Unanimous Jury Voting with an Ambiguous Likelihood*

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Abstract

We study collective decision-making in a voting game with an ambiguous likelihood and ambiguity-averse voters who are MaxMin Expected Utility maximizers. We demonstrate that there are instances when, in equilibrium, ambiguity helps support voting informatively under the unanimity rule. We further investigate related voting behaviors in a laboratory experiment. Our results guide the use of unanimity voting with the aim of minimizing type I errors as a function of the jury size, the threshold of reasonable doubt and the severity of the ambiguous likelihood.

Keywords: *ambiguity, voting, belief updating, pivotality, experiments*

JEL classification: *C91,C92,D7,D81*

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1 Introduction

> "...two factors [are] commonly used to determine a choice situation, the relative desirability of the possible pay-offs and the relative likelihood of the events affecting them, but in a third dimension of the problem of choice: the nature of one's information concerning the relative likelihood of events. What is at issue might be called the ambiguity of this information, a quality depending on the amount, type, reliability and 'unanimity' of information, and giving rise to one's degree of confidence in an estimate of relative likelihoods." (Ellsberg, 1961, pp. 657–659)

A fundamental question in social choice, political economy, and political science is to identify which institutions achieve the best collective decisions. These decisions impact, for instance, the lives of organ recipients, the fates of defendants in jury trials, and the allocation of research funding. Yet, decision-makers in reality, often need to reach decisions based on information whose reliability (likelihood) cannot be perfectly assessed. Indeed, ambiguity is not only embedded in the language, signals, and social norms used by agents to communicate with one another, but it also exists because of the inability to assign well-defined, numerical probabilities to specific events in many decision-making contexts, as pointed out by Ellsberg (1961). In spite of this, there are virtually no models of voting under ambiguity of this nature, for us to predict the likely consequences of facing such an ambiguous world.[1,2,3]

There remain many open questions on this subject: What is the nature of one's information concerning the relative likelihood of events? What if the reliability (likelihood) of information provided to decision-makers cannot be precisely measured? How would jurors, in the face of ambiguous information behave, when forming and revising their

[1] Ellis (2016) studies information aggregation exclusively under the majority rule in the presence of ambiguity on the common prior jurors assign to a defendant's guilt. In this environment, voters who exhibit Ellsberg's type preferences strictly prefer randomizing as compared to adopting informative voting strategies, especially if the precision of their information is too low to overcome the uncertainty of the prior. This leads to inefficient information aggregation. Ryan (2018a,b) also study voting games with ambiguity on the common prior jurors assign to a defendant's guilt, however, under the unanimity rule, thereby indicating conditions under which information aggregation improves when compared to decision-making without ambiguity.

[2] Only a few studies exist, which introduce ambiguity in the information provided to agents in a game-theoretical situation. Keller, Sarin, and Sounderpandian (2007) shows that ambiguity aversion persists in two-person group decisions. Similarly, Brunette, Cabantous, and Couture (2015) finds that individuals are less risk-averse and more ambiguity-averse in groups than in individual decision-settings. In contrast, Keck, Diecidue, and Budescu (2012) suggests that individuals in groups are likely to make ambiguity-neutral decisions, provided the opportunity to exchange information and deliberate. Grant, Rich, and Stecher (2019) discusses how individuals who are globally ambiguity neutral still need to take ambiguity into consideration when interacting strategically. It demonstrates that the borrower's probability of lying about the ability to repay the debt decreases (honest reporting increases) in an illustrative debt contracting game in which the opportunities to default on the debt are perceived to be ambiguous.

[3] Instead, Pan, Fabrizi, and Lippert (2018) offers a characterization for when voters with non-congruent views are reluctant to vote against their private information.

beliefs leading to their casting of votes? How would ambiguous information thereby contribute to the quality of the collective decision? Our goal is to contribute to answering these questions.

Specifically, we investigate unanimous voting scenarios characterized by *ambiguous information*, when the distribution of the reliability of the information (likelihood) given to voters is not precisely known. We do so, in the presence of ambiguity-averse voters who are MaxMin Expected Utility (MMEU) maximizers, à la Gilboa and Schmeidler (1989). Voters assign their priors in an act-contingent manner: They assess each of their actions by its associated minimum expected utility. To capture voters' belief formation and revision in the face of ambiguity, we allow for Full-Bayesian Updating, as in Pires (2002).[4]

Our analysis demonstrates that, in stark contrast with the received literature, in spite of adhering to unanimous voting there exist instances in which voters facing ambiguous information would revert to informative voting equilibrium strategies, where they would have voted strategically against their private information in the absence of ambiguity.

This implies that under ambiguity the unanimity voting need not be incompatible with an efficient information aggregation.

12-person jury in Feddersen and Pesendorfer (1998) (herein FP) Let us consider, for instance, the predictions of a 12-person jury example from FP, which is a clear illustration of the failure for unanimity to deliver high quality collective decisions. Take the level of the reliability (likelihood) that a voter's information is correct to be exactly equal to 75%. This determines the posterior belief that a defendant is guilty, to be contrasted with the level of reasonable doubt, $q \in (0,1)$, which, in this illustration is set to $q = 0.90$. In this environment, the example shows that informative voting cannot prevail as an equilibrium, as such equilibrium would require the reasonable doubt to be very close to 1, namely $q > 0.99998$. Instead, under the unanimity rule, jurors randomize their vote after receiving an innocent signal, which, in turn, increases the occurrence of convicting innocent defendants, thereby exacerbating type I errors.

In contrast to these predictions, our model shows that if the unanimity rule is used in a 12-person jury, with ambiguity-averse voters who only know that their evidence is informative, but not to which extent – the reliability (likelihood) of their information is ambiguous – then informative voting would be observed in equilibrium for a much larger range of thresholds of reasonable doubts, than when ambiguity is absent.

Table 1 compares the scenarios of the canonical 12-person jury example in FP and modified ones where ambiguity in the likelihood of the information provided to jurors is considered instead. In the extreme case in which jurors only know that their signals

[4] Eichberger, Grant, and Kelsey (2007) provide an axiomatic foundation for updating non-additive capacities to be equivalent to the Full-Bayesian Updating rule.

are informative, but not how informative, the reasonable doubt required for informative voting to be an equilibrium under the unanimity rule with a 12-person jury can be almost as low as 0.50.

Table 1: *Informative voting in a 12-person jury example as in FP and under ambiguous likelihood of information*

Signal Precision	*Informative Voting Condition*
75%	$0.99998 < q \leq 1$
[55%, 95%]	$0.90091 < q \leq 1$
]50%, 100%[	$0.50 < q \leq 1$

This surprising result is not peculiar to the selected 12-person jury example and the particular spread considered for the interval within which the reliability of the information given to voters lies within. Our analysis provides a much wider support for when informative voting equilibrium prevails over mixed strategy voting equilibria under the unanimity rule. This, in turn, validates the claim that unanimity voting can preserve the efficient aggregation of information in some collective decision-making scenarios, thereby providing the basis as to when to restore it as a desirable voting rule. Therefore, our results are relevant for many real-world decision-making situations, involving medium-to-large size groups.

The intuition for these results lies in the observation that when the likelihood of the informative signals becomes ambiguous, voters are more reluctant to rely on each piece of the collective information available to them. Due to their ambiguity aversion and their evaluating the worse case scenarios of each possible final verdict, right or wrong, and be it achieved thanks to their being pivotal in that decision or not, pivotality is not a necessary and sufficient condition any longer to determine their voting behavior.[5] Applying more caution in their casting of votes, makes it less likely also to vote against one's information, reducing the instances of non-informative voting, as an equilibrium prediction for such ambiguous voting games. This intuition is consistent with other settings analyzing, for instance, the effect of ambiguity on the private provision of public goods. In those settings, it has been shown that in large societies a unique equilibrium exists characterized by less free-riding than in the absence of ambiguity.[6]

Further to that, we test our theoretical model in a laboratory setting emulating such ambiguous environment. This provides some evidence in support of our theoretical predictions, thereby guiding the use of unanimity voting with the aim of minimizing

[5] In voting games such as Ellis (2016), Ryan (2018a,b), as well as ours, given a closed and convex set of priors, ambiguity-averse voters would select their prior from this set in a strategy-contingent manner. As a consequence, both the pivotal and non-pivotal events matter to voters when deciding their votes. Pan (2018) provides a formal proof about the conditional probability of being pivotal alone being no longer sufficient to determine voters' best responses for ambiguous voting games.

[6] See, for example, Bailey, Eichberger, and Kelsey (2005).

type I errors as a function of the jury size, the threshold of reasonable doubt and the severity of the ambiguous likelihood.

Therefore, and as indicated above, our study challenges the widely accepted view that out of all voting rules, unanimity is an inferior voting criterion, as it fails to aggregate information efficiently. The implication is that unanimity voting should be abandoned in any medium-to-large collective decision settings. This view is rooted in two major findings, the Condorcet Jury Theorem (CJT)[7], and what we could refer to as the Jury Paradox.

The CJT establishes that if voters receive informative private signals, which are not perfectly correlated, and if they cast their vote in accordance to their information, then collective decisions generated by majority voting have a higher probability of selecting the correct alternative than the decision made by a single expert, especially as the size of the group grows, making the unanimity requirement redundant for a good quality collective decision to be reached.[8]

The Jury Paradox posits that increasing the hurdle for a conviction verdict to be reached – asking for higher consensus than simple majority – need not reduce *type I* errors. This is because the informative voting condition, which is necessary for the CJT to hold, does not always constitute a Nash equilibrium of the underlying voting game, especially with the unanimity rule. The results derived from strategic voting games were established in the seminal papers of Austen-Smith and Banks (1996) and FP, which investigate the CJT within Bayesian-Nash Equilibrium (BNE) settings. Namely, that if informative voting constitutes a pure strategy equilibrium for their voting behaviour the resulting collective decision is more reliable than the decision made by any single individual due to virtues of (truthful) information aggregation. Less trivially, if informative voting is likely not to prevail as a Bayesian-Nash Equilibrium, i.e., if strategic voting equilibria with randomization become pervasive, unanimity voting still leads to information aggregation of inferior quality to that obtainable under other non-unanimous voting rules for medium-to-large jury sizes.

This is essentially so, because – out of all voting rules – unanimity gives individuals the strongest incentives to strategically vote against their private information, leading to suboptimal decisions.

Our study is among the first ones to challenge this negative result in the literature.[9] Contrary to this result, we demonstrate how an ambiguous likelihood of the information provided to voters prior to their casting of votes need not lead to an inefficient in-

[7]Marquis de Condorcet, *Essai sur l'Application de l'Analyse à la Probabilité des Décisions Rendues à la Pluralité des Voix*, L'Imprimerie Royale, Paris, 1785.

[8]This also resonates with the idea that when making decisions on imperfect information, the "Wisdom of the Crowds" leads to better outcomes than individual decision-making, so that good quality decisions can be reached by simply aggregating the information possessed by a subset of a crowd.

