The Value of Consensus

An Experimental Analysis of Costly Deliberation*

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Abstract

Combining theory and experiments, we examine decision-making with endogenous deliberation across different voting rules: consensus and veto unanimity, and simple majority. Before voting, asymmetrically informed agents choose whether to engage in potentially costly communication to aggregate their private information. In line with existing studies, we find that free communication minimizes differences in decision-making across rules. In contrast, with costly communication, differences in decision-making re-emerge as the voting rules affect communication and private information aggregation. Consensus unanimity frequently outperforms the other rules because it induces more communication among agents. This work provides a new rationale for the legitimacy of the commonly used consensus unanimity voting rule in jury trials.

Keywords: Group Decision-Making, Voting Rules, Endogenous Communication, Costly Communication, Experts, Juries, Economic Experiments.

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1. Introduction

Collective decision-making occurs in various contexts, including committees, boards, juries, and legislative bodies. Deliberation enables the agents to pool individual knowledge, experience, judgment, and insights, to enhance decision outcomes. Nevertheless, while the concept of the "wisdom of the many" is ancient,[1] deliberation dynamics remain understudied, particularly when communication among agents is costly.

Previous studies have focused on the impact of voting rules on collective decision-making without communication (Austen-Smith and Banks, 1996; Feddersen and Pesendorfer, 1998; Ali et al., 2008; Battaglini et al., 2008; Bouton et al., 2016, 2017). Other studies have examined the issue of truthful revelation in deliberation, demonstrating that communication allows for efficient decisions by removing asymmetric information (Coughlan, 2000; Austen-Smith and Feddersen, 2006; Gerardi and Yariv, 2007; Goeree and Yariv, 2011). The experimental literature supports these findings in the case of free communication, showing that voting rules perform equally well (e.g. Guarnaschelli et al., 2000; Goeree and Yariv, 2011).

However, costless communication may be an unrealistic assumption. Rational agents are likely to trade off the opportunity cost of communicating with the improvement in decision-making they can obtain through communication. To analyze the communication properties of voting rules, we develop a theoretical model of endogenous communication that is potentially costly and study how voting rules affect communication dynamics and efficiency.[2]

In our environment, agents have private information but share the same preferences. Their goal is to identify the optimal decision, which is easier if they can aggregate their private information through communication. However, creating a communication model that accurately captures this process is not straightforward. In deliberative contexts, social and cultural norms can influence communication practices, making it difficult to separate communication and voting rules theoretically. Communication costs can further complicate decision-making, as some agents may want to continue communicating while others may want to end it. Our model addresses these challenges by deriving communication rules from voting rules, ensuring consistency, and avoiding issues that can arise when communication rules are not explicitly stated.

[1] Aristotle suggested that group decision-making is superior to the individual one (Aristotle, 2017).

[2] We complement Goeree and Yariv (2011), where communication is exogenously imposed and costless.

More specifically, when the voting rule requires at least k agents to vote for the same alternative to implement a decision, the group continues communicating until k agents agree to a decision. For instance, in a simple majority group of five agents, communication starts as long as three or more agents wish to communicate and continues until three or more agents are ready to decide.

To analyze the impact of voting rules on communication, we compare simple majority to two forms of unanimity: "veto" unanimity (used by institutions like the U.N. Security Council, the International Monetary Fund, and the World Bank) and "consensus" unanimity (used in U.S. criminal jury trials).[3] These rules have distinct implications for communication. Veto unanimity requires unanimous agreement to start communication and ends if any agent imposes a status-quo decision (e.g., acquittal). Consensus unanimity demands all agents' votes for any decision outcome. Communication starts when at least one agent desires to communicate and ends when all agents agree to stop. Consensus also allows for a "no-decision" outcome, which differs from opting for the status-quo outcome.[4] Therefore, consensus unanimity involves a trade-off between the benefits of thorough information aggregation through extended communication and the risk of ending with a no-decision.

We use this theoretical framework to derive empirical predictions, which we test in a laboratory experiment. Groups of five individuals are tasked with guessing which of two boxes containing a different mix of red and blue balls has been randomly selected by a computer. Members draw a ball from the box to obtain an informative signal before voting on the box's color mix. Before that, they decide whether to communicate with others, which can include sharing the signal or additional information. In the final stage, members cast their votes for a box. We compare the effects of different voting rules on communication and decision outcomes in different experimental treatments, where communication is either free or costly. We also vary the information available to the groups, with some members, "experts," receiving a higher precision signal than others.

In the empirical results, we first examine the communication patterns of groups and find that

[3]The difference between these rules of unanimity is largely overlooked in the literature, which has focused on veto unanimity (e.g. Feddersen and Pesendorfer, 1998; Guarnaschelli et al., 2000; Goeree and Yariv, 2011; Bouton et al., 2017; Le Quement and Marcin, 2020). Two notable exceptions are Coughlan (2000) and Breitmoser and Valasek (2022), which analyze consensus unanimity.

[4]A supermajority rule (e.g., requiring two-thirds of the group votes to implement an alternative) can also lead to a no-decision if there is no status quo option.

costless communication leads to longer conversations. While agents primarily share their private information, they also coordinate their voting for a box, suggesting that communication serves a purpose beyond just aggregating information. We then analyze efficiency in two contexts: informational efficiency, which is a measure of how often the optimal decision was made, and outcome efficiency, which is a measure of how often a wrong decision was avoided.[5]

Free communication yields the highest rate of communication and informational efficiency rates across all voting rules. Majority and consensus unanimity rules show similar efficiency rates, replicating previous findings under our endogenous communication choice framework (Guarnaschelli et al., 2000; Goeree and Yariv, 2011). This result holds for both expert and no-expert treatment conditions. The veto unanimity rule results in slightly lower efficiency rates than the other two rules.

Costly communication, in contrast, draws out differences between voting rules: (i) consensus unanimity drives more communication compared to the other rules; (ii) consensus and majority outperform veto in informational efficiency, and when no-decisions are excluded, consensus also outperforms majority; (iii) consensus unanimity is more likely to minimize wrong outcomes.

Although consensus unanimity generally enhances decision outcomes, individuals may not experience the same payoff advantage when communication is costly (based on individual payoffs), implying that consensus unanimity benefits society at a higher cost for individual decision-makers. As an application, we use these results to establish a basis for the effectiveness of jury trials. Since no-decisions (i.e., mistrials) are never the final node of a game tree, we can compare consensus informational efficiency predictions under two possible game continuations: a retrial or a forced acquittal. Our findings provide suggestive evidence that a consensus unanimity rule with retrial can enhance efficiency (like in Coughlan, 2000), though more empirical testing would be necessary for firm conclusions.

The rest of the paper proceeds as follows. In Section 2, we discuss our contribution to

[5] The consensus unanimity rule is the only rule that generates a no decision which makes a clear comparison of informational efficiency measures across rules more challenging - how should one account for the efficiency of a decision process that doesn't produce a decision? To address this challenge, we use different empirical strategies. First, we use a conservative approach that treats no-decisions and non-optimal decisions as inefficient, while optimal decisions are efficient. Second, we use the same measure but exclude no-decisions from the set of inefficient decisions, so efficiency is only measured on decisions made. Third, we shift the focus from decisions to the outcome where we classify a no-decision and a correct decision as efficient outcomes - in other words, both are considered "not wrong" outcomes.

the existing literature. In Section 3, we describe the theoretical model and derive equilibrium communication and voting predictions. Section 4 describes the experimental design and derives the empirical predictions. Section 5 describes our implementation choices. Section 6 presents our results. Section 7 discusses the implications of our findings for jury trials. Section 8 concludes.

2. Related literature

Our paper contributes to the literature on group decision-making, pioneered by de Condorcet (1785). Early theoretical works, such as those by Austen-Smith and Banks (1996), Feddersen and Pesendorfer (1998), and Myerson (1998), highlighted the negative effects of strategic behavior on information aggregation, including strategic voting under veto unanimity. More recently, Coughlan (2000) demonstrated that unanimity can be efficient when preferences are homogeneous and communication is allowed (see also Austen-Smith and Feddersen, 2006). We build on this literature stream by considering communication costs and a richer information structure (i.e., adding an expert).

In the experimental literature, Guarnaschelli et al. (2000) confirmed the theoretical prediction of Feddersen and Pesendorfer (1998) for strategic voting under veto unanimity. Other studies such as Battaglini et al. (2008); Ali et al. (2008); Morton et al. (2019) have explored the effects of biases on decision outcomes. Goeree and Yariv (2011) were the first to examine communication in the Feddersen and Pesendorfer (1998) model. We extend Goeree and Yariv (2011) by endogenizing communication, adding costs to communication, and studying the implications of adding an expert agent on strategic voting. To our knowledge, this is also the first experiment analyzing the effects of consensus unanimity on outcomes in an endogenous, free-form deliberation setting.[6]

Our results point to consensus unanimity as the most favorable unanimity-type voting rule for policy. This finding is rather new in the literature and complements the recent work by Breitmoser and Valasek (2022), who found that consensus unanimity maximizes efficiency as long as the agents' payoff reflects their vote and not just the group decision. However, while veto unanimity is always dominated by consensus, we show that a majority rule may be suitable

[6]In Breitmoser and Valasek (2022) agents communicate by casting votes over repeated rounds.

for relatively simple information structures and high communication costs.

Our paper is also related to Chan et al. (2018), who developed a model that analyzes costly deliberation and was experimentally tested in Reshidi et al. (2021). This model extends the static binary decision model with communication to a dynamic deliberation game, where the agents trade off the benefit of acquiring more information with the cost of waiting for the final decision outcome. Our model differs in that group members have a common interest in the final decision outcome but are privately informed about the true state of the world, offering a complementary contribution to the topic.

3. A Theoretical Framework

This section presents the model and theoretical predictions underlying the experimental design presented in Section 4. The model considers small groups of agents making a decision, with reference to the jury context for added concreteness.

3.1. Basics

Society (e.g., a benevolent planner) needs to choose a decision alternative $a \in \{0, 1\}$ (e.g., acquit or convict), which is optimal when it matches an unknown and equiprobable state of nature $\theta \in \{0, 1\}$ (e.g., innocent or guilty). The planner delegates the choice of a to a group of $n \geq 3$ agents (e.g., jurors), where n is odd and each agent is indexed by $i \in \{1, \dots, n\}$. The planner sets a voting rule $K \equiv \{k_0, k_1\}$, where $k_0 \in \{1, \dots, n\}$ (resp. $k_1 \in \{n - k_0 + 1, \dots, n\}$) represents the minimum number of votes required to implement $a = 0$ (resp. $a = 1$).

3.1.1. Decision outcomes, voting rules, and information

Once each agent i has simultaneously and privately cast a vote $v_i \in \{0, 1\}$, a decision alternative $a = 0$ (resp. $a = 1$) is implemented, subject to having at least k_0 (resp. k_1) agents vote for that alternative. When the votes for an alternative do not reach the minimum number, a no-decision outcome $\emptyset$ is implemented. Therefore, agents' voting can generate three different outcomes $d \in \{0, 1, \emptyset\}$ (e.g., acquittal, conviction, or hung-jury). We consider three different voting rules: (i) majority, i.e., $K^M = \{\frac{(n+1)}{2}, \frac{(n+1)}{2}\}$; (ii) veto unanimity, i.e., $K^V = \{1, n\}$; and (iii) consensus unanimity, i.e., $K^C = \{n, n\}$. Majority and veto unanimity always result in a decision outcome; consensus unanimity instead results in either a decision outcome or a no-decision.

Before voting, each agent i privately observes an independent informative binary signal $s_i \in \{0,1\}$, with precision $p \equiv \mathbb{P}(s_i = \theta|\theta) > \frac{1}{2}$. We also consider the case where one agent – the "expert" – receives superior information, that is, a non-binary signal with precision e, with $\frac{1}{2} < p < e < 1$, and the remaining $n-1$ agents receive a binary signal with precision p. The information structure is common knowledge in both cases (with or without the expert).

3.1.2. Communication

Before casting their votes, the agents can communicate. Upon observing the signal, each agent i makes a communication choice $c_i^{open} \in \{0,1\}$, where $c_i^{open} = 1$ (resp. $c_i^{open} = 0$) means that agent i would like to open (resp., not open) communication.

Communication and voting rules are often not specified separately in deliberative contexts, as social and cultural norms can influence communication practices. For example, even if an agent can impose a decision, she may not have the power to control communication. In veto unanimity, other agents can continue to communicate and frustrate the veto-wielding agent's power. Communication costs add further economic implications. A coalition with decision-making power may want to end communication to avoid costs, while other agents may want to continue. This creates a problem, as the coalition's authority is thwarted: communication costs are imposed on members of the coalition who would rationally prefer to stop communication and use the formal power from voting rules to govern communication indirectly. Our model works to circumvent some of these issues by directly deriving communication rules from voting rules. By doing so, the relationship between communication and decision-making is made more consistent.

Formally, a group communicates when at least $\Phi_K^{open} \equiv n - \min\{k_0, k_1\} + 1$ agents choose $c_i = 1$; otherwise the agents directly move to vote, without communicating. Under majority, any majoritarian coalition can implement an alternative so that the same coalition can open communication, i.e., $\Phi_M^{open} = \frac{(n+1)}{2}$. Under veto unanimity, communication opens only when all agents choose to communicate, i.e., $\Phi_V^{open} = n$. Finally, under consensus unanimity, n agents must agree to implement an alternative, so communication opens if at least one agent chooses to communicate, i.e., $\Phi_C^{open} = 1$.

During communication, each agent i publicly sends a message $m_i \in M$, where M is the set of all possible messages, including the possibility to remain silent. Communication ends when at least $\Phi_K^{close} \equiv n - \Phi_K^{open} + 1$ agents decide to close communication, choosing $c_i^{close} \in \{0,1\}$, with $c_i^{close} = 1$ (resp. $c_i^{close} = 0$) representing agent i's choice to close (resp. not close) communication.[7] Therefore, under majority $\Phi_M^{close} = \frac{(n+1)}{2}$, under veto unanimity $\Phi_V^{close} = 1$, and under consensus unanimity $\Phi_C^{close} = n$.

We consider both free and costly communication. When communication begins, each agent i pays a cost $\gamma \in [0, 1)$ to aggregate information, which we assume to be invariant across voting rules and group members. Communication is free when $\gamma = 0$.

3.1.3. Payoffs and timing

Each agent's net payoff function, $\pi(d, \theta) - \gamma$, maps a state of nature $\theta \in \{0, 1\}$ and an outcome $d \in \{0, 1, \emptyset\}$ into a payoff $\pi \in \{0, \mu, 1\}$, with $\mu \in (0, 1)$. The agents' payoffs (i) are maximized ($\pi = 1$) when they choose the right decision alternative ($d = \theta$); (ii) are minimized ($\pi = 0$) when they choose the wrong decision alternative ($d \neq \theta$ and $d \neq \emptyset$); and (iii) are equal to μ when they fail to make a decision (i.e., $d = \emptyset$).[8]

The game evolves as follows:

1. Nature randomly selects θ.
2. Each agent i observes s_i.
3. Each agent i chooses c_i^{open}.
4. When at least Φ_K^{open} agents choose $c_i^{open} = 1$, the group communicates (i.e., each agent i sends m_i) until Φ_K^{close} agents choose $c_i^{close} = 1$. Otherwise, agents do not communicate and directly move to vote.
5. Each agent i casts v_i.
6. Net payoffs $\pi(d, \theta) - \gamma$ are realized.

3.2. Efficiency

To assess voting rule efficiency, we use the standard measure of selecting the most likely alternative conditional on the collectively held information (as in Guarnaschelli et al., 2000; Goeree and Yariv, 2011) and refer to this as "informational efficiency."[9] This is equivalent to

[7]Like the requirements to open communication, the requirements to close communication are the same as those to make a decision outcome under a given voting rule, meaning that the coalition of agents that can make a decision also has authority over communication.

[8]Similar to Coughlan (2000), μ can also be interpreted as the reservation payoff of the agents when a decision outcome is implemented in the future either by the planner or another group of agents.

[9]That is the most likely alternative given the group's posterior belief.

maximizing (or minimizing) the probability of a correct (or wrong) outcome under majority or veto unanimity, respectively, based on the available information (i.e., signals). Society's problem can thus be written as

$$\max_{K} \mathbb{P}_K(d = \theta | \{s_1, \ldots, s_n\})$$

where $\mathbb{P}_K(\cdot)$ is the probability measure induced by the voting rule K.

