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Group decisions under ambiguity: Convergence to neutrality

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ABSTRACT

This paper focuses on decisions under ambiguity. Participants in a laboratory experiment made decisions in three different settings: (a) individually, (b) individually after discussing the decisions with two others, and (c) in groups of three. We show that groups are more likely to make ambiguity-neutral decisions than individuals, and that individuals make more ambiguity-neutral decisions after discussing the decisions with others. This shift toward higher ambiguity neutrality in groups and after a group discussion is associated with a reduction in the rates of both ambiguity aversion and ambiguity seeking. We suggest that the results might be driven by effective and persuasive communication that takes place in groups.

1. Introduction

Keynes (1921) and Knight (1921) emphasized that most economic decisions involve imprecise probabilities (ambiguity)[1] as opposed to precisely defined probabilities (risk). Ellsberg (1961) showed that for decisions under ambiguity, individuals' preferences cannot always be reconciled with subjective expected utility (Savage, 1954). In a thought experiment, Ellsberg suggested that individuals prefer risky prospects over ambiguous ones, a phenomenon which is referred to as ambiguity aversion. This was confirmed in many studies (see review by Camerer and Weber, 1992), but the result is not universal. Ambiguity seeking has been commonly observed in the domain of losses (Abdellaoui et al., 2005; Du and Budescu, 2005; Einhorn and Hogarth, 1986; Kahn and Sarin, 1988) and for small probabilities of gains (Curley and Yates, 1989). For a complete list of references of heterogeneity in individual ambiguity attitudes, refer to Wakker (2010). Since the 1980s models focusing on attitudes to ambiguity have been introduced (Gilboa, 1987; Gilboa and Schmeidler, 1989; Klibanoff et al., 2005; Maccheroni et al., 2006; Neilson, 2010; Schmeidler, 1989).

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[1] Following Ellsberg (1961), imprecise probabilities are commonly referred to as "ambiguous". We follow this convention in our paper. However, see Budescu et al. (2002) for a discussion pointing out the inadequacy of ambiguity as a descriptive term and advocating the use of imprecision or vagueness instead.

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Prior studies have focused on decisions made by individuals. However many decisions in organizations are delegated to groups of decision makers (DMs), for example, committees, management teams and boards of directors. Our aim is to understand whether individuals and groups differ with respect to their attitudes to ambiguity. Standard economic theory is silent on the distinction between individual vs. group decision making and empirical work comparing individuals and groups with respect to deviations from normative models for decisions under risk has produced mixed results. Groups showed fewer violations of stochastic dominance and Bayesian updating rules (Charness et al., 2007), and made better investment decisions (Rockenbach et al., 2007; Sutter, 2007). Bone et al. (1999) reported that decisions under risk made by individuals and groups showed similar rates of expected utility violations such as the common ratio effect. Rockenbach et al. (2007) confirmed this result and also found no differences between individuals and groups with respect to rates of preference reversals.

Several studies have investigated differences between individual and group attitudes toward risk. Zhang and Casari (2009) found groups to be less risk averse than individuals. In contrast, Harrison et al. (2013), Ambrus et al. (2009) and Deck et al. (2012) found no differences between the risk attitudes of individuals and groups. Shupp and Williams (2008) showed that groups were less risk averse in low-risk situations, and more risk averse when decisions involved high levels of risk. Baker et al. (2008) and Masclet et al. (2009) found a similar pattern.

A small number of studies have investigated the effects of interpersonal interactions on decisions under ambiguity. Curley et al. (1986) found that individuals who were observed by uninvolved others during decision making and the resolution of uncertainty exhibited significantly more aversion to ambiguity than individuals who made decisions alone. Curley et al. attributed this finding to the participants' fear of being evaluated negatively in the event that the chosen ambiguous alternative had undesirable outcomes. Muthukrishnan et al. (2009) obtained a similar result: in their study, participants who expected to be informed in the presence of others about the true probability of winning a prize in an ambiguous gamble were more ambiguity averse than participants who expected to be informed in private. Trautmann et al. (2008) reported the results of an experiment in which the participants' preferences were withheld from the experimenters, so the possibility of a negative evaluation by others was ruled out. This treatment significantly decreased ambiguity aversion, supporting the interpretation proposed by Curley et al. (1986). Charness et al. (2013) studied the effect of direct communication on ambiguity attitudes and found that individuals were more likely to make ambiguity neutral choices after consulting with an ambiguity neutral participant. The shift toward ambiguity neutrality was particularly pronounced when the ambiguity neutral participant had a financial incentive to persuade others. Charness et al. concluded that ambiguity neutrality might have a "persuasive edge" over other attitudes during interpersonal interactions.

In contrast to these findings, Engle et al. (2011) who studied the effects of a computer-mediated discussion did not find an effect of communication with others on subsequent individual ambiguity attitudes.

Closest to our study, Keller et al. (2009) compared the willingness of individuals and dyads to pay for risky and ambiguous gambles. Dyads tended to be more risk averse than their individual members, but there was no difference with respect to ambiguity attitudes. Brunette et al. (2011) investigated the effect of group decision rules (unanimity vs. majority) on attitudes to risk and ambiguity, and found that under a unanimity rule the groups' risk attitudes differed significantly from those of individuals. However, like Keller et al. (2009), they found no difference between individuals and groups with respect to ambiguity attitudes (irrespective of the group decision rule).

Our study contributes to the existing literature in the following ways. First, we employ a design that allows us to test the effects of joint group decisions as in Keller et al. (2009) and Brunette et al. (2011) as well as the effects of communication between individuals as in Charness et al. (2013) and Engle et al. (2011). Second, whereas prior work on group decision making has been limited to the case of dyads (Keller et al., 2009) or did not allow for any verbal interaction between participants (Brunette et al., 2011) we explore the effects of group decision making with direct communication in three-person groups. Third, unlike previous studies that have mostly focused on the two classical Ellsberg problems, we consider a wide range of uncertain prospects that vary in their level of riskiness and ambiguity. This allows us to test for possible interactions between the effects of probability levels and group decisions on ambiguity attitudes, as prior studies have reported for the case of risk attitudes (Baker et al., 2008; Masclet et al., 2009; Shupp and Williams, 2008).