[9]Exceptions are Ryan (2018a,b), which investigate unanimity voting in the presence of ambiguity on the pay-off relevant state instead.

formation aggregation, in spite of adhering to the unanimity rule. Thereby, we provide a rationale for resurrecting the unanimity rule as a viable voting option, particularly when caring about building consensus and making all voters really ‘count’ (not just when pivotal, that is).

2 The Model

Let there be a set of jurors, $I = \{1, 2, \ldots, N + 1\}$, with each member making a decision $d \in D = \{A, B\}$ by secret ballot. We use the same notation to signify decisions and votes: A can be interpreted as the decision to “A-cquit” as well as the vote for “A-cquittal” and B as the decision to “Convict” as well as the vote for “Conviction”. We consider the unanimity rule where the defendant is acquitted unless all voters vote to convict.

We represent the defendant’s guilt by the state of nature $s \in S = \{a, b\}$, where $s = a$ signifies the defendant is “innocent” (deserving a verdict to A-cquit) and $s = b$ signifies the defendant is “guilty” (non-deserving a verdict to A-cquit). Jurors have a common prior probability of $s = a$, denoted by $p \in (0, 1)$.

Before casting their vote, each juror receives a private signal $t \in T = \{a, b\}$, where $t = a$ signifies information that points towards the defendant’s “innocence” and $t = b$ information that points towards the defendant’s “guilt”. Conditional on $s \in S$, these signals are independently and identically distributed with $Pr(t = a|s = a) = Pr(t = b|s = b) = r$, with r known to lie in the interval $[\underline{r}, \overline{r}]$, where $\frac{1}{2} < \underline{r} \leq \overline{r} < 1$. This likelihood, which represents the reliability of voters’ private information, indicates that signals are drawn from a common, yet ambiguous distribution function.

We denote the state space characterizing all ex ante uncertainty by $\Omega = S \times T^I$. Each $r \in [\underline{r}, \overline{r}]$ together with p determines a probability over Ω. The closed and convex set of these probabilities is denoted by Π. After receiving their signal, each juror updates each element of Π using Bayes’ Rule, obtaining a set of posterior probabilities on Ω. We denote the posterior interval for the conditional posterior probability $Pr(s = a|t_i = t)$ by $\Pi_t = [\underline{\pi}_t, \overline{\pi}_t] \subseteq (0, 1)$.

Voters have a common loss function, $u : D \times S \to \mathbb{R}$ given by $u(A, a) = u(B, b) = 0$, $u(A, b) = 1 - q$ and $u(B, a) = q$, where $q \in (0, 1)$, stands for the classical minimum threshold of reasonable doubt required for a vote to convict to be casted.

A voting problem with ambiguous likelihood is a vector $V = (N, q, \underline{r}, \overline{r}, p)$, with $N \in \{1, 2, \ldots\}$, $q \in (0, 1)$, $\frac{1}{2} < \underline{r} \leq \overline{r} < 1$, and $p \in (0, 1)$. The set of all such voting problems is denoted by $\mathcal{V}$.

Strategies Denote by σ_t^i the probability that juror $i \in I$ votes B after observing $t \in T$, and let $\sigma^i = (\sigma_a^i, \sigma_b^i)$ denote voter i’s strategy. We concentrate on symmetric strategy profiles and therefore omit the i superscript, denoting a strategy profile by $\sigma = (\sigma_a, \sigma_b)$ as the strategy of a generic voter and as the symmetric profile itself.

Consider a particular voter i who believes all other voters follow the (symmetric) strategy $\sigma = (\sigma_a, \sigma_b)$. Let ρ_s denote the probability that voter i's vote is pivotal, conditional on being in state $s \in S$ and let θ_s denote the probability that voter i is not pivotal and a correct decision is made, conditional on being in state $s \in S$. With the unanimity rule, we have $\theta_a = 1 - \rho_a$, $\theta_b = 0$,

$$\rho_a = (r\sigma_a + (1-r)\sigma_b)^N$$

and

$$\rho_b = ((1-r)\sigma_a + r\sigma_b)^N$$

Equilibria Having observed their private signal $t \in T$, each voter i chooses σ_t^i using the MaxMin expected utility rule. Hence, σ_t^i solves

$$\max_{\sigma_t^i \in [0,1]} \min_{\pi_t \in \Pi_t} V(\sigma_t^i, \sigma; \pi_t)$$

where

$$\begin{aligned} V(\sigma_t^i, \sigma; \pi_t) = &-\pi_t[\rho_a(\sigma_t^i q + (1-\sigma_t^i) \times 0) + (1-\rho_a) \times 0] \\ &- (1-\pi_t)[\rho_b(\sigma_t^i \times 0 + (1-\sigma_t^i)(1-q)) + (1-\rho_b)(1-q)] \end{aligned}$$

or, equivalently,

$$V(\sigma_t^i, \sigma; \pi_t) = -\pi_t \rho_a \sigma_t^i q - (1-\pi_t)(1-\rho_b \sigma_t^i)(1-q).$$

Using Bayes' Rule for any $r \in [\underline{r}, \overline{r}]$, we obtain

$$\pi_a = \frac{pr}{pr + (1-p)(1-r)},$$
$$\pi_b = \frac{p(1-r)}{p(1-r) + (1-p)r}.$$

Note that for $p = \frac{1}{2}$, those expressions simplify to $\pi_a = r$ and $\pi_b = 1 - r$. From now on, we concentrate on this case, which corresponds to jurors putting equal weight on their common prior of a defendant's guilt or innocence.

2.1 Analysis

For the rest of the analysis we concentrate on symmetric equilibria, in which $\sigma^* = (\sigma_a^*, \sigma_b^*) = (\sigma_a^*, 1)$.[10]

Next, note that if $\sigma^* = (\sigma_a^*, \sigma_b^*) = (0,0)$, $\rho_a = \rho_b = 0$. In this case, a defendant would be acquitted irrespective of each juror i's vote. This is always an equilibrium of our ambiguous voting game. In order to concentrate on more interesting scenarios for the best response of each voter i, we rule this case out from the rest of our analysis.

Therefore, to solve for a symmetric voting equilibrium $\sigma^* = (\sigma_a^*, 1)$, is equivalent to solving the following problem for each voter i

$$\max_{\sigma_a^i \in [0,1]} \min_{r \in [\underline{r}, \overline{r}]} \Big[-\Big[q r \sigma_a^i \rho_a + (1-q)(1-r)(1-\rho_b \sigma_a^i) \Big] \Big].$$

Using the Minimax theorem, we know that, for every i

$$V(\sigma_a^i, \sigma, r^*) \leq V((\sigma_a^i)^*, \sigma, r^*) \leq V((\sigma_a^i)^*, \sigma, r)$$

By means of the Envelope theorem, we can start by stating the following, which holds at r^* and for every i:

$$\frac{dV(\sigma_a^i, \sigma, r^*)}{d\sigma_a^i} = \frac{\partial V(\sigma_a^i, \sigma, r^*)}{\partial \sigma_a^i} + \frac{\partial V(\sigma_a^i, \sigma, r^*)}{\partial r} \frac{\partial r^*(\sigma_a^i, \sigma)}{\partial \sigma_a^i}.$$

If $r^*(\sigma_a^i, \sigma)$ is an interior solution, then it must be that $\frac{\partial V(\sigma_a^i, \sigma, r^*(\sigma_a^i, \sigma))}{\partial r} = 0$. Alternatively, if $r^*(\sigma_a^i, \sigma)$ is a boundary solution, then $\frac{\partial r^*(\sigma_a^i, \sigma)}{\partial \sigma_a^i} = 0$. Either way, the derivative of V with respect to σ_a^i reduces to

$$\frac{dV(\sigma_a^i, \sigma, r^*)}{d\sigma_a^i} = \frac{\partial V(\sigma_a^i, \sigma, r^*)}{\partial \sigma_a^i} = -q r^* \rho_a + \rho_b (1-q)(1-r^*).$$

By examining the sign of this derivative, we can distinguish relevant symmetric equilibria of our ambiguous likelihood voting game.

First of all, we can rule out non-responsive voting equilibria in which voters always vote to convict irrespective of their signals, $\sigma = (\sigma_a^*, \sigma_b^*) = (1,1)$, for any $q > \frac{1}{2}$, using the following result.

Lemma 1 *Assume $q \geq \frac{1}{2}$. Then there is no symmetric voting equilibrium, in which $\sigma_a^* = \sigma_b^* = 1$.*

[10] **A formal proof of $\sigma_b^* = 1$ is to be added.**

Proof. For $\sigma_a^* = 1$, it ought to be that

$$\frac{\partial V(\sigma_a^i, \sigma, r^*)}{\partial \sigma_a^i} = -qr^*\rho_a + \rho_b(1-q)(1-r^*) \geq 0 \Leftrightarrow \frac{(1-q)(1-r)}{qr} \geq \frac{\rho_a}{\rho_b}$$

Using the definition of ρ_a and ρ_b, at $(\sigma_a^i)^* = \sigma_a^* = \sigma_b^* = 1$, this condition can be rearranged to highlight the following

$$\frac{(1-q)(1-r^*)}{qr^*} \geq \left(\frac{r^* + (1-r^*)}{(1-r^*) + r^*}\right)^N \Leftrightarrow \frac{(1-q)(1-r^*)}{qr^*} \geq 1 \tag{1}$$

Because $r > \frac{1}{2}$ for any r, including r^*, condition (1) is violated for any $q \geq \frac{1}{2}$, leading to responsive equilibria. ■

For the rest of the analysis, we concentrate on examining responsive, (symmetric) informative and non-informative mixed strategy voting equilibria.

If $\frac{\partial V}{\partial \sigma_a^i} < 0$, then the optimal voting strategy satisfies $\sigma^* = (0, 1)$: Informative voting is the equilibrium.

To better study how to get to this equilibrium, we take several steps, starting with Lemma 2, which establishes a necessary condition for a (symmetric) informative voting to be an equilibrium.

Lemma 2 *A symmetric informative voting equilibrium,* $\sigma^* = (\sigma_a^*, \sigma_b^*) = (0, 1)$, *exists only if* $q > \frac{1}{2}$.

Proof. In a symmetric informative voting equilibrium,

$$\left.\frac{dV(\sigma_a^i, \sigma, r^*)}{d\sigma_a^i}\right|_{\sigma_a^*=0} = -qr^*\rho_a + \rho_b(1-q)(1-r^*)\Big|_{\sigma_a^*=0} \leq 0.$$

Equivalently,

$$-qr^*(r^*\sigma_a + (1-r^*))^N + ((1-r^*)\sigma_a + r^*)^N(1-q)(1-r^*)\Big|_{\sigma_a^*=0} \leq 0$$
$$\Leftrightarrow \left(\frac{1-r^*}{r^*}\right)^{N-1} \geq \frac{1-q}{q}. \tag{2}$$

Because $r > \frac{1}{2}$ for any r, including r^*, a necessary condition for inequality (2) to hold is given by $q > \frac{1}{2}$. ■

If $\frac{\partial V}{\partial \sigma_a^i} = 0$, the best response of each voter i satisfies $0 \leq (\sigma_a^i)^* \leq 1$.