While the optimization problem under majority and veto is dual, it is not under consensus, as consensus can result in no-decision outcomes (i.e., $\emptyset \neq \theta$).[10] To measure efficiency in the case of a no-decision, we identify three approaches: (i) treating no-decisions as informational inefficient; (ii) excluding no-decisions from the set of decisions while retaining the concept of informational efficiency; (iii) treating no-decisions as "not wrong" decisions and focusing on decision outcomes, which we call "outcome efficiency."

The theoretical model focuses on informational efficiency and takes the most conservative approach, treating no-decisions as inefficient decisions.[11] However, the specific institutional details of the deliberation process, such as in jury deliberation, may require different approaches to assess the efficiency of consensus, which we will discuss in Section 7. The empirical analysis (Section 6) examines all three approaches.

3.3. Equilibrium predictions

Before voting for a decision alternative, each agent decides whether to communicate. In the subsequent analysis, we solve the agent's communication choice problem by backward induction. We look for symmetric response equilibria, where agents who receive the same signal play the same strategies (Martinelli and Palfrey, 2020), using Perfect Bayesian Equilibrium as the solution concept of the game.

[10] That is, the maximization problem is isomorphic to

$$\min_{K} \mathbb{P}_K(d \neq \theta | \{s_1, \ldots, s_n\})$$

[11] From a theoretical perspective, when a group communicates, these three approaches coincide because rational agents will never produce a no-decision.

3.3.1. Voting with no communication

Voting behavior, absent communication, is shaped by voting rules. Under majority rule, agents vote sincerely (i.e., $v_i = s_i$) at the equilibrium, independent of their information (Austen-Smith and Banks, 1996; Feddersen and Pesendorfer, 1998).[12] Sincere voting also takes place under consensus unanimity (Coughlan, 2000). In contrast, under veto unanimity, sincere voting is no longer an equilibrium strategy since an agent who receives information favoring the status quo, i.e., $s_i = 0$, may strategically vote against their private information, i.e., $v_i = 1$ (Feddersen and Pesendorfer, 1998).[13]

3.3.2. Voting with communication

When communication takes place, it is a dominant strategy for each agent i to: (i) truthfully share her private information (see Austen-Smith and Feddersen, 2006; Goeree and Yariv, 2011), leading them to form a common posterior belief, $\mathbb{P}(\theta|\{s_1, ..., s_n\})$, and (ii) end communication by choosing $c_i^{close} = 1$. Once agents aggregate their information, they all vote in unison, implying that individual voting behavior is independent of a given voting rule (as in Goeree and Yariv, 2011; Chan et al., 2018).

Since communication can be costly, agents communicate whenever their expected payoff with communication exceeds that without communication; that is when:

$$\underbrace{\mathbb{E}_K[\pi(d,\theta)|s_i]}_{\text{Expected payoff without communication}} \leq \underbrace{\mathbb{E}[\pi(d,\theta)|\{s_1,\ldots,s_n\}] - \gamma}_{\text{Expected payoff with communication}} \tag{1}$$

where $\mathbb{E}_K[\cdot]$ is the expectation operator under voting rule K. Because the likelihood of a correct decision is higher when agents are more informed, when communication is free (i.e., $\gamma = 0$), agents can achieve a higher expected payoff by communicating. However, with costly communication (i.e., $\gamma > 0$), agents trade off the increased likelihood of a correct decision with γ.

From (1) let $\gamma_K^*(s_i)$ be the threshold cost that an agent is willing to pay to choose to

[12] More specifically, if all agents vote according to their signal, a pivotal agent knows that $((n-1)/2)$ agents observed $s = 0$ and $((n-1)/2)$ agents observed $s = 1$. Because these two events cancel each other out, a pivotal agent best responds by voting according to her signal.

[13] See Table A.1 in Appendix A.1 for the equilibrium voting predictions under veto unanimity that are generated by our experimental design.

communicate upon observing signal s_i, that is

$$\gamma_K^* (s_i) \equiv \mathbb{E}[\pi(d,\theta)| \{s_1, \ldots, s_n\}] - \mathbb{E}_K[\pi(d,\theta)|s_i]$$

This threshold equals the expected payoff increase achievable with a fully informed decision relative to a non-informed one. So γ^* can be interpreted as the value of communication.

An agent will choose to communicate under K as long as

$$\gamma \leq \gamma_K^* \tag{2}$$

Comparing thresholds across voting rules, agent i is more likely to communicate under K rather than under $K' \neq K$ whenever

$$\gamma_{K'}^* \leq \gamma_K^* \iff \mathbb{E}_K[\pi(d,\theta)|s_i] \leq \mathbb{E}_{K'}[\pi(d,\theta)|s_i]$$

Since the expected decision payoffs with communication are the same across voting rules, we can compare γ_K^* across different voting rules by looking at the expected decision payoffs without communication. We are now able to formulate the following proposition:

Proposition 1. *When communication is free, $\gamma = 0$, agents communicate under all voting rules and information conditions. As a result, all voting rules are equally informational efficient.*

Proof.

Proposition 1 follows directly from condition (1). With $\gamma = 0$, the agents' choice to communicate is a weakly dominant strategy, as the agents aggregate all private information and make an informational efficient decision.[14] ∎

Proposition 1 is consistent with previous theoretical and empirical results (e.g. Goeree and Yariv, 2011). With costly communication, however, this rule irrelevance result no longer holds, and voting rules do matter. For simplicity, we illustrate the relevance of voting rules by fixing the parameters (i.e., n, p, and e) that we use in our experimental design. Furthermore, we also

[14]Under majority, agents can aggregate their binary signal with a binary vote, meaning that communication has no value. Therefore, for simplicity, we assume that the agents always prefer to aggregate their information through communication when this is free.

set the no-decision payoff sufficiently low to avoid agents opportunistically choosing to secure a reservation value with no communication.[15] More specifically, we assume that:

$$\mu < \overline{\mu} \equiv \frac{1}{\mathbb{P}\left(d = \emptyset \,|s_i\right)} \sum_{\theta} \left(\mathbb{P}_{K'}\left(d = \theta \,|\theta\right) - \mathbb{P}_{K^C}\left(d = \theta \,|\theta\right)\right) \mathbb{P}\left(\theta \,|s_i\right) \tag{3}$$

for any rule $K' \in \{K^M, K^V\}$, with $\mathbb{P}\left(d = \emptyset \,|s_i\right) > 0$. We can now state the following proposition:

Proposition 2. *Under costly communication, $\gamma > 0$, for $K \in \{K^M, K^V, K^C\}$ and $K' \in \{K^M, K^V\}$:*

(i) the communication cost threshold is maximal under consensus , i.e. $\gamma^*_{K'} < \gamma^*_{K^C}$;

(ii) when $\gamma \leq \gamma^*_K$, for any K, agents communicate under all rules, which are equally informational efficient;

(iii) when $\gamma > \gamma^*_K$, for any K, agents never communicate, and only majority is informational efficient;

(iv) when $\gamma^*_{K'} < \gamma \leq \gamma^*_{K^C}$, agents communicate only under consensus. However,

(a) when there is no agent with superior information (i.e., no expert), majority and consensus unanimity are both informational efficient;

(b) when there is an agent with superior information (i.e., an expert), only consensus is informational efficient.

Proof. See Appendix A.1. ■

Proposition 2 shows that the communication behavior of agents depends on voting rules when communication is costly. Under consensus unanimity, agents are more likely to communicate (Case *(i)*) because the probability of selecting a no-decision is positive when they do not communicate. Case *(ii)* is straightforward: all voting rules are equally informational efficient when communication costs are very low, implying that agents always communicate like in Proposition 1. In case *(iii)*, when communication costs are very high, agents *never* communicate and majority is the only informational efficient rule. Without communication, veto unanimity induces strategic voting and is inefficient (Feddersen and Pesendorfer, 1998).

[15] This is consistent with the idea that when agents fail to make a decision, they are frustrated for not being able to fulfill their duty in decision-making (Asch, 1956).

Conversely, majority induces sincere voting and, unlike consensus unanimity, always produces a decision outcome.

Case *(iv)* is more complex. Agents communicate only under consensus unanimity. However, without an expert (i.e., case *(iv)-a*), decision outcomes generated under consensus with communication are equivalent to those generated by majority without communication.[16] Conversely, with an expert (i.e., case *(iv)-b*), only consensus unanimity is informational efficient because communication is always necessary to aggregate (non-binary) private information.[17] Finally, veto unanimity is less desirable than the other two rules, as veto without communication induces strategic voting.

These theoretical statements are used to derive empirically testable predictions in the following experimental design.

4. Experiment Design

The experiments are designed to empirically test how deliberation and collective decision-making are affected by the cost of communication and the underlying information structure (i.e., whether there is an expert in the group of decision-makers) under different voting rules. The design is based on a standard group decision game setting which considers two boxes containing a mix of red and blue balls (as in Guarnaschelli et al., 2000; Goeree and Yariv, 2011). The first box (blue) has 7 blue and 3 red balls, while the second box (red) has 7 red and 3 blue balls. A third box contains an unknown distribution of red and blue balls that matches the first or second box with equal probability. The task facing each group of five subjects (randomly rematched in each round) is to decide which color distribution is the most likely match for the unknown box they are presented with, using a voting rule to make the decision. Treatments vary the voting rule, the cost of communication, and the presence of an expert in a $3 \times 3 \times 2$ experimental design.

[16] Under majority, agents can aggregate all the relevant information through a binary and sincere vote.

[17] Within our experimental design, there is the possibility that an expert under veto can efficiently prevent the group from communicating and implement the status quo alternative (i.e. when the precision of her posterior belief cannot be improved by communication). However, as this happens only under one possible –and rare– signals' realization, we will show in Section 5 that veto unanimity is never (in expectation) optimal compared to majority or consensus unanimity.

4.1. Voting rules

Using a between-subjects design, we implement three voting rule treatments: majority (Maj), veto unanimity (Veto), and consensus unanimity (Cons). Under Maj, three (out of the five) group members need to vote for either the blue or red box to select one of the two boxes. Under Veto, the status quo is defined as the blue box. To select the red box, all five group members need to vote for the red box; otherwise, the group's decision outcome is the blue box. Cons requires all five group members to vote for either the blue or the red box to make a decision; if not, the outcome is recorded as a "no-decision."

4.2. Payoffs

All subjects in a group have identical payoffs. If the decision is correct, each group member receives a payoff of 100 experimental currency units (ECUs). If the group makes the wrong decision, they earn zero. When the group fails to make a decision (a no-decision, only under consensus unanimity), the payoff is 1 ECU. These parameters ensure that a no-decision outcome results in a slightly higher payoff than a wrong decision but also that the payoff is low enough that a group prefers a correct decision to no decision.[18]

4.3. Information

At the beginning of a round, each member of the group selects a ball from the unknown box and observes the color of that ball (i.e., the signal). The draws are made with replacement and are independent between group members. Subjects play nine rounds under this information structure. We refer to these rounds as the No Expert treatment condition. Beginning in the tenth round, one subject per group (the expert), who is randomly chosen at the beginning of each round, observes the color of three simultaneously drawn (i.e., without replacement) balls.[19] In this treatment, the other four group members continue drawing a single ball with replacement.[20] We refer to the last rounds with an expert as the Expert treatment condition.

[18] This design choice is the experimental counterpart of theoretical condition (3), and is set to the lowest possible (positive) integer value to avoid agents strategically opting for a no-decision.

[19] During the experiment, that there is an expert is common knowledge, however, this player is never referred to as "the expert" and their identity is unknown to the others.

[20] The expert's three-ball draw is also put back into the box, so between players the draws are always with replacement.

The No Expert vs. Expert treatment manipulations always take place within a session (within-subjects design) and in the order of No Expert followed by Expert. The No Expert treatment always had 9 rounds, and the Expert Treatment had between 9 and 11 rounds.[21]

4.4. Communication

After receiving their private signals, the subjects are asked if they want to communicate with the other members of their group before the vote. Voting rules also govern communication. Under majority, to communicate, at least three members of the group must choose to start communication. Under veto unanimity, communication begins only if all five members of the group agree to start, while under consensus unanimity, communication begins if at least one member chooses to start communication. If the minimum number of group members required to communicate is reached, the subjects enter into a virtual chat room, where they can free-form chat with the other members.[22]

Using a between-subjects design, the cost of communication is varied between free communication (F), low cost (LC), and a high cost (HC) condition. In the LC treatment, groups are charged 20 ECUs per minute (0.33 per second), while in the HC treatment groups are charged 60 ECUs per minute (1 per second). The cost of communication is subtracted from the final decision payoffs at the end of each round for each group member. In the chat room, there is a "cost clock" showing both the time and the total cost of communicating. Under free communication, the clock only updates with the time of communication.

Groups that enter into communication must also agree to end communication.[23] Under majority, communication ends when at least three members choose to end communication. Under veto, communication ends when one member chooses to end, and under consensus, communication ends when all members of the group choose to end communication. Choices

[21] Sessions 1 - 19 had a total of 20 periods, while Sessions 20-24 had a total of 18 periods. The first nine periods were always played under the No Expert condition and the Expert condition always started in the tenth period. So in the first nineteen sessions, we have two additional expert periods. In the analysis presented in Section 6, we use all data (including the extra Expert periods) since additional analysis comparing the main results between the complete data set and the restricted data set (excluding the extra periods) did not change the qualitative results.

[22] The only restriction placed on the subjects' chat is that the subjects cannot identify themselves. The subjects were also asked to refrain from the use of profanity.

[23] The maximum time allowed for communication is 5 minutes. This is not a binding time limit as the average length of communication is 15.93 seconds, and the maximum length is 174 seconds (2.9 minutes).

to end communication are tabulated in real-time in the chat room until the necessary number is achieved to close the chat room. When the chat room closes, the subjects are immediately directed to a new screen where they cast their vote for a box. If the group chooses not to communicate, the subjects are promptly directed to the voting screen, skipping the chat room.

The votes required for selecting a box and the number of individuals that must choose to start and end communication are summarized in Table 1.

Required Number (out of 5)	Maj	Veto	Cons
Votes to Select Blue Box / Red Box	3 / 3	1 to 4 / 5	5 / 5
Start Communication	3	5	1
End Communication	3	1	5

Table 1: Voting and communication rules

The treatments resulting from the between-subjects/within-subjects hybrid design are summarized in Table 2.

Treatment	Subjects	Description
Maj F	50	simple majority, free communication, no expert/expert
Veto F	45	veto unanimity, free communication, no expert/expert
Cons F	50	consensus unanimity, free communication, no expert/expert
Maj LC	55	simple majority, low cost communication, no expert/expert
Veto LC	55	veto unanimity, low cost communication, no expert/expert
Cons LC	55	consensus unanimity, low cost communication, no expert/expert
Maj HC	60	simple majority, high cost communication, no expert/expert
Veto HC	55	veto unanimity, high cost communication, no expert/expert
Cons HC	60	consensus unanimity, high cost communication, no expert/expert

Table 2: Experiment treatments

The experiment sessions were conducted at the EIEF Laboratory in Rome, Italy. The number of subjects in each treatment is in Table 2. We used the same signal and box draws across all treatments to ensure session comparability. Before each session, subjects were given instructions that included an example of a voting round with communication. Subjects were also given additional instructions when the treatment changed from No Expert to Expert. The experiment was programmed using z-Tree software (Fischbacher 2007). In each session, subjects' earnings in ECUs were exchanged into Euros at a rate of €0.01 per ECU. We gave each subject an endowment of 500 ECUs, to which losses and profits were added during the experiment. Subjects earned an average of €18.87 for an average session length of 90 minutes.[24]

5. Testable Hypotheses

In this section, we present testable hypotheses which are based on the previous theoretical analysis and the experiment parameters.

5.1. Communication

We calculate the communication threshold for each voting rule, γ_K^*, which is defined as the expected payoff with communication less the expected payoff without communication, by using the average expected payoffs with and without communication. These thresholds are presented in Table 3.

γ_K^*	Maj	Veto	Cons
No Expert	0	17.0	66.1
Expert	1.9	19.2	68.3

Table 3: Communication thresholds

The threshold for communication is highest for consensus unanimity, followed by veto and then majority. This ranking between rules remains the same with an expert, but having an expert in the group increases the value of communication and therefore the threshold across all treatments. Note that majority with no expert implies no communication value (i.e., a threshold of 0), as votes perfectly aggregate private information. With this calibration, we develop the following hypotheses for communication.

Hypothesis 1. *When communication is free, groups communicate under all rules.*

Hypothesis 2. *When communication is costly (both LC and HC), the communication likelihood is ranked as $Cons > Veto > Maj$.*

Hypothesis 3. *Experts increase the communication likelihood across all rules.*

[24] Not including the extra periods, subjects earned an average of €17.78 over 19 rounds.

