.)/\mu]$, where $\Pi_i^e(.) \equiv U^e(d_i = 2) - U^e(d_i = 1) - c$ gives her expected *net payoff* of choosing signal-*X* and F is the distribution function of the difference $\epsilon_1 - \epsilon_2$. Taking the inverse of $\lambda = F(.)$ and multiplying both sides by μ yields $\mu F^{-1}(\lambda) = \Pi_i^e(.)$. Finally, using the logistic distribution, $F(x) = 1/(1 + e^{-x})$, yields our logit equilibrium condition

$$\mu\Big[-ln\big(\tfrac{1-\lambda}{\lambda}\big)\Big] = \Pi_i^e(\lambda, \nu^*, p_X, p_Y, n, M, c). \qquad (A1)$$

If $\mu = 0$, then $LHS(A1)|_{\lambda\in[0,1]} = 0$ and $(A1)$ turns into the BNE condition. And, if $\mu > 0$, then $LHS(A1)$ has the following properties: regarding λ, $\frac{\partial LHS(A1)}{\partial\lambda} = \frac{\mu}{\lambda(1-\lambda)} > 0$ for $\lambda \in (0, 1)$, $\lim_{\lambda\to 0} LHS(A1)$=-$\infty$, $LHS(A1)|_{\lambda=1/2} = 0$, and $\lim_{\lambda\to 1} LHS(A1)$ = +∞; and regarding μ, $\frac{\partial LHS(A1)}{\partial\mu} < 0$ for $\lambda \in \big(0, \frac{1}{2}\big)$, $\frac{\partial LHS(A1)}{\partial\mu} = 0$ for $\lambda = \frac{1}{2}$, and $\frac{\partial LHS(A1)}{\partial\mu} > 0$ for $\lambda \in \big(\frac{1}{2}, 1\big)$.

We take μ=0.70 and for the parameters in our experiment, we find our (unique) λ^* in each setting: 0.783, 0.500 and 0.054 for p_Y = 0.51, 0.60 and 0.80, respectively, in *Individual*. Similarly, λ^*: 0.124, 0.081 and 0.021, respectively, in *Three-member group*; and λ^*: 0.044, 0.031 and 0.015, respectively, in *Nine-member group*.

[30] We assume without loss of generality that an indifferent individual i chooses signal-*X*.

Appendix B: Experimental instructions

Welcome

Welcome to the Birmingham Behavioural, Experimental and Data Science Laboratory.
This is an experiment in decision-making.
The University of Birmingham has provided funds for this research. Just by showing up, you have already earned £3.
You can earn additional money depending on the decisions you will make in today's experiment. It is therefore very important that you **read these instructions with care**.
It is important that you **remain silent** and do **not look** at the screens of other participants. Please remember to switch off your phones or keep them in silent mode.
If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you.
If you do not remain silent during the experiment, you will be asked to leave and you will not be paid. We appreciate your following of these rules.
You will **first go over the instructions**, which are shown on-screen. After you have read the instructions, you will have time to **ask clarifying questions**.
We would like to stress that any choices you make in this experiment are **entirely anonymous**.

Overview

Welcome to this experiment on decision-making.

Three parts

There will be three separate parts (Part 1, Part 2 and Part 3) in this experiment.
In each part, there will be a decision task that we will explain to you before you start making choices.
The choices you make in one part will have no influence on what happens in the other parts.
Once you complete a part, you will learn about the rules of the next part.

Payments

At the end of the experiment, one of the three parts will be randomly selected, for which you will receive a payment.
This payment will depend on the choices you and other participants in this room make, and on chance.