Next, we investigate the mixed strategy voting equilibria resulting from these best responses before deriving a sufficient condition for an informative equilibrium, in particular, to exist.

In a symmetric mixed strategy voting equilibrium,

$$\left.\frac{dV(\sigma_a^i,\sigma,r^*)}{d\sigma_a^i}\right|_{0\le(\sigma_a^i)^*\le 1} = -qr^*\rho_a + \rho_b(1-q)(1-r^*)\Big|_{0\le(\sigma_a^i)^*\le 1} \le 0.$$

Equivalently, using the definition of ρ_a and ρ_b,

$$\frac{r^*\sigma_a^* + (1-r^*)}{(1-r^*)\sigma_a^* + r^*} \ge \left(\frac{(1-q)(1-r^*)}{r^*q}\right)^{1/N}.$$

Denoting $A \equiv \left(\frac{(1-q)(1-r^*)}{r^*q}\right)^{1/N}$, we derive the condition for the probability of voting to convict upon receiving an innocent signal to be an equilibrium, namely

$$\sigma_a^* = \min\left\{\max\left\{0, \frac{1-r^*(1+A)}{A-r^*(1+A)}\right\}, 1\right\}.$$

The reason for this is that for σ_a^* to be a proper probability measure, we need it to be comprised between zero and one. The ratio $\frac{1-r^*(1+A)}{A-r^*(1+A)}$ is always lower than one. However, it could take up negative values, in which case the mixed strategy equilibrium corresponds to a degenerate probability of voting to convict upon receiving an innocent signal such that $\sigma_a^* = 0$. Lemma 3 below shows these properties.

Lemma 3 *Assume $q \ge \frac{1}{2}$. Then,*

1. $\frac{1-r^*(1+A)}{A-r^*(1+A)} > 0 \Leftrightarrow r^* > \frac{1}{1+\left(\frac{1-q}{q}\right)^{\frac{1}{N+1}}}$.

2. $\frac{1-r^*(1+A)}{A-r^*(1+A)} < 1$.

Proof. Using the definition of A, we write

$$A - r^*(1+A) = \left(\frac{1-q}{q}\right)^{\frac{1}{N}}\left(\frac{1-r^*}{r^*}\right)^{\frac{1}{N}} - r^*\left(1 + \left(\frac{1-q}{q}\right)^{\frac{1}{N}}\left(\frac{1-r^*}{r^*}\right)^{\frac{1}{N}}\right) < 0$$

$$\Leftrightarrow \left(\frac{1-q}{q}\right)^{\frac{1}{N}}\left(\frac{1-r^*}{r^*}\right)^{\frac{1+N}{N}} < 1,$$

Note this inequality holds for all N, $q \ge \frac{1}{2}$, and $r^* > \frac{1}{2}$. Hence,

$$sign\left(\frac{1-r^*(1+A)}{A-r^*(1+A)}\right) = -sign(1-r^*(1+A)).$$

Again, using the definition of A, and some algebra we derive

$$1 - r^*(1+A) = 1 - r^*\left(1 + \left(\frac{1-q}{q}\right)^{\frac{1}{N}}\left(\frac{1-r^*}{r^*}\right)^{\frac{1}{N}}\right) < 0 \Leftrightarrow r^* > \frac{1}{1+\left(\frac{1-q}{q}\right)^{\frac{1}{N-1}}}.$$

We know that for all N, $q \geq \frac{1}{2}$, and $r^* > \frac{1}{2}$, $A - r^*(1+A) < 0$, hence

$$\frac{1 - r^*(1+A)}{A - r^*(1+A)} < 1 \Leftrightarrow 1 - r^*(1+A) > A - r^*(1+A) \Leftrightarrow 1 > A,$$

which holds for all N, $q \geq \frac{1}{2}$, and $r > \frac{1}{2}$. ■

These intermediate results allow us to write the optimal probability of voting to convict upon receiving an innocent signal, as follows.

Proposition 1 *Assume $q \geq \frac{1}{2}$. Then,* $\sigma_a^* = \max\left\{0, \frac{1-r^*(1+A)}{A-r^*(1+A)}\right\}$.

Denote the likelihood above which $\sigma_a^* > 0$ by $\widehat{r} = \frac{1}{1+\left(\frac{1-q}{q}\right)^{\frac{1}{N-1}}}$. The mixed strategy equilibrium delivers informative voting for certain combinations of the r, q and N. This leads to Proposition 2.

Proposition 2 *Assume $q > \frac{1}{2}$. Then for all $N > 2$, there exists a unique maximum threshold $\widehat{r} > \frac{1}{2}$, such that, the symmetric voting equilibrium is informative, $\sigma^* = (\sigma_a^*, \sigma_b^*) = (0,1)$, if and only if $\underline{r} \leq \widehat{r}$.*

To prove Proposition 2, we first show that, in any symmetric mixed strategy voting equilibrium, $q \geq \frac{1}{2}$ is a sufficient condition for $r^*(\sigma_a^i, \sigma) = \underline{r}$.

By means of the Envelope theorem, we can also state the following, which holds at $(\sigma_a^i)^*$ and for every i:

$$\frac{dV((\sigma_a^i)^*, \sigma, r)}{dr} = \frac{\partial V((\sigma_a^i)^*, \sigma, r)}{\partial r} + \frac{\partial V((\sigma_a^i)^*, \sigma, r)}{\partial \sigma_a^i} \frac{\partial (\sigma_a^i)^*}{\partial r}.$$

If $(\sigma_a^i)^*$ is an interior solution, then it must be that $\frac{\partial V((\sigma_a^i)^*, \sigma, r)}{\partial \sigma_a^i} = 0$. Alternatively, if $(\sigma_a^i)^*$ is a boundary solution, then $\frac{\partial (\sigma_a^i)^*}{\partial r} = 0$. Either way, and denoting $\tau_a = r\sigma_a + (1-r)\sigma_b$ and $\tau_b = (1-r)\sigma_a + r\sigma_b$, the derivative of V with respect to r reduces to

$$\frac{\partial V((\sigma_a^i)^*, \sigma, r)}{\partial r} = -q\rho_a(\sigma_a^i)^* + Nqr\frac{\rho_a}{\tau_a}(1-\sigma_a)(\sigma_a^i)^* + N(1-q)(1-r)\frac{\rho_b}{\tau_b}(1-\sigma_a)(\sigma_a^i)^* + (1-q)(1-\rho_b(\sigma_a^i)^*).$$

Note that the sign of this derivative varies depending on different combinations of its arguments and the level of the parameter q: the r^* can be an interior or a boundary solution. In Lemma 4, we provide a sufficient condition for r^* to be a boundary solution at $r^* = \underline{r}$.

Lemma 4 *Assume $q \geq \frac{1}{2}$. Then, in any symmetric mixed strategy voting equilibrium,* $\frac{\partial V}{\partial r} \geq 0$.

Proof. We know

$$\frac{\partial V}{\partial r} = -q\rho_a(\sigma_a^i)^* + Nqr\frac{\rho_a}{\tau_a}(1-\sigma_a)(\sigma_a^i)^* + \underbrace{N(1-q)(1-r)\frac{\rho_b}{\tau_b}(1-\sigma_a)(\sigma_a^i)^*}_{\geq 0} + \underbrace{(1-q)(1-\rho_b(\sigma_a^i)^*)}_{\geq 0}.$$

Then, a sufficient condition for $\frac{\partial V}{\partial r} \geq 0$ is

$$-q\rho_a(\sigma_a^i)^* + Nqr\frac{\rho_a}{\tau_a}(1-\sigma_a)(\sigma_a^i)^* \geq 0.$$

If $(\sigma_a^i)^* = 0$, then the condition trivially holds and we have $\frac{\partial V}{\partial r} \geq 0$. If $(\sigma_a^i)^* > 0$, then the condition simplifies to

$$\frac{Nr}{\tau_a}(1-\sigma_a) \geq 1.$$

Recall that $\tau_a = r\sigma_a + (1-r)\sigma_b$ and that we are solving for an equilibrium in which $\sigma_b = 1$. Hence, the sufficient condition for $\frac{\partial V}{\partial r} \geq 0$ can be rewritten as

$$\frac{Nr}{r\sigma_a + (1-r)}(1-\sigma_a) \geq 1 \Leftrightarrow (N+1)r - 1 \geq (N+1)r\sigma_a \Leftrightarrow \sigma_a \leq \frac{(N+1)r-1}{(N+1)r}.$$

Now, recall that in the symmetric mixed strategy voting equilibrium, $\sigma_a^*(r) = \max\left\{0, \frac{1-r(1+A)}{A-r(1+A)}\right\}$, where $A \equiv \left(\frac{(1-q)(1-r)}{rq}\right)^{1/N}$, so a sufficient condition at the equilibrium for $\frac{\partial V}{\partial r} \geq 0$ is

$$\max\left\{0, \frac{1-r(1+A)}{A-r(1+A)}\right\} \leq \frac{(N+1)r-1}{(N+1)r}.$$

Clearly, this holds for $\sigma_a^* = 0$. Next, note that while the right-hand side is independent of q, the left-hand side is weakly decreasing in q:

$$\frac{\partial \frac{1-r(1+A)}{A-r(1+A)}}{\partial q} = \frac{(2r-1)\left(\frac{(q-1)(r-1)}{qr}\right)^{1/N}}{N(q-1)q\left((r-1)\left(\frac{(q-1)(r-1)}{qr}\right)^{1/N} + r\right)^2} < 0.$$

Hence, if the inequality holds for $q = \frac{1}{2}$, then it holds for any $q \geq \frac{1}{2}$. If we evaluate the left-hand side at $q = \frac{1}{2}$, we get the condition

$$\max\left\{0, \frac{r\left(\frac{1}{r}-1\right)^{1/N} + r - 1}{(r-1)\left(\frac{1}{r}-1\right)^{1/N} + r}\right\} \leq \frac{(N+1)r-1}{(N+1)r}.$$

It is easy to show that, for $r > \frac{1}{2}$ and $N > 2$, the left-hand side is weakly decreasing in r, whereas the right-hand side is increasing in r. Hence, we compute

$$\lim_{r \to \frac{1}{2}} \max \left\{ 0, \frac{r\left(\frac{1}{r}-1\right)^{1/N} + r - 1}{(r-1)\left(\frac{1}{r}-1\right)^{1/N} + r} \right\} = \frac{N-1}{N+1},$$

and, since

$$\frac{N-1}{N+1} = \frac{\frac{1}{2}(N+1)-1}{\frac{1}{2}(N+1)}, \ \forall N,$$

we have

$$\frac{Nr}{\tau_a}(1-\sigma_a^*(r)) \geq 1, \quad \forall r \in [\underline{r}, \bar{r}].$$

Because of Lemma 1, we cannot have $\sigma_a^*(r) = 1$. Hence, we have shown that for $q \geq \frac{1}{2}$, in any symmetric voting equilibrium, $\frac{\partial V}{\partial r} \geq 0$. ■

We are now in a position to prove Proposition 2.