5.2. Efficiency

Using the agents' predicted voting behavior in equilibrium we can also rank the voting rules in terms of informational efficiency, with no-decisions interpreted as inefficient decisions. This ranking is presented in Table 4 and is based on average expected efficiency predictions by treatment, without communication (No Communication) and with communication (Communication).

	No Communication			Communication		
Efficiency	Maj	Veto	Cons	Maj	Veto	Cons
No Expert	1	.70	.17	1	1	1
Expert	.97	.72	.20	1	1	1

Table 4: Equilibrium efficiency predictions

With communication, groups make efficient decisions regardless of the voting rule in place (as in Goeree and Yariv, 2011). When groups choose not to communicate, differences between rules reemerge. In the absence of an expert, majority always leads to fully efficient decisions. However, when an expert is involved, even the majority rule is imperfect in aggregating private information. Meanwhile, the other two rules – consensus and veto – are unlikely to result in efficient decision outcomes due to strategic voting behavior in the case of veto and the high risk of no-decision outcomes without coordination in the case of consensus (see Section 3.2).[25]

As the agents have the freedom to choose whether to communicate or not, the efficiency predictions need to account for the likelihood of communication across the different voting rules, which depends on the expected costs and benefits of communication (i.e., the threshold). Theoretically, communication should be brief and minimally expensive, with the cost typically falling below the threshold. In practice, however, communication may serve other purposes than just information sharing. Hence, we need empirical evidence to answer the question of the role of communication in decision-making. Based on the analysis above, we propose the following hypotheses regarding informational efficiency.

Hypothesis 4. *When communication is free, all voting rules are equally efficient.*

[25]Note, however, that if no-decisions are omitted, consensus becomes fully efficient.

This prediction is straightforward. When communication is free, groups always prefer to communicate, regardless of the voting rule, and always make an informational efficient decision. For the costly treatments, using the calibration of cost thresholds in Table 3 and assuming that the average communication time spent by agents is above the cost threshold for Veto but below that of Cons – meaning they always communicate in Cons and never in Maj and Veto, we formulate the following predictions:

Hypothesis 5. *When communication is costly with no expert, informational efficiency is ranked* $Cons = Maj > Veto$.

Hypothesis 6. *When communication is costly with an expert, informational efficiency is ranked* $Cons > Maj > Veto$.

6. Results

6.1. Communication

We begin our analysis of the experimental data with the frequency of individual votes for communication within a group by treatment in Figure 1. The x-axis is the number of choices within a group for communication. Groups almost always unanimously choose to communicate when communication is costless (F) in all voting rules. However, with communication costs, substantial differences emerge across voting rules in both the LC and HC treatments, as shown by the left shift of the distribution against communication. Consistent with the theory, the value provided by experts in communication helps mitigate this shift. Regression analysis confirms this visual evidence (see appendix, Table A.3).[26]

Whether a group enters into communication depends on the number of choices for communication and the voting rule (see Table 1). In Table 5, we present the percentage of groups who entered into communication.

Hypothesis 1 predicts that when communication is free (F), groups always communicate (i.e., 100%) under all voting rules and information conditions. This hypothesis is fully supported by

[26]The LC and HC treatment significantly reduce ($p < 0.01$) individual choices for communication under all rules. Experts primarily play a role when communication is costly in the consensus treatments, significantly increasing ($p < 0.01$) choices for communication in both Cons and Veto. This effect is less pronounced under Maj, with the only significant positive impact occurring under LC ($p = 0.005$). Differences in the choices for communication between the LC and HC treatments are not statistically significant (at the 5% level) in either the No Expert or Expert treatments across all rules.

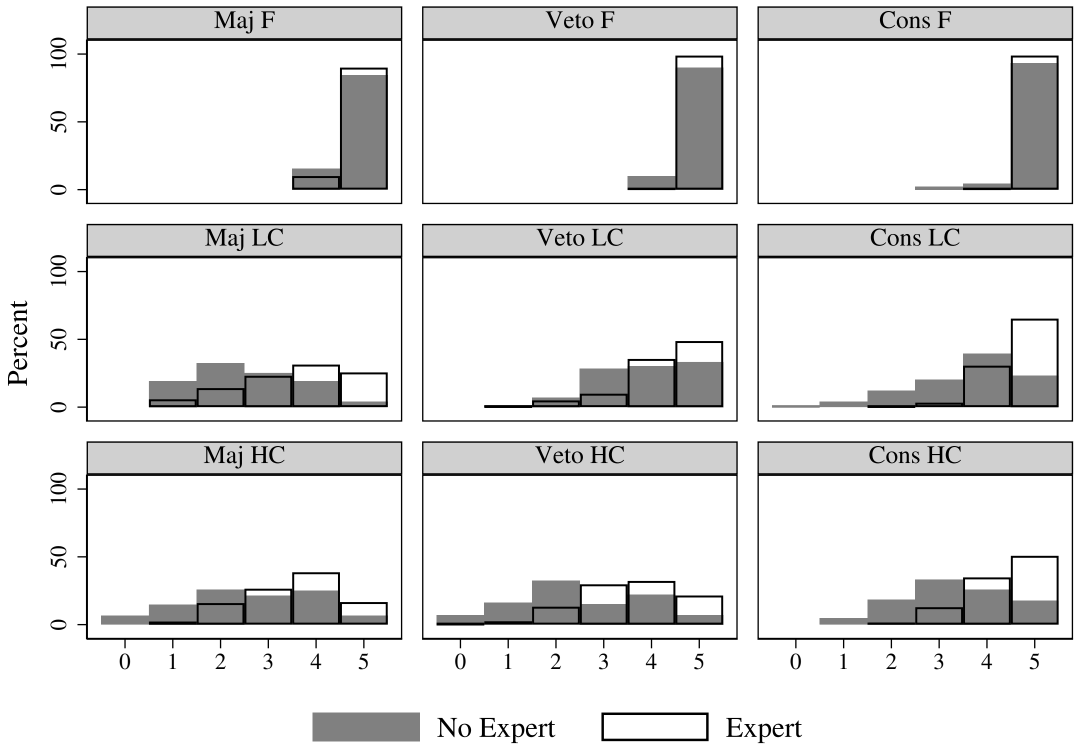

Figure 1: Frequency of individual votes for communication within a group

	F			LC			HC		
	Maj	Veto	Cons	Maj	Veto	Cons	Maj	Veto	Cons
No Expert	100	90.0	100	48.5	33.3	99.0	52.8	7.1	100
Expert	100	98.9	100	80.2	48.8	100	81.8	21.5	100

Table 5: Percentage of communicating groups

Maj and Cons. Under Veto, rates are slightly lower; 8 groups out of 80 chose not to communicate with no expert, and with an expert, only 1 group out of 89 chose not to communicate.[27] Even though rates are lower than 100% under Veto, free communication does result in the highest rates of communication for this rule when compared to rates under costly communication.

Hypothesis 2 predicts that when communication is costly (LC and HC), the frequency of communication is ranked $Cons > Veto > Maj$ under both information conditions. The rates of communication are highest under Cons for both cost conditions, consistent with our theoretical

[27]Fisher's exact tests only support Hypothesis 1 under Expert conditions, $p = 0.331$. No Expert conditions find significant differences between Veto and the other two rules, $p < 0.001$.

prediction. Maj, however, results in much higher rates of communication than Veto, which is in contrast to the theory.[28]

Empirical Result 1. *Across cost treatments, the rate of communication is highest with free communication; across voting rules, when communication is costly, the rate of communication is highest under consensus unanimity.*

Hypothesis 3 predicts that experts increase communication. We find support for this hypothesis across all rules, with the largest rate increase under Maj with costly communication as groups are, on average, 30% more likely to choose to communicate with an expert. Veto only averages a 15% increase in communication under costly conditions with an expert.[29]

Empirical Result 2. *Experts increase communication rates under all treatment conditions.*

6.1.1. Analysis of Communication

Theoretically, communication between agents serves the purpose of sharing information, and any additional communication beyond this is redundant. However, we may observe behavioral deviations from this prediction toward richer dialogue. In our experiment, subjects are able to communicate freely using electronic chat so we use the qualitative data from these conversations to gain insight into what individuals actually choose to discuss.

We identified 12 major categories (nodes) of discussion, which are provided in Table 6. Two graduate students independently coded each message sent in the e-chat into the identified categories. For example, if a message contains the sentence "I have a blue signal," this message is coded as *Sharing Information*, while a message such as "Let's vote for the red box" is coded as *Coordinating on a Decision*.[30] For each category, we report the relative frequency of groups out of all groups in that particular condition (e.g., Maj F) which had the discussion category in their group chat.

[28] Fisher's exact tests demonstrate significant differences in communication rates between rules under all treatment conditions, i.e. under both LC and HC and No Expert/Expert ($p < 0.001$).

[29] Fisher's exact tests on data where differences are observed from the expert, i.e., Veto under free communication and Maj and Veto under costly communication, demonstrate significant differences in favor of Hypothesis 3, ($p \leq 0.014$). The only group that did not choose communication under Cons was under the no expert condition, so the expert condition also trivially increases the communication frequency under Cons.

[30] For a complete description of the chat coding methodology, see Appendix Table A.2.

The majority of communication falls under the category *Sharing Information* across all treatments and voting rules.[31] Almost all communicating groups shared signal information.[32] The second most discussed category is *Coordination on a Decision.* The highest levels are observed under free communication, where differences between voting rules are minimized. When communication is costly, the differences in the level of coordination discussion between voting rules become more prominent.[33] Moving from free to low cost and then to a high cost of communication, the share of messages dedicated to coordination monotonically decreases under both Maj and Veto. In contrast, all groups under Cons continue to communicate about coordination, regardless of the cost. This aligns with the idea that the discussion of coordination is more critical under consensus unanimity to avoid a no-decision outcome.

The last trend to note highlights the opportunity cost of discussion of non-essential topics (i.e., any category between 3 and 12). While free communication results in a high frequency of all types of chat, costly communication significantly reduces this variety, shifting the focus to the essentials: *Sharing Information* and *Coordination on a Decision.*

At the bottom of Table 6, we also report the average length of communication (in seconds) for each treatment condition. Unsurprisingly, free communication results in the longest communication, while costly conditions reduce communication time. Comparing communication length across rules, we observe that Cons always leads to the longest communication.[34] Comparing the No Expert and Expert conditions, we observe that communication is shorter with an expert. There are two possible explanations. First, an expert may help the agents coordinate given the extra information they possess, reducing the group's communication time. Second, the expert condition was in the last half of the session, so the time reduction may be due to the learning effect of playing the game through multiple rounds. To disentangle these possibilities,

[31]While theoretically predicted in most cases, it was not predicted under Maj/No Expert because the voting rule perfectly aggregates the information. Notably, this high frequency of sharing information holds even under costly communication (LC and HC).

[32]Only three groups, one in each of the Cons treatments (F, LC, and HC), were not coded as having explicitly shared information. In the C and HC treatments, this occurred in the first period of play, and in the F treatment, this occurred in Period 9. In all cases, the conversation was dominated by a discussion of coordination rather than signal sharing.

[33]The relatively high frequency of coordination discussion across rules suggests the behavioral hypothesis that subjects may not always make perfect Bayesian updates and so communication plays a role beyond that of simply sharing information.

[34]This is consistent with the observation that the Cons rule requires additional communication to coordinate a decision outcome.

regression analysis presented in the Appendix, Table A.4, examines the impact of the voting rule, the presence of an expert, and the round of play (Period) on communication time under free and costly communication. These results point to a learning effect as the coefficient on the variable Period is always significant ($p \leq 0.012$) and negative, meaning that subjects need to communicate less with more experience. Simultaneously, almost all coefficients associated with the expert treatment are either positive or insignificant, so experts are mainly increasing the length of communication once the round of play is controlled for in the analysis.[35]

[35]The one exception is the Cons LC treatment, where an expert significantly reduces communication time ($p = 0.004$).

Chat category	Information	F			LC			HC		
		Maj	Veto	Cons	Maj	Veto	Cons	Maj	Veto	Cons
1. Sharing Information ($\kappa = .96$)	NE	1	1	.99	1	1	.99	1	1	.99
	E	1	1	1	1	1	1	1	1	1
2. Coordination on a Decision ($\kappa = .91$)	NE	.98	.90	1	.69	.55	1	.30	.29	1
	E	.99	.89	1	.68	.41	1	.32	.12	1
3. Asking for Information ($\kappa = .74$)	NE	.46	.14	.30	.10	.09	.17	.07	.29	.06
	E	.27	.18	.13	.01	.02	.15	.03	.04	.05
4. Asking for Coordination ($\kappa = .86$)	NE	.74	.67	.76	.38	.03	.59	.18	.29	.25
	E	.47	.40	.46	.11	.02	.34	.07	0	.13
5. Summarizing Information ($\kappa = .70$)	NE	.49	.21	.36	.02	0	.15	0	0	.02
	E	.29	.09	.28	0	.02	.08	0	0	.04
6. Reference to Time ($\kappa = .66$)	NE	.08	.04	.41	0	.03	.07	0	0	.02
	E	.18	.01	.34	0	0	.01	0	.04	.02
7. Reference to Communication Cost ($\kappa = .49$)	NE	.08	0	.02	0	0	.02	0	0	.01
	E	.06	0	.01	0	0	0	0	0	0
8. Asking to Communicate More ($\kappa = .13$)	NE	.03	0	.03	0	0	0	0	0	0
	E	.01	.01	0	0	0	.01	.02	0	0
9. Asking to Stop Communication ($\kappa = .83$)	NE	.32	.04	.78	.10	0	.83	.07	0	.56
	E	.17	0	.59	0	0	.51	.01	0	.36
10. Agreement ($\kappa = .80$)	NE	.82	.68	.86	.44	.03	.91	.09	.29	.46
	E	.71	.54	.77	.06	0	.74	.02	0	.30
11. Disagreement ($\kappa = .54$)	NE	.13	.10	.07	.02	0	.06	0	0	.01
	E	.08	.01	.06	.03	0	.02	0	0	0
12. General Discussion about Game ($\kappa = .61$)	NE	.44	.28	.36	.04	.03	.26	.09	0	.06
	E	.2	.1	.14	.02	0	.07	0	0	.04
Avg. Time Communicating (seconds)	NE	84.2	40.8	57.7	14.7	10.5	39.1	10.5	12.9	17.5
	E	45.9	23.5	33.3	9.2	6.3	22.8	7.0	6.2	10.7

Table 6: The relative frequency of coded chat categories by treatment and information condition, i.e., without an expert (NE) or with an expert (E). Next to each category, we include Cohen's κ coefficient (Cohen, 1960) of inter-rater agreement, measured as $\kappa = .01$-.20 (slight), .21-.40 (fair), .41-.60 (moderate), .61-.80 (substantial), $>$.80 (almost perfect). The bottom row of the table presents the average time spent communicating (in seconds) by treatment.

6.2. Efficiency

In this section on efficiency, we first present the results on informational efficiency, which is defined by the optimal decision-making of the group. We then turn to the results for outcome efficiency, focusing on how often a wrong decision was avoided.

Prior to this discussion, since the results on efficiency may differ depending on how a no-decision outcome in the Cons rule is considered, we provide an overview of the relative frequency of no-decisions in Table 7.

	F	LC	HC
No Expert	1.1	8.1	15.7
Expert	3.3	4.1	7.6

Table 7: Relative frequency of no-decision outcomes under Cons

The clear implication is that as the cost of communication increases, the frequency of no-decision outcomes also increases.[36]

6.2.1. Informational Efficiency

We provide the relative frequency of informational efficient decisions across treatments in Table 8. Under all voting rules, if a group reaches an informational efficient decision (the most likely color was selected given all available information in the group), this decision is recorded as one, otherwise zero. In the Cons treatment, no-decisions are either treated as informational inefficient, i.e., recorded as zero, or omitted (omitted results reported in parentheses).

	F			LC			HC		
	Maj	Veto	Cons	Maj	Veto	Cons	Maj	Veto	Cons
No Expert	95.6	86.3	94.4 (95.5)	75.8	76.8	82.8 (90.1)	87.0	70.7	81.5 (96.7)
Expert	94.4	89.9	95.6 (98.9)	86.8	71.1	90.1 (94.0)	92.4	55.4	87.1 (94.3)

Table 8: Frequency of informational efficient outcomes. Values inside parentheses are calculated on decisions only, i.e., omitting no decisions.

[36]The bottom row of Table 6 demonstrated that higher communication costs result in shorter communication length, which likely directly impacted the ability of a group to reach full consensus. There are also plausible time pressure arguments that could be made given that groups participating under the Cons rule were more likely to have a discussion related to time (see Table 6, category 6).

