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Abstract

We investigate experimentally whether collective choice matters for individual attitudes to ambiguity. We consider a two-urn Ellsberg experiment: one urn offers a 45% chance of winning a fixed monetary prize, the other an ambiguous chance. Participants choose either individually or in groups of three. Group decision rules vary. In one treatment the collective choice is taken by majority; in another it is dictated by two group members; in the third it is dictated by a single group member. We observe high proportions of ambiguity averse choices in both individual and collective decision making. Although a majority of participants display consistent ambiguity attitudes across their decisions, collective choice tends to foster ambiguity aversion, especially if the decision rule assigns asymmetric responsibilities to group members. Previous participation in laboratory experiments may mitigate this.

Keywords: Ambiguity aversion, majority voting, dictatorship

JEL Classification: C91, C92, D71, D81

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1 Introduction

Reliable probabilistic information about all possible consequences of a decision is the exception rather than the rule not only for individual but also for important collective decisions. The ambiguities associated with an individual's choice, for instance, to date a particular person, to accept a job offer, or to buy a house have their analogues in the decisions of company boards, international councils, government cabinets, or hiring committees to install new management, to take military action, to endorse a reform, to select a candidate, and so on. Such collective decisions often affect many individuals—sometimes very many—that either are not involved in the decision making or share responsibility for the outcome asymmetrically. We investigate whether this affects individual behavior. Namely, we consider collective choices under ambiguity and ask if they can be conceived as a simple superposition of individual choices under ambiguity; and, if they cannot, whether this is merely a consequence of collective choice as such or depends on the decision rules being used.

It is well-known since the contribution of Ellsberg (1961) that individual decision making under ambiguity can substantially differ from that under risk. In particular, the analytically convenient assumption that people choose as if they maximized expected utility for some subjective probabilistic assessment (*subjective expected utility theory*) is now understood to have clear limits. Participants in experiments have consistently revealed a significant distaste for ambiguity that differs from traditional risk aversion. A recent survey of 39 experimental studies indicates that, on average, slightly more than 50% of subjects can be classified as ambiguity averse (Oechssler and Roomets, 2014).[1]

While much research has been conducted on the reaction of individual decision makers to ambiguity, surprisingly few studies have investigated the reaction of groups. The existing results are mixed. Keller et al. (2007) asked for individuals' and dyads' hypothetical willingness to pay for ambiguous gambles and reported no conclusive differences between individual and group attitudes towards ambiguity. Brunette et al. (2011) investigated the impact of two collective decision rules—unanimity and majority—on the

[1] Also see Camerer and Weber (1992) for a comprehensive review of early empirical and theoretical work on ambiguity.

"group shift" effect, according to which groups are less risk-averse than individuals. They confirmed the group shift under unanimity rule in a risky situation, but did not detect any group shift regarding ambiguity. Keck et al. (2014) distinguished between a treatment where participants had to make individual decisions, a treatment where participants had to decide individually after a group discussion, and a treatment where group members had to arrive at a joint decision after face-to-face interaction. They observed that groups as well as individuals after group discussion took more ambiguity neutral decisions than individuals who decided in isolation. The robustness of ambiguity attitudes to social interaction has been investigated also by Charness et al. (2013) who found that the number of ambiguity neutral subjects increased after communication with another participant, though only in the presence of monetary incentives to persuade the other. This increase was obtained mainly at the expense of ambiguity seeking and ambiguity incoherent behavior and to a lesser extent at the expense of ambiguity averse behavior.

The literature that examines the effects of peer pressure on ambiguity attitude is also closely related to our study. Curley et al. (1986) found that ambiguity aversion is enhanced when people know that their decision is observed by a group of peers. A hypothesis advanced by the authors to explain this finding is that subjects fear the negative evaluation of their own decisions by others and want to avoid the undesirable outcome that may result from the ambiguous alternative.[2]

The present paper extends the literature by exploring how making decisions with, and also for, others influences individual ambiguity attitudes. We consider three collective decision rules that involve different levels of individual responsibility for the group's choice: majority rule, dictatorship of two group members, and dictatorship of one group member.

No matter which psychological mechanisms motivate individuals to avoid ambiguity,[3] there is no imperative reason why a decision maker's ambiguity attitudes should differ between collective and individual choice contexts.

[2]The relevance of external judgments to ambiguity attitudes has been confirmed by Trautmann et al. (2008) and Muthukrishnan et al. (2009). It has also been shown that ambiguity aversion is affected by the comparison with more familiar events or more knowledgeable individuals (e.g., Fox and Tversky, 1995; Chow and Sarin, 2002; and Fox and Weber, 2002).

[3]For a variety of potential causes of ambiguity aversion see, e.g., Curley et al. (1986).

But neither is there any reason why they should be the same. We explore if ambiguity aversion is 'an issue' also in collective choice, and investigate the extent to which the details of the collective decision environment matter—specifically the rules transforming individual actions into a social choice. Our focus is not on whether different rules produce less or more ambiguity neutral decisions by virtue of the different aggregation mechanisms; rather we concentrate on whether rules affect individual evaluations of ambiguous vis-à-vis risky prospects.

Our initial hypothesis is that full or partial responsibility for the payoff of others will induce a more neutral attitude, i.e., make subjective expected utility maximization a more convincing assumption. A possible motive for such shift is individual fear of appearing over-cautious: after all, privately tossing a coin to decide which of the two colors in the ambiguous urn to bet on yields a 50% chance of winning. This is 5 percentage points greater than the chance provided by the risky alternative in our experiment. Yet it is possible that the fear of implicit blame may induce a member or leader of a group to play it 'safe' by going for a known chance instead of betting 'recklessly' on an event that may turn out to have been nigh impossible to realize. Concern about appearing over-cautious and avoidance of implicit blame might neutralize each other.