Instructions Part 1

Task

This task involves guessing a colour. The correct colour is equally likely to be red or blue. You can think of a coin flip, where heads means the correct colour is red, and tails means the correct

colour is blue.
Your task is to guess the correct colour.
To help you guess, we will give you the chance to draw a ball from a (virtual) bag.
There are two bags to choose from.
Bag-*X* has 90 balls of the "correct" colour, and 10 balls of the "incorrect" colour.
Bag-*Y* has less than 90 balls of the "correct" colour, and more than 10 balls of the "incorrect" colour. You will learn about the exact number of these balls in Bag-*Y* each time that you have make a bag-choice.
Each time that you make a bag-choice, you will do so from a new set of these bags.
If you choose Bag-*X*, you will see a ball from that bag, which has a 90% chance of being the correct colour.
If you choose Bag-*Y*, you will see a ball from that bag, which has a less than 90% chance of being the correct colour. Choosing Bag-*Y* gives you an immediate bonus payment of £3.

Instructions Part 1

Task

After you have seen the ball from your chosen bag, you will be given the chance to guess the correct colour, Red or Blue.
If you decide not to guess, then your guess will be determined by the flip of a (virtual) fair coin.
If you guess the correct colour, you will win and receive an additional payment of £10. However, if your guess is incorrect, you will not win the additional payment.
At the end of a round, you will **not** learn whether your guess was correct or not.

Instructions Part 1

Three Rounds

In this part, there will be three rounds. In each round, we will draw a new colour.
In each round, you get to choose a bag and submit a guess. Between rounds, the properties of the bags may change.

Payments for Part 1

If this Part is selected for payment at the end of the experiment, then one round will be randomly selected.
If you chose Bag-*X* in this round, then you will win £10 if you guess the correct colour for this round, and £0 if you guess incorrectly.
If you chose Bag-*Y* in this round, then you will win £10 if you guess the correct colour for this round, and £0 if you guess incorrectly. In addition, you will receive £3 as a bonus payment for choosing Bag-*Y*.

Instructions Part 2

Allocation to Teams

In this part, you are a member of a team of three people.

The other two members of your team are other participants in this room.

Task

As before, the task involves guessing a colour. The correct colour will be randomly determined at the beginning of a round. Again, it is equally likely to be red or blue.

To help you guess, we will give you the chance to draw a ball again from a (virtual) bag.

There are two bags to choose from: Bag-*X* and Bag-*Y*. If you choose Bag-*X*, you will see a ball from that bag, which has a 90% chance of being the correct colour.

If you choose Bag-*Y*, you will see a ball from that bag, which has a less than 90% chance of being the correct colour. Choosing Bag-*Y* gives you an immediate bonus-payment of £3.

Each time that you make a bag-choice, you will do so from a new set of these bags.

Instructions Part 2

After you have seen the ball from your chosen bag, you and all other team members can submit a guess, Red or Blue. All team members will submit their guess at the same time and cannot see the guesses made by other team members.

Your final payoff depends on how many team-members guess the correct colour. If a majority of team members (at least 2 out of 3) submit a correct guess, then each team-member will receive an additional payment of £10.

There is also the option not to submit a guess. If some team-members abstain from guessing, then the receipt of an additional payment will be determined by whether the majority of the remaining team-members submit a correct guess. For instance, if one of the three team-members correctly guesses the colour and the remaining two team-members choose to not place a guess, then each team-member will receive an additional payment of £10.

In case of a tie, or if no one in your team chooses to place a guess, then, the outcome will be determined by the flip of a coin.

At the end of the round, you will **not** learn whether your team's guess by majority was correct or not.

Instructions Part 2

Three Rounds

In this part, there will be three rounds. In each round, we will draw a new colour.

In each round, you get to choose a bag and submit a guess. Between rounds, the properties of the bags may change.

Payments for Part 2

If this Part is selected for payment at the end of the experiment, then one round will be randomly selected.

If a team-member chose Bag-X in this round, then they will win £10 if their team guesses the correct colour for this round, and £0 if their team guess incorrectly.
If a team-member chose Bag-Y in this round, then they will win £10 if their team guesses the correct colour for this round, and £0 if their team guess incorrectly. In addition, they will receive £3 as a bonus payment for choosing Bag-Y.