We conducted a laboratory experiment in which DMs (individuals or groups) made binary choices between sure amounts of money and different risky and ambiguous gambles. We distinguish between "regular" individual decisions, individual decisions made after exchanging information with others, and group decisions. This distinction allows us to disentangle two effects often confounded in studies of group decisions. The first is the influence of discussing decisions and exchanging information and opinions with others (Trautmann and Vieider, 2011). This factor affects both group decisions and individual decisions after a group discussion. The second is the process of aggregating individual preferences into a joint decision, and it affects only group decisions.

2. Experimental method

2.1. Experimental tasks

DMs (individuals or groups of three participants) made choices between sure amounts of money and 15 two-outcome gambles; outcomes were fixed at \$20 and \$0. Ambiguity in the probability p of winning \$20 was operationalized by considering probability ranges Δ. We varied the probability of winning ($p = 0.20, 0.35, 0.50, 0.65$ and 0.80) and considered different levels of imprecision Δ ($\Delta = 0, 0.05, 0.10, 0.20, 0.30$, and 0.50). The degenerate case of $\Delta = 0$ refers to decisions under risk.

Table 1
List of the gambles used in the study.

p	Δ	Range of sure amounts of money			No. of choices
		Lowest	Highest	Increments	
0.20	0.00	\$0.50	\$7.50	\$0.50	15
0.20	0.05	\$0.50	\$7.50	\$0.50	15
0.20	0.10	\$0.50	\$7.50	\$0.50	15
0.20	0.20	\$0.50	\$7.50	\$0.50	15
0.35	0.00	\$0.50	\$13.50	\$1.00 and \$0.50	15
0.50[a]	0.00	\$1.00	\$19.00	\$1.00	19
0.50	0.05	\$1.00	\$19.00	\$1.00	19
0.50	0.10	\$1.00	\$19.00	\$1.00	19
0.50	0.30	\$1.00	\$19.00	\$1.00	19
0.50	0.50	\$1.00	\$19.00	\$1.00	19
0.65	0.00	\$6.50	\$19.50	\$1.00 and \$0.50	15
0.80	0.00	\$12.50	\$19.50	\$0.50	15
0.80	0.05	\$12.50	\$19.50	\$0.50	15
0.80	0.10	\$12.50	\$19.50	\$0.50	15
0.80	0.20	\$12.50	\$19.50	\$0.50	15

[a] Presented twice.

All choices were presented in the form of a price list (e.g., Andersen et al., 2006; Binswanger, 1981). Each price list consisted of a number of binary choices (15 or 19 depending on the gamble) between the gamble and increasing sure amounts of money. Price lists were built such that for the first decision a DM should always prefer the gamble, and for the last decision always prefer the sure amount of money. The 15 gambles (and their respective price lists) were presented in random order. We presented one of the price lists ($p = 0.50$, $\Delta = 0$) twice to test for consistency. Table 1 summarizes the 15 gambles and the price lists used as stimuli. Examples of price lists for risky and ambiguous gambles are in Appendix A. In addition to the 15 price lists we included the two classical Ellsberg tasks. Descriptions of the Ellsberg tasks and a brief overview of our findings can be found in the online supplementary materials.

We calculated certainty equivalents (CEs) for each gamble by considering the point at which preferences between the two alternatives – the gamble and the sure amount – switched. A DM with monotonic preferences for money should have a unique switching point. For example, if on a particular price list a DM preferred the gamble over all sure amounts of money ≤\$8, and the sure amount over the gamble for all amounts ≥\$9, we assume that the CE is (\$8.00 + \$9.00)/2 = \$8.50.[2,3]

Participants had the option of using computer assistance in making their decisions (see Andersen et al., 2006 for a discussion of a similar procedure). The computer assistance automatically filled in all choices located on the price list above (below) the choice for which a participant preferred the sure amount of money (the gamble) over the gamble (the sure amount of money). For example, if a participant indicated a preference for \$10 over the gamble, the computer-assistance automatically determined that she would also prefer all sure amounts > \$10. Similarly, if a participant indicated a preference for the gamble over \$9, the computer assistance automatically determined that she would also prefer the gamble over all sure amounts < \$9. Used effectively, the computer assistance allowed participants to complete a particular price list with only two clicks by indicating their switching point. By default the computer assistance was activated, but participants could change the setting of the computer assistance (on or off) at any time they wished.

2.2. Experimental design

We recruited 240 undergraduate students (90 male and 150 female) via an e-mail announcement. Students were from a wide number of majors. The average age of participants was 20.7 years. All sessions were run at the NYU Center for Experimental Social Science in April 2009. Participants were paid a \$5 show-up fee plus what they won (individually or in groups) during the experiment, and earned \$23.2 on average. They were randomly assigned to one of the three experimental treatments summarized in Table 2.

The experiment consisted of two stages (individual and group decision making) in treatments I-G and G-I, and of three stages (individual decisions, group discussion, and second round of individual decisions) in treatment I-C-I. At each stage, except for the group discussion in treatment I-C-I, participants made decisions for all 16 (15+1 repeated) price lists. In treat-

[2] In 16 (out of the 6800 price lists = 0.2%) cases, participants had multiple switches. In these cases we use the mid-point between the switching points on the price list to calculate the CEs. 15 of these 16 cases were caused by three individuals who had multiple switches on several price lists. To test for the robustness of our results we also ran our analyses excluding those participants and their groups. This had no influence on the significance of our results.

[3] In 253 (out of the 6,800 price lists = 3.7%) cases, decision makers preferred either the gamble over all sure amounts (176 cases = 2.6%) or all sure amounts over the gamble (77 cases = 1.1%) and never switched between the two. To calculate a CE in these cases, we assumed that the decision maker would have switched at the next item that could have been listed on the price list. For example, if a decision maker preferred a gamble to win \$20 with $p = 0.20$ over all amounts between \$0 and \$7.50 (the upper end on this price list) we assumed that the decision maker would have switched for the sure amount of \$8.00 and infer the CE to be \$7.75 (the midpoint between \$7.50 and \$8.00). To test for the robustness of our results we also ran our analyses excluding those participants and their groups. This had no influence on the significance of our results.