We next describe the experiment, laying out our design and procedures. We present the results in Section 3, and conclude in Section 4.

2 Experimental design

2.1 Tasks and treatments

Our basic setting is a variation of the standard Ellsberg two-urn experiment. There are two urns: urn K and urn U. Each urn contains 40 balls. Urn K is *known* to contain 18 yellow balls and 22 balls of various other colors. Urn U contains an *unknown* proportion of black and white balls.[4]

Participants are required to express their preferences for three prospects that are simple bets. In particular, one ball is drawn at random from each urn at the end of the experiment. Call U_B the event "black ball drawn from urn U", U_W the event "white ball drawn from urn U", and K_Y the event

[4]In the experiment, the K-urn is labelled 'A', and the U-urn 'B'.

"yellow ball drawn from urn K". Each participant places three bets on these events in the following order:

(i) betting €20 on either U_B or K_Y,
(ii) betting €20 on either U_W or K_Y,
(iii) betting €20 on either U_B or U_W.

The first two binary choices elicit preferences over bets that relate to the ambiguous and risky urns, while the bet in the last binary choice concerns only the ambiguous urn.

The possible combinations of choices are indicated in column 1 of Table 1. Assuming a strict preference for winning one's bets, we can impute possible subjective beliefs about the number w of white balls from each binary choice. We classify a choice combination as consistent with subjective expected utility maximization (SEU) if the same w can rationalize all three choices. If no such w exists and cyclical preferences can be ruled out, the choices exhibit ambiguity aversion (AA). Remaining combinations are classified as intransitive (INTR).[5]

We study an *individual* and three *group conditions*: majority voting, dictatorship with two 'dictators', and full dictatorship. In the *individual condition (I)*, each subject's possible winnings are influenced only by the individual binary choices (i)–(iii) presented above. These choices are evaluated so as to place a single bet for the subject. Allowing for individual intransitivities, this single bet is determined by a sequential procedure, which is the same in the individual and the group conditions.[6] More specifically, we first look at choice (iii), i.e., at the bet on the color of the ball drawn from urn U. Then we consider the participant's preferences between the preferred bet on urn U and the bet on a yellow ball being drawn from urn K. That is, we look at either choice (i) if the participant has preferred betting on U_B to betting on U_W, or choice (ii) if the participant has preferred betting on U_W to betting on U_B.

In each of the three group conditions, each subject is assigned to an anonymous group of three. This group places a single collective bet based on individual responses to problems (i)–(iii) and a collective decision rule.

[5] Note that we cannot understand if subjects are ambiguity seeking. This would require two additional binary choices: U_B versus $K_{\neg Y}$, and U_W versus $K_{\neg Y}$, where $K_{\neg Y}$ stands for the event "non-yellow ball drawn from urn K".

[6] The sequence obviously makes no difference in case of transitive preferences.

Choices (i)–(iii)	Implied # of white balls w	INTR	AA	SEU
$K_Y \succsim U_B$ $U_W \succsim K_Y$ $U_W \succsim U_B$	$w \in [22, \ldots, 39]$			X
$U_B \succsim K_Y$ $K_Y \succsim U_W$ $U_B \succsim U_W$	$w \in [1, \ldots, 18]$			X
$U_B \succsim K_Y$ $U_W \succsim K_Y$ $U_W \succsim U_B$	$w \in [20, \ldots, 22]$			X
$U_B \succsim K_Y$ $U_W \succsim K_Y$ $U_B \succsim U_W$	$w \in [18, \ldots, 20]$			X
$K_Y \succsim U_B$ $K_Y \succsim U_W$ $U_W \succsim U_B$	$w \leq 18 \wedge w \geq 22$		X	
$K_Y \succsim U_B$ $K_Y \succsim U_W$ $U_B \succsim U_W$	$w \leq 18 \wedge w \geq 22$		X	
$K_Y \succsim U_B$ $U_W \succsim K_Y$ $U_B \succsim U_W$	$w \geq 22 \wedge w \leq 20$	X		
$U_B \succsim K_Y$ $K_Y \succsim U_W$ $U_W \succsim U_B$	$w \leq 18 \wedge w \geq 20$	X		

Table 1: Choices and implied preferences

The three conditions differ in the level of individual influence on the group's bet, but all follow the same structure as the I condition. In particular, when deriving the group's collective decision—that is, when determining in which event each group member gains €20—we first evaluate the group's choice between U_B and U_W and then compare the event collectively chosen for urn U to K_Y. Before each group member is asked to reveal preferences over U_B, U_W and K_Y by responding to problems (i)–(iii), all participants are informed about the applicable decision rule.

- In the *majority voting (MV)* condition, group members are informed that the two relevant choices (U_B versus U_W, and then either U_B versus K_Y or U_W versus K_Y) will be made by majority rule. So, for example, if the majority (at least two out of three members) prefers U_B to U_W, the majority choice between U_B and K_Y defines the bet of the group.

- In the *two-dictator (D2)* condition, group members are informed that one of them will randomly be selected to dictate the choice between U_B and U_W, and another one will randomly be picked to dictate the choice between the selected color from urn U and K_Y. Thus, for example, if the first dictator prefers U_B to U_W, the second dictator's preferences between U_B and K_Y determine the group's choice of bet.

- In the *one-dictator (D1)* condition, group members are informed that one of them will randomly be selected to act as a dictator whose individual choices directly determine the group's ones.

The random selection of dictators in conditions *D1* and *D2* takes place after each subject has responded to problems (i)–(iii).