Within each voting rule, informational efficiency is highest with free communication, although groups never achieve 100% efficiency as predicted. Comparing across rules, under the F treatment, Maj and Cons result in similar efficiency rates while Veto performs slightly worse. Costly communication (LC and HC) reduces informational efficiency across all rules. Our predicted efficiency for both costly treatments is $Cons = Maj > Veto$ with no expert and $Cons > Maj > Veto$ with an expert. While both Maj and Cons consistently outperform Veto, the relative efficiency of Cons over Maj is less clear as it depends on the type of informational efficiency we consider. When we consider no-decisions as inefficient, Cons outperforms Maj in the LC treatment without and with an expert, while Maj outperforms Cons in the HC treatment without and with an expert. If we omit no-decisions, Cons outperforms Maj in all treatments.

We also observe that Cons does not produce a level of efficient decisions consistent with the level of communication it induces (almost 100%). Theoretically, when agents communicate they should always produce an efficient decision and a no-decision should not occur. This discrepancy highlights the behavioral result that subjects may actually fail to coordinate on a decision outcome, even when they share all the relevant information.[37]

[37]The percentage of no-decisions in Table 7 shows a positive relationship between the frequency of no-decisions and the cost of communication. Consistent with this, we also observe that the change in informational efficiency is increasing in the communication cost, and this holds for both the no expert and expert conditions. This suggests that coordination on a decision outcome under Cons likely requires communication beyond sharing information, and when communication is more costly, the agents fail to coordinate at a higher rate.

	Decisions + No Decisions				Decisions Only			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Informational Efficiency	Free	Costly	No Expert	Expert	Free	Costly	No Expert	Expert
Veto	-0.610*	-0.267	-0.610**	-0.318***	-0.610*	-0.267	-0.610**	-0.318***
	(0.318)	(0.201)	(0.297)	(0.083)	(0.318)	(0.201)	(0.297)	(0.083)
Cons	-0.108	0.018	-0.108	0.108	-0.005	0.605***	-0.005	0.680**
	(0.199)	(0.219)	(0.185)	(0.185)	(0.183)	(0.232)	(0.171)	(0.288)
LC			-1.003***	-0.477**			-1.003***	-0.477**
			(0.216)	(0.196)			(0.216)	(0.196)
HC			-0.573	-0.159*			-0.573	-0.159*
			(0.389)	(0.084)			(0.389)	(0.084)
Veto×LC			0.642*	-0.242			0.642*	-0.242
			(0.330)	(0.202)			(0.330)	(0.202)
Veto×HC			0.026	-0.981***			0.026	-0.981***
			(0.469)	(0.129)			(0.469)	(0.129)
Cons×LC			0.357	0.062			0.595***	-0.244
			(0.232)	(0.263)			(0.223)	(0.350)
Cons×HC			-0.124	-0.410			0.716	-0.537
			(0.444)	(0.284)			(0.450)	(0.382)
Expert (Exp)	-0.108	0.364*			-0.108	0.364*		
	(0.107)	(0.201)			(0.107)	(0.201)		
Veto×Exp	0.292	-0.662***			0.292	-0.662***		
	(0.241)	(0.219)			(0.241)	(0.219)		
Cons×Exp	0.216	-0.082			0.686**	-0.306		
	(0.281)	(0.203)			(0.322)	(0.237)		
Constant	1.701***	0.902***	1.701***	1.593***	1.701***	0.902***	1.701***	1.593***
	(0.183)	(0.188)	(0.171)	(0.072)	(0.183)	(0.188)	(0.171)	(0.072)
Observations	529	1,360	872	1,017	525	1,320	846	999

Table 9: Probit regressions on an informational efficient decision, standard errors clustered at the session level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

To formally test our hypotheses on informational efficiency, Table 9 provides probit regressions where the dependent variable is equal to 1 if the group made an informational efficient decision and 0 otherwise. Standard errors are clustered at the session level. Models 1 - 4 are based on all data, counting no decisions as inefficient, and Models 5 - 8 repeat the first four models on the restricted data set that omits no decisions. Models 1 and 2 (5 and 6 for decisions only) restrict the data by cost treatment to isolate the differences between voting rules within a particular cost condition, allowing us to directly test our hypotheses. We pool the LC and HC data in the costly treatments (Models 2 and 6) since the hypothesis predictions are the same. We also test for behavioral differences resulting from differing cost conditions in the last models (3, 4, 7, and 8) which are separately run for the No Expert and Expert conditions. All independent variables represent treatment dummy variables that are equal to 1 in the event the treatment was in place and 0 otherwise.[38]

Hypothesis 4 states that when communication is free, decisions will be efficient across all rules and information conditions. This is partially confirmed in Model 1 of Table 9 which shows that while efficiency levels in Maj and Cons are not statistically different from each other, Veto performs worse.[39] The Veto difference is relatively weaker under no expert conditions as the coefficient on Veto and the post-estimation test on Veto versus Cons ($p = 0.064$) are only significant at the 10% level. With an expert, Veto performs significantly worse than both Maj ($p < 0.001$) and Cons ($p = 0.024$). When the measure of informational efficiency focuses only on decisions actually taken (Model 5), the main results remain except for one case - under the expert treatment Cons now significantly outperforms Maj ($p = 0.028$).

Empirical Result 3. *Free communication maximizes informational efficiency and minimizes differences across voting rules. When no-decisions are omitted, Cons outperforms the other rules under the Expert treatment.*

Hypothesis 5 predicts that when communication is costly, and there is no expert, the efficiency rank order will be $Maj = Cons > Veto$. Model 2 shows no significant differences between Maj and either Veto or Cons, but post-estimation tests demonstrate a significant difference between Veto and Cons ($p = 0.030$), providing only partial support for Hypothesis 5. Model 6 reruns Model 2 but with no decisions omitted. In this case, Cons results in a sig-

[38] Alternative specifications, where each model is broken down by cost type, are presented in the appendix, Table A.5.

[39] Post-estimation test for differences between Maj and Cons under expert conditions results in ($p = 0.587$).

nificantly higher level of informational efficiency than both Veto and Maj without an expert ($p \leq 0.010$).

The prediction for the expert treatment in Hypothesis 6 states that under costly communication the efficiency rank order will be $Cons > Maj > Veto$. Post-estimation tests from Model 2 demonstrate that with an expert both Cons and Maj outperform Veto ($p < 0.001$), but Cons and Maj are not statistically different from each other ($p = 0.725$), again providing only partial support for this hypothesis. When we exclude no-decisions (Model 6), the qualitative results for the expert case remain unchanged; no significant differences are found between Maj and Cons ($p = 0.110$) but both rules are significantly higher than Veto ($p < 0.001$).

Empirical Result 4. *Under costly communication, Maj and Cons result in a higher level of informational efficiency than Veto. When no-decisions are omitted, Cons also outperforms Maj in the No Expert treatment.*

To examine the behavioral responses to differing cost conditions we turn to Models 3 and 4 (7 and 8 on the restricted data) for the No Expert and Expert conditions, respectively. These models demonstrate that while costly conditions (LC and HC) typically lower efficiency from what is observed under the baseline free condition (F), there is no clear monotonic relationship moving from F to LC to HC.[40]

6.2.2. Outcome Efficiency

We now turn to the efficiency of decision outcomes. There are three possible outcomes: a correct decision where the box color chosen by the group matches the true color of the unknown box, a wrong decision where the chosen box color does not match the true color of the unknown box, and a no-decision outcome where the group fails to make a decision. To define a binary variable for outcome efficiency we focus on "not wrong" as the efficient outcome and wrong decisions as inefficient. Under this approach, a no-decision outcome, unique to Cons, is interpreted as a "not wrong" decision in addition to correct decisions. We compare voting rules to determine which minimizes the rate of wrong decisions and consequently maximizes outcome efficiency. Analyzing outcome efficiency allows us to investigate the primary benefit of having

[40] A priori, we anticipated a larger difference between the LC and HC treatments, but given that the design of cost treatments is between-subjects rather than within-subjects, it is not surprising that we do not find a consistent effect as there likely is heterogeneity in cost tolerance among subjects.

an expert, which is to reduce the probability of making a wrong decision.[41]

	F			LC			HC		
	Maj	Veto	Cons	Maj	Veto	Cons	Maj	Veto	Cons
No Expert	26.7	31.3	20.0	32.3	28.3	31.3	24.1	29.3	23.2
Expert	17.8	15.7	7.8	19.0	31.4	9.9	15.9	46.3	15.2

Table 10: Frequency of wrong decisions.

Table 10 provides the relative frequency of wrong decisions (inefficient outcomes) across rules by treatment. The clear pattern is that Cons is associated with a lower frequency of wrong decisions than the other rules.[42] Having an expert in the group always reduced the rate of wrong decisions under Maj and Cons, but only improved decision-making under Veto when communication was free.

[41]In theory, a communicating group will make an informational efficient decision with or without an expert, but having the expert increases the information available to the group, lowering the probability of a wrong decision. Even without communication, having at least one agent with a more informative signal (the expert) is helpful as that agent can vote with better information.

[42]The one exception to this is under LC with no expert where Veto has a slightly lower rate of wrong decisions than Cons.

Wrong Decision	(1) Free	(2) LC	(3) HC	(4) Maj	(5) Veto	(6) Cons
Expert (Exp)	-0.301***	-0.419**	-0.294***	-0.950***	0.695***	-0.784***
	(0.066)	(0.166)	(0.032)	(0.221)	(0.188)	(0.252)
LC				0.201*	0.071	0.433***
				(0.104)	(0.073)	(0.119)
HC				-0.051	0.139	0.079
				(0.152)	(0.090)	(0.138)
LC×Exp				-0.183	0.614***	-0.404***
				(0.250)	(0.222)	(0.144)
HC×Exp				-0.117	0.962***	0.244
				(0.164)	(0.230)	(0.201)
Hard				0.892***	0.552***	0.916***
				(0.080)	(0.198)	(0.202)
Hard×Exp				0.587***	0.052	0.069
				(0.198)	(0.208)	(0.222)
Communication Time				0.000	0.004	-0.001
				(0.001)	(0.004)	(0.002)
Period				0.042	-0.116***	0.031*
				(0.028)	(0.020)	(0.018)
Veto	0.134	-0.116	0.159			
	(0.178)	(0.100)	(0.111)			
Cons	-0.219***	-0.028	-0.030			
	(0.061)	(0.129)	(0.107)			
Veto×Exp	-0.216	0.509***	0.746***			
	(0.264)	(0.170)	(0.123)			
Cons×Exp	-0.278***	-0.380*	-0.002			
	(0.066)	(0.206)	(0.123)			
Constant	-0.623***	-0.459***	-0.704***	-1.401***	-0.277	-1.531***
	(0.000)	(0.088)	(0.093)	(0.206)	(0.225)	(0.190)
Observations	529	660	700	640	609	640

Table 11: Probit regressions on a wrong decision, standard errors clustered at the session level. *** p<0.01, ** p<0.05, * p<0.1

Table 11 examines the probability of reaching a wrong decision (inefficient outcome) using probit regressions. The dependent variable is equal to 1 in the case of a wrong decision and 0 in the case of a correct decision and the case of a no-decision. Standard errors are clustered at the session level. Models 1 - 3 are restricted by cost treatment and are used to compare voting rules across the cost conditions. Models 4 - 6 are restricted by voting rule, providing a clearer picture of the impact of an expert within each voting rule.[43] In these last three models (4 - 6), we introduce three new behavioral control variables. Hard is a binary variable used to measure the difficulty level of the decision. It is based on the probability of making the correct decision given all information in the group (posterior probability) and is equal to 1 if the probability of choosing the correct box is less than 0.927 and 0 otherwise.[44] Communication time is the length of time in seconds the group communicated,[45] and Period is the round of play.

In Model 1, the negative and significant coefficient on Cons and post-estimation tests between Cons and Veto ($p = 0.061$) demonstrate that when communication is free, Cons is significantly less likely to result in a wrong decision, and adding an expert only strengthens this result (post-estimation tests between Cons and Maj or Veto with an expert, $p < 0.001$).

Empirical Result 5. *Under free communication, Cons minimizes the likelihood of wrong decisions.*

Models 2 and 3 compare the rules under costly conditions. With no expert, Cons only outperforms Veto under HC conditions ($p = 0.019$) and no other significant differences are found ($p \geq 0.151$). With an expert, Cons outperforms both Veto ($p < 0.001$) and Maj ($p = 0.054$) under LC conditions (Model 2). Higher costs of communication (Model 3) lead to Cons only outperforming Veto ($p < 0.001$) as no statistical differences are found between Maj and Cons ($p = 0.825$).

Empirical Result 6. *Under costly communication, Cons always minimizes the likelihood of wrong decisions compared to Veto but only minimizes wrong decisions more than Maj when costs are relatively low (LC) and there is an expert.*

To examine the impact of an expert, we shift to Models 4 - 6. In theory, an expert should lower the probability of a wrong decision. The negative and significant coefficients on the variable Expert in Models 4 and 6 provide evidence in support of the helpful role of the expert

[43]Table A.6, presented in the appendix presents a specification identical to that shown in Table 9 for the comparison models using a wrong decision as the dependent variable.

[44]The highest probability is 0.99 which occurs, for example, in the expert treatment when the expert has an all red signal (RRR) and the four remaining signals are also all red (RRRR). The lowest probability is 0.541 and is also found in the expert treatments (expert draws BBB, other group members draw RRRR). In the non-expert treatments, the highest probability is 0.98 and the lowest probability is 0.7. The defining probability of 0.927 is associated with a draw of 1 blue ball (4 red) or 4 blue balls (1 red) in the no expert treatment. Probabilities below 0.927 are categorized as hard.

[45]Communication time is set to 0 in groups that chose not to communicate.

for Maj and Cons under free communication. We also find that this result continues to hold when communication is costly (post estimation tests: $p < 0.001$ under LC and HC for Maj; $p < 0.001$ under LC and $p = 0.091$ under HC for Cons). However, in contrast to predictions, Experts are not helpful under Veto. Model 5 demonstrates that experts actually increase the probability of a wrong decision under Veto and this holds under all cost conditions ($p < 0.01$).[46]

Empirical Result 7. *Experts reduce the likelihood of a wrong decision under Maj and Cons. Experts increase the likelihood of a wrong decision under Veto.*

6.3. Welfare

Efficiency metrics can be used as a measure of the social welfare brought about by group decisions, which can be different from the individual welfare of the agents involved. This discrepancy may arise because of two reasons. First, the costs of decision-making are borne by group members while both the group and society share the benefits. More communication can improve decision quality, but it can reduce individual payoffs, creating a positive externality for society. Second, a no-decision represents a failure for the group, but not necessarily for society, which can delegate decision-making to another group or authority.[47] Individual and social welfare, therefore, can coincide only when communication is free and the voting rule always produces a decision (e.g. Guarnaschelli et al., 2000; Austen-Smith and Feddersen, 2006; Goeree and Yariv, 2011).

In the following, we provide the agents' individual (net) payoffs as a measure of individual welfare. Recall that decision payoffs across the group were identical and equal to 100 for a correct decision, 0 for a wrong decision, and 1 for a no-decision. Communication costs were also identical across group members and the final individual (net) payoffs were equal to the decision payoff less any communication costs.

[46] This may seem surprising that it also holds under free communication since Table 10 demonstrates a drop in wrong decisions with an expert for Veto. However, Model 6 controls for learning effects through the inclusion of the variable Period. The coefficient on Period is negative and significant, so the drop in wrong decisions is more of a learning effect as the Expert treatment was always conducted in the second half of the experiment.

[47] Group members are also part of society. However, it is reasonable to assume that their individual failure as group members is more significant to them than the benefit they can extract from future decision-making.

	F			LC			HC		
	Maj	Veto	Cons	Maj	Veto	Cons	Maj	Veto	Cons
No Expert	73.3	68.8	78.9	67.1	71.4	57.5	70.4	69.8	43.8
Expert	82.2	84.3	88.9	80.4	68.3	84.1	78.4	52.4	66.7

Table 12: Average individual earnings (net communication costs).

Table 12 shows the average individual earnings for each treatment. Assuming a random decision as a benchmark performance measure with an expected payoff of 50,[48] the average earnings with no expert are higher than the benchmark, except for Cons under HC where the average payoff is only 43.8. With an expert, earnings are higher than the benchmark across rules and experts increase earnings in all cases but costly Veto (LC and HC) due to the higher incidence of wrong outcomes.