Table 2
Experimental treatments and sample sizes.

Treatment	Stage 1	Stage 2	Stage 3	No. of groups	No. of participants
I-G	Individual decisions	Group decisions		30	90
G-I	Group decisions	Individual decisions		15	45
I-C-I	Individual decisions	Group communication	Individual decisions	35	105

ment I-G, participants started the experiment with the individual decision-making stage. This was followed by a group stage. The order of the two stages was reversed in treatment G-I. In treatment I-C-I, participants first made decisions individually, then had the possibility of discussing their decisions with two other participants, and finally made another round of individual decisions. The price-lists used during the individual and the group stage were identical. In the group stage, participants were told that the values on the price-lists represented the payoff for each group member.

During the group stage in treatments I-G and G-I, the three group members had to make a joint decision about how to fill in the price lists. They were allowed to discuss their choices in a face-to-face interaction for as long as they wished before making a joint decision. Disagreements were resolved by discussing the problem and, if necessary, by a majority vote. In the group communication stage in treatment I-C-I, participants were asked to discuss their decisions with others but did not make binding group decisions. Participants worked through the decision sheets together on their group computer, just as in the group stage in treatments I-G and G-I, but were not required to actually enter their choices into the computer.

To determine the final payment for participants, we employed the random incentive system (Hey and Lee, 2005; Starmer and Sudgen, 1991). One of the choices made at each stage (except the group discussions in treatment I-C-I) was randomly selected at the end of the experiment and participants were paid according to their decisions. For all gambles, drawing a red chip from a physical urn filled with red and black chips resulted in winning $20; drawing a black chip in winning nothing. As explained to participants in the instructions, all urns contained a total of 100 red and black chips in a proportion corresponding to the characteristics of the chosen gamble. For example, a gamble with $p = 0.50$ and $\Delta = 0.10$ was represented by a draw from an urn containing 100 chips in total, where 40–60 were red and the rest black. The 15 urns (one corresponding to each gamble) were prepared before the experiment by one of the authors and were placed in the front of the room such that they would be visible to the participants. The actual composition of the urns representing the ambiguous gambles was determined randomly (based on a uniform distribution over the possible compositions), within the parameters of the gambles, and remained the same throughout the experiment. Participants were solely told that the actual composition of the ambiguous urns was determined by "chance", but did not receive any information about the underlying distribution.

We chose this procedure to make the characteristics of the gambles and the resolution of uncertainty as vivid as possible for participants. The procedure had the potential drawback of introducing concerns about the possibility that the urn is "biased" and increase aversion toward ambiguity. To alleviate this concern, participants were explicitly reminded that the proportion of red and black chips was – within the parameters of the gambles – determined purely by chance and they had the possibility of inspecting the urns after the payment had taken place (see also Curley et al., 1986 who did not find a significant effect of ruling out such potential concerns; a similar finding is obtained by Pulford, 2009).

Participants were informed that the payoffs for the group stage (independent of the payoff for their individual decisions) in treatments I-G and G-I would be determined according to one, randomly selected, choice the group made. All group members were paid equally according to the group decision. In two additional treatments we manipulated the payoff-sharing arrangement among the group members. In these treatments, participants were informed that gambles would be played out for each group member separately, such that the financial outcome of a group decision could differ across the individual members. We found that the procedure by which payoffs were determined for group members did not influence risk or ambiguity attitudes. Given our focus on differences between individuals and groups, we do not distinguish between the various payment arrangements and we report results based on the data from all groups combined.

2.3. Procedure

As part of the procedure to ensure their informed consent, participants were informed that the experiment consisted of several stages and involved group interactions, but were not told any details about the tasks they were to going to perform.

All instructions were presented to participants on their computer screens and a hard copy of the instructions was made available for reference. To ensure that all participants fully understood the instructions, they were required to pass four quiz questions before being allowed to start the experiment. Participants were also encouraged to ask questions at any time they wished.

In treatment I-G, all participants completed the price lists individually and were then instructed to move to their group computers which were located in a large room. Three participants were randomly assigned to the same group computer and could communicate with each other but no inter-group communication was allowed. Several groups were making decisions at the same time in different corners of the room. We chose a room of very large size for the experiment and it is very unlikely that group members were able to understand conversations of the other groups.

In treatment G-I, the order was reversed: all participants started the experiment at the group computers and then moved to the individual computers. In treatments I-G and G-I, the experiment ended after the second stage and all group members

Table 3
Mean certainty equivalents (CEs) and standard deviations for the two group treatments.

p	Δ	I-G		G-I	
		Individuals (N = 90)	Groups (N = 30)	Individuals (N = 45)	Groups (N = 15)
0.20 (EV = 4)	0.00	3.65 (1.57)	4.07 (1.07)	4.04 (1.46)	4.18 (1.52)
0.20	0.05	3.33 (1.47)	4.2 (0.90)	4.10 (1.37)	3.67 (1.77)
0.20	0.10	3.45 (1.60)	4.12 (0.87)	3.89 (1.67)	3.43 (1.98)
0.20	0.20	3.73 (1.50)	3.93 (0.84)	4.07 (1.54)	3.58 (1.84)
0.35 (EV = 7)	0.00	5.14 (2.06)	5.83 (1.77)	5.80 (2.21)	5.70 (2.31)
0.50 (EV = 10)	0.00	9.18 (2.02)	9.68 (1.14)	9.11 (2.65)	9.73 (1.76)
0.50	0.05	8.81 (2.38)	9.63 (1.25)	8.89 (2.81)	9.77 (1.78)
0.50	0.10	8.69 (2.05)	9.5 (1.53)	8.77 (2.68)	9.53 (1.87)
0.50	0.30	7.99 (2.97)	8.73 (1.79)	8.62 (3.15)	9.30 (2.08)
0.50	0.50	7.57 (3.15)	8.42 (2.07)	7.70 (3.28)	8.53 (2.89)
0.65 (EV = 13)	0.00	11.4 (2.24)	12.1 (1.91)	11.04 (2.80)	12.12 (2.40)
0.80 (EV = 16)	0.00	15.7 (1.70)	15.6 (0.81)	15.32 (1.82)	16.08 (1.46)
0.80	0.05	15.6 (1.75)	15.5 (0.85)	15.10 (1.58)	16.05 (1.35)
0.80	0.10	16 (1.46)	15.5 (0.89)	15.48 (1.77)	16.42 (1.22)
0.80	0.20	14.8 (1.50)	15.1 (0.91)	14.71 (1.60)	15.40 (1.71)

Note: Mean values; standard deviation in parentheses.

were paid and debriefed. In treatment I-C-I, participants returned to their individual computers after the group stage and repeated the same tasks individually. Upon completion of the task, they were debriefed and paid.