Asking for three individual choices and then using the described two-stage procedure for selecting a single bet in both I and the three group conditions facilitates comparability across conditions. It has a price though: choice (i) or choice (ii) is not incentivized in conditions I and *D1*. A diagnosed intransitivity may hence be spurious in the sense that it can also reflect somewhat sophisticated ambiguity aversion. We are however quite confident that participants in I and *D1* choose truthfully because, in the experiment, we present choices (i)–(iii) one after another on a clean computer screen. Hence, an ambiguity averse participant who wants to bet on

K_Y would return an intransitive pattern such as "$K_Y \succsim U_B \succsim U_W \succsim K_Y$" only if he were aware, when making choices (i) and (ii), that choice (iii) will render choice (ii) irrelevant. We shall return to the implausibility of such sophisticated behavior when we discuss the experimental results.

Individual responsibility for the payoffs of other group members differs across the three group conditions. It is arguably maximal in *D1*: when a group member is drawn as the dictator, his own choices (i)–(iii) determine the group's bet. In *D2*, responsibility is shared with one other dictator. In *MV*, responsibility is shared with both other group members.[7]

For our exploration of possible preference shifts—whether ambiguity averse (neutral) subjects continue to prefer urn K when their choices (do not) affect others—we employ a within-subjects design. That is, each participant must make decisions in condition I and in one of the three group conditions. We run six treatments in order to control for potential order effects: in treatments *I-MV*, *I-D2* and *I-D1* subjects are first confronted with condition I and then with the respective group condition; treatments *MV-I*, *D2-I* and *D1-I* reverse this order.

2.2 Procedures

The experiment was programmed in Fischbacher's (2007) z-Tree software and conducted in the experimental laboratory of the Max-Planck Institute of Economics in Jena, Germany. The participants—undergraduate students from the Friedrich-Schiller University of Jena—were recruited using Greiner's (2004) ORSEE software. Upon entering the laboratory, they were randomly assigned to visually isolated computer terminals.

The two urns (one clear, one opaque) were on display on the experimenter's desk, so that subjects could be certain that their contents could not be manipulated. Participants were invited to check the contents of the urns after completion of the experiment and some did.

Each session consisted of two parts as explained in the previous section. The full sequence of events unfolded as follows. First, the instructions for Part 1 were distributed and read aloud in order to establish public knowl-

[7] We refer readers to Braham and van Hees (2012) for a philosophical discussion of degrees of responsibility and the thorny issue of how individuals can be held responsible for a collective outcome for which their individual choices played no pivotal role.

edge.[8] Participants were instructed about their task and the determination of the bet relevant to them (in the *I* condition of treatments *I-MV*, *I-D*2, and *I-D*1) or to their group (in the *MV*, *D2*, and *D1* conditions of treatments *MV-I*, *D*2-*I*, and *D*1-*I*, respectively). Before making their choices, participants had to go through a series of control questions. Only after the experimenter had ensured that everyone understood the instructions, the corresponding condition started and subjects submitted their choices. After all participants had made their decisions for Part 1, they received the instructions for Part 2. Finally, participants were administered a post-experimental questionnaire, collecting socio-demographic characteristics such as age and gender.

In order to minimize portfolio effects (see, e.g., Cox et al., 2014), only one of the two parts was paid out. At the end of each session, a randomly selected participant determined the part that was paid out by drawing one of two cards numbered "1" and "2" from an opaque bag; then another randomly selected participant drew a ball from each urn. Subjects were paid €20 if the color of the ball drawn from the (individually or collectively) chosen urn matched that of their bets, and nothing otherwise.

Sessions lasted about 50 minutes. 447 students participated in the experiment in total. Average earnings were approximately €15 (inclusive of a €4 show-up fee).

3 Results

Table 2 shows the number of subjects who chose in accordance with SEU, AA and INTR preferences (as listed in Table 1), separately for each treatment.

We start the analysis by allaying concerns about spuriously diagnosing an intransitivity rather than ambiguity aversion because one of the three decisions in *I* and *D1* was not payoff-relevant. Note first that INTR is rare in Part 1 and becomes very rare in Part 2. Moreover, if lack of incentive compatibility were the reason for INTR observations, then one should expect a greater proportion of them in conditions *I* and *D1* compared to conditions *MV* and *D2*. This is not observed.[9] We can also rule out the possibility

[8] A translated version of the instructions can be found in the appendix.

[9] Considering Part 1 choices, possibly intransitive preference patterns are diagnosed for 5.56% (10/180) of the subjects in condition *I*, 4.44% (4/90) in *D2* and *MV*, and 3.45% (3/87) in *D1*. Fisher's exact tests fail to reject the null hypothesis that these ratios are

Choices	Pref.	Freq. I				Freq. D2		Freq. MV		Freq. D1	
		I-XX†	*MV-I*	*D2-I*	*D1-I*	*D2-I*	*I-D2*	*MV-I*	*I-MV*	*D1-I*	*I-D1*
$U_W \succsim K_Y \succsim U_B$	SEU	21	13	11	9	7	3	12	7	7	6
$U_B \succsim K_Y \succsim U_W$	SEU	31	11	13	14	12	7	16	5	12	9
$U_W \succsim U_B \succsim K_Y$	SEU	25	12	13	8	7	6	10	11	8	5
$U_B \succsim U_W \succsim K_Y$	SEU	20	7	14	16	12	7	7	8	12	7
$K_Y \succsim U_W \succsim U_B$	AA	41	26	20	26	20	16	22	15	27	14
$K_Y \succsim U_B \succsim U_W$	AA	32	16	17	13	28	20	19	13	18	18
$U_W \succsim K_Y \succsim U_B \succsim U_W$	INTR	6	3	1	1	2	0	2	1	3	1
$U_B \succsim K_Y \succsim U_W \succsim U_B$	INTR	4	2	1	0	2	1	2	0	0	0
	Σ	180	90	90	87	90	60	90	60	87	60

† This column reports the results from treatments *I-MV*, *I-D2*, and *I-D1* (60 subjects each).