In sum, while Cons often outperforms the other rules in terms of social welfare measured through efficiency, in terms of individual welfare, when communication bears a high cost or information is relatively simple (no expert), Cons is weaker than Maj and even Veto.

7. An Application: Juries

Our experimental results considered three different approaches to informational efficiency that differ only on how no-decision outcomes are treated. However, if a no-decision outcome is not final for society, then social welfare should be measured based on how other societal institutions fill in the gap of no-decisions. This analysis goes beyond the scope of this research but is relevant in the jury context.[49] When a jury produces a no-decision, the game does not end but instead can lead to a retrial or a status-quo decision, as the government (e.g., the prosecutor) can decide either to opt for retrial or acquittal. Table 13 shows the efficiency of using a rule of consensus unanimity in jury trials based on the respective occurrence of a status-quo decision or retrial after a no-decision.[50] Comparing Table 13 with Table 8, we observe a clear improvement in efficiency when there is a retrial. However, imposing a status-quo decision makes consensus unanimity similar to veto. It is important to note that the assessment of these alternative voting rules for the jury context depends on the principles governing a given legal regime, where a

[48]We assume a random decision chooses the box matching the true state of the world with 50% probability with zero communication costs and no chance of a no-decision.

[49]For a historical account of juries, see Langbein et al. (2009), Part III.

[50]The details of this computation are available in Appendix A.2.3. This approach differs from that used in Coughlan (2000), which uses exogenous mistrial utilities.

conviction may only be inflicted when jurors are certain beyond any reasonable doubt. The implementation of a status quo decision (acquittal) may be defensible as a deontological choice desirable for society but for reasons other than informational efficiency.

No Decisions as:	Acquittal			Future Trials		
	F	LC	HC	F	LC	HC
No Expert	95.6	83.8	88.0	94.8	89.7	96.3
Expert	97.8	92.6	90.9	99.6	96.1	97.7

Table 13: Frequency of informational efficient decisions under alternative jury scenarios

Our study of consensus unanimity in the jury context is relevant to the debate on the normative desirability of the rule (Sunstein, 2014). Other scholars argue that the consensus rule is too costly and should be replaced with a supermajority or simple majority rule. However, our results suggest that consensus has an overlooked benefit of inducing more communication among jurors, which facilitates the aggregation of private information.

An objection to this argument is that jurors may not reveal their private information truthfully if they have heterogeneous preferences. However, our setting with agents having homogeneous preferences can be seen as reflecting an ideal jury, where selected jurors have non-extreme and more aligned moral views. Moreover, communication may also lead to changes in jurors' preferences about the threshold of evidence needed to condemn a defendant, ultimately leading to more convergence and a higher likelihood of reaching a consensus. These considerations highlight the importance of the jury selection process in eliminating jurors with extreme views and selecting decision-makers based on facts rather than preferences.

8. Concluding remarks

We conducted an experiment on endogenous costly communication in a collective decision-making context and found that voting rules impact voting and communication behavior, with differing effects on the decision outcome. Our results indicate that voting rules are communication devices and affect the deliberative process of collective decision-making.

Our findings suggest that consensus unanimity involves a trade-off between inducing more communication and better information aggregation but risks a no-decision because of coordination failure. However, to the extent agents have "similar" preferences and their "frictions" are information dependent, the risk of coordination failure is small (or less relevant than what we estimated in the experiment). In support of this conclusion, the data on the use of consensus in jury trials show that the frequency of no decisions is low (about 5.5%, as reported in Hans et al., 2003). This might be because in a real deliberation room, unlike in our experimental setting, agents sit face-to-face and exchange information with immediate feedback. Further, even when agents are not perfect Bayesian updaters, they may have superior knowledge about the deliberative procedure and the governing voting rule relative to the subjects in our experiment. This means that ending up with a no-decision "by mistake" is not a likely hypothesis. Of course, this does not exclude that agents might end up with a no-decision intentionally. Therefore, real institutions should be designed to avoid agents cashing a high individual payoff in case of disagreement and a no-decision. To work, consensus necessarily requires the members of a group to understand the importance of their decision-making duty and perceive the no-decision as a form of individual failure. How an institution can transmit these "values" to agents is a question for future research.

We assumed homogeneous communication costs and explicitly controlled for this in our experimental design, however, it is likely more realistic to assume that agents face heterogeneous opportunity costs of communication, for example, due to different discount rates. Yet, we can still expect consensus to outperform other rules if group members have similar levels of impatience. This expectation stems from the correspondence between voting rules and communication. With consensus, communication opens when at least one agent desires it, so the agent with the lowest opportunity cost can initiate communication. Veto, on the other hand, requires all agents to be ready to communicate, so communication only opens when the agent with the highest opportunity cost is also ready. Despite the reduction in payoff for the agent with the highest opportunity cost under consensus, it may still be optimal from a social welfare perspective as more information is collected.

Finally, as a matter of policy, we do not recommend consensus as a general rule for collective decision-making, but our results suggest that veto unanimity is not an efficient rule. Veto unanimity, however, might respond to societal issues that are independent of information. For example, in a world of heterogeneous political preferences, the bias of veto for the status quo may be justifiable to the extent important changes need large (actually, unanimous) political consent, for stability reasons. When analyzing information issues only, majority and consensus are desirable rules for collective decision-making, and which one to prefer depends on the risk of a no-decision and the ability to procrastinate. In business contexts, where decisions typically need to be taken with no delay, or other contexts where disagreement may not be determined solely by asymmetric information, a majority is preferable to consensus, which risks generating persistent disagreement. In all other cases, consensus is a superior rule, but more experimentation is required beyond the jury experience.

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Appendix A. Further results

Appendix A.1. Theoretical Appendix

Proof of Proposition 2. Under costly communication, i.e. $\gamma \in (0,1)$, for $K \in \{K^M, K^V, K^C\}$ and $K' \in \{K^M, K^V\}$:

(i) *the communication cost threshold is maximal under consensus unanimity, i.e.* $\gamma^*_{K'} < \gamma^*_{K^C}$*;*

(ii) *when* $\gamma \leq \gamma^*_K$*, for any* K*, agents communicate under all rules, which are equally efficient;*

(iii) *when* $\gamma > \gamma^*_K$*, for any* K*, agents never communicate and majority is efficient;*

(iv) *when* $\gamma^*_{K'} < \gamma \leq \gamma^*_{K^C}$*, agents communicate only under consensus unanimity. However,*

   (a) *when there is no agent with superior information (i.e., no expert), majority and consensus unanimity are both efficient;*

   (b) *when there is an agent with superior information (i.e., an expert), only consensus unanimity is efficient.*

Proof.

Part *(i)*. Let $\gamma^*_K \equiv \mathbb{E}[u(d,\theta)|s_1,...,s_n] - \mathbb{E}_K[u(d,\theta)|s_i]$ be the maximum communication cost an agent will pay to achieve full information aggregation under the voting rule K. We say that agents are more likely to communicate under rule K than rule $K' \neq K$ if

$$\gamma^*_K \geq \gamma^*_{K'}$$

Comparing voting rules, agents are more likely to communicate under consensus unanimity when

$$\gamma^*_C \geq \gamma^*_M \text{ and } \gamma^*_C \geq \gamma^*_V \tag{A.1}$$

Let us show that (A.1) holds for both the information conditions (i.e., with or without an expert in the group).

Case 1: No expert

(a) Consensus vs. Majority

Under majority, agents vote sincerely (Feddersen and Pesendorfer, 1998). Furthermore, a binary signal is perfectly revealed by a binary sincere vote. This means that communication is redundant to aggregate private information under majority rule. Therefore, an agent's expected payoff conditional on the full signal profile has to be equal to the expected payoff conditional on her private signal only. This implies:

$$\gamma_M^* = \mathbb{E}[u(d,\theta)|s_1,...,s_n] - \mathbb{E}_M[u(d,\theta)|s_i] = 0$$

When $\gamma > 0$, agents have no incentives to communicate under majority rule. From (3), $\gamma_C^* \geq 0$, proving that $\gamma_C^* \geq \gamma_M^* = 0$.

(b) Consensus vs. Veto

Agents' communication is more likely under consensus than under veto unanimity if

$$\begin{aligned}
& \gamma_C^* \geq \gamma_V^* \\
\iff \quad & \mathbb{E}_C[u(d,\theta)|s_i] \leq \mathbb{E}_V[u(d,\theta)|s_i] \\
\iff \quad & \mathbb{P}_C(d=1|\theta=1)\mathbb{P}(\theta=1|s_i) + \mathbb{P}_C(d=0|\theta=0)\mathbb{P}(\theta=0|s_i) \\
& +\mathbb{P}_C(d=\emptyset)\mu \\
& \leq \mathbb{P}_V(d=1|\theta=1)\mathbb{P}(\theta=1|s_i) + \mathbb{P}_V(d=0|\theta=0)\mathbb{P}(\theta=0|s_i)
\end{aligned}$$

$$\iff \mu \leq \frac{1}{1-\sum_\theta \mathbb{P}_C(d=\theta|\theta)\mathbb{P}(\theta|s_i)} \sum_\theta \left[\mathbb{P}_V(d=\theta|\theta) - \mathbb{P}_C(d=\theta|\theta)\right]\mathbb{P}(\theta|s_i) \equiv \overline{\mu}_V \qquad \text{(A.2)}$$

with $\mathbb{P}_C(d=\emptyset) = 1-\sum_\theta \mathbb{P}_C(d=\theta|\theta)\mathbb{P}(\theta|s_i) \neq 0$.

Condition (A.2) is implied by condition (3). Therefore, we must show that $\overline{\mu}_V$ is strictly positive. As consensus unanimity induces sincere voting (Coughlan, 2000), the probability that a decision alternative is implemented without communication under Consensus is equal to the probability that all agents receive the same signal. That is:

$$\begin{aligned}
\mathbb{P}_C(d=\theta|\theta) &= \mathbb{P}_C(\text{all } i \text{ receive } s_i=\theta|\theta) \\
&= p^n
\end{aligned}$$

Veto unanimity with no communication induces agents to vote strategically (Feddersen and Pesendorfer, 1998). This means an agent must be indifferent between the probability the state is $\theta = 1$ conditional on her being pivotal (i.e., when $n-1$ agents are voting $v=1$) and the probability the state is $\theta = 1$ conditional on her private signal. Letting ω represent the probability of voting $v = 1$ when $s = 0$, this indifference condition becomes

$$\frac{[p + (1-p)\,\omega]^{n-1}}{[p + (1-p)\,\omega]^{n-1} + [1 - p + p\omega]^{n-1}} = p \tag{A.3}$$

In our experimental design, as $p = 0.7$ and $n = 5$, so (A.3) can be rewritten as

$$\frac{[0.7+0.3\omega]^4}{[0.7+0.3\omega]^4+[0.3+0.7\omega]^4} = 0.7$$

$$\Longleftrightarrow \omega \approx 0.58$$

implying the agents receiving signal $s = 0$, strategically vote $v = 1$ with 0.58 probability. Therefore,

$$\begin{aligned}\mathbb{P}_V(d = 1|\theta = 1) &= \mathbb{P}(\{\text{all } i \text{ choose } v_i = 1\}|\theta = 1)\\ &= (p + (1-p)\omega)^n\end{aligned}$$

and

$$\begin{aligned}\mathbb{P}_V(d = 0|\theta = 0) &= \mathbb{P}(\{\text{at least one } i \text{ chooses } v_i = 0\}|\theta = 0)\\ &= (1 - (1 - p + p\omega)^n)\end{aligned}$$

We can now explicitly compute $\overline{\mu}_V$.

When $s = 1$, $\overline{\mu}_V$ can be rewritten as

$$\frac{1}{1-p^n}\left[\left((p + (1-p)\omega)^n - p^n\right)p + \left(1 - (1 - p + p\omega)^n - p^n\right)(1-p)\right] \tag{A.4}$$

which is approximately equal to 0.52 using our experimental parameters. Similarly, when $s = 0$, we obtain $\overline{\mu}_V \approx 0.68$.[51] Therefore, we have that $\gamma_C^* \geq \gamma_V^* \geq \gamma_M^* = 0$.

Case 2. Expert

Let $q_e \equiv \mathbb{P}\left(s^e = \theta \,|\theta\right)$ be the probability of receiving the expert signal s^e, conditional on state θ. In the experiment, we let the expert signal precision take value $e \in \{\underline{e}, \overline{e}\}$, with $\frac{1}{2} < p < \underline{e} < \overline{e} < 1$.[52]

(a) Majority vs Consensus

[51] Note that, for $n = 5$, $\overline{\mu}_V$ is always bounded between zero and one for any $\omega \in (0,1)$ and $p \in (0,1)$.

[52] The high precision signal (i.e., $s^{\overline{e}}$) corresponds to an expert drawing three balls of the same color (i.e., all red or all blue), while the low precision signal (i.e. $s^{\underline{e}}$) is equivalent to the case where the expert draws two balls from one color, and one ball of the other color.

With an expert, agents may also want to communicate a majority rule. However, agents are still more likely to communicate under consensus than under majority if

$$\begin{aligned}
& \gamma_C^* \geq \gamma_M^* \\
\iff\ & \mathbb{E}_C[u(d,\theta)|s_i] \leq \mathbb{E}_M[u(d,\theta)|s_i] \\
\iff\ & \mu \leq \tfrac{1}{1-\sum_\theta \mathbb{P}_C(d=\theta|\theta)\mathbb{P}(\theta|s_i)} \textstyle\sum_{d,\theta} \left[\mathbb{P}_M(d=\theta|\theta) - \mathbb{P}_C(d=\theta|\theta)\right] \mathbb{P}(\theta|s_i) \equiv \overline{\mu}_M
\end{aligned}$$

with $1-\sum_\theta \mathbb{P}_C(d=\theta|\theta)\mathbb{P}(\theta|s_i) \neq 0$. As in *Case 1*, we need to prove that $\overline{\mu}_M$ is strictly positive.

As the agents vote sincerely under majority, the probability that $d=1$ (resp. $d=0$), conditional on θ, is equal to the probability that at least $\frac{n+1}{2}$ agents to vote $v=1$ (resp. $v=0$). That is

$$\begin{aligned}
\mathbb{P}_M(d=1|\theta=1) &= \mathbb{P}_M(d=0|\theta=0) \\
&= \sum_{z=\frac{n-1}{2}}^{n-1} \tbinom{n-1}{z} p^z (1-p)^{n-1-z} q_e^{\mathbb{I}_{\left\{z=\frac{n-1}{2}\right\}}}
\end{aligned}$$

with $\mathbb{I}_{\{\cdot\}}$ being the indicator function equal to one (resp. zero) if $z=\frac{n-1}{2}$ (resp. $z\neq\frac{n-1}{2}$).

As consensus unanimity induces sincere voting, the probability that $d=1$ (resp. $d=0$) conditional on θ, is equal to the probability that all agents receive the signal supporting state $\theta=1$ (resp. $\theta=0$). That is, $\mathbb{P}_C(d=1|\theta=1)=\mathbb{P}_C(d=0|\theta=0)=p^{n-1}q_e$.

It follows that agents are more likely to communicate under consensus than majority if

$$\mu \leq \frac{1}{1-p^{n-1}q_e}\left(\sum_{z=\frac{n-1}{2}}^{n-1}\binom{n-1}{z} p^z (1-p)^{n-1-z} q_e^{\mathbb{I}_{\left\{z=\frac{n-1}{2}\right\}}} - p^{n-1}q_e\right) \equiv \overline{\mu}_M \tag{A.5}$$

Using the parameters of our experimental design (i.e., $q_e=0.82$, $p=0.7$ and $n=5$) $\overline{\mu}_M$ is equal to

$$\begin{aligned}
& \tfrac{1}{1-0.7^4\times 0.82}\left(\tbinom{4}{2}0.7^2\times 0.3^2\times 0.82 + \tbinom{4}{3}0.7^3\times 0.3 + \tbinom{4}{4}0.7^4 - 0.7^4\times 0.82\right) \\
\approx\ & 0.84
\end{aligned}$$

Also notice that $\overline{\mu}_M$ is always strictly positive for any $p>\frac{1}{2}$. Therefore, $\gamma_C^*-\gamma_M^*\geq 0$.

(b) Veto vs. Consensus

Finally, we need to show that agents communicate more under consensus than veto unanimity if

$$\mu \leq \frac{1}{1 - \sum_{\theta} \mathbb{P}_C(d = \theta|\theta)\mathbb{P}(\theta|s_i)} \sum_{d,\theta} \left[\mathbb{P}_V(d = \theta|\theta) - \mathbb{P}_C(d = \theta|\theta)\right] \mathbb{P}(\theta|s_i) \equiv \overline{\mu}_V \tag{A.6}$$

To derive the probability of a decision outcome under veto unanimity, like in the non-expert case, we need to characterize the equilibrium voting strategies. Again from Feddersen and Pesendorfer (1998), we know that an agent may find it optimal to vote strategically against her private information in the event she is pivotal in the final decision.