3. Results

3.1. Monotonicity and reliability

Monotonicity of the CE's in p was fully satisfied for 173 of the 240 individual participants (72%) in all three treatments (excluding stage 3 decisions in treatment I-C-I) and 39 of the 45 groups (87%) in the two group treatments. Groups showed fewer violations of monotonicity than individuals, consistent with Charness et al. (2007).

To measure the reliability of the participants' decisions, we calculated the mean absolute difference (MAD) between the two CEs obtained from the replicated price list (p = 0.50, Δ = 0). Across all treatments groups made more reliable decisions than individuals (MAD = 0.34 for groups compared with MAD = 0.91 for individuals). We also found that individual decisions made after group discussions were more reliable (MAD = 0.70) than those made before (MAD = 1.00). In the subsequent analysis we averaged the two CEs (rounded up or down) obtained from the repeated gamble, leaving us with 15 observations for each individual/group at each stage of the experiment.[4]

3.2. Group vs. individual decisions

Table 3 shows the mean individual and group CEs for the 15 gambles (risky and ambiguous) in treatments I-G and G-I.

3.2.1. Risk attitudes

We analyze first the risky gambles (Δ = 0). For all probability levels p > 0.20, the means of individual and group CEs of risky gambles were lower than the gambles' expected values indicating risk aversion for individuals and groups. For p = 0.20, the mean of group CEs and the gamble's expected value are approximately equal. An OLS regression[5] on the certainty equivalents of the risky gambles revealed no significant effect of group decision making on CEs. There was also no significant difference between treatments I-G and G-I or interactions between the treatments and group decisions. Table 4 shows the detailed results.

3.2.2. Ambiguity attitudes

We used a measure of ambiguity attitudes that compares the CEs of risky and ambiguous gambles. For each of the 10 ambiguous gambles, we compared the CE of the ambiguous gamble with the CE of the risky gamble with the same probability level (Budescu et al., 2002; Chen et al., 2007; Halevy, 2007). If the CE for the ambiguous gamble was higher (equal, smaller) than the CE for the risky gamble, we classified a choice as ambiguity seeking (neutral, averse). Based on this classification, we computed the proportion of individual and group choices that exhibited a particular ambiguity attitude (seeking, neutral,

4 We also conducted the data analysis for p = 0.5 using only the CE from the price list that was presented first. All our main results remain significant.

5 For all OLS and logit regressions we followed the recommendation by Cameron and Miller (2011) and clustered the standard error at the highest level (in our case always the group level).

Table 4
Results from OLS regression; Dependent variable: Certainty equivalents of risky gambles in treatments I-G and G-I.

Independent variable	Coefficient	Robust standard error	*t*	*p*-Value
Constant	3.93	0.16	23.87	<0.001
GroupDM	0.14	0.19	0.76	0.45
Order (=1 for G-I)	−0.04	0.35	−0.11	0.92
P35	1.67	0.15	11.49	<0.001
P50	5.22	0.17	29.97	<0.001
P65	7.25	0.21	35.05	<0.001
P80	11.54	0.19	61.9	<0.001
GroupDM × Order (=1 for G-I)	0.15	0.25	0.61	0.54
GroupDM × P35	0.54	0.25	0.06	0.95
GroupDM × P50	0.37	0.24	1.57	0.12
GroupDM × P65	0.74	0.28	2.66	0.01
GroupDM × P80	0.09	0.19	0.47	0.64

Note: Standard errors are clustered at group level; total number of observations = 900; 45 clusters of 20 observations (3 individuals + group = 4 × 5 gambles). Model: $F(11, 44) = 648.72$, $p < 0.001$, $R^2 = 0.81$.

Table 5
Ambiguity attitudes in treatments I-G and G-I.

p	*Δ*	I-G						G-I					
		Individual ambiguity attitudes[a] (*N* = 90)			Group ambiguity attitudes[a] (*N* = 30)			Individual ambiguity attitudes[a] (*N* = 45)			Group ambiguity attitudes[a] (*N* = 15)		
		A	N	S	A	N	S	A	N	S	A	N	S
0.20	0.05	0.33	0.31	0.36	0.10	0.67	0.23	0.42	0.31	0.27	0.40	0.53	0.07
0.20	0.10	0.43	0.32	0.24	0.20	0.60	0.20	0.42	0.24	0.33	0.27	0.67	0.07
0.20	0.20	0.38	0.30	0.32	0.27	0.47	0.27	0.31	0.24	0.44	0.47	0.40	0.13
Total *p* = 0.20		0.38	0.31	0.31	0.19	0.58	0.23	0.39	0.27	0.35	0.38	0.53	0.09
0.50	0.05	0.36	0.31	0.33	0.23	0.57	0.20	0.47	0.27	0.27	0.13	0.67	0.20
0.50	0.10	0.43	0.22	0.34	0.23	0.50	0.27	0.49	0.27	0.24	0.33	0.47	0.20
0.50	0.30	0.47	0.19	0.34	0.63	0.20	0.17	0.76	0.09	0.16	0.47	0.33	0.20
0.50	0.50	0.58	0.22	0.20	0.63	0.27	0.10	0.64	0.18	0.18	0.67	0.20	0.13
Total *p* = 0.50		0.46	0.24	0.31	0.43	0.38	0.18	0.59	0.20	0.21	0.40	0.42	0.18
0.80	0.05	0.42	0.32	0.26	0.33	0.50	0.17	0.42	0.27	0.31	0.27	0.60	0.13
0.80	0.10	0.38	0.26	0.37	0.37	0.40	0.23	0.38	0.18	0.44	0.07	0.53	0.40
0.80	0.20	0.60	0.18	0.22	0.50	0.40	0.10	0.64	0.18	0.18	0.67	0.27	0.07
Total *p* = 0.80		0.47	0.25	0.28	0.40	0.43	0.17	0.48	0.21	0.31	0.33	0.47	0.20
Total		0.44	0.26	0.30	0.35	0.46	0.19	0.50	0.22	0.28	0.37	0.47	0.16

[a] Proportion of decisions that are ambiguity averse (A), ambiguity neutral (N) or ambiguity seeking (S).

averse). Table 5 presents the distribution of ambiguity attitudes for each of the 10 ambiguous gambles for individuals and groups in both treatments.