Table 2: Number of participants for each type of preference

that subjects were indifferent to winning their bets and chose at random. If that were the case, we should expect a distribution close to 50% SEU, 25% AA and 25% INTR—which we don't.[10] We can thus safely assume that the binary choices represent actual preferences over the prospects, and that these are predominantly strict.

Turning to our main research interest, rows 5 and 6 of Table 2 indicate that the percentage of ambiguity averse choices is non-negligible in all conditions: it ranges from 40.6% (73 out of 180) in condition *I* of treatments *I-MV*, *I-D2* and *I-D1* to 60.0% (36 out of 60) in condition *D2* of treatment *I-D2*. Ambiguity aversion *is* an important issue also in collective choice.

Figure 1 illustrates the relative proportions of ambiguity averse choices observed in the various treatments, considering only the 418 out of 447 subjects with transitive choice patterns in both parts of the experiment. The figure consists of four blocks (of four or two bars each) that refer to the frequency of ambiguity averse choices in conditions *I* (leftmost block), *MV*, *D2*, and *D1* (rightmost block). The first bar of each block refers to the treatment where subjects were confronted with the block's pertinent condition first, i.e., in Part 1 rather than Part 2. The data suggest that the frequencies of ambiguity averse choices in *I*, *MV*, *D2* and *D1* have not been

the same across conditions (p-values ≥ 0.367 uniformly).

[10] Exact goodness-of-fit tests reject the null hypothesis that the data come from a multinomial distribution with parameters 0.5, 0.25, and 0.25 in all conditions (p-values < 0.001).

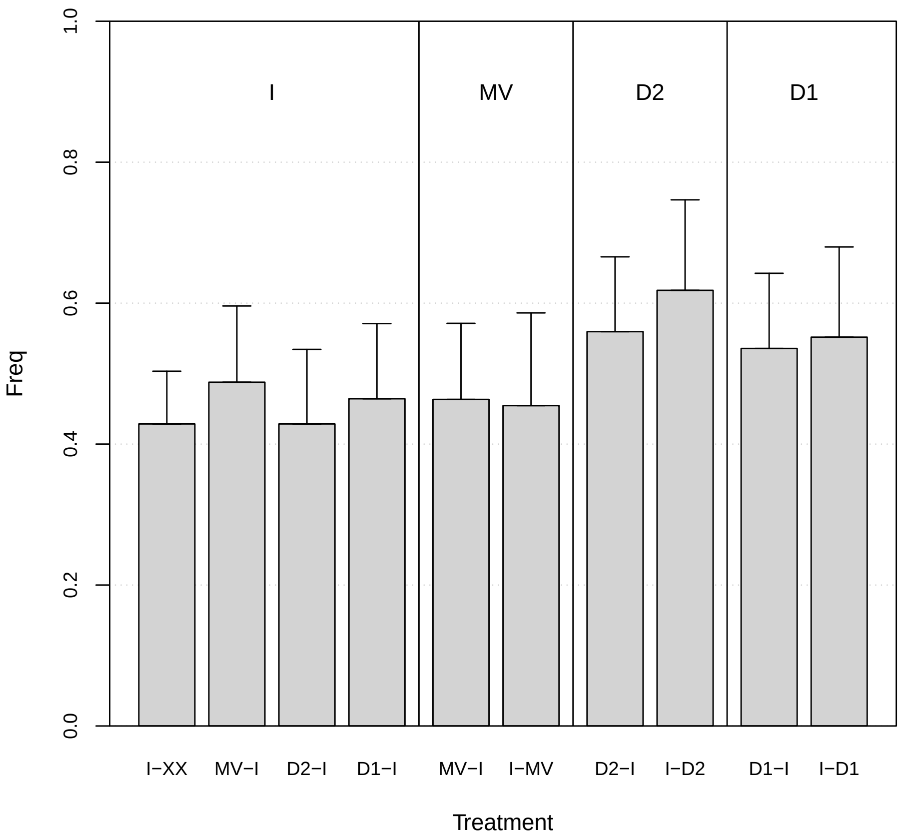

Figure 1: Frequency of ambiguity averse choices by treatment (transitive subjects only)

affected by the order in which the condition was faced. A series of χ^2-tests confirm that there are no significant order effects.[11] Thus, in investigating how often subjects prefer betting on the known urn in each condition compared to betting on either color from the unknown urn, we will pool the data from different sequences.

Comparing the last two blocks in Figure 1 (*D2* and *D1*) to the first two ones (*I* and *MV*) reveals that the frequency of ambiguity averse choices is *higher* when one or two group members impose their preferences on the oth-

[11] The test results are: $\chi^2(3) = 1.000$ with p-value $= 0.801$ for I; $\chi^2(1) = 0.010$ with p-value $= 0.919$ for MV; $\chi^2(1) = 0.470$ with p-value $= 0.493$ for *D2*; and $\chi^2(1) < 0.001$ with p-value $= 0.987$ for *D1*.