We start by considering the expert voting strategy. An expert may observe either $s = 1$ ($s = 0$) with precision $\overline{e}$, or $s = 1$ ($s = 0$) with precision $\underline{e}$. Under veto unanimity, agents do not have an incentive to vote against their private information if their vote does not change the final decision outcome. This implies that the expert receiving $s^e = 1$ will always vote for alternative $v = 1$. An expert observing $s^e = 0$, however, may find it optimal to vote strategically for $a = 1$ if the posterior probability that $\theta = 1$ conditional on her being pivotal is higher than one half. Using the parameters of our experimental design we have

$$\begin{aligned}
\mathbb{P}\left(\theta = 1 \,\middle|\, \{\text{expert } i \text{ is pivotal}\}, s_i^{\overline{e}} = 0\right) &= \mathbb{P}\left(\theta = 1 \,\middle|\, s_i^{\overline{e}} = 0, \{s_j = 1\}_{j=1}^4\right) \\
&= \frac{\mathbb{P}\left(s_i^{\overline{e}}=0, \{s_j=1\}_{j=1}^4 | \theta=1\right)}{\sum_{\theta} \mathbb{P}\left(s_i^{\overline{e}}=0, \{s_j=1\}_{j=1}^4 | \theta\right)} \\
&= \frac{\mathbb{P}\left(s^{\overline{e}}=0|\theta=1\right)\mathbb{P}(s=1|\theta=1)^4}{\sum_{\theta} \mathbb{P}(s^{\overline{e}}=0|\theta)\mathbb{P}(s=1|\theta)^4} \\
&= \frac{\left(\frac{3}{10} \times \frac{2}{9} \times \frac{1}{8}\right) \times \frac{7}{10}^4}{\left(\frac{3}{10} \times \frac{2}{9} \times \frac{1}{8}\right) \times \frac{7}{10}^4 + \left(\frac{7}{10} \times \frac{6}{9} \times \frac{5}{8}\right) \times \frac{3}{10}^4} \approx 0.46
\end{aligned}$$

implying that a pivotal expert observing $s_i^{\overline{e}} = 0$ (i.e. favoring the status-quo with high probability) votes for alternative $a = 0$, even when all the other agents $j \neq i$ are observing the opposite signal $s_j = 1$. Therefore, the pivotal expert receiving a strong signal in favor of $\theta = 0$ would not vote against their private information. Furthermore, when communication is costly, an expert with signal $s_i^{\overline{e}} = 0$ strategically chooses not to communicate (i.e. setting $c = 0$), and votes $v = 0$ to implement the status-quo alternative $a = 0$. Conversely, we can verify that $\mathbb{P}\left(\theta = 1 \,\middle|\, s_i^{\underline{e}} = 0, \{s_j = 1\}_{j=1}^4\right) > \frac{1}{2}$ implying that a pivotal expert observing $s^{\underline{e}} = 0$ strategically votes against her signal.

Because the non-expert agents also strategically vote against their private information when $s = 0$, the expert and the non-expert agents' equilibrium mixed strategies are determined by a system of two indifference conditions. Specifically, these conditions specify that: (i) the expert posterior probability that $\theta = 1$ conditional on her being pivotal (i.e. $\mathbb{P}\left(\theta = 1 \left| s_i^{\underline{e}} = 0, \{s_j = 1\}_{j=1}^{n-1}\right.\right)$) must be equal to the posterior probability that $\theta = 0$ conditional on observing $s^{\underline{e}} = 0$ (i.e. $\mathbb{P}(\theta = 0 \,|s^{\underline{e}} = 0))$; and (ii) a non-expert posterior probability that $\theta = 1$ conditional on her being pivotal (i.e. $\mathbb{P}\left(\theta = 1 \left| s^e = 1, \{s_j = 1\}_{j=1}^{n-2}\right.\right)$) must be equal to the posterior probability that $\theta = 0$ conditional on observing $s = 0$.

Let ω (resp. β) be the non-expert (resp. expert) probability of strategically voting $v = 1$ when $s = 0$ (resp. $s^{\underline{e}} = 0$), and q_e be the probability that the expert receives signal $s^e = \theta$ in state θ. In equilibrium, the following conditions must hold:

$$\begin{array}{rl}
\text{(Expert) } (i) & \frac{[p+(1-p)\omega]^{n-1}}{[p+(1-p)\omega]^{n-1}+[(1-p)+p\omega]^{n-1}} = \mathbb{P}(\theta = 0 \,|s^{\underline{e}} = 0) \\
\text{(Non-expert) } (ii) & \frac{[p+(1-p)\omega]^{n-2}\left(q_{\overline{e}}+q_{\underline{e}}+\left(1-\left(q_{\overline{e}}+q_{\underline{e}}\right)\right)\beta\right)}{[p+(1-p)\omega]^{n-2}\left(q_{\overline{e}}+q_{\underline{e}}+\left(1-\left(q_{\overline{e}}+q_{\underline{e}}\right)\right)\beta\right)+[(1-p)+p\omega]^{n-2}\left(\left(1-\left(q_{\overline{e}}+q_{\underline{e}}\right)\right)+\left(q_{\overline{e}}+q_{\underline{e}}\right)\beta\right)} = p
\end{array} \tag{A.7}$$

Using the parameters of our experimental design (i.e., $n = 5$, $p = 0.7$, $q_{\overline{e}} = \mathbb{P}\left(s^{\overline{e}} = \theta \,|\theta\right) = \frac{7}{10} \times \frac{6}{9} \times \frac{5}{8} \approx 0.29$, and $q_{\underline{e}} = \mathbb{P}(s^{\underline{e}} = \theta \,|\theta) = 3 \times \frac{7}{10} \times \frac{6}{9} \times \frac{3}{8} \approx 0.53$), the (unique positive) solution to $(A.7)$ is $\omega^* \approx \frac{1}{2}$ and $\beta \approx 0.96$.

We can now verify that $(A.6)$ holds:

$$\begin{aligned}
\overline{\mu}_V &= \frac{1}{1-\sum_{d,\theta}\mathbb{P}_C(d=\theta|\theta)\mathbb{P}(\theta|s_i)} \sum_{d,\theta} \left[\mathbb{P}_V(d = \theta|\theta) - \mathbb{P}_C(d = \theta|\theta)\right] P(\theta|s_i) \\
&= \frac{1}{1-p^{n-1}\left(q_{\overline{e}}+q_{\underline{e}}\right)} \Big[\Big(\left[p + (1-p)\omega\right]^{n-1}\left(q_{\overline{e}} + q_{\underline{e}} + \left(1 - \left(q_{\overline{e}} + q_{\underline{e}}\right)\right)\beta\right) - p^{n-1}\left(q_{\overline{e}} + q_{\underline{e}}\right)\Big)\mathbb{P}(\theta = 1|\sigma) \\
&\quad + \Big(\Big(1 - (1 - p + p\omega)^{n-1}\left(\left(1 - \left(q_{\overline{e}} + q_{\underline{e}}\right)\right) + \left(q_{\overline{e}} + q_{\underline{e}}\right)\beta\right)\Big) - p^{n-1}\left(q_{\overline{e}} + q_{\underline{e}}\right)\Big)\left(1 - \mathbb{P}(\theta = 1|\sigma)\right)\Big]
\end{aligned} \tag{A.8}$$

where σ can be either the non-expert signal s or the expert signal s^e. Substituting $\omega^* = \frac{1}{2}$, $\beta^* = 0.96$, $n = 5$, and $p = 0.7$ in $(A.8)$, it is always verified that $\overline{\mu}_V$ is strictly positive for every σ, proving that $\gamma_C^* - \gamma_V^* \geq 0$.

The remaining parts of the proof are straightforward. Under *(ii)*, when *(i)* holds and $\gamma \leq \gamma_K^*$, for any K, agents always communicate, implying that $\mathbb{E}_V[u(d,\theta)|s_1, ..., s_n] = \mathbb{E}_C[u(d,\theta)|s_1, ..., s_n] = \mathbb{E}_M[u(d,\theta)|s_1, ..., s_n] = \mathbb{E}[u(d,\theta)|s_1, ..., s_n]$ and that all rules are efficient.

Under *(iii)*, agents never communicate as $\gamma > \gamma_K^*$, for any K, and majority is the efficient rule. While veto unanimity is inefficient because it induces strategic voting, majority induces sincere voting but, contrary to consensus unanimity, does not generate no-decisions.

Finally, under *(iv)*, agents communicate only under consensus unanimity.

Case (iv-a). When there is no expert, by sincere voting, we have $\mathbb{E}_M[u(d,\theta)|s_i] = \mathbb{E}_C[u(d,\theta)|s_1,...,s_n]$. This equivalence stems again from the logic that a binary signal is perfectly revealed by a binary sincere vote. As sincere voting allows the agents to aggregate all decision-relevant information made of binary signals through binary votes, both majority and consensus are efficient.

Case (iv-b). When there is an expert, by sincere voting, we have

$$\mathbb{E}_M[u(d,\theta)|s_i] < \mathbb{E}_C[u(d,\theta)|s_1,...,s_n].$$

This inequality holds because, absent communication, sincere voting under majority does not allow the agents to aggregate the (non-binary) expert's information. To conclude the proof, we show that under majority the agents do not have a profitable deviation to communicate with the expert. Let $c_M^* = 0$ be agent's i equilibrium communication choice under majority. Suppose, by contradiction, that $\frac{n}{2}$ agents choose to communicate and the pivotal agent i has a profitable deviation $c_M' = 1$, implying that she brings the group to communicate. By choosing $c_M' = 1$, the pivotal agent brings every other agent to get $\mathbb{E}_M[u(d,\theta)|s_1,...,s_n]$ which is, by definition, larger than $\mathbb{E}_M[u(d,\theta)|s_i]$. Therefore, the expected net payoff of choosing $c_M' = 1$ is

$$\mathbb{E}_M[u(d,\theta)|s_1,...,s_n] - \gamma > \mathbb{E}_M[u(d,\theta)|s_i]$$

which is equivalent to

$$\gamma < \mathbb{E}[u(d,\theta)|s_1,...,s_n] - \mathbb{E}_M[u(d,\theta)|s_i] \equiv \gamma_M^*$$

a contradiction. ■

Voting predictions. The following Table A.1 summarizes the strategic voting predictions under the veto unanimity rule.

	s	$\mathbb{P}(v=R\|s)$		
No Expert treatment	R	1		
	B	0.5825		
	s	$\mathbb{P}(v=R\|s)$	s^e	$\mathbb{P}(v=R\|s^e)$
Expert treatment	R	1	RRR	1
	B	0.4912	RRB	1
			RBB	0.9543
			BBB	0

Table A.1: Strategic voting predictions under the veto unanimity rule

More specifically, we indicate, for each possible signal s, the probability that a strategic agent (i.e., an agent that takes into account the probability to be pivotal for the final decision) votes for "Red", i.e. $\mathbb{P}(v = R|s)$.

Appendix A.2. Empirical Appendix

Appendix A.2.1. Chat Analysis

Before hiring two independent coders to analyze the qualitative content of the chats, we identified 12 chat categories, reported in the first column of Table A.2. We describe each category's content (second column) and provide a sample message (third column). We then instructed the coders to assign each message sent by a subject to the relevant categories. For example, if a subject sent the message "I observed three red balls. Let's go for red!", coders should assign the message to categories 1 (*Sharing Information*) and 2 (*Coordination on a Decision*). Across treatments for paid periods, the data contains 19,295 distinct coded (by both coders) messages.

Category	Message description	Sentence example
1. Sharing Information	Color of the signal.	"I've got the red." or "I observed two blue, and one red."
2. Coordination on a Decision	Guide other members towards a decision.	"Let's all vote for blue."
3. Asking for Information	Request to disclose the signal's color.	"What did you observe?"
4. Asking for Coordination	Request to find a shared decision.	"What should we vote for?"
5. Summarizing Information	Summary of the signals available in the group.	"We have two red and three blue."
6. Reference to Time	Messages referencing time.	"Hurry up!" or "Slow down"
7. Reference to Communication Cost	Reference to costly (free) communication	"We are paying money to communicate (communication is free)!"
8. Asking to Communicate More	Request to communicate More	"How many red signals do we have? Let's talk a bit more before making a final decision."
9. Asking to Stop Communication	Request to end the chat	"Please end the chat!"
10. Agreement	Reference to finding an agreement	"We need to find a common agreement / Do we agree?"
11. Disagreement	Reference to the current disagreement	"I do not agree"
12. General Discussion about Game	General discussion only related to game	"Do we all need to agree? / Does the position of the ball observed in the box reveal the color of the unknown box?"

Table A.2: Description of Chat Categories

Appendix A.2.2. Additional Tables

Communication Choices	(1) Maj	(2) Veto	(3) Cons
LC	-2.279***	-1.021***	-1.285***
	(0.303)	(0.252)	(0.176)
HC	-2.215***	-2.395***	-1.578***
	(0.544)	(0.584)	(0.215)
Expert (Exp)	0.056*	0.089	0.078
	(0.025)	(0.056)	(0.059)
LC×Exp	0.949***	0.297**	0.899***
	(0.253)	(0.113)	(0.177)
HC×Exp	0.830	0.952***	0.937***
	(0.492)	(0.195)	(0.116)
Constant	4.844***	4.900***	4.911***
	(0.050)	(0.064)	(0.050)
Observations	3,200	3,045	3,200
R-squared	0.437	0.435	0.373

Table A.3: Pooled OLS regressions on communication choices in a group. Standard errors clustered at the session level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Communication Time	(1) Free	(2) Low Cost	(3) High Cost
Veto	-47.581	-3.626**	-4.609**
	(35.703)	(1.323)	(1.665)
Cons	-26.567	31.626***	11.944***
	(34.404)	(2.042)	(2.183)
Expert (Exp)	-13.849	7.646***	7.396*
	(17.405)	(1.951)	(3.256)
Veto×Exp	26.264	-0.638	0.197
	(17.316)	(0.727)	(2.231)
Cons×Exp	13.967	-16.205***	-6.982**
	(20.168)	(0.797)	(2.532)
Period	-2.724**	-0.741***	-0.718**
	(0.724)	(0.193)	(0.223)
Constant	100.567**	11.557***	9.826***
	(34.522)	(1.846)	(2.039)
Observations	529	660	700
R-squared	0.230	0.461	0.415

Table A.4: Pooled OLS regressions on communication choices in a group. Standard errors clustered at the session level. *** p<0.01, ** p<0.05, * p<0.1

	Decisions + No Decisions			Decisions Only		
Informational Efficiency	(1) F	(2) LC	(3) HC	(4) F	(5) LC	(6) HC
Veto	-0.610*	0.033	-0.583	-0.610*	0.033	-0.583
	(0.318)	(0.149)	(0.377)	(0.318)	(0.149)	(0.377)
Cons	-0.108	0.249*	-0.232	-0.005	0.589***	0.711
	(0.199)	(0.144)	(0.419)	(0.183)	(0.148)	(0.433)
Expert (Exp)	-0.108	0.417*	0.306	-0.108	0.417*	0.306
	(0.107)	(0.233)	(0.384)	(0.107)	(0.233)	(0.384)
Veto×Exp	0.292	-0.593**	-0.716*	0.292	-0.593**	-0.716*
	(0.241)	(0.235)	(0.404)	(0.241)	(0.235)	(0.404)
Cons×Exp	0.216	-0.079	-0.070	0.686**	-0.153	-0.568
	(0.281)	(0.233)	(0.384)	(0.322)	(0.240)	(0.400)
Constant	1.701***	0.699***	1.128***	1.701***	0.699***	1.128***
	(0.183)	(0.137)	(0.362)	(0.183)	(0.137)	(0.362)
Observations	529	660	700	525	647	673

Table A.5: Probit regressions on informational efficiency. Standard errors clustered at the session level. *** p<0.01, ** p<0.05, * p<0.1