A Mann–Whitney *U*-test revealed no significant difference in the proportion of ambiguity neutral decisions (aggregated over all levels of p and Δ) between individual decisions in treatments I-G and G-I ($N = 45$, $z = -0.77$, $p = 0.44$). Similarly, there was no significant difference in the level of ambiguity neutrality in group decisions between the two treatments ($N = 45$, $z = 0.41$, $p = 0.68$).

Importantly, in both treatments, for all levels of p and Δ the proportion of ambiguity neutral decisions was higher for groups than for individuals. Aggregated over all levels of p and Δ and the two treatments, 46% of all group choices were ambiguity neutral compared to only 25% of individual choices. This difference between individuals and groups was significant according to a Wilcoxon Signed-Rank Test (WST), $N = 45$, $z = 4.41$, $p < 0.01$.[6] This shift toward ambiguity neutrality was caused by a reduction in both ambiguity-averse and ambiguity-seeking group decisions: Aggregated over both treatments 46% of individuals decisions were ambiguity averse but only 36% of all group decisions showed ambiguity aversion, WST: $N = 45$, $z = -2.84$, $p < 0.01$; 29% of all individual decisions were ambiguity seeking, compared to only 18% of group decisions, WST: $N = 45$, $z = -3.29$, $p < 0.01$.

In treatment I-G group decisions (46%) were significantly more often ambiguity neutral than individual decisions (26%), WST: $N = 30$, $z = 2.98$, $p < 0.01$. In this treatment individual decisions were followed by the group decisions. Thus, it is possible that the shift toward ambiguity neutrality in group decisions reflects a repetition effect or learning. Importantly, in treatment

[6] All Wilcoxon Signed-Rank Tests are based on proportions aggregated over all levels of p and Δ. For each group, the total number of ambiguity neutral decisions that were made by the three group members at the individual stage, was added up and divided by the total number of their individual decisions for ambiguous gambles (30). Similarly, the ambiguity neutral group decisions were added up and divided by the total number of group decisions for ambiguous gambles (10). The two proportions were then compared with the Signed-Rank Test.

Table 6
Results from logit regression; dependent variable: probability of ambiguity neutral decision in treatments I-G and G-I.

Independent variable	Coefficient	Robust standard error	*z*	*p*-Value
Constant	−0.67	0.17	−4.02	<0.001
GroupDM	1.04	0.30	3.43	<0.01
Order (=1 for G-I)	−0.23	0.20	−1.13	0.26
P50	0.01	0.22	0.01	0.99
P80	−0.08	0.17	−0.47	0.64
P20Delta10	−0.05	0.19	−0.27	0.79
P20Delta20	−0.31	0.21	−1.49	0.14
P50Delta10	−0.34	0.17	−1.96	0.05
P50Delta30	−1.04	0.21	−4.89	<0.001
P50Delta50	−0.79	0.22	−3.60	<0.001
P80Delta10	−0.37	0.18	−2.07	0.04
P80Delta20	−0.71	0.20	−3.63	<0.001
GroupDM × Order (G-I)	0.27	0.31	0.88	0.38
GroupDM × P50	−0.28	0.33	−0.85	0.40
GroupDM × P80	−0.16	0.37	−0.43	0.66

Note: Standard errors are clustered at group level; total number of observations = 1800; 45 clusters of 40 observations (3 individuals + group = 4 × 10 gambles). Model: Wald χ^2 (14) = 146.42; $p < 0.001$; Pseudo-$R^2 = 0.05$.

G-I the decision order was reversed, but (as shown in Table 5) we found the same pattern as in treatment I-G. 47% of all group decisions in treatment G-I were ambiguity neutral compared to only 22% of individual decisions, WST: $N = 15$, $z = 3.24$, $p < 0.01$. In fact, a Mann–Whitney U test revealed that group decisions made at stage 1 of the experiment in treatment G-I were significantly more often ambiguity neutral than individual decisions made at stage 1 in treatments I-G ($N = 45$; $z = -3.31$, $p < 0.01$). Thus learning or mere repetition effects are not driving our results. To analyze the data further we conducted a logit-regression with the probability of ambiguity neutral decisions as the dependent variable. The results are summarized in Table 6.

Consistent with the non-parametric analysis, group decision making had a significantly positive influence on the probability of ambiguity neutral decisions. The decision order (I-G vs. G-I) did not influence the probability of ambiguity neutrality. There was no significant influence of the gambles' overall probability levels or any interaction between probability levels and group decision making.

Can the results be explained by simple aggregation of individual preferences? Fig. 1 presents the proportion of ambiguity neutral decisions for individuals and groups aggregated over the two group treatments, and the predictions from two group decision models. The first model ("median ambiguity attitude model") corresponds to the proportion of ambiguity-neutral choices that would be predicted if each group had systematically implemented the median individual ambiguity attitude of its members. For example, if, for a particular decision, one group member made an ambiguity-seeking decision, one an ambiguity-neutral decision, and one an ambiguity-averse decision, the median model prediction for this decision would be ambiguity neutrality. The second model ("median CE model") corresponds to the ambiguity neutral choices that would be predicted if each group had always implemented the median CE of the three group members for each risky and ambiguous gamble. Thus the model predicts a decision to be ambiguity neutral if the median CE for a risky gamble equaled the median CE for the ambiguous gamble at the same probability level.