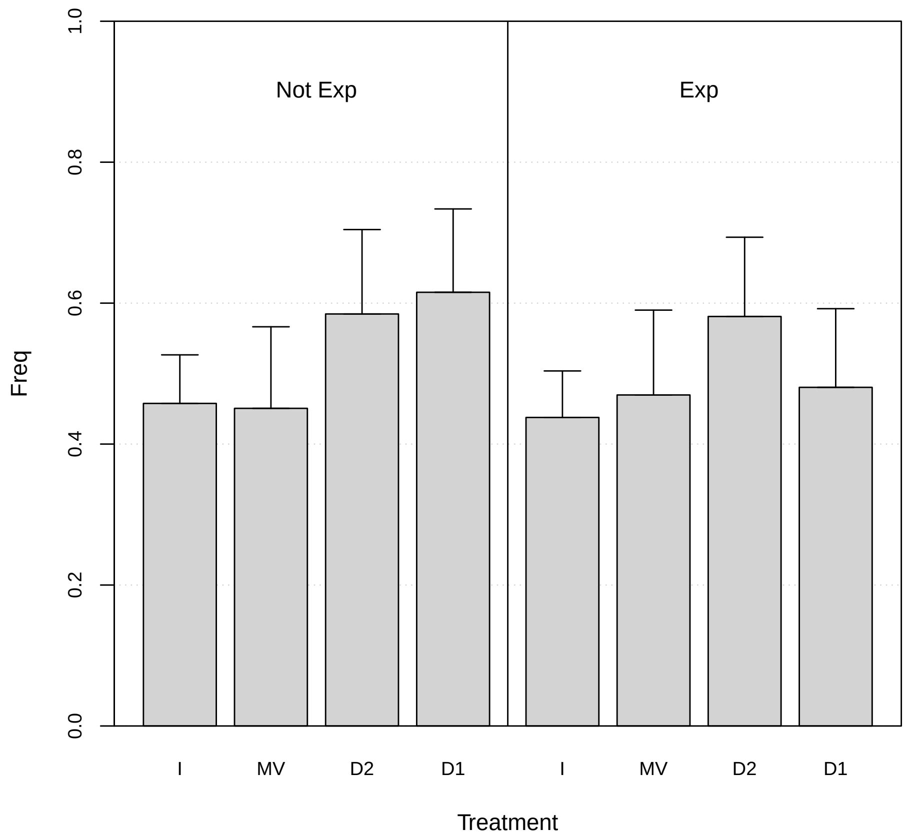

Figure 2: Frequency of ambiguity averse choice by treatment and lab experience (transitive subjects only)

ers than when subjects choose either individually or under majority rule. According to a series of χ^2-tests, subjects make more ambiguity averse choices in *D1* and *D2* compared to I and in *D2* compared to MV (p-value = 0.006 for *D2* vs. I, 0.050 for *D1* vs. I, and 0.041 for *D2* vs. MV), whereas the differences in ambiguity averse choices between I and MV and between *D1* and MV are not significant (p-value = 0.799 for I vs. MV, and 0.169 for *D1* vs. MV).[12]

Life experiences undoubtedly influence decision making in the laboratory. Since experience accumulated in the laboratory is a part of real life (Smith,

[12]These results do not qualitatively change if we apply Fisher exact tests rather than χ^2-tests.

2010), we deem it important to check whether collective choices under ambiguity are affected by previous participation in laboratory experiments.[13] Figure 2 shows the frequency of ambiguity averse choices when we split the sample according to subjects' previous experience with experiments. We refer to subjects who participated in at most seven experiments as *inexperienced*, and to subjects who took part in more than seven experiments as *experienced*.[14] While for the inexperienced sub-sample the frequency of ambiguity averse choices increases noticeably with the level of individual responsibility for the group (conditions *D2* and *D1*), ambiguity averse choices are more frequent for the experienced sub-sample only in condition *D2*. χ^2-tests corroborate the visual comparisons: the difference between *I* and *D1* is significant at the 5% level only for the inexperienced (p-value = 0.027), whereas the difference between *I* and *D2* is significant at the 10% level for the inexperienced (p-value = 0.076) and at the 5% level for the experienced (p-value = 0.033).[15] In the light of these differences, the separation of the sample into inexperienced and experienced has proven to be a meaningful control.

Table 3 reports a detailed within-subject classification of all transitive choices. It enables us to assess the potential presence of a shift in ambiguity aversion when we move from individual to collective choices and vice versa in a less aggregated form. The six panels correspond to our six treatments (*I-MV*, *I-D2*, *I-D1*, *MV-I*, *D2-I*, and *D1-I*). Each panel classifies participants in the corresponding treatment as ambiguity averse (*AA*) or subjective expected utility maximizers (*SEU*). In panel/treatment *I-MV*, for instance, 26 subjects are consistently *SEU* in both experimental parts, 19 subjects are consistently *AA*, 4 subjects switch from being *AA* in Part 1 (condition *I*) to being *SEU* in Part 2 (condition *MV*), and 6 subjects switch from being *SEU* in Part 1 to being *AA* in Part 2.

We can see that the great majority of observations lie on the main diagonal. That is, subjects reveal consistent ambiguity attitudes across both parts (the lowest level of consistency, 70.9%, is observed in treatment *I-D2*). However, while the number of subjects switching in the two directions

[13]There is work studying how experience in one experiment impacts willingness to take risk in later experiments (see, e.g., Chuang and Schechter, 2014, and references therein).

[14]Seven was the median participation in previous experiments. We chose this threshold in order to obtain groups of similar sizes.

[15]Again, results remain qualitatively unchanged if we apply Fisher exact tests.