Wrong Decision	(1) Free	(2) Costly	(3) No Expert	(4) Expert
Veto	0.134	0.023	0.134	-0.082
	(0.178)	(0.089)	(0.166)	(0.095)
Cons	-0.219***	-0.029	-0.219***	-0.496***
	(0.061)	(0.112)	(0.057)	(0.083)
LC			0.164*	0.046
			(0.085)	(0.146)
HC			-0.081	-0.074
			(0.089)	(0.134)
Veto×LC			-0.250	0.475***
			(0.192)	(0.173)
Veto×HC			0.025	0.987***
			(0.197)	(0.165)
Cons×LC			0.190	0.088
			(0.137)	(0.221)
Cons×HC			0.189	0.465***
			(0.118)	(0.162)
Expert (Exp)	-0.301***	-0.357***		
	(0.066)	(0.086)		
Veto×Exp	-0.216	0.633***		
	(0.264)	(0.133)		
Cons×Exp	-0.278***	-0.175		
	(0.066)	(0.158)		
Constant	-0.623***	-0.582***	-0.623***	-0.924***
	(0.000)	(0.081)	(0.000)	(0.062)
Observations	529	1,360	872	1,017

Table A.6: Probit regressions on wrong decision, standard errors clustered at the session level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

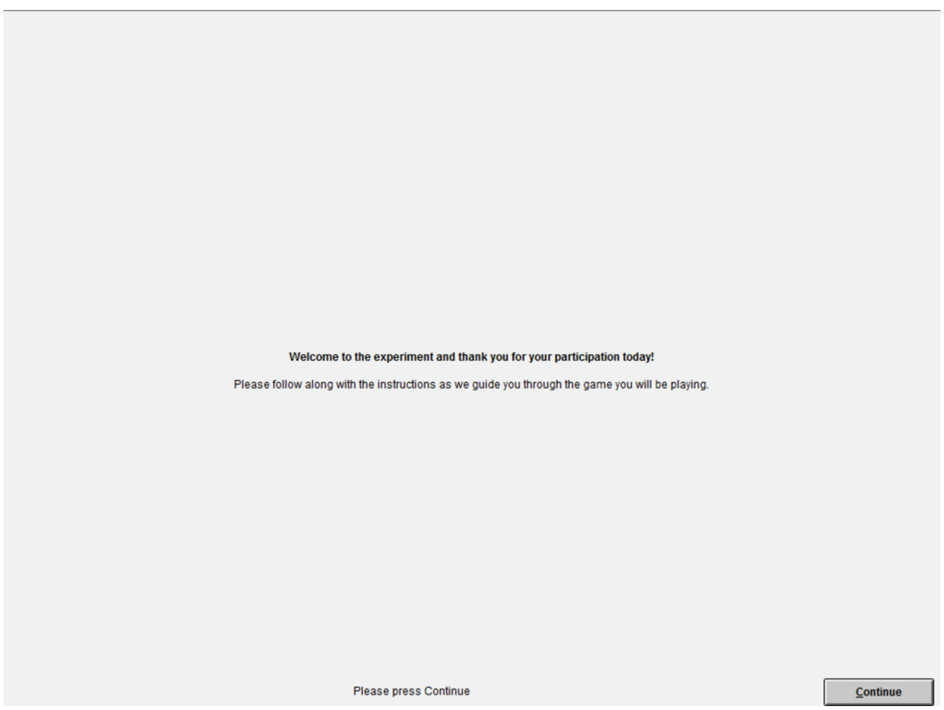
Appendix A.2.3. Simulation of future efficiency of no-decisions

We use the following procedure to calculate the probability that a group will turn a no-decision into an efficient one. First, we record for each experimental condition the specific signals drawn (i.e., the information available to the group) that were associated with a no-decision outcome. Second, we estimate a probit regression model for each experimental treatment with efficient decisions as the dependent variable and the number of blue signals as the independent variable. Third, we calculate the marginal probability that a group makes an efficient decision given the identical signal draw under which a no-decision occurred. This probability is used as the expected future efficiency.

Appendix B. Sample experimental instructions - Maj, LC

The actual instructions were in Italian, and the instructions below are the translation of the original instructions into English for the Maj LC treatment. The instructions for Veto and Consensus unanimity only differed in the description of the voting rules. Differences in cost treatments are also noted, except for free communication, which omitted the discussion of costs.

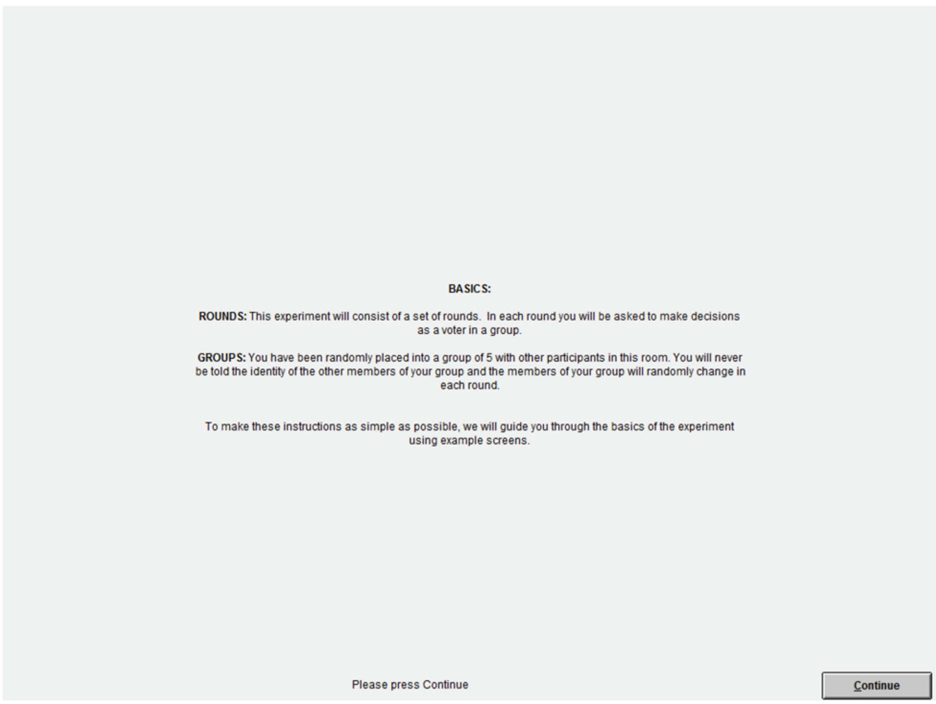
Welcome to the experiment and thank you for your participation today! Please follow along with the instructions as we guide you through the game you will be playing. Please do not hit continue until instructed to do so. I will read through a script to explain to you the nature of today's experiment as well as how to work the computer interface you will be using. I will be using this script to make sure that all sessions of this experiment receive the same information, but please feel free to ask questions as they arise. We ask that everyone please refrain from talking or looking at the monitors of other subjects during the experiment. The purpose of this experiment is to study how people make decisions in a particular situation. You will receive an endowment of 5 Euros for showing up for the experiment. You will also make additional money during today's experiment. Payments will be in cash at the end of the experiment and are confidential. Please press continue to enter into the basics of the experiment.



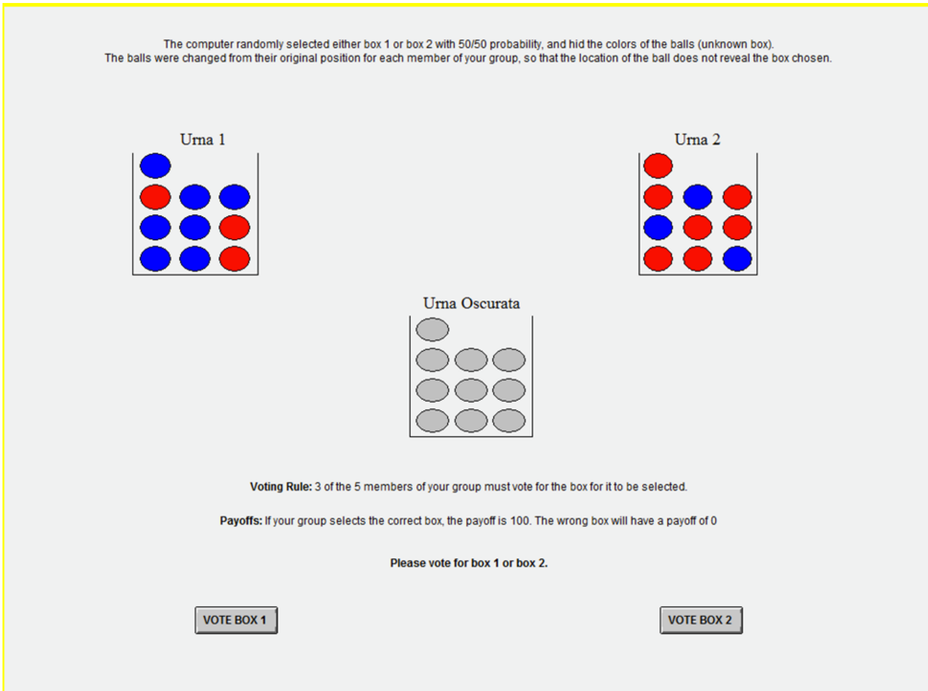
Basics

Rounds. This experiment will consist of a series of rounds. In each round you will be asked to make decisions as a voter in a group.

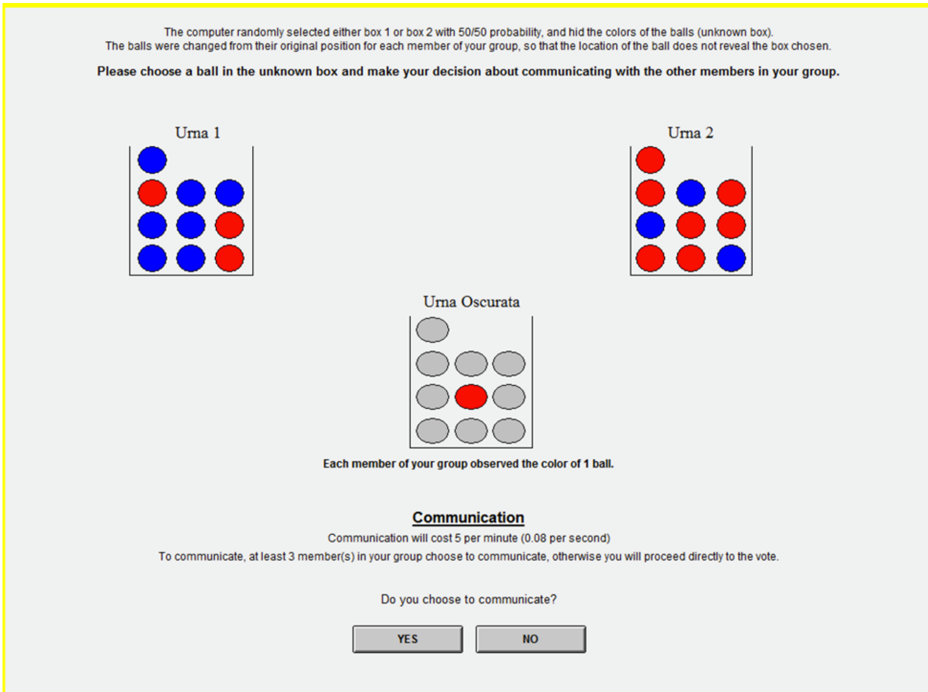
Groups. You have been randomly placed into a group of 5 with other participants in this room. You will never be told the identity of the other members of your group, and the members of your group will randomly change at each round. To make these instructions as simple as possible, we will guide you through the basics of the experiment using example screenshots.



Please press continue to see the basic decision your group must take at each round.

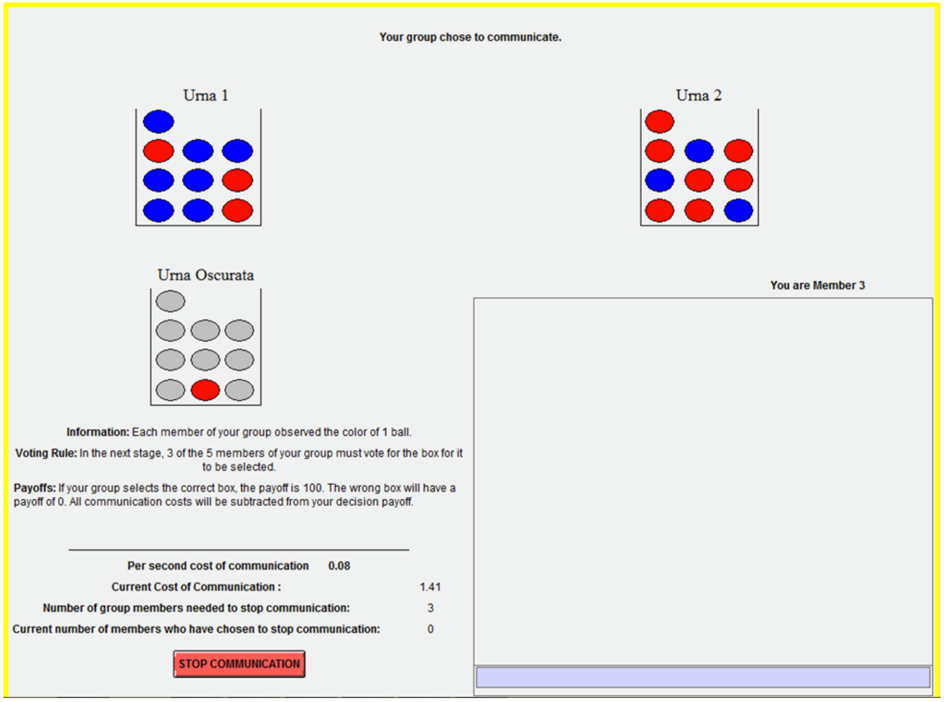


Two boxes are shown at the top of the screen, each containing 10 colored balls. The box on the left, Box 1, contains 7 blue and 3 red balls. The box on the right, Box 2, contains 7 red and 3 blue balls. Below this, in the middle of the screen, there is an "unknown box" with 10 grey balls. The true color of these balls is currently hidden but the mixture of blue and red balls box matches either box 1 or box 2. Whether or not the unknown box matches box 1 or box 2 was randomly determined by the computer with 50/50 probability (like a coin flip). Your group's objective in each round is to try to determine if the unknown box matches either box 1 or box 2. To reach a joint decision, you and the other members of your group will vote for either box 1 or box 2 and these votes will be tallied to determine the group's decision. Below the unknown box, you will see the voting rule in bold, for reference. The voting rule is that 3 of the 5 members of your group must vote for the box for it to be selected. This rule will remain the same throughout all rounds of today's experiment. Below the information about the voting rule you will find information about how to make money in today's experiment. Payoffs: If your group correctly matches the unknown box to the box the computer selected, you and the other members of your group will earn 100 points. If your group chooses the wrong box, all members will have a payoff of 0 points. Points convert into Euros at a rate of 1 point = 1 euro cent. Please press either one of the vote buttons to continue.



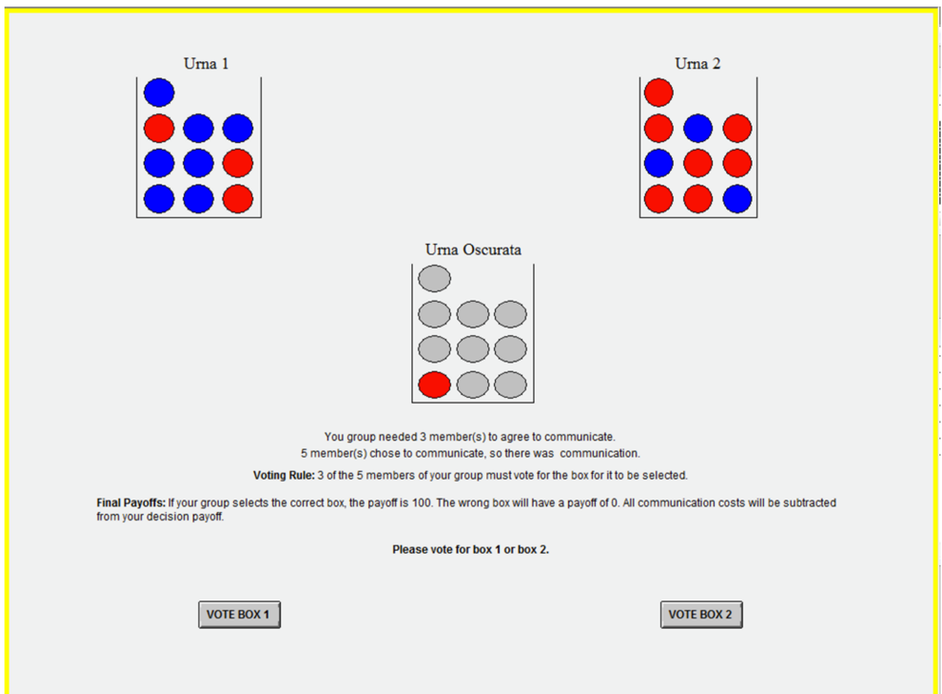
To help you make this decision, we will give you some information by allowing you and the other members of your group to uncover the color of 1 ball. To see how this works, please select a ball in the unknown box, by pointing the mouse to any ball and clicking on it. You should now see the color of the selected ball displayed on your screen. You can only choose 1 ball. Please note that the balls in the selected box have been shuffled for you. This means that the location of the colored ball that you see does not indicate the box chosen. The balls have also been shuffled differently for each member of your group, which means that even if you and another member choose the same ball location, it does not necessarily imply that the color will match. In sum, the location of the ball doesn't matter, only the color does.