The figure shows, that for all levels of p and Δ, the proportion of ambiguity neutral group decisions was higher than the prediction from the two aggregation models. A Wilcoxon Signed-Rank Test confirmed that, aggregated over all levels of p and Δ and the two group treatments, the proportion of ambiguity-neutral decisions was significantly higher in groups compared to the median ambiguity attitude model (WST: $N = 45$, $z = 2.47$, $p = 0.02$) and the median CE model (WST: $N = 45$,

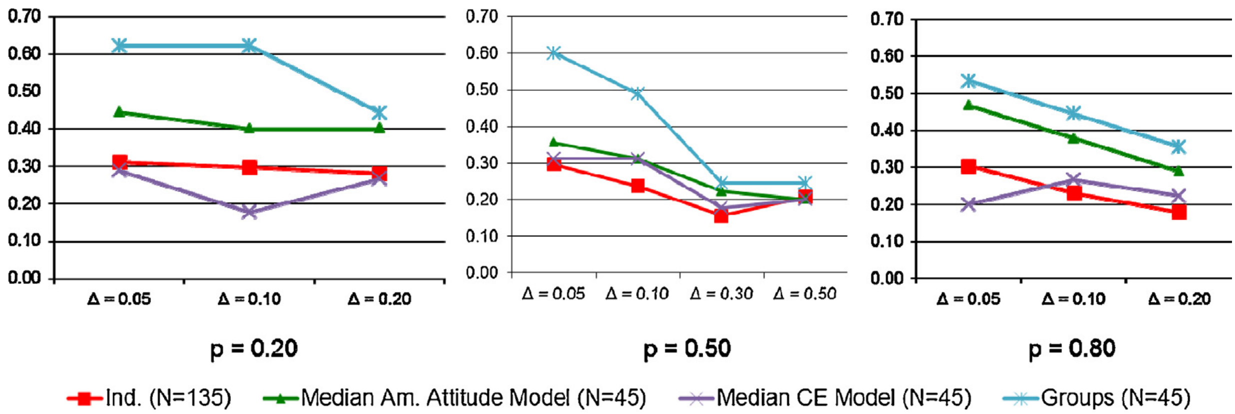

Fig. 1. Proportion of ambiguity neutral decisions.

Table 7
Mean certainty equivalents and standard deviations for treatment I-C-I.

p	Δ	Before	After
0.20 (EV = 4)	0.00	3.945 (1.48)	3.85 (1.19)
0.20	0.05	4.045 (1.56)	3.81 (1.26)
0.20	0.10	3.779 (1.58)	3.76 (1.29)
0.20	0.20	3.974 (1.57)	3.91 (1.30)
0.35 (EV = 7)	0.00	5.645 (2.63)	5.55 (2.02)
0.50 (EV = 10)	0.00	9.533 (2.42)	9.17 (2.00)
0.50	0.05	8.967 (2.47)	8.95 (2.11)
0.50	0.10	9.148 (2.43)	8.73 (2.16)
0.50	0.30	8.567 (2.67)	8.21 (2.64)
0.50	0.50	8.233 (3.26)	8.19 (2.91)
0.65 (EV = 13)	0.00	11.8 (2.87)	11.7 (2.64)
0.80 (EV = 16)	0.00	15.92 (1.98)	15.7 (1.78)
0.80	0.05	15.48 (1.78)	15.5 (1.74)
0.80	0.10	15.67 (1.97)	15.7 (1.93)
0.80	0.20	14.98 (1.75)	15.1 (1.66)

Note: $N = 105$; Mean values; standard deviation in parentheses.

$z = 4.28$, $p < 0.001$). This result indicates that the increase in ambiguity neutrality in group decisions cannot be explained by the simple aggregation of group members' individual ambiguity attitudes. Further evidence of this is provided by an analysis of individual ambiguity attitudes and the corresponding group decision. In 94 cases, at least two of the three players decided individually in an ambiguity-seeking fashion, but the modal choice of the group (51%) was for ambiguity neutrality. The most common pattern was to have a majority of ambiguity avoiders (200 cases), yet over one third (39%) of these groups provided ambiguity-neutral CEs.

3.3. Individual decisions before and after group discussion

We now turn to comparing risk and ambiguity attitudes before and after the group communication stage in treatment I-C-I. Table 7 shows the mean CEs before and after the group discussion for each gamble.

An OLS regression on the certainty equivalents of the risky gambles showed no significant difference between individual decisions before (stage 1) and after the group discussion (stage 3). The results also did not indicate any interactions between the decision making stage and probability levels. The detailed results are summarized in Table 8.

Table 9 shows the distribution of ambiguity attitudes (based on the categorization of ambiguity attitudes introduced in Section 3.2.2) before and after the group discussion.

We found that after the group discussion, individual decisions shifted toward ambiguity neutrality (36% aggregated over all levels of p and Δ) compared to individual decisions before the discussion (26% aggregated over all levels of p and Δ). This difference was significant (WST: $N = 35$, $z = 2.88$, $p < 0.01$). In addition, as shown in Table 9, individual decisions after the group discussion were less likely to be ambiguity averse or ambiguity seeking compared to individual decisions before the discussion. We next conducted a logit-regression on the probability of ambiguity neutral decisions. The results are shown in Table 10.

Confirming the findings of the non-parametric analysis the dummy variable for stage 3 decisions was significant and positive. The results also indicated that overall decisions at a medium probability level ($p = 0.5$) were less likely to be ambiguity neutral, but importantly there was no significant interaction between the probability level and the decision making stage.

Table 8
Results from OLS regression; dependent variable: certainty equivalents of risky gambles in treatment I-C-I.

Independent variable	Coefficient	Robust standard error	t	p-Value
Constant	3.95	0.14	29.17	<0.001
Stage3	−0.09	0.10	−0.87	0.39
P35	1.70	0.24	6.98	<0.001
P50	5.59	0.23	23.96	<0.001
P65	7.85	0.28	27.94	<0.001
P80	11.97	0.22	55.49	<0.001
Stage3 × P35	0.00	0.28	−0.01	0.99
Stage3 × P50	−0.28	0.21	−1.34	0.19
Stage3 × P65	−0.03	0.28	−0.09	0.93
Stage3 × P80	−0.15	0.18	−0.85	0.40

Note: Standard errors are clustered at group level; total number of observations = 1050; 35 clusters of 30 observations (3 individuals before and after discussion = 6 × 5 gambles). Model: $F(9, 34) = 438.09$; $p < 0.001$; $R^2 = 0.80$.