I-MV

		MV		
		SEU	*AA*	
I	*SEU*	26	6	32
	AA	4	19	23
		30	25	

I-D2

		D2		
		SEU	*AA*	
I	*SEU*	20	15	35
	AA	1	19	20
		21	34	

I-D1

		D1		
		SEU	*AA*	
I	*SEU*	20	9	29
	AA	6	23	29
		26	32	

MV-I

		MV		
		SEU	*AA*	
I	*SEU*	35	7	42
	AA	9	31	40
		44	38	

D2-I

		D2		
		SEU	*AA*	
I	*SEU*	33	15	48
	AA	4	32	36
		37	47	

D1-I

		D1		
		SEU	*AA*	
I	*SEU*	33	12	45
	AA	6	33	39
		39	45	

Table 3: Frequency counts of ambiguity averse (*AA*) and subjective expected utility (*SEU*) preferences

is about the same in *I-MV* and *MV-I*, there is noticeably more switching in one direction than in the other in *I-D2* and *D2-I*. More specifically, in *I-D2*, 15 subjects with *SEU* preferences in Part 1 (condition *I*) shift to *AA* in Part 2 (condition *D2*), while only 1 subject changes from *AA* in Part 1 to *SEU* in Part 2. Conversely, in *D2-I*, subjects more often switch from *AA* in Part 1 to *SEU* in Part 2 than vice versa (15 vs. 4). The direction of the shifts in *I-D1* and *D1-I* resembles that observed in the treatments with *D2*, but the magnitudes are smaller. These observations corroborate the finding already derived from the aggregate data: the dictator conditions *D1* and *D2* foster ambiguity aversion rather than lead to more ambiguity neutrality.

In order to gain further insights into the relationship between individual ambiguity aversion and the applicable collective decision rule, we have conducted three random effect logit regressions with ambiguity averse choices as dependent variable. Table 4 reports the results. Model (1) is estimated from the entire sample; Models (2) and (3) are estimated on the sub-samples of experienced and inexperienced participants, respectively.[16] In all three models, regressors include (i) three treatment dummies (*MV*, *D2*, and *D1*), (ii) a dummy taking value 1 if a condition is faced in Part 2 ("choice2"), (iii) the interactions between "choice2" and each treatment dummy, (iv) a gender dummy (1 for female), and (v) two dummies ("More difficult" and

[16]Intransitive observations were dropped from all three regressions.

	Model (1) All Sbj (n=418 × 2) Coef.	S.E.		Model (2) Exp Sbj (n=217 × 2) Coef.	S.E.		Model (3) Inexp Sbj (n=201 × 2) Coef.	S.E.	
(Intercept)	0.194	1.632		−0.807	3.042		0.637	2.022	
More difficult	−0.934	0.703		−0.859	0.977		−1.030	1.070	
Less difficult	−0.775	0.543		−0.810	0.811		−0.572	0.764	
age	−0.178	0.061		0.028	0.114		−0.037	0.074	
chtime	−0.013	0.010		−0.022	0.016		−0.009	0.013	
female	0.840	0.466	°	1.491	0.695	*	0.068	0.690	
choice2	0.121	0.511		−0.427	0.724		0.640	0.756	
MV	0.189	0.619		0.482	0.906		0.024	0.890	
D2	1.534	0.638	*	1.159	0.922		1.934	0.924	*
D1	0.964	0.621		0.313	0.847		1.717	0.959	°
choice2 × *MV*	−0.118	1.065		−0.870	1.539		0.511	1.541	
choice2 × *D2*	0.433	1.068		1.158	1.505		−0.291	1.620	
choice2 × *D1*	−0.460	1.053		−0.198	1.493		−0.819	1.552	
mixing distr. par.	3.547	0.462	***	3.649	0.705	***	3.550	0.656	***
LogLik	−494.9			−252.3			−237.6		

Significance codes: *** 0.001 ** 0.01 * 0.05 ° 0.10

Table 4: Random effect logit regressions on ambiguity aversion choices

"Less difficult") which indicate whether subjects found the instructions for this experiment more difficult or less difficult than those for other experiments that they had taken part in. Further control variables are the age of each subject ("age") and the time a subject needed to make a choice ("chtime").

Model (1)—the full sample regression—confirms the impression from Table 2 and our non-parametric analysis: the probability of ambiguity averse choices is significantly higher in condition *D2* than in condition *I*, and there are no order effects.[17] Additionally, the model shows that the coefficient of "female" is positive and weakly significant, implying that females in our sample were more likely to select ambiguous prospects compared to males.

Models (2) and (3)—referring to the experienced and inexperienced subsamples, respectively—indicate that previous participation in laboratory ex-

[17]We fail to reject the hypothesis that the estimates of the coefficient of the order-effect dummy ("choice2") and of the interactions between "choice2" and the treatment dummies are significantly different from zero.

periments seems to play an important role in shaping ambiguity attitudes. Participants are more likely to make ambiguity averse choices in *D1* and *D2* only when they are inexperienced: in Model (3), the effect of *D2* is significant at the 5% level, and the effect of *D1* is weakly significant (p-value = 0.073). The other control variables are not statistically significant, except for "gender" in case of experienced.

4 Concluding remarks

This study indicates that ambiguity aversion is a significant issue not only in individual but also in collective decision making. As a matter of fact, we detected high proportions of ambiguity averse choices both in our individual Ellsberg condition (on average 43%) and in our three group conditions (where ambiguity averse choices range from 46% in the MV condition of treatment MV-I to 60% in the *D2* condition of treatment *I-D2*).

Comparing choices in the individual and group conditions reveals that (i) between 70% and 82% of the subjects do not exhibit differences in their individual and collective ambiguity attitudes, and (ii) those with differences are predominantly *more ambiguity averse* when they bear responsibility for others' payoffs. These results contrast with our initial hypothesis that collective decisions foster ambiguity neutrality, and lend tentative support to the conjecture that fear of implicit blame encourages some of the anonymous group members to play it 'safer' and to go for a known chance of winning €20.

Keck et al. (2014) and Charness et al. (2013) reported more ambiguity neutral choices following social and face-to-face interaction. Our data suggest that people react to responsibility for a group with a per se more averse attitude to ambiguity. This—as our split of the sample into experienced and inexperienced subjects shows—may be mitigated by familiarity with the laboratory environment, experience with game and decision-theoretic problem solving, and perhaps also experience with collective decision making more generally. The latter would be relevant for boards, councils or committees in practice.