Proof of Proposition 2. Lemmas 3 and 4 establish Proposition 2. ■

2.2 Discussion of Results

2.2.1 Comparative Statics

We are now in a position to study the occurrence of an informative equilibrium under the unanimity rule with an ambiguous likelihood.

For that, we provide the following comparative statics of $\widehat{r}$ with respect to q and N:

$$\frac{\partial \widehat{r}}{\partial N} = \frac{\left(\frac{1}{q}-1\right)^{\frac{1}{N+1}} \ln\left(\frac{1}{q}-1\right)}{(N+1)^2\left(\left(\frac{1}{q}-1\right)^{\frac{1}{N+1}}+1\right)^2} < 0,$$

$$\frac{\partial \widehat{r}}{\partial q} = -\frac{\left(\frac{1}{q}-1\right)^{\frac{1}{N+1}}}{(N+1)(q-1)q\left(\left(\frac{1}{q}-1\right)^{\frac{1}{N+1}}+1\right)^2} > 0.$$

As the size of the jury grows, the condition for the lowest bound of the likelihood interval to be below $\widehat{r}$ becomes more stringent. Hence, informative voting equilibria are more difficult to be sustained. This is in line with existing results in the literature on jury voting.

However, by increasing the threshold of the reasonable doubt, it is possible to relax the condition for which informative equilibria can be sustained. However, unlike in the existing literature, under ambiguous likelihood, the threshold of the reasonable doubt needed for informative voting equilibria to be sustained is much lower.

Similarly, we can provide comparative statics of σ_a^* with respect to q and N, and for given $\underline{\mathrm{r}}$, as follows

$$\frac{\partial \sigma_a^*}{\partial N} = -\frac{(2\underline{\mathrm{r}}-1)\left(\frac{(q-1)(\underline{\ }-1)}{q\underline{\mathrm{r}}}\right)^{1/N} \ln\left(\frac{(q-1)(\underline{\mathrm{r}}-1)}{q\underline{\mathrm{r}}}\right)}{N^2\left((\underline{\mathrm{r}}-1)\left(\frac{(q-1)(\underline{\mathrm{r}}-1)}{q\underline{\mathrm{r}}}\right)^{1/N}+\underline{\mathrm{r}}\right)^2} > 0,$$

$$\frac{\partial \sigma_a^*}{\partial q} = \frac{(2\underline{\mathrm{r}}-1)\left(\frac{(q-1)(\underline{\mathrm{r}}-1)}{q\underline{\mathrm{r}}}\right)^{1/N}}{N(q-1)q\left((\underline{\mathrm{r}}-1)\left(\frac{(q-1)(\underline{\mathrm{r}}-1)}{q\underline{\mathrm{r}}}\right)^{1/N}+\underline{\mathrm{r}}\right)^2} < 0.$$

The first of these comparative statics implies that as the jury size grows, jurors randomize their votes to convict upon receiving an innocent signal with higher probability. This is also in line with existing results in the literature.

And, related, as the threshold of reasonable doubt increases, such randomization involves a lower probability for jurors to vote to convict against their signals, which is also in line with existing results in the literature.

2.2.2 Illustrative Examples

Next, we provide some illustration of our results, by means of examples of voting situations in contexts with medium to relatively small jury sizes.

Recall the FP's canonical 12-juror unanimity voting example with precision (likelihood) $r = 0.80$ and $q = 0.90$. Informative voting was not an equilibrium in such settings. Now, assume, instead that jurors face an ambiguous likelihood $r \in [\underline{\mathrm{r}}, \bar{r}]$ with $r > \frac{1}{2}$. The left-hand panel of figure 1 below shows a plot of $\frac{\partial V}{\partial r}$, as a function of r, evaluated at $\sigma_a^* = \frac{1-r^*-Ar^*}{A-Ar^*-r^*}$, $n = 12$, and $q = 0.9$. The right-hand panel shows the equilibrium mixed strategy σ_a^* as a function of r evaluated at $n = 12$, and $q = 0.9$. Notably, it shows that an informative voting equilibrium can be sustained so long that $\frac{1}{2} < \underline{\mathrm{r}} \leq \widehat{r} = 0.549772$. This implies that, under an ambiguous likelihood, compatible with relatively low levels of trust in the evidence provided in a jury trial, ambiguity-averse jurors would be more reluctant to vote to convict, when receiving an innocent signal. This, in turn, help decrease the occurrence of type I errors, in spite of adhering to the unanimity rule.

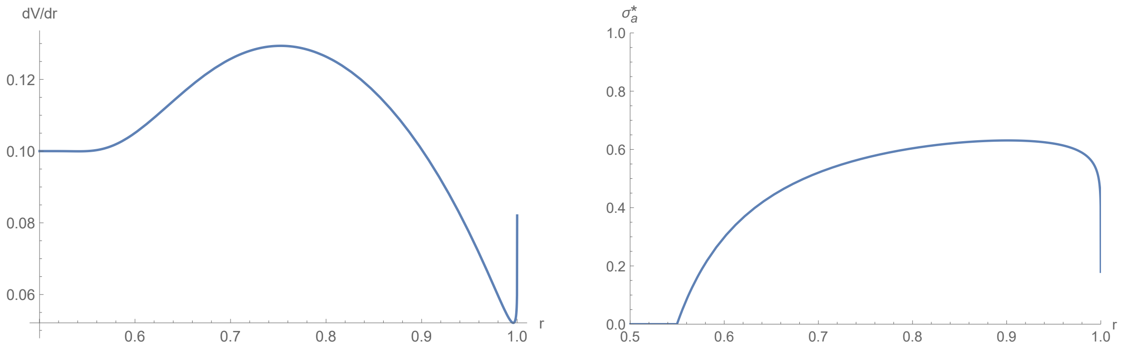

Figure 1: *The left-hand panel shows a plot of* $\frac{\partial V}{\partial r}$, *as a function of* r, *evaluated at* $\sigma_a^* = \frac{1-r^*-Ar^*}{A-Ar^*-r^*}$, $n = 12$, *and* $q = 0.9$. *The right-hand panel shows the equilibrium mixed strategy* σ_a^* *as a function of* r *evaluated at* $n = 12$, *and* $q = 0.9$.

Let us modify the example above by reducing the number of jurors to $n = 6$, keeping the rest unchanged. Informative voting cannot be an equilibrium, when the precision (likelihood) of the information given to jurors is equal to 0.80. For an ambiguous likelihood, the left-hand panel of figure 2 shows a plot of $\frac{\partial V}{\partial r}$, as a function of r, evaluated at $\sigma_a^* = \frac{1-r^*-Ar^*}{A-Ar^*-r^*}$, $n = 6$, and $q = 0.9$. The right-hand panel shows the equilibrium mixed strategy σ_a^* as a function of r evaluated at $n = 6$, and $q = 0.9$. In this case, an informative voting equilibrium can be sustained so long that $\frac{1}{2} < \underline{r} \leq \widehat{r} = 0.608127$. Once again, this implies that, under an ambiguous likelihood, compatible with relatively low levels of trust in the evidence provided in a jury trial, ambiguity-averse jurors would be more reluctant to vote to convict, when receiving an innocent signal. Again, the unanimity rule is not incompatible with voting informatively, in equilibrium.

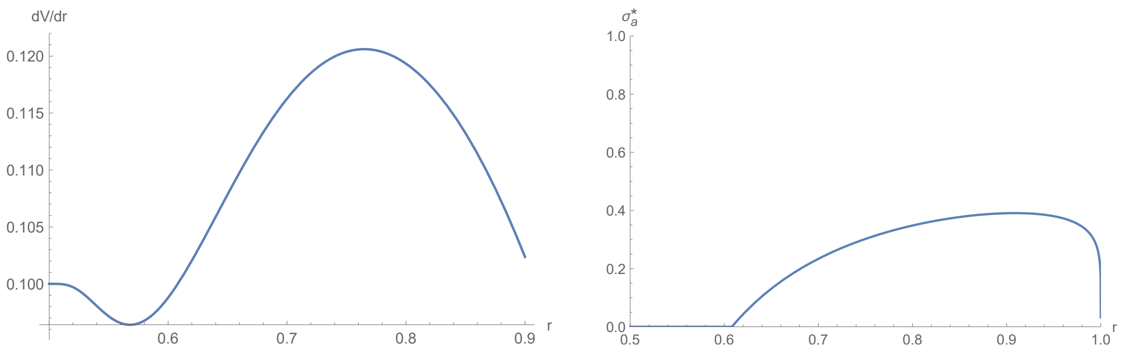

Figure 2: *The left-hand panel shows a plot of* $\frac{\partial V}{\partial r}$, *as a function of* r, *evaluated at* $\sigma_a^* = \frac{1-r^*-Ar^*}{A-Ar^*-r^*}$, $n = 6$, *and* $q = 0.9$. *The right-hand panel shows the equilibrium mixed strategy* σ_a^* *as a function of* r *evaluated at* $n = 6$, *and* $q = 0.9$.

Lastly, we provide an illustration of our results, by means of contexts where we vary the minimum threshold of reasonable doubt given to jurors to cast a vote to convict.

Let us use again the FP's canonical 12-juror unanimity voting example, with precision (likelihood) $r = 0.80$. To sustain an informative voting in such setting, a level of the reasonable doubt above 0.9999 was required. Now, assume, that jurors face an ambiguous likelihood $r \in [\underline{r}, \bar{r}]$ with $r > \frac{1}{2}$. Figure 3 illustrates what the level of the minimum threshold for the reasonable doubt sustaining informative voting as an equilibrium ought to be, as a function of $\underline{r} = \widehat{r}$, for a jury size of $n = 12$. Once more, especially when ambiguity-averse jurors are affected by low enough ambiguous likelihood intervals, distrusting the precision of the evidence plays the role of a substitute to requiring a very high level of reasonable doubt for jurors to be willing to vote to convict in the first place. This, in turn, makes informative voting possible as an equilibrium in instances when it would have not been, namely in the absence of such ambiguity.

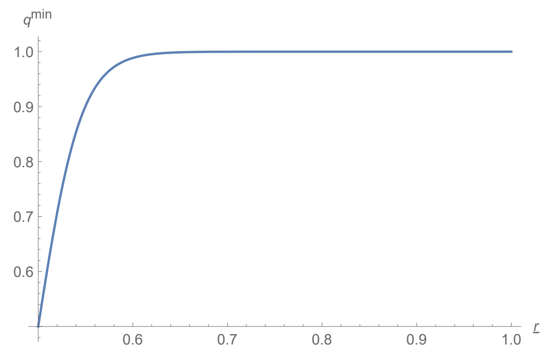

Figure 3: *This is an illustration of what the minimum threshold for the reasonable doubt sustaining informative voting as an equilibrium ought to be, as a function of* $\underline{r} = \widehat{r}$*, for a jury size of* $n = 12$.