Table 9
Ambiguity attitudes in treatment I-C-I before and after the group discussion.

p	Δ	Before (N = 105) Am. attitudes[a]			After (N = 105) Am. attitudes[a]		
		A	N	S	A	N	S
0.20	0.05	0.32	0.30	0.37	0.30	0.48	0.22
0.20	0.10	0.34	0.38	0.28	0.33	0.46	0.21
0.20	0.20	0.32	0.30	0.38	0.30	0.43	0.28
Total p = 0.20		0.33	0.33	0.34	0.31	0.45	0.23
0.50	0.05	0.53	0.20	0.27	0.43	0.32	0.25
0.50	0.10	0.46	0.26	0.29	0.50	0.31	0.19
0.50	0.30	0.59	0.19	0.22	0.51	0.30	0.19
0.50	0.50	0.60	0.20	0.20	0.52	0.28	0.20
Total p = 0.50		0.55	0.21	0.24	0.49	0.30	0.21
0.80	0.05	0.50	0.29	0.22	0.41	0.39	0.20
0.80	0.10	0.43	0.29	0.29	0.30	0.37	0.33
0.80	0.20	0.57	0.24	0.19	0.53	0.30	0.16
Total p = 0.80		0.50	0.27	0.23	0.41	0.36	0.23
Total		0.47	0.26	0.27	0.41	0.36	0.22

[a] Proportion of decisions which are ambiguity averse (A), ambiguity neutral (N) or ambiguity seeking (S).

Finally, we compared individual decisions after the group discussion in treatment I-C-I with group decisions in treatments I-G and G-I. Aggregated over all levels of p and Δ, 36% of individual decisions after the group discussion in treatment I-C-I were ambiguity neutral compared to an average of 47% of group decision in treatments I-G and G-I. It appears that the effects of the group discussion on subsequent individual decisions is somewhat weaker than its effects when making group decisions, but this difference is not significant (Mann–Whitney: $N = 80$, $z = -1.73$, $p = 0.08$).

4. General discussion

4.1. Summary of main findings

We compared individual and group decisions under risk and ambiguity and we explored the effects of exposure to other individuals' opinions and attitudes on subsequent individual decisions. Differences between individuals and groups in their attitudes toward ambiguity have not been comprehensively addressed in the past, and we documented three new empirical results: (1) For all probability levels and all levels of ambiguity, groups made ambiguity-neutral choices more often than individuals, and more often than predicted by the median preferences of the group. (2) This shift toward ambiguity neutrality is not unidirectional and it is caused by a significant reduction in ambiguity seeking *and* ambiguity aversion in groups. (3) Choices made after non-binding group discussions with other DMs are more ambiguity neutral than decisions before the interaction.

Our results demonstrate that direct extrapolations from individual decisions to group decisions, can be misleading. For decisions under ambiguity groups show considerably fewer violations of subjective expected utility. This suggests that group decision making could be used as a remedy for deviations from normative decision models.

Table 10
Results from logit regression; dependent variable: probability of ambiguity neutral decisions in treatment I-C-I.

Independent variable	Coefficient	Robust standard error	z	p-Value
Constant	−0.72	0.17	−4.33	<0.001
Stage3	0.54	0.22	2.49	0.01
P50	−0.57	0.26	−2.15	0.03
P80	−0.16	0.28	−0.56	0.58
P20Delta10	0.12	0.15	0.80	0.43
P20Delta20	−0.12	0.17	−0.71	0.48
P50Delta10	0.12	0.13	0.94	0.35
P50Delta30	−0.10	0.20	−0.52	0.60
P50Delta50	−0.13	0.18	−0.71	0.48
P80Delta10	−0.04	0.16	−0.27	0.79
P80Delta20	−0.32	0.18	−1.73	0.08
Stage3 × P50	−0.06	0.29	−0.21	0.84
Stage3 × P80	−0.14	0.32	−0.43	0.67

Note: Standard errors are clustered at group level; total number of observations = 2100; 35 clusters of 60 observations (3 individuals before and after discussion = 6 × 10 gambles). Model: Wald χ^2 (12) = 44.90; $p < 0.001$; Pseudo-R^2 = 0.02.

One part of our results requires further interpretation. Individuals in the I-C-I treatment made significantly more ambiguity neutral decisions after the group discussion than before. However, we did not find a significant difference in ambiguity neutrality between individual decisions in treatment G-I compared to individual decisions in treatment I-G. Interestingly, prior work on risk attitudes in groups has shown similar differences with respect to the effect of group interactions on subsequent individual decisions. Masclet et al. (2009) did not find differences in individual risk attitudes in two treatments with a very similar general setup as our treatments I-G and G-I which indicates that the group stage did not influence subsequent individual choices. In contrast Baker et al. (2008) and Shupp and Williams (2008) using an I-C-I design, similar to ours, found that the group stage did have a significant effect on subsequent individual risk attitudes.

Several factors in our study could account for this difference in the effect of group interactions on subsequent individual decisions between the two treatments. First, the group stage in the I-C-I treatment was not incentivized and explicitly framed as a group discussion that gave participants the opportunity to consider the opinions of the other group members. In contrast, no such framing was used in the group stage in treatment G-I. Moreover, in treatment I-C-I participants had already made an individual decision before they entered the group stage and this might have influenced the degree to which they revised their attitudes. For example, it is possible that the initial stage made group members more aware of the differences between their individual attitudes and that of their group members, and that this awareness led to stronger revision of their individual attitudes. Similarly, prior experience with the task might have increased group members' participation and engagement in the group discussion and thus increased the effect of the interaction on subsequent individual decisions.

To investigate this difference we conducted an additional experiment with a sample of 66 participants (22 groups). Participants were assigned to a modified version of treatment I-C-I in which we incentivized the group stage and used the same instructions for the group stage as we used in treatment G-I. A detailed description of the experiment and full analysis of the data can be found in the online supplementary materials. We replicated our basic finding that individual decisions were more likely to be ambiguity neutral after the group discussion. Aggregated over all levels of p and Δ, 26% of decisions before the group discussion were ambiguity neutral compared to 35% of ambiguity neutral decisions after the discussion ($t[21] = 2.37$, $p = 0.03$). This result rules out factors related to incentives or the framing of the group stage in the instructions, and indicates that it is the initial stage of individual decision making before the group stage in treatment I-C-I that causes the difference in the effect of the group stage on subsequent individual decisions.