Interestingly, we do not observe a change in ambiguity attitudes for every group condition: preferences under majority rule (MV) do not differ significantly from those under individual choice. So one's evaluation of ambiguity is not (only) a question of facing a prize scalar vs. a prize vector. The applicable aggregation mechanism matters, even though rule differences between the single (*D1*) and dual (*D2*) dictator conditions do not translate into significant differences in ambiguity attitudes. This observation calls for more research into collective choice under ambiguity, both in general and specifically with regard to the effects of different rules and differential responsibility for collective outcomes.

Although more of our participants switch from behavior that is consistent with subjective expected utility theory in the individual condition to ambiguity averse behavior in a group condition, we also observe a few switches in the opposite direction. In fact, unchanged revealed preferences do not necessarily imply that participants are insensitive to whether choices between risky and ambiguous prospects affect others or not. Different motives—such as a desire to appear hard-nosed vs. fear of negative evaluation vs. easy justifiability of one's action—can push in different directions and may, for our treatments, happen to cancel each other. Future studies should try to shed more light on the specific drivers of group shifts in ambiguity attitudes. Controlled variations in the possibilities of group members to justify their choices to their peers and to provide ex post feedback seem fruitful avenues for further research.

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Appendix. Experimental instructions

This appendix reports the instructions (originally in German) that we used for the three treatments where condition I was faced in Part 1. The instructions for the other treatments were adapted accordingly and are available upon request.

INSTRUCTIONS

Welcome! You are about to participate in an experiment funded by the Max Planck Institute of Economics. Please remain silent and switch off your mobile. If you have any questions during the experiment please raise your hand.

You will receive €4.00 for participating in this experiment. Beyond this you can earn more money, depending partly on the decisions that you take during the experiment and partly on chance. There are no right or wrong ways to complete the experiment, but what you do will have implications for what you are paid at the end of the experiment. Please read these written instructions carefully before you turn to the computer.

The experiment consists of two parts. The instructions for the first part follow on the next page. The instructions for the second part will be distributed after all participants have completed the first part.

After Part 2 is over, we will randomly invite one participant to draw one ball from a bag containing two balls labeled 1 and 2.

- If the ball labeled 1 is drawn, all of you will be paid your earnings in Part 1.
- If the ball labeled 2 is drawn, all of you will be paid your earnings in Part 2.

Thus, you will be paid your earnings in Part 1 OR your earnings in Part 2, and both parts will have an equal chance of being selected for payment.

The €4.00 participation fee and any additional amounts of money you may earn will be paid to you in cash at the end of the experiment. Payments are carried out privately, i.e., without the other participants knowing the extent of your earnings.

Instructions for Part 1

The experimenter has two urns on his table: Urn A is clear while Urn B is opaque. Each urn contains exactly 40 balls. Specifically:

- Urn A contains 18 yellow balls and 22 balls of various colors (green, pink, red, blue, and brown); there is at least one ball of each of these non-yellow colors.
- Urn B contains 40 black and white balls in a proportion unknown to you. That is, any combination is possible for Urn B, from 1 black ball (that is, 39 white balls) to 39 black balls (that is, 1 white ball).

After completion of the experiment, you are invited to check the content of the two urns.

At the end of the experiment, a ball will be drawn from each urn. The ball drawn from an urn represents the *outcome* of that urn.

Your task

Your task is to select one urn and to bet on its outcome. There are three alternative options:

1. to bet on a yellow ball to be drawn from Urn A ("yellow ball from Urn A"),
2. to bet on a white ball to be drawn from Urn B ("white ball from Urn B"), and
3. to bet on a black ball to be drawn from Urn B ("black ball from Urn B").

To express your preferences for the three possible bets, you will proceed as follows.

(*i*) First, you will be asked whether you prefer "black ball from Urn B" OR "yellow ball from Urn A".

(*ii*) Then, you will be asked whether you prefer "white ball from Urn B" OR "yellow ball from Urn A".

(*iii*) Finally, you will be asked whether you prefer "black ball from Urn B" OR "white ball from Urn B".

Determination of the bet relevant to you

After you have completed the task above, the computer software will check your preferences between "black ball from Urn B" and "white ball from Urn B".

If you preferred "black ball from Urn B", the software will check your preferences between "black ball from Urn B" and "yellow ball from Urn A".

- If you preferred "black ball from Urn B", this becomes the bet relevant to you.
- If you preferred "yellow ball from Urn A", this becomes the bet relevant to you.

If you preferred "white ball from Urn B", the software will check your preferences between "white ball from Urn B" and "yellow ball from Urn A".

- If you preferred "white ball from Urn B", this becomes the bet relevant to you.
- If you preferred "yellow ball from Urn A", this becomes the bet relevant to you.

Your earnings

As we have already noted, you are guaranteed a €4 participation fee. You may also win an additional €20. How this works is as follows. At the end of the experiment, if Part 1 is randomly selected for payment, we will ask a randomly selected participant to extract one ball from each urn. You are interested only in the outcome of the urn associated to your relevant bet.

- If your relevant bet is **"yellow ball from Urn A"** and the randomly selected participant draws a yellow ball from Urn A, you will earn the extra €20. If he/she draws a ball of a different color from Urn A, you will not earn the extra €20 and will be paid only the €4 participation fee.
- If your relevant bet is **"white ball from Urn B"** and the randomly selected participant draws a white ball from Urn B, you will earn the extra €20. If he/she draws a black ball, you will not earn the extra €20 and will be paid only the €4 participation fee.
- If your relevant bet is **"black ball from Urn B"** and the randomly selected participant draws a black ball from Urn B, you will earn the extra €20. If he/she draws a white ball, you will not earn the extra €20 and will be paid only the €4 participation fee.