Let us repeat the exercise above, by reducing the size of the jury to $n = 6$. To sustain an informative voting in such setting, a level of the reasonable doubt above 0.9961 was required. Now, assume, that jurors face an ambiguous likelihood $r \in [\underline{r}, \bar{r}]$ with $r > \frac{1}{2}$. Figure 4 illustrates what the level of the minimum threshold for the reasonable doubt sustaining informative voting as an equilibrium ought to be, as a function of $\underline{r} = \widehat{r}$, for a jury size of $n = 6$. Once more, this suggests that justice is better served under voting unanimously with an ambiguous likelihood. A distrust of the precision of the evidence provided to ambiguity-averse jurors can be a substitute to requiring a very high level of reasonable doubt for jurors to be willing to vote to convict in the first place. This, in turn, helps sustain informative voting equilibria under the unanimity rule that would have not been feasible otherwise.

3 Our Experiment

Whether these theoretical predictions have any bearing on the behavior we would observe in the real world, is an empirical question.

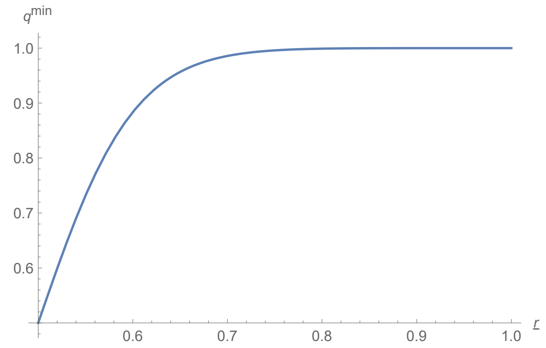

Figure 4: *This is an illustration of what the minimum threshold for the reasonable doubt sustaining informative voting as an equilibrium ought to be, as a function of* $\underline{r} = \widehat{r}$*, for a jury size of* $n = 6$.

Therefore, it is pertinent to advance our understanding of voting behavior in the presence of ambiguity also by means of a laboratory experiment.

Our main interest is in exploring voting behavior in the ambiguous environment we described, and to relate this behaviour to an individual's attitude towards ambiguity.

This is not a trivial task: How does an individual's attitude toward ambiguity in single-person decisions translate in that individual's behaviour when confronted with an ambiguous game-theoretical voting situation?

We are not the first to elicit subjects' attitudes toward ambiguity in an attempt to infer their behaviour in a group setting. For example, Kelsey and le Roux (2018) reports on a set of experiments to compare the effect of ambiguity as identified in single-person decisions on games involving two players. These experiments confirm a theoretical prediction made by Eichberger and Kelsey (2002) that ambiguity increases/decreases the equilibrium strategy in games with strategic complements/substitutes and positive externalities; and that the reverse is true for games with negative externalities. Furthermore, and consistent with the findings of Kelsey and le Roux (2015), Kelsey and le Roux (2018) also notes that subjects' ambiguity attitudes appear to be context dependent: ambiguity loving in single-person decisions and ambiguity averse in games.

A voting scenario involves each individual's decision (single vote), which though only partially determines the overall group decision (final verdict, made up of all votes), as a function of the adopted voting rule. Since there is no established result in the literature that provides a clear link between an individual's attitude towards ambiguity and that individual's tendency to vote in accordance to their private and ambiguous signal in a voting scenario, there is room to provide novel insights about the direction of such link, if any, using a suitable laboratory experiment. In our laboratory setting, we can account for subjects who exhibit varying attitudes toward ambiguity, as well as revealed updating behaviours, when examining their voting choices.

3.1 Experimental Design

For our experimentation, we implement *four within-subjects treatments*. All four treatments contain two stages of various decision tasks and one questionnaire about the subjects' social and personal characteristics. The first stage and the questionnaire are the same across all treatments. The differences across treatments are only featured by the set-ups of the second stage.

Specifically, in the first stage our design offers a variation of the Ellsberg three-color urn game à la Cohen, Gilboa, Jaffray, and Schmeidler (2000) aimed at identifying each subject's attitude towards ambiguity and their chosen updating rule when confronted with it.

In the second stage, the four treatments differ as follows. Two of the treatments consist of a voting environment à la FP, with a signal precision of either $r = 0.7$ or $r = 0.8$, each subjected to the 'U'-nanimity voting rule (FP-U). The remaining treatments, consider a modified voting environment with an 'A'-mbiguous signal precision, such that $P(g|G) = P(i|I) = r \in [0.6, 0.8]$ or $P(g|G) = P(i|I) = r \in [0.7, 0.9]$, each subjected to the unanimity voting rule (A-U).

Our experimental design allows us to introduce an ambiguous signal-state correlation to examine subjects' voting behaviour according to attitudes towards ambiguity and updating rules as revealed in the first stage of our experiment. Hence, two of the four treatments considered in the second stage not only replicate the jury model as found in FP, but, by doing so, also provide us with the necessary control group (baseline) for our data analysis of the additional two treatments, allowing for an alternative environment, namely those with an ambiguous information structure.

Stage 1 We computerize the experiment of Cohen et al. (2000) and conduct it with real cash prizes. Subjects are asked to place three consecutive bets on the colors of a randomly selected ball from a standard 3-color Ellsberg urn. Subjects are initially told that the urn contains 90 balls, of which 30 are white, and the remaining 60 are either black or yellow. The exact composition of the Ellsberg urn is then determined at random by the computer and not revealed to the subjects.[11] Next, the computer

[11]To generate ambiguity in the laboratory setting, we adopted the method of Stecher, Shields, and Dickhaut (2011) – so that, for instance, the true composition of the urn remains unavailable to both the subjects and the experimenters throughout the experiment. This has been shown to help to lower subjects' reluctance to engage in an ambiguous bet (Chow and Sarin, 2002). To induce ambiguity in the lab, we first generated 10,000 realizations of the relative proportion of black and yellow balls, and then selected one uniformly from these realisations and took it as the real proportion of black and yellow balls in the urn. By doing so, the randomly determined proportion of the black and yellow balls and the color of the selected ball for Bets 1 and 2 were not known to anyone for the duration

randomly selects a ball from that urn with replacement until a 'non-yellow' ball is selected. Subjects are not told about the color of the selected ball. Then subjects place Bets 1 and 2. Each bet has four alternatives. In Bet 1, subjects choose: (i) To bet on the color of the selected ball to be 'White'; (ii) To bet on the selected color of the ball to be 'Black'; (iii) To be 'Indifferent' between betting on the color of the selected ball to be 'White' or 'Black', leaving the computer to place a bet on their behalf by choosing to bet on either of these colors with equal probability; and, lastly, (iv) To choose 'Do Not Bet' on any specific color for the selected ball, thereby renouncing to the prospect of having a positive earning. In Bet 2, subjects choose: (i) To bet on the color of the selected ball to be 'White or Yellow'; (ii) To bet on the color of the selected ball to be 'Black or Yellow'; (iii) To be 'Indifferent' between betting on the color of the selected ball to fall under the option 'White or Yellow' or 'Black or Yellow', letting the computer choose among those options with equal probability; and, once again, (iv) To choose 'Do Not Bet', renouncing to the prospect of any positive earning. Therefore, Bets 1 and 2 are variants of the Ellsberg three-color urn experiment, in the sense that they are designed to have two more options than the two alternatives of the original Ellberg experiment, namely the 'Indifferent' and the 'Do Not Bet' options. Those additional options were added to allow for SEU or inconsistent subjects' preferences types, respectively. After Bet 2, subjects were told that the ball selected for Bets 1 and 2 was 'non-yellow' and that it was placed back into the urn. Next, the computer draws another ball, the color of which is once again not revealed to the subjects. Subjects then place Bet 3, consisting of the same options as in Bet 1.

For each of those bets, subjects could receive a NZD2.00 prize if placing a correct bet. Otherwise, subjects would receive no prize, that is if placing the wrong bet or if choosing not to bet. In any event, subjects receive no feedback on the outcome of their bets. Instead, subjects do receive payments according to the quality of their choices in Stages 1 and 2, but only at the very end of the experimental session they participated in.

Stage 2 To emulate the jury voting scenario, Stage 2 consists of one trial round and twenty subsequent rounds of decision-making between two alternatives. Specifically, at the beginning of each round, the computer randomly and independently selects one among two possible urns, a 'Blue' or a 'Red' one, with equal probability. Each urn contains 100 balls, either red or blue. The urn is said to be Red (Blue) if it predominantly contains Red (Blue) balls. Next, the computer randomly and independently assigns each subject to a group of other five subjects, tasked with guessing the right color of the urn selected for that round. Before each subject casts their vote about what they believe the color of the selected urn for that round to be, they receive a private information regarding the color of a randomly and independently drawn ball, with replacement, from that urn. For the ambiguous treatments only, before the computer randomly draws the ball for each subject, a graph of 10 bar charts is shown to all subjects. Each of the bar charts contains 10,000 realizations of either 21 different proportions of the two col-

of the experiment.

ors, comprised between 60/40 and 80/20, that is any realisation of the percentage of the predominant balls of a given color in the set $P = \{0.60, 0.61, \ldots, 0.79, 0.80\}$; or 31 different proportions of the two colors, comprised between 70/30 and 90/10, that is any realization of the percentage of the predominant balls of a given color in the set $P = \{0.70, 0.71, \ldots, 0.89, 0.90\}$[12] Once subjects cast their vote, each vote gets next aggregated to form a specific group decision in accordance with the unanimity voting rule. The default for the group decision is set to be 'Blue' if that group falls short of meeting the minimum number of red votes for a 'Red' decision to be reached: Given the unanimity voting rule that minimum number of red votes is six out of six.[13] No feedback regarding either the color of the selected urn, or other subjects' votes are provided during the experimental session. Only at the very end of the experimental session, subjects are revealed the quality of their decision in one randomly and independently selected round – out of the twenty rounds of decision-making they participated in – and are paid accordingly.

Questionnaire Lastly, subjects are asked to complete a questionnaire after Stage 2. The questionnaire involves personality traits, locus of control and a few demographic questions. Answers in the questionnaire are only meant to be used as control variables in our empirical analysis of the experimental data. Subjects are informed that their answers to the questionnaire do not affect the payments they receive at the very end of the experimental sessions they participated in.

Payments Subjects are incentivized in taking part in the experiment and paying attention to their choices during the experiment as follows. They receive NZD10.00 as a show-up fee, NZD2.00 for each correctly placed bet, for a maximum of NZD6.00 attainable for choices made in Stage 1. Additionally, they receive NZD14.00 if their group decision in the randomly selected round out of the twenty rounds they were involved in is correct. Otherwise, they receive respectively (i) NZD13.00 or (ii) NZD5.00 if their group decision is incorrect in that randomly selected round. This can be either (i) because their choice is 'Blue' when the correct color of the selected urn is 'Red' (playing the same role as type II error, that is choosing to acquit the guilty), or (ii) it is 'Red' when the true color of the selected urn is 'Blue' instead (playing the same role as type I error, that is choosing to convict the innocent). The variation in the payments subjects receive following a wrong group decision relates to the gravity of that decision: It mirrors the same asymmetry that exists between the loss associated with type I and type II errors. It is easy to derive that the loss in earnings when committing type I errors is equal to $14-5=$9; whereas the loss in earnings when committing type II errors is equal to $14-13=$1. Therefore, the relative importance between type I and type

[12] These realisations are obtained in much the same way as the ones for Stage 1.