Unfortunately, we cannot determine the precise mechanism by which the prior stage in treatment I-C-I causes the difference in our findings compared to treatment G-I. Future research could explore the reasons for this interesting discrepancy, for example by analyzing the content of the group discussion in groups that are already familiar with the task and in groups that are not.

Our results are different from Brunette et al. (2011) and Keller et al. (2009) who did not find significant differences between individual and group attitudes. One crucial difference is that in the Brunette et al. (2011) experiment participants were not allowed to discuss decisions with each other (interaction was limited to voting about different choices). Thus, participants could not be influenced by the exchange of opinions and arguments with other group members.

Another important difference between the two studies and our experiment is the methodology used to measure ambiguity attitudes. Our measure of ambiguity attitudes was based on certainty equivalents for risky and ambiguous gambles. Certainty equivalents were derived from participants' binary choices between playing the gamble and receiving a sure amount of money. In contrast Brunette et al. (2011) asked participants to make direct tradeoffs between ambiguous and risky gambles with varying outcomes based on the procedure suggested by Chakravarty and Roy (2009). Keller et al. (2009) measured ambiguity attitudes by asking participants to state their willingness to pay for gambles in the classical Ellsberg task as well as for bets on natural events with varying degrees of ambiguity such as outcomes of baseball game vs. the outcome of a women's soccer game. A final difference is that both Keller et al. (2009) and Brunette et al. (2011) only considered a relatively small number of gambles with a 50% probability of winning. This might have limited their statistical power to find significant differences.

4.2. Explaining the key findings

One possible explanation for the increase in ambiguity neutrality is that making a joint group decision, or at least having the possibility of interacting with others before a decision, reduces the fear of negative evaluation (Curley et al., 1986; Trautmann et al., 2008). Although this is consistent with the reduction in ambiguity aversion in groups, it cannot explain our finding that groups are significantly less likely to make ambiguity-seeking decisions.

A second explanation is that ambiguity attitudes are influenced by persuasive arguments in favor of ambiguity neutrality during the group interaction. In general persuasive arguments have a strong effect on group decisions and group members' subsequent individual decisions (Burnstein and Vinokur, 1977). Previous research has shown that attitudes to ambiguity are robust to persuasion attempts by the experimenter (Curley et al., 1986; MacCrimmon, 1968; Slovic and Tversky, 1974). However, ambiguity attitudes might be more malleable when persuasive arguments are put forward by group members, with aligned interests and shared goals, as in our study. This explanation is also consistent with results reported by Charness et al. (2013) who found that in pairs with one ambiguity-neutral and one non-neutral DM, there were significantly more non-neutral DM's who changed their attitudes toward neutrality than ambiguity-neutral DM's who changed their attitudes toward non-neutrality.

The persuasive power of ambiguity neutrality during a group discussion, could explain most of our findings: the shift toward ambiguity neutrality in group decisions, the reduction in ambiguity-aversion *and* ambiguity-seeking decisions. It is also consistent with the shift toward neutrality in individual decisions after a group interaction in treatment I-C-I. However, our results for treatment G-I also indicate that the effects of group interactions might not always be sufficiently strong to influence subsequent individual decision. One possible interpretation of this pattern of results is that persuasive arguments have most of their influence during the process of group decision making and win out when group members are forced to agree on a joint decisions, but have weaker influence on the members' individual ambiguity attitudes, especially when they do not have prior experience with the task.

Our results provide some support for the suggestion that persuasive arguments are driving, at least in part, the observed increase in ambiguity neutrality in groups. However, more research is clearly needed to identify the precise mechanisms that cause groups to shift toward ambiguity neutrality.

An alternative, simpler, explanation for any group effect is that the members "compromise" and converge to a central, less controversial position. Two results in our study suggest that this is not case. First, we have shown that groups are systematically and significantly more neutral than the median opinion (which would be expected from a pure compromise model). Second, we have shown that ambiguity neutrality is a prominent outcome even when a majority of the participants hold views that are inconsistent with this pattern: obviously, the group interaction does more than simply aggregate the individual opinions.

An interesting direction for future research is to record the content of the verbal interactions between group members to test directly for different possible explanations for the convergence toward ambiguity neutrality in groups.

4.3. Practical implications

We pointed out in the introduction that many important decisions are delegated to groups (panels, committees, juries, etc.). The commonly held view in the literature is that teams are better at solving intellective tasks (e.g., Laughlin, 1980; Maciejovsky and Budescu, 2007), and play more strategically and rationally (closer to the equilibrium) in a variety of games (e.g., Bornstein and Yaniv, 1998; Cooper and Kagel, 2005; Kocher and Sutter, 2005; Kugler et al., 2007). Part of teams' successes can be attributed to their ability to engage in effective communication and persuasion (e.g., Cooper and Kagel, 2005) that is relevant to the task at hand.

Our results suggest that those teams could also foster better outcomes in tasks that require proper estimation and use of imprecise probabilities. Such situations are common in a variety of domains, such as planning in the face of long-term environmental and climatological uncertainties, etc. Probably the most familiar domain is insurance that requires the estimation of various risks and potential losses and setting proper premiums. In some cases (such as life insurance for healthy individuals or car insurance), all relevant parameters are well understood and reliably quantified, hence insurance underwriters face decisions under risk, whereas in cases such as insurance against unintended side-effects of newly developed technologies, materials, drugs, etc., they face decisions with imprecise probabilities. Several studies (Cabantous, 2007; Cabantous et al., 2011; Hogarth and Kunreuther, 1989; Kunreuther et al., 1995; Viscusi and Chesson, 1999) have documented the sensitivity of insurance professionals to the source and the perceived (im)precision of probabilities. The most consistent result is that for events of low probability (especially with high consequences) their actions are consistent with ambiguity avoidance. The intriguing possibility suggested by our laboratory experiment is that this tendency could be reduced, or perhaps eliminated, if such decisions were assigned to groups rather than individuals.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2014.03.026.

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