Please turn your attention to the bottom portion of the screen labeled with communication. In addition to selecting a ball, you can also communicate via chat with the other members of your group. If you choose to chat, press the YES button, otherwise press NO. If at least 3 of the 5 members of your group press the "Yes" button, your group will enter into a chat room. Note that even if you DO NOT choose to communicate, but at least 3 other members of your group DO choose to communicate, then your entire group will enter the chat room. If fewer than 3 members in your group choose to communicate, then your group will proceed immediately to the voting stage. Please note that communication does bear a cost. If your group decides to communicate you will each be charged fee of <low 0.08> <high 1> point per second you spend communicating. These costs will be deducted from final payoffs at the end of the vote. Please press "Yes" to be taken to the communication stage for this example.



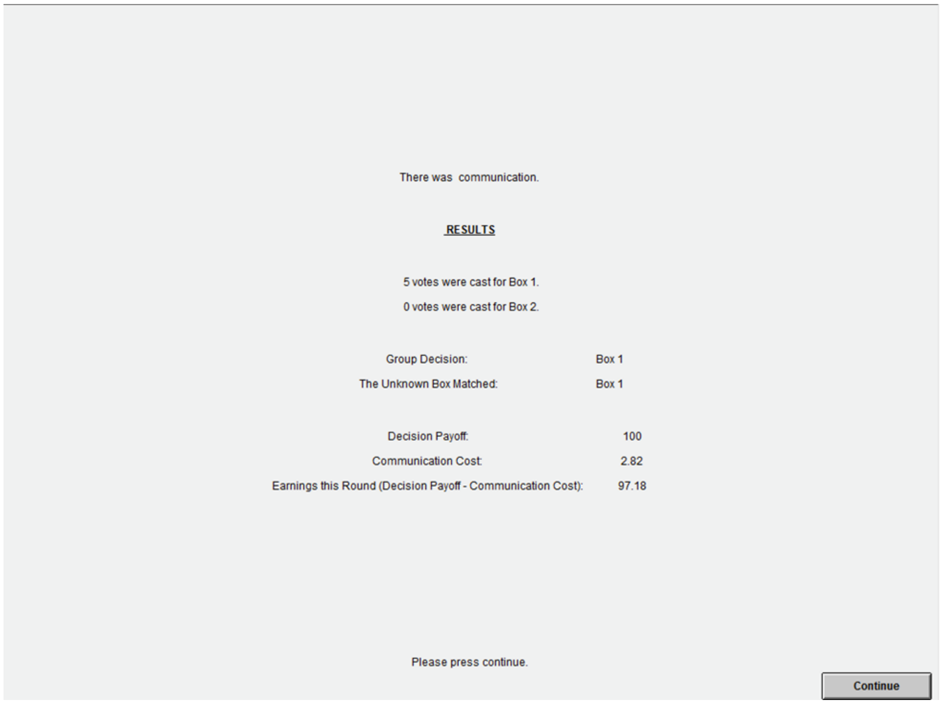
Communication

You have now been directed to the communication screen. On the top of the screen, you are reminded of the composition of box 1 and box 2. You have also been given the reminder of the ball you chose on the previous screen. Directly below the unknown box with your selected ball, you will see a summary of the information in the experiment, the voting rule, and payoffs. Directly below the summary, at the bottom left of the screen you will then see the current cost of communication. This is updating continuously for as long as you remain in this stage. On the right side of the screen, you will see a chat box, where you can communicate with the other members of your group. We kindly ask everyone to type a message to the members of your practice group, for example "HI," and press enter. You must press enter for your message to be sent. You should now see that your message appears on the screen as "Member #." If you are unsure of your member number, look at the top of the chat box. There you will see text that reminds you of your number so that you can track your text. Member numbers were assigned randomly, and are only used to maintain anonymity in your group. We only have two rules that we ask you to follow regarding chat: 1. Please do not use the chat box to reveal identifying information about yourself. 2. Please also refrain from using profanity. To exit communication, at least 3 of the 5 members of your group need to choose to stop. Once you would like to stop communicating, please click on the red "STOP COMMUNICATION" button on the bottom left. Important: communication will not end until at least 3 members press the "STOP COMMUNICATION" button. Above the red button, the number of people who have chosen to stop communication is updated "live" until the necessary number of members deciding to quit is achieved. If 3 members do not agree to stop communication, you will have up to 5 minutes to communicate, at which point you will be automatically redirected to the next stage. Please now click on the "Stop Communication" to be taken to the final decision screen for a round.

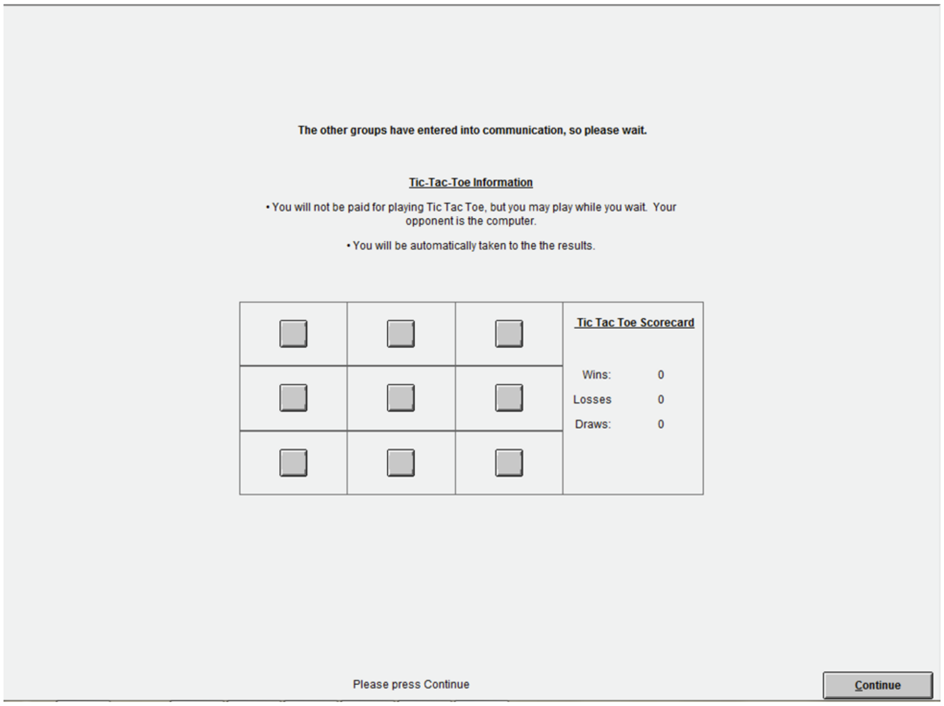


You will now see the screen where you and the other members of your group will vote to make a decision. The box your group chooses will be based on a voting rule, shown below the unknown box. 3 of the 5 members of your group must vote for a box for it to be selected. You are also given information about the final payoffs for a round. If your group selects the correct box in a round, the payoff to each member will be 100. If you group has selected the wrong box, each member of your group will earn 0. Final earnings will also include communication costs - all communication costs will be subtracted from your decision payoff. Note that if your group did not vote for communication, you would be immediately directed to this screen instead of being taken to the communication chat stage. You will find a summary of the communication decision below the unknown box. To conclude a round, you will vote for either box 1 or box 2.

Please vote for box 1.

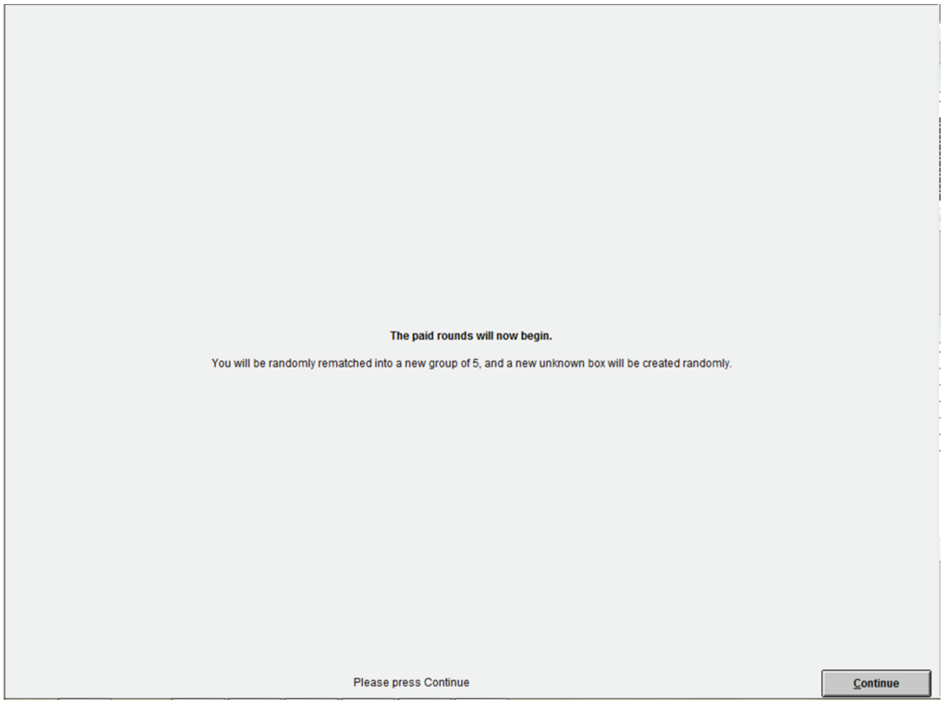


Now that you have all placed your vote, you will be taken to a sample results screen for the round. At the top of the screen, you will see a recap of communication for the round. Below "Results" you will see a summary of the votes placed for box 1 and for box 2. You will also see the group's decision based on the voting outcome beneath this. In this example, your group selected box 1. You can also see that the unknown box matched box 1, so your group made the correct decision. Since the unknown box matched box 1 and your group voted for box 1, the decision payoff is 100. The communication costs are listed below the decision payoff, and final earnings for the round, which are equal to the decision payoff less the communication cost, are provided last. Note that it is possible to make negative earnings if your communication costs exceed the earnings from your decision. Recall that you have been given an endowment of 500 points (5 euros) from which losses will be subtracted and profits will be added. If your overall balance falls below zero you will be initialized with your endowment again and continue playing. 2-time bankrupt participants will be asked to leave the experiment with your show-up fee. Please click "Continue."



One last screen not directly related to the game. In the event that your group chooses not to communicate, but another group does choose to communicate, you will be taken to a tic-tac-toe screen similar to the one you see now, where you can play against the computer until all other groups finish communicating. In this game, you click a square and your computer opponent responds. You will not earn anything for playing tic-tac-toe, and will be immediately redirected to your next stage when the communicating groups finish.

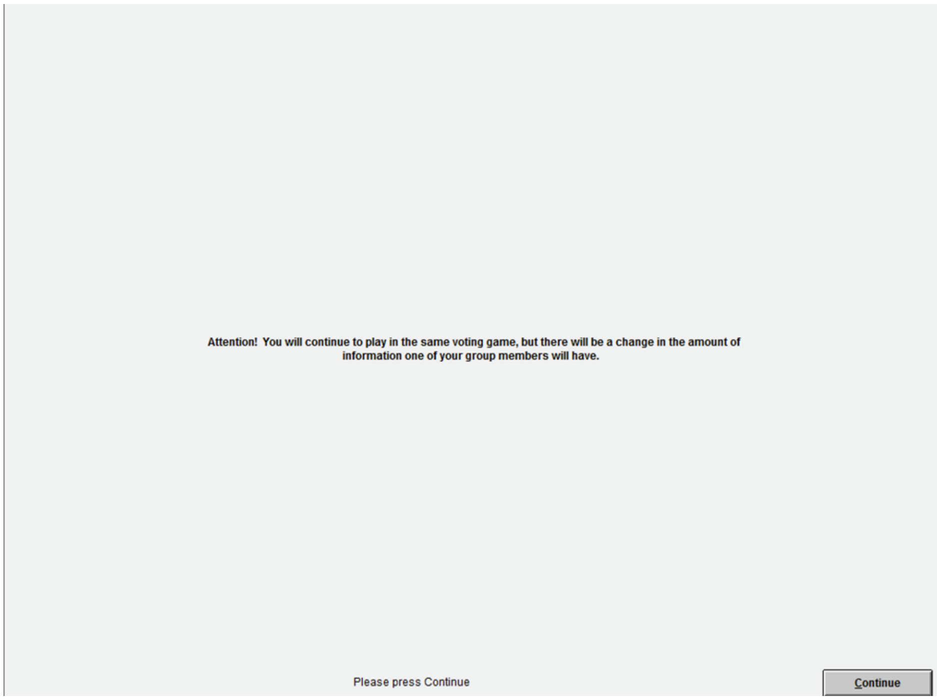
Please click "Continue."



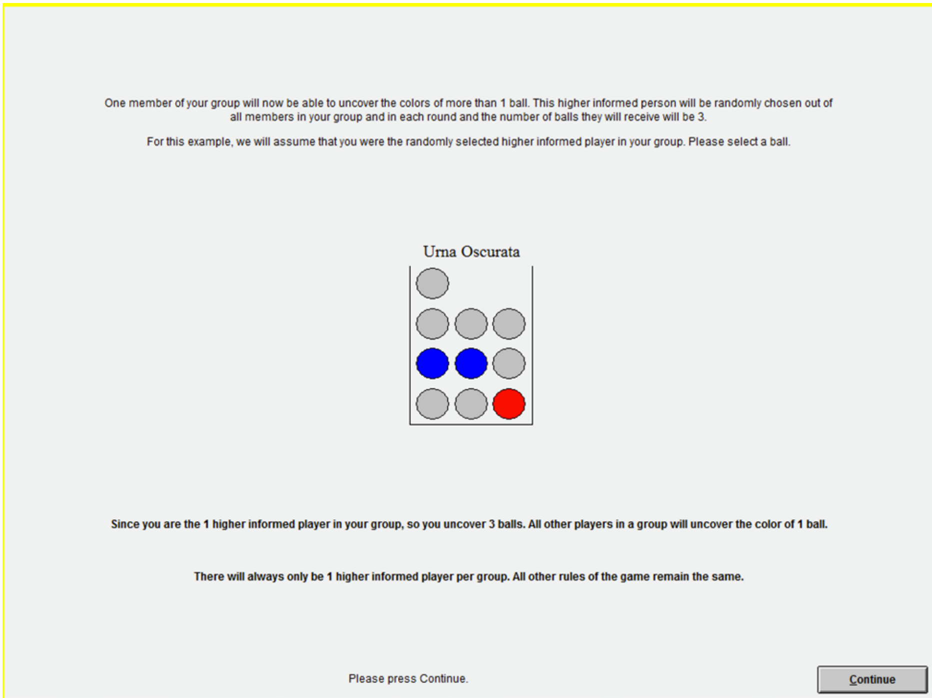
The paid rounds will now begin. You will be randomly rematched into a new group of 5, and a new unknown box will be created randomly. Please press continue to begin. You are now participating at your own pace, please make decisions when you are ready and click continue buttons when they are available so that they experiment can continue.

Treatment change to expert treatment

Attention! You will continue to play the same voting game, but there will be a change in the amount of information one of your group members will have. Please press continue for more information about this change.



One member of your group will now be able to uncover the colors of three balls. This more informed person will be randomly chosen out of all members in your group at each round. For this example, we will assume that you were the randomly selected higher informed player in your group. Please click on a ball. Since you are the more informed player in your group, you will see that you have uncovered the colors of three balls. All other players in a group will uncover the color of just one ball. There will always only be one more informed player per group. Being selected as the more informed person in one round does not imply that the same person will be (or will not be) selected as the more informed person in the next round. All other rules of the game remain the same. Please press continue.



A new round is about to begin. A new unknown box will be created and you will be randomly rematched into a new group of five members. In the middle of the screen you will see whether or not you are the higher informed player this round. You and all other members of your group will be told your information role at the beginning of all remaining rounds. Please press continue to enter into the new round with the new rules. You are again participating at your own pace.

Thank you for participating. We will now proceed to the payment phase.