[13] Put differently, under the unanimity voting rule the group decision is 'Blue' if at least one of the subjects votes for blue.

II errors is exactly 9:1, mirroring $q = 0.9$. Hence, the maximum and minimum payments subjects can receive in an experimental session are NZD30.00 and NZD15.00, respectively.

3.2 Revealed Preferences and Updating Rules

Table 2 states all possible decisions from the first two bets and the possible corresponding revealed attitudes towards ambiguity. We identify each subject's decision regarding the bets from Stage 1 by acts of betting on d_W, d_B, $d_{W\cup Y}$ and $d_{B\cup Y}$, where W stands for 'W-hite', B stands for 'B-lack', '$W \cup Y$' stands for 'W-hite or Y-ellow', and '$B \cup Y$' stands for 'B-lack or Y-ellow'. So, for instance, think of a subject betting on d_W. If the color of the selected ball for that bet were indeed white, that subject would receive a prize of NZD2.00. Otherwise, if the color of the selected ball for that bet were not white, the subject would have placed a wrong bet and get no rewards.

If a subject were to select (i) 'White' in the first bet and 'White or Yellow' in the second bet, or (ii) 'Black' in the first bet and 'Black or Yellow' in the second bet, this would indicate the following alternative idiosyncratic preference patterns for that subject: (i) $d_W \succ d_B$ and $d_{W\cup Y} \succ d_{B\cup Y}$; or (ii) $d_W \prec d_B$ and $d_{W\cup Y} \prec d_{B\cup Y}$. Each of these two preference patterns satisfy the 'Sure-Thing Principle'. Thus, they are consistent with the SEU model and subjects exhibiting such preferences could be considered to be ambiguity neutral. If instead a subject's preference patterns were to exhibit a reversed preference ordering between the first and the second bet, that subject's preference towards ambiguity would likely satisfy – be consistent with – the multiple prior model. In particular, preference patterns consistent with the Hurwicz α-criteria, would allow subjects to have a whole range of intermediate attitudes with respect to ambiguity, rather than allowing only the extreme cases. Thus, if the revealed preference pattern were $d_W \succ d_B$ and $d_{W\cup Y} \prec d_{B\cup Y}$, it would indicate that subjects are likely to be ambiguity-averse, or equivalenty that their α satisfies the condition $\alpha > 1/2$. The opposite pattern $d_W \prec d_B$ and $d_{W\cup Y} \succ d_{B\cup Y}$ would suggest that subjects are likely to be ambiguity-loving, or equivalently that their α satisfies the condition $\alpha < 1/2$. Subjects who were to exhibit the pattern ($d_W \sim d_B$, $d_{W\cup Y} \sim d_{B\cup Y}$) would either have SEU preferences or adhere to the Hurwicz criteria, although with an $\alpha = 1/2$. Other decisions, not easily associated with either of those preference patterns, and corresponding attitudes towards ambiguity, would then indicate some form of inconsistency.

Remember that, for bet 3, before placing their bet, subjects are told that the previously drawn ball for bets 1 and 2 was not yellow. This is done in order for subjects to make decisions for the third bet depending on their updating of their subjective prior beliefs. If any differences were to be observed in the decisions made by the different subjects, we could then reconcile those differences as resulting from varying updating rules subjects would adopt, depending on their attitudes towards ambiguity. For instance, subjects with SEU preferences would use the standard Bayesian updating rule. Therefore, for those subjects the preference ordering between the alternatives in bet 3 would not

Table 2: Revealed Preferences

	Bet 1			
	White	Black	Indifferent	Do Not Bet
Bet 2				
White or Yellow	SEU	$\alpha < 1/2$	inconsistent	inconsistent
Black or Yellow	$\alpha > 1/2$	SEU	inconsistent	inconsistent
Indifferent	inconsistent	inconsistent	SEU or $\alpha = 1/2$	inconsistent
Do Not bet	inconsistent	inconsistent	inconsistent	inconsistent

be altered from that expressed in bet 1. We could, for example, clearly identify the preference types of the subjects who were indifferent between betting on 'White' and 'Black'; or 'White or Yellow' and 'Black or Yellow'. Therefore, if those same subjects were to express choices in line with $d_W \sim d_B$ also in bet 3, they could be classified as belonging to the SEU type. For the remaining subjects who were also to exhibit consistent preferences, but with a preference pattern for the third bet such that $d_W \succ d_B$, we could conclude that their updating rule falls into the category of Full Bayesian Updating (FBU). The opposite pattern $d_W \prec d_B$ would indicate that the Maximum Likelihood Upating (MLU) were used instead. Any remaining cases, not falling in either of those categories, would then be labelled as 'others'.

Table 3 provides a summary of all the updating rules, including those that are inconsistent with any of the categories described above.

Table 3: Revealed Updating Rules

	Bet 3			
	White	Black	Indifferent	Do Not Bet
Bet 1, Bet 2				
White, White or Yellow	Bayes' Rule	others	others	others
Black, Black or Yellow	others	Bayes' Rule	others	others
White, Black or Yellow	FBU	MLU	others	others
Black, White or Yellow	FBU	MLU	others	others
Indifferent, Indifferent	FBU	MLU	Bayes' Rule	others

3.3 Experimental Data

Our experiment was conducted between July and September 2017 and May 2018 at DECIDE (Laboratory for Business Decision Making) based at the University of Auckland.[14,15] Subjects were recruited among students at the University of Auckland using ORSEE (Greiner, 2015). A total of 192 subjects participated in 9 experimental sessions. Five sessions were conducted for the ambiguity treatments, and four sessions were conducted for the FP treatments. All sessions were computerized, using z-Tree (Fishbacher, 2007). Preceding each stage, in each of these treatments, separate instructions were given to subjects by the experimenter as per our description in Section 3.[16] The subjects' total rewards from this experiment consisted of the earnings from Stage 1, Stage 2 and the show-up fee, as described in details in Section 3. This resulted in an average reward per subject of NZD26.00.

3.3.1 Descriptive Statistics and Data Analysis

Below we reproduce some summaries for the descriptive statistics of our experiment.

Table 4 offers a summary of the individual and group decisions as well as their consequences in terms of type I and type II errors for the baseline treatments à la FP.

According to FP's framework, for the parameter values chosen for our experimental setting informative voting is not an equilibrium strategy under the unanimous voting rule. Previous experimental evidence has investigated group-decision making and tested Nash predictions for varying jury sizes and voting rules in the absence of ambiguity. These studies confirm the Nash prediction that unanimity voting rule underperforms against the majority voting rule, triggering (more) strategic voting, with subjects with blue (innocent) signals mixing between voting for blue (acquit) and red (convict) more than they would do under the majority voting rule.[17] In practice though, and including in our baseline treatment, subject randomize their votes even when receiving a red signal.

Absent ambiguity, and in line with existing studies, Table 4 highlights that subjects in our experiment are also inclined to randomize their votes towards red (alias conviction) upon receiving a blue (innocent) signal when the unanimity voting rule is in place.

When looking at the experimental data generated in treatments with ambiguity, as highlighted in Table 4, it is possible to observe instances in which subjects randomize considerably less upon receiving a blue (innocent) signal than compared to when ambiguity is absent. Consistent with our theoretical model, this corresponds to situations

[14]The experimental sessions were funded with grants from the University of Auckland Faculty Research Development Fund titled 'Deliberation under Ambiguity' and the Royal Society of New Zealand (Marsden Grant UOA16174).

[15]The 3-year ethical approval to conduct this research with human subjects was obtained from the University of Auckland Human Participants Ethics Committee on the 18th of June 2015 (with reference number 014565).

[16]See supplementary material for detailed instructions given in each of the treatments listed in this study.

[17]Guarnaschelli, McKelvey, and Palfrey (2000), and Goeree and Yariv (2011).

Table 4: Descriptive Statistics
Experimental Realizations for
$r = 0.70$, $r = 0.8$, $r \in [0.60, 0.80]$ and $r \in [0.70, 0.90]$

$N = 6$	$r = 0.7$	$r = 0.8$	$r \in [0.6, 0.8]$	$r \in [0.7, 0.9]$
Number of individual decisions	720	720	1,680	720
Number of group decisions	120	120	280	120
All subjects				
Red votes with red signals	43.9%	68.5%	57.7%	46.4%
Red votes with blue signals	16.6%	24.4%	17.9%	21.2%
Ambiguity-loving subjects				
Red votes with red signals	87.9%	60.7%	66.7%	55.6%
Red votes with blue signals	14.9%	31.3%	22.2%	47.7%
SEU maximising subjects				
Red votes with red signals	30.9%	65.5%	58.7%	56.7%
Red votes with blue signals	9.0%	19.0%	18.2%	20.2%
Ambiguity-averse subjects				
Red votes with red signals	47.1%	75.4%	45.8%	38.1%
Red votes with blue signals	27.4%	30.4%	13.0%	12.6%
Wrong group outcomes	51.7%	45.8%	52.5%	45.0%
True jar 'Blue' (Type I error)	0.0%	0.0%	0.0%	0.0%
True jar 'Red' (Type II error)	100%	94.8%	98.7%	98.2%

in which the interval ambiguity of the likelihood of the precision of these signals has a lower bound which is strictly below the level of the precision used to compare these results against.

For instance, absent ambiguity, for $r = 0.8$ the probability across all subjects to vote for red when receiving blue signals is 24.4%. However, this probability reduces to only 21.2% with an ambiguous likelihood $r \in [0.7, 0.9]$, and further decreases to 17.9% with an ambiguous likelihood $r \in [0.6, 0.8]$ instead.

These first remarks can be further broken down into different categories depending on the idiosyncratic attitudes of subjects towards ambiguity, as measured in single-person decisions, that is based on the results from Stage 1 of our experiment.

At a first glance, it appears that especially individuals identified as ambiguity-averse in single-person decisions behave more in accordance with the prediction of our theoretical model, which is consistent with ambiguity-averse decision makers' behavior in a voting situation; whereas individuals identified as ambiguity-loving in single-person decisions behave less in accordance to what our theoretical model of ambiguity-averse decision-makers in a voting situation would predict.

For instance, and strikingly so, absent ambiguity and for $r = 0.8$ the probability for subjects who exhibited ambiguity-averse attitudes in single-person decisions to vote for red when receiving blue signals is 30.4%. However, the probability of voting to convict upon receiving an innocent signal drops to less than 13% under either of the allowed interval ambiguity in our experiment. Conversely, absent ambiguity and for $r = 0.8$ the probability for subjects who exhibited ambiguity-loving attitudes in single-person decisions to vote for red when receiving blue signals is 31.3% . And, such probability of voting to convict upon receiving an innocent signal can either increase or decrease depending on the allowed interval ambiguity in our experiment.