Quiz

There will now be a short comprehension quiz to check your understanding of the instructions.

Quiz

Before we start Part 2 of today's experiment, we ask you to answer the following quiz questions that are intended to check your comprehension of the instructions.
The numbers in these quiz questions are illustrative; the actual numbers in the experiment may be quite different.
If there are any incorrect answers by a participant, we will provide clarifying explanations for each of them, regarding the relevant part of the instructions.
The answers that you provide to these quiz questions will have no impact on your earnings from today's Experiment.

Question 1
Consider the following scenario in a round. One member of your team chooses to guess that the colour is Blue, the other chooses to guess that the colour is Red, and the third member chooses to not place a guess.
What is your team's guess?

Feedback
Well done, that is the correct answer! [or]
Sorry, that is an incorrect answer!
Actually, if one member of your team guesses Red, the other Blue, and the third member doesn't place a guess, then there is no majority guess.
In such situation, a coin toss will resolve the tie resulting in a team guess of either Blue or Red with a 50-50 chance.
We hope that this explanation has clarified this part of the instructions to you. However, if you find this explanation to be unsatisfactory, then please raise your hand, and an experimenter will come over to clear your doubts.

Question 2
Consider the following scenario in a round. All three members of your team choose to not

place a guess.
What is your team's guess?

Feedback

Well done, that is the correct answer! [or]
Sorry, that is an incorrect answer!
Actually, if all the members of your team don't place a guess, then there is no majority guess. In such situation, a coin toss will resolve the tie resulting in a team guess of either Blue or Red with a 50-50 chance.
We hope that this explanation has clarified this part of the instructions to you. However, if you find this explanation to be unsatisfactory, then please raise your hand, and an experimenter will come over to clear your doubts.

Question 3

Consider the following scenario in a round. The correct colour has been randomly picked to be Blue. One member of your team chooses to guess that the colour is Blue, whereas, the other two members of your team choose to guess that the colour is Red.
If this round is selected at the end of the experiment to be paid out, then, apart from any bonus payments arising from the members' bag-choices, and the guaranteed show-up fee, what would your team's payoffs look like?

Feedback

Well done, that is the correct answer! [or]
Sorry, that is an incorrect answer!
Actually, if one member of your team chooses to guess that the colour is Blue, while the other two members choose to guess that the colour is Red, then there is a majority of guesses favouring the colour Red. The team's guess is therefore Red.
Since the correct colour for this round is Blue, the team's guess of Red is incorrect.
As a result, if this round is randomly selected at the end of the experiment to be paid out, then each one of the team-members will not win anything, apart from any bonus payments arising from their bag-choices and the guaranteed show-up fee.
We hope that this explanation has clarified this part of the instructions to you. However, if you find this explanation to be unsatisfactory, then please raise your hand, and an experimenter will come over to clear your doubts.

Question 4

Consider the following scenario in a round. The correct colour has been randomly picked to be Red. One member of your team chooses to guess that the colour is Red, whereas, the other two

members of your team choose to not place a guess.
If this round is selected at the end of the experiment to be paid out, then, apart from any bonus payments arising from the members' bag-choices, and the guaranteed show-up fee, what would your team's payoffs look like?

Feedback

Well done, that is the correct answer! [or]
Sorry, that is an incorrect answer!
Actually, if one member of your team chooses to guess that the colour is Red, while the other two members choose to not place a guess, then there is a majority of guesses favouring the colour Red. The team's guess is therefore Red.
Since the correct colour for this round is Red, the team's guess of Red is correct.
As a result, if this round is randomly selected at the end of the experiment to be paid out, then each one of the team-members will win £10, apart from any bonus payments arising from their bag-choices and the guaranteed show-up fee.
We hope that this explanation has clarified this part of the instructions to you. However, if you find this explanation to be unsatisfactory, then please raise your hand, and an experimenter will come over to clear your doubts.