Instructions for Part 1 are over. We will now ask you to answer some questions to ensure that you understand the instructions completely. Please raise your hand if you have any questions. Click "OK" (on your computer screen) when you are finished with the instructions for this part of the experiment.

Instructions for Part 2

The second part of the experiment involves the same two urns as in Part 1: Urn A with 18 yellow balls and 22 balls of various colors (green, pink, red, blue, and brown), and Urn B with 40 black and white balls in a proportion unknown to you.

As before:

- there will be three possible bets ("yellow ball from Urn A", "white ball from Urn B", and "black ball from Urn B");
- to express your preferences for these bets, you will be asked whether you prefer
  (*i*) "black ball from Urn B" OR "yellow ball from Urn A";
  (*ii*) "white ball from Urn B" OR "yellow ball from Urn A";
  (*iii*) "black ball from Urn B" OR "white ball from Urn B".

But now:

- your choices can affect the determination of the bet relevant to two other participants (and thus their earnings), and similarly the choices of two other participants can affect the determination of the bet relevant to you (and thus your earnings). Each *group* consists of three randomly selected individuals, and you will not know the identity of the two other members of your group.
- The relevant bet is dictated by [*participants in condition D1 read:* one person] [*participants in condition D2 read:* two persons] [*participants in condition MV read:* majority] in the group. How this works is described next.

Determination of the bet relevant to your group

After you (and the two other members of your group) have completed your task, the computer software will

[*participants in condition D1 read:* (*i*) randomly select one person in your group (call this person **member X**), and (*ii*) check his/her preferences between "black ball from Urn B" and "white ball from Urn B".

If the selected member X preferred "black ball from Urn B", the software will check his/her preferences between "black ball from Urn B" and "yellow ball from Urn A".

- If member X preferred "black ball from Urn B", this becomes the bet relevant to your group.

– If member X preferred "yellow ball from Urn A", this becomes the bet relevant to your group.

If the selected member X preferred "white ball from Urn B", the software will check his/her preferences between "white ball from Urn B" and "yellow ball from Urn A".

– If member X preferred "white ball from Urn B", this becomes the bet relevant to your group.
– If member X preferred "yellow ball from Urn A", this becomes the bet relevant to your group.

Notice that each of you has an equal chance of being selected as member X and, thus, of determining the bet relevant to your group.]

[*participants in condition D2 read:* (*i*) randomly select two persons in your group (call them **member X** and **member Y**), and (*ii*) check the preferences between "black ball from Urn B" and "white ball from Urn B" of **member X**.

If **member X** preferred "black ball from Urn B", the software will check the preferences between "black ball from Urn B" and "yellow ball from Urn A" of **member Y**.

– If **member Y** preferred "black ball from Urn B", this becomes the bet relevant to your group.
– If **member Y** preferred "yellow ball from Urn A", this becomes the bet relevant to your group.

If **member X** preferred "white ball from Urn B", the software will check the preferences between "white ball from Urn B" and "yellow ball from Urn A" of **member Y**.

– If **member Y** preferred "white ball from Urn B", this becomes the bet relevant to your group.
– If **member Y** preferred "yellow ball from Urn A", this becomes the bet relevant to your group.

Notice that each of you has an equal chance of being selected as member X or as member Y and, thus, of influencing the determination of the bet relevant to your group.]

[*participants in condition MV read:* check the preferences between "black ball from Urn B" and "white ball from Urn B" of all three group members.

If the majority (i.e., at least two out of three members) preferred “black ball from Urn B”, the software will check the preferences between “black ball from Urn B” and “yellow ball from Urn A” of all three group members.

- If the majority preferred “black ball from Urn B”, this becomes the bet relevant to your group.
- If the majority preferred “yellow ball from Urn A”, this becomes the bet relevant to your group.

If the majority preferred “white ball from Urn B”, the software will check the preferences between “white ball from Urn B” and “yellow ball from Urn A” of all three group members.

- If the majority preferred “white ball from Urn B”, this becomes the bet relevant to your group.
- If the majority preferred “yellow ball from Urn A”, this becomes the bet relevant to your group.]

Your earnings

If Part 2 is selected for payment, whether or not you receive the extra €20 will be determined like in the previous part. This time, however, your earnings will depend on the decisions made by [*participants in D1 read:* member X] [*participants in D2 read:* members X and Y] [*participants in MV read:* the majority] of your group. Specifically, we will ask a randomly selected participant to draw a ball from each urn. You are interested only in the outcome of the urn relevant to your group.

- If the bet relevant to your group is **“yellow ball from Urn A”** and the randomly selected participant draws a yellow ball from Urn A, you and the two other persons in your group will earn the extra €20. If he/she draws a ball of a different color from Urn A, no one in your group will earn the extra €20 and all three of you will be paid only the €4 participation fee.
- If the bet relevant to your group is **“white ball from Urn B”** and the randomly selected participant draws a white ball from Urn B, you and the two other persons in your group will earn the extra €20. If he/she draws a black ball, no one in your group will earn the extra €20 and all three of you will be paid only the €4 participation fee.
- If the bet relevant to your group is **“black ball from Urn B”** and the randomly selected participant draws a black ball from Urn B, you

and the two other persons in your group will earn the extra €20. If he/she draws a white ball, no one in your group will earn the extra €20 and all three of you will be paid only the €4 participation fee.

Instructions for Part 2 are over. We will now ask you to answer some questions to ensure that you understand the instructions completely. Please click "OK" if you have finished reading the instructions for the present part and have no questions.