This suggests that there exists a potentially important link between one's attitude toward ambiguity in single-person decisions and how that translates in one's attitude toward ambiguity in an ambiguous voting game. This link deserves further attention and analysis, to reveal any systematic relationship between one's attitude toward ambiguity in single-person decisions and that in an ambiguous voting scenario.

3.3.2 The Impact of Ambiguity on Voting to Convict

The rest of this section is devoted to assessing this link, by means of appropriate econometric models and controls, which can also inform us about what the statistical significance of any such link really is.

Here, we provide results of our econometric analysis, focussing on estimating the determinants of the probability to vote for red (alias of voting to convict) at the subject level. First of all, we are able to obtain results for a battery of Probit estimations that explain individual decisions to vote to convict, respectively for the ambiguity-loving, SEU, and ambiguity-averse subjects as identified in Stage 1 of our experiment, that is based on their attitudes toward ambiguity in single-person decisions. Our conjecture, based on our theoretical model, is that the interaction between ambiguity and unanimity should decrease an ambiguity-averse subject's probability of voting to convict upon receiving a blue (innocent) signal. Indeed, Tables 5-8 in Appendix A provide support for such conjecture. The coefficient for the combined marginal effect of adopting the unanimity rule when the signal precision is ambiguous is negative and highly statistically significant (at the 95% level). Holding everything else fixed, subjects identified as ambiguity-averse in single-person decisions, behave as ambiguity-averse subjects in voting scenarios we analyzed. This behavior is best captured especially when giving a chance to the lower bound of the interval of the ambiguous likelihood to be below a critical level. Specifically, Tables 9-12 in Appendix A show how this effect is mitigated when reducing the scope for the interval ambiguity to play a role. Namely, ambiguity ceases to reduce the probability of voting to convict upon receiving an innocent signal whenever the lower bound of the interval ambiguity is too close to what the level of the precision would have been in the absence of ambiguity. These are instances, for which informative voting is unlikely to be the equilibrium of the corresponding ambiguous voting game. In general, subjects are less likely to vote to convict in later rounds. This is in spite of not receiving any feedback on their performance round by round. These results persist when controlling for various personality traits.

4 Conclusion

We break new ground by providing both a theoretical foundation and evidence that an individual's attitude towards ambiguity in single-person decisions can be systematically related to that individual's behaviour in collective decision-making. We do so by providing a modified version of the canonical jury model, embedding ambiguity in the likelihood of the signals jurors receive before casting their votes, and allowing for jurors to be ambiguity-averse. We do so to explore, both theoretically and experimentally, how the presence of an ambiguous environment affects individual voting behaviour in juries.

Whenever ambiguity affects choices at an individual level, ambiguity also matters in determining that individual's behaviour in a voting situation. Remarkably, both ambiguity-averse and ambiguity-loving attitudes translate in more cautious voting behaviour, that is in more reluctance to vote against the default, especially so for those subjects who were identified as exhibiting ambiguity-averse attitudes in single-person decisions. When thinking about a jury setting, such reluctance determines fewer instances of voting to convict, thereby redeeming the unanimity voting rule and making it desirable yet again when wanting to increase consensus building without compromising the efficiency of information aggregation. Ambiguity can help restore efficiency even for medium size juries.

With our work we contribute to the study of collective decision-making, particularly in those more realistic scenarios where voters do not have access to information whose accuracy is precisely measured. Therefore, by stressing the strong link between ambiguity attitudes and voting behavior under ambiguity, our study encourages further exploration of such a link also for alternative sources of ambiguity and alternative voting rules, beyond unanimity.

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A Appendix: Tables

Table 5: All subjects: $r = 0.8$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.328***	-0.327***	-0.328***	-0.326***	-0.325***
	(0.0249)	(0.0249)	(0.0245)	(0.0246)	(0.0245)
Ambiguity	-0.0161	-0.0160	-0.0157	-0.0176	-0.0204
	(0.0421)	(0.0421)	(0.0413)	(0.0412)	(0.0409)
Round		-0.00344***	-0.00349***	-0.00347***	-0.00347***
		(0.00116)	(0.00115)	(0.00115)	(0.00115)
Overall Ability			-0.0183	-0.0143	-0.0144
			(0.0220)	(0.0288)	(0.0284)
Maths Ability			-0.0372*	-0.0403*	-0.0409*
			(0.0203)	(0.0217)	(0.0216)
Verbal Ability			-0.0405**	-0.0374*	-0.0345
			(0.0204)	(0.0212)	(0.0213)
Motivation			-0.0397*	-0.0308	-0.0291
			(0.0238)	(0.0246)	(0.0250)
Extroversion				-0.0148	-0.0132
				(0.0208)	(0.0209)
Agreeableness				-0.00716	-0.00935
				(0.0272)	(0.0270)
Contientiousness				0.0111	0.0113
				(0.0243)	(0.0243)
Emotional Stability				0.0205	0.0194
				(0.0207)	(0.0207)
Openness to Experience				-0.0159	-0.0173
				(0.0239)	(0.0237)
Age					0.00815
					(0.00797)
Observations	3,840	3,840	3,840	3,840	3,840

Logit, marginal effects

Robust standard errors clustered at subject level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Ambiguity-averse subjects in single decision-making: $r = 0.8$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.297***	-0.296***	-0.297***	-0.293***	-0.289***
	(0.0477)	(0.0477)	(0.0477)	(0.0464)	(0.0454)
Ambiguity	-0.169**	-0.168**	-0.158**	-0.198**	-0.197**
	(0.0696)	(0.0697)	(0.0746)	(0.0781)	(0.0772)
Round		-0.00226	-0.00236	-0.00246	-0.00249
		(0.00196)	(0.00195)	(0.00195)	(0.00196)
Overall Ability			-0.0293	-0.0253	-0.0241
			(0.0408)	(0.0436)	(0.0428)
Maths Ability			-0.0303	-0.0623	-0.0622
			(0.0322)	(0.0449)	(0.0447)
Verbal Ability			-0.0421	-0.0368	-0.0286
			(0.0385)	(0.0384)	(0.0399)
Motivation			0.0108	0.0273	0.0301
			(0.0409)	(0.0423)	(0.0427)
Extroversion				-0.0631*	-0.0594*
				(0.0345)	(0.0357)
Agreeableness				-0.0420	-0.0435
				(0.0459)	(0.0453)
Contientiousness				0.0270	0.0297
				(0.0372)	(0.0370)
Emotional Stability				0.0305	0.0323
				(0.0379)	(0.0376)
Openness to Experience				0.0239	0.0175
				(0.0490)	(0.0479)
Age					0.0133
					(0.0160)
Observations	1,240	1,240	1,240	1,240	1,240

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Ambiguity-loving subjects in single decision-making: $r = 0.8$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.350***	-0.352***	-0.346***	-0.345***	-0.344***
	(0.0557)	(0.0558)	(0.0560)	(0.0569)	(0.0573)
Ambiguity	-0.00323	-0.00316	0.0206	0.0266	0.0211
	(0.0781)	(0.0779)	(0.0792)	(0.0742)	(0.0750)
Round		-0.00513	-0.00515	-0.00515	-0.00511
		(0.00358)	(0.00361)	(0.00360)	(0.00359)
Overall Ability			-0.0107	-0.0488	-0.0509
			(0.0322)	(0.0560)	(0.0563)
Maths Ability			0.0388	0.0406	0.0446
			(0.0347)	(0.0357)	(0.0379)
Verbal Ability			-0.00725	0.0120	0.0166
			(0.0370)	(0.0280)	(0.0303)
Motivation			-0.0419	-0.0173	-0.00876
			(0.0407)	(0.0418)	(0.0491)
Extroversion				0.00420	0.00304
				(0.0506)	(0.0498)
Agreeableness				-0.0442	-0.0455
				(0.0375)	(0.0394)
Contientiousness				0.0319	0.0414
				(0.0523)	(0.0591)
Emotional Stability				0.0582	0.0541
				(0.0396)	(0.0398)
Openness to Experience				0.0929	0.0864
				(0.0597)	(0.0624)
Age					-0.0117
					(0.0178)
Observations	520	520	520	520	520

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: SEU-maximizing subjects in single decision-making: $r = 0.8$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.338***	-0.337***	-0.337***	-0.335***	-0.335***
	(0.0358)	(0.0359)	(0.0357)	(0.0346)	(0.0347)
Ambiguity	0.0870	0.0867	0.0826	0.0794	0.0784
	(0.0586)	(0.0586)	(0.0557)	(0.0561)	(0.0557)
Round		-0.00400**	-0.00399**	-0.00388**	-0.00388**
		(0.00168)	(0.00166)	(0.00164)	(0.00163)
Overall Ability			-0.0418	-0.0621*	-0.0617*
			(0.0271)	(0.0343)	(0.0344)
Maths Ability			-0.0528*	-0.0455*	-0.0458*
			(0.0279)	(0.0271)	(0.0268)
Verbal Ability			-0.0633**	-0.0457*	-0.0452*
			(0.0247)	(0.0234)	(0.0238)
Motivation			-0.0193	0.0125	0.0128
			(0.0347)	(0.0317)	(0.0320)
Extroversion				0.00514	0.00525
				(0.0261)	(0.0261)
Agreeableness				0.00751	0.00655
				(0.0315)	(0.0320)
Contientiousness				0.0543*	0.0544*
				(0.0311)	(0.0310)
Emotional Stability				0.0151	0.0141
				(0.0256)	(0.0257)
Openness to Experience				-0.0552**	-0.0552**
				(0.0262)	(0.0262)
Age					0.00190
					(0.0110)
Observations	1,820	1,820	1,820	1,820	1,820

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: All subjects: $r = 0.7$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.333***	-0.333***	-0.333***	-0.332***	-0.332***
	(0.0314)	(0.0315)	(0.0307)	(0.0308)	(0.0306)
Ambiguity	0.0770	0.0769	0.0699	0.0812	0.0750
	(0.0604)	(0.0604)	(0.0604)	(0.0600)	(0.0623)
Round		-0.00328**	-0.00334**	-0.00337**	-0.00337**
		(0.00151)	(0.00150)	(0.00150)	(0.00150)
Overall Ability			-0.0167	-0.0345	-0.0347
			(0.0295)	(0.0451)	(0.0450)
Maths Ability			-0.0493**	-0.0401	-0.0401
			(0.0250)	(0.0272)	(0.0272)
Verbal Ability			-0.0106	-0.00768	-0.00728
			(0.0256)	(0.0261)	(0.0262)
Motivation			-0.0399	-0.0369	-0.0374
			(0.0357)	(0.0340)	(0.0341)
Extroversion				-0.00808	-0.00746
				(0.0258)	(0.0261)
Agreeableness				0.0264	0.0253
				(0.0306)	(0.0310)
Contientiousness				-0.00217	-0.00187
				(0.0354)	(0.0354)
Emotional Stability				0.0573**	0.0567**
				(0.0278)	(0.0279)
Openness to Experience				0.00669	0.00546
				(0.0315)	(0.0319)
Age					0.00396
					(0.0101)
Observations	2,400	2,400	2,400	2,400	2,400

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Ambiguity-averse subjects in single decision-making: $r = 0.7$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.280***	-0.280***	-0.284***	-0.286***	-0.288***
	(0.0593)	(0.0594)	(0.0574)	(0.0546)	(0.0535)
Ambiguity	-0.0792	-0.0793	-0.0397	-0.0406	-0.0230
	(0.110)	(0.110)	(0.110)	(0.108)	(0.121)
Round		-0.00113	-0.00110	-0.00126	-0.00123
		(0.00261)	(0.00258)	(0.00257)	(0.00257)
Overall Ability			-0.0450	-0.0684	-0.0674
			(0.0478)	(0.0515)	(0.0505)
Maths Ability			-0.0656	-0.0629	-0.0639
			(0.0429)	(0.0635)	(0.0610)
Verbal Ability			0.00139	0.0178	0.0159
			(0.0445)	(0.0394)	(0.0389)
Motivation			0.0273	0.0258	0.0300
			(0.0606)	(0.0633)	(0.0632)
Extroversion				-0.0461	-0.0478
				(0.0550)	(0.0527)
Agreeableness				0.0142	0.0113
				(0.0624)	(0.0608)
Contientiousness				0.0129	0.0145
				(0.0464)	(0.0465)
Emotional Stability				0.0696*	0.0700*
				(0.0414)	(0.0408)
Openness to Experience				0.0805*	0.0925
				(0.0461)	(0.0589)
Age					-0.00996
					(0.0213)
Observations	780	780	780	780	780

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Ambiguity-loving subjects in single decision-making: $r = 0.7$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.425***	-0.434***	-0.426***	-0.427***	-0.426***
	(0.0423)	(0.0413)	(0.0436)	(0.0462)	(0.0441)
Ambiguity	-0.0552	-0.0554	-0.0686	-0.137	-0.116
	(0.0710)	(0.0707)	(0.101)	(0.107)	(0.109)
Round		-0.00835**	-0.00827**	-0.00823**	-0.00810*
		(0.00415)	(0.00415)	(0.00419)	(0.00419)
Overall Ability			-0.0172	-0.184	-0.205*
			(0.0400)	(0.117)	(0.106)
Maths Ability			0.0514	0.0835**	0.0736**
			(0.0446)	(0.0326)	(0.0321)
Verbal Ability			-0.0146	0.0860	0.122
			(0.0744)	(0.0937)	(0.0828)
Motivation			-0.0132	0.120	0.177
			(0.0820)	(0.126)	(0.112)
Extroversion				0.0328	0.0550
				(0.0632)	(0.0605)
Agreeableness				0.0165	0.0247
				(0.0467)	(0.0446)
Contientiousness				0.126	0.158*
				(0.0956)	(0.0857)
Emotional Stability				0.105*	0.0989*
				(0.0537)	(0.0562)
Openness to Experience				0.150	0.136
				(0.107)	(0.121)
Age					-0.0256
					(0.0356)
Observations	320	320	320	320	320

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: SEU-maximizing subjects in single decision-making: $r = 0.7$ vs. $r \in [0.6, 0.8]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.318***	-0.317***	-0.316***	-0.316***	-0.316***
	(0.0494)	(0.0496)	(0.0483)	(0.0459)	(0.0457)
Ambiguity	0.192**	0.192**	0.165**	0.198***	0.214***
	(0.0749)	(0.0750)	(0.0726)	(0.0735)	(0.0810)
Round		-0.00427**	-0.00436**	-0.00432**	-0.00434**
		(0.00213)	(0.00213)	(0.00209)	(0.00208)
Overall Ability			-0.0426	-0.0904*	-0.0917*
			(0.0306)	(0.0472)	(0.0471)
Maths Ability			-0.0581*	-0.0435	-0.0419
			(0.0301)	(0.0291)	(0.0305)
Verbal Ability			-0.0363	-0.0393	-0.0398
			(0.0311)	(0.0283)	(0.0286)
Motivation			-0.0356	-0.00897	-0.00949
			(0.0513)	(0.0447)	(0.0456)
Extroversion				0.000908	0.000960
				(0.0320)	(0.0317)
Agreeableness				0.0327	0.0365
				(0.0341)	(0.0341)
Contientiousness				0.0178	0.0150
				(0.0396)	(0.0395)
Emotional Stability				0.0803**	0.0860**
				(0.0369)	(0.0419)
Openness to Experience				-0.0353	-0.0347
				(0.0354)	(0.0357)
Age					-0.00974
					(0.0258)
Observations	1,140	1,140	1,140	1,140	1,140

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: All subjects: $r = 0.8$ vs. $r \in [0.7, 0.9]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.316***	-0.315***	-0.319***	-0.310***	-0.310***
	(0.0398)	(0.0397)	(0.0396)	(0.0386)	(0.0385)
Ambiguity	-0.121*	-0.121*	-0.0919	-0.109*	-0.112*
	(0.0625)	(0.0625)	(0.0623)	(0.0581)	(0.0593)
Round		-0.00369**	-0.00377**	-0.00374**	-0.00376**
		(0.00176)	(0.00178)	(0.00176)	(0.00175)
Overall Ability			-0.0172	0.0123	0.0127
			(0.0346)	(0.0298)	(0.0296)
Maths Ability			-0.0203	-0.0153	-0.0149
			(0.0320)	(0.0350)	(0.0352)
Verbal Ability			-0.0908***	-0.0733**	-0.0755**
			(0.0343)	(0.0302)	(0.0312)
Motivation			-0.0274	-0.00414	-0.00598
			(0.0294)	(0.0291)	(0.0299)
Extroversion				-0.0196	-0.0207
				(0.0321)	(0.0319)
Agreeableness				-0.0418	-0.0410
				(0.0390)	(0.0397)
Contientiousness				0.0176	0.0179
				(0.0329)	(0.0328)
Emotional Stability				-0.0331	-0.0327
				(0.0303)	(0.0304)
Openness to Experience				-0.0810**	-0.0813**
				(0.0384)	(0.0387)
Age					-0.00340
					(0.00985)
Observations	1,440	1,440	1,440	1,440	1,440

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: Ambiguity-averse subjects in single decision-making: $r = 0.8$ vs. $r \in [0.7, 0.9]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.315***	-0.312***	-0.331***	-0.293***	-0.286***
	(0.0776)	(0.0771)	(0.0743)	(0.0699)	(0.0696)
Ambiguity	-0.255**	-0.254**	-0.163	0.0366	0.0740
	(0.104)	(0.104)	(0.153)	(0.115)	(0.131)
Round		-0.00405	-0.00415	-0.00433	-0.00437
		(0.00284)	(0.00292)	(0.00283)	(0.00285)
Overall Ability			-0.0106	0.0965	0.0995
			(0.0874)	(0.0617)	(0.0617)
Maths Ability			-0.0269	-0.120**	-0.115**
			(0.0430)	(0.0537)	(0.0567)
Verbal Ability			-0.181*	-0.282***	-0.263***
			(0.107)	(0.0832)	(0.0955)
Motivation			-0.00879	0.0215	0.0437
			(0.0492)	(0.0469)	(0.0434)
Extroversion				-0.218***	-0.227***
				(0.0692)	(0.0747)
Agreeableness				-0.0375	-0.0318
				(0.0460)	(0.0477)
Contientiousness				0.0995*	0.120*
				(0.0602)	(0.0612)
Emotional Stability				-0.0569	-0.0528
				(0.0714)	(0.0700)
Openness to Experience				-0.259***	-0.266***
				(0.0657)	(0.0692)
Age					0.0201
					(0.0314)
Observations	460	460	460	460	460

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 15: Ambiguity-loving subjects in single decision-making: $r = 0.8$ vs. $r \in [0.7, 0.9]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.202*	-0.199*	-0.195*	-0.218**	-0.218**
	(0.107)	(0.109)	(0.111)	(0.104)	(0.104)
Ambiguity	0.0658	0.0657	0.0807	0.591***	0.591***
	(0.114)	(0.114)	(0.116)	(0.0182)	(0.0182)
Round		-0.00295	-0.00294	-0.00220	-0.00220
		(0.00518)	(0.00515)	(0.00522)	(0.00522)
Overall Ability			0.00416	0.461***	0.461***
			(0.0931)	(0.0218)	(0.0218)
Maths Ability			0.0355	0.361***	0.361***
			(0.0454)	(0.00950)	(0.00950)
Verbal Ability			0.0484	0.369***	0.369***
			(0.0418)	(0.00495)	(0.00495)
Motivation			-0.106	-1.726***	-1.726***
			(0.0675)	(0.0141)	(0.0141)
Extroversion				0.199***	0.199***
				(0.00774)	(0.00774)
Agreeableness				1.462***	1.462***
				(0.0158)	(0.0158)
Contientiousness				-1.059***	-1.059***
				(0.00947)	(0.00947)
Emotional Stability				-0.508***	-0.508***
				(0.0125)	(0.0125)
Openness to Experience = o,				-	-
Age = o,					-
Observations	200	200	200	200	200

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: SEU-maximizing subjects in single decision-making: $r = 0.8$ vs. $r \in [0.7, 0.9]$

VARIABLES	(1) Logit	(2) Logit	(3) Logit	(4) Logit	(5) Logit
bluesignal	-0.365***	-0.364***	-0.368***	-0.359***	-0.358***
	(0.0467)	(0.0467)	(0.0484)	(0.0474)	(0.0478)
Ambiguity	-0.0370	-0.0371	-0.0186	-0.0814	-0.0851
	(0.0893)	(0.0893)	(0.0895)	(0.0829)	(0.0812)
Round		-0.00325	-0.00334	-0.00283	-0.00283
		(0.00276)	(0.00273)	(0.00267)	(0.00264)
Overall Ability			-0.0293	-0.0389	-0.0407
			(0.0399)	(0.0363)	(0.0377)
Maths Ability			-0.0286	0.00215	0.00337
			(0.0665)	(0.0628)	(0.0610)
Verbal Ability			-0.0883**	-0.00534	-0.0111
			(0.0416)	(0.0343)	(0.0347)
Motivation			0.0127	0.103**	0.0976**
			(0.0491)	(0.0462)	(0.0483)
Extroversion				0.0233	0.0219
				(0.0424)	(0.0426)
Agreeableness				-0.0101	-0.00293
				(0.0590)	(0.0605)
Contientiousness				0.130***	0.130***
				(0.0439)	(0.0438)
Emotional Stability				-0.0248	-0.0212
				(0.0360)	(0.0346)
Openness to Experience				-0.107**	-0.107**
				(0.0433)	(0.0437)
Age					-0.00770
					(0.0100)
Observations	680	680	680	680	680

Logit, marginal effects
Robust standard errors clustered at subject level in parentheses
*** p<0.01, ** p<0.05, * p<0.1