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Ambiguity attitudes and social interactions: An experimental investigation

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Abstract This paper reports the results of experiments testing prevalence of non-neutral ambiguity attitudes and how these attitudes change as a result of interpersonal interactions. To address the first question we conducted experiments involving individual choice between betting on ambiguous and unambiguous events of the subject's choice. We found that a large majority of subjects display ambiguity neutral attitudes, many others display ambiguity incoherent attitudes, and few subjects display either ambiguity-averse attitudes or ambiguity-seeking attitudes. To address the second question we designed a new experiment with a built-in incentive to persuade. We found that interpersonal interactions without incentives to persuade have no effect on behavior. However, when incentives were introduced, the ambiguity neutral subjects were better able to persuade ambiguity seeking and ambiguity incoherent subjects to adopt ambiguity neutral choice behavior and, to a lesser extent, also ambiguity averse subjects.

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The hypothetical experimental findings reported by Ellsberg (1961) indicate that many individuals facing a choice between betting on an event whose probability is objectively known and an event of the same nature, whose probability is unknown, express a strict preference for the former over the latter. Moreover, according to Ellsberg, "... the choices themselves do not appear to be careless or random. They are persistent, reportedly deliberate, and they seem to predominate empirically; many of the people who take them are eminently reasonable, and they insist that they *want* to behave that way ..." (Ellsberg 1961, p. 656). In one of these experiments, there is an urn containing 90 balls, 30 of which are red and the rest are either black or yellow. A ball is drawn at random and its color observed. Individuals participating in this experiment are asked to express their preference for betting on red (that is, winning a prize if a red ball is drawn and nothing otherwise) or betting on black. Moreover, they are also asked to express their preference for betting on black and yellow (that is, winning a prize if a black or a yellow ball is drawn and nothing otherwise) over betting on red and yellow. According to Ellsberg, the prevalent choices are for betting on red in the former case and betting on black or yellow in the latter. These preferences are inconsistent with the existence of additive probabilities on the events under consideration. Moreover, these preferences also indicate what has become known as ambiguity aversion.

The Ellsberg experiments spawned a large body of theoretical models designed to capture ambiguity aversion[1] as well as experimental work that tests the robustness of the phenomenon identified by Ellsberg.[2] This paper belongs to the second category.

Ambiguity attitudes are broadly classified into three categories: Ambiguity aversion, or willingness to pay to avoid ambiguous alternatives; ambiguity neutrality, or unwillingness to pay to avoid ambiguous situations; and ambiguity seeking, or willingness to pay to avoid unambiguous alternatives. Of these three general attitudes, neutrality towards ambiguity is the only one consistent with subjective expected utility maximizing behavior and, consequently, with well-defined additive subjective probabilities. To the extent that subjective expected utility embeds tenets of rational choice behavior under uncertainty that are broadly regarded as normatively compelling, it can be used as an argument in favor of ambiguity neutral choice behavior and as a challenge to other ambiguity attitudes. For instance, in the Ellsberg experiments described earlier, if a decision maker prefers to bet on red as opposed to any

[1] See Schmeidler (1989), Gilboa and Schmeidler (1989), Klibanoff et al. (2005), Seo (2009).

[2] See Becker and Brownson (1964), MacCrimmon (1968), MacCrimmon and Larsson (1979), Fox and Tversky (1995), Chow and Sarin (2001), Halevy (2007), Liu and Colman (2009), Ahn et al. (2011), Bossaerts et al. (2010), Keck et al. (2011), Keller et al. (2009), Binmore et al. (2012). Ambiguity aversion seems to also extend to non-Western, non-student populations. Akay et al. (2011) find ambiguity with Ethiopian farmers in the two-color problem.

of the other colors and is willing to pay to avoid betting on any one of the other colors, he can be confronted with the argument that by flipping a fair coin to determine which other color to bet on, he equalizes his chance of winning to that of winning on red. Therefore, paying something to avoid betting on one of the other colors in favor of betting on red makes no sense.

In this work we set out to investigate two questions. First, how prevalent and how intense are non-neutral ambiguity attitudes in general, and ambiguity aversion in particular? Second, how resistant are ambiguity attitudes in general, and ambiguity aversion in particular, to arguments advocating alternative preferences, in the context of interpersonal interactions?

To address the first question we conduct experiments with the three-color urn of Ellsberg (1961) in which subjects are allowed to place their bet on the color(s) of their choice. We find that (a) A large majority of subjects (60.3%) displayed ambiguity neutral attitudes, (b) Few subjects (8.1%) displayed ambiguity averse attitudes, (c) Few subjects (11.8%) displayed ambiguity seeking attitudes, and (d) More subjects (19.9%) displayed choice behavior that is incoherent, in the sense of being inconsistent with any of the three ambiguity attitudes mentioned above, than either ambiguity averse or ambiguity seeking attitudes. Our results about the prevalence of ambiguity averse attitudes are at variance with many of the previous studies of this issue.[3] According to our findings ambiguity averse attitudes are much less prevalent than the consensus in the literature dealing with this subject.[4] We conjecture that this difference is due, in part, to the fact that subjects in Ellsberg type experiments are typically asked to choose between betting on the unambiguous event and a specific ambiguous event. This may raise a suspicion in subjects' minds that if they choose to bet on the ambiguous events, somehow the deck is stacked against them and, as a result, their manifested preference for betting on the unambiguous event reflects this suspicion rather than genuine ambiguity aversion.[5] Moreover, in experiments involving actual payments, this suspicion may be rationalized, since, by reducing the subject's probability of winning, the experimenter stands to benefit from the reduced cost of the experiments. While some readers may feel that it is dubious to think that subjects are dubious about the veracity of the experimenter, Frohlich et al. (2001) find that subjects in dictator-game experiments may in fact have doubts about the statements made to them about the experimenter. Hsu et al. (2005) takes the suspicion

[3]The claim that ambiguity aversion is displayed by the majority of subjects is not uncommon. See, for example, Becker and Brownson (1964) and Liu and Colman (2009).

[4]Binmore et al. (2012) also found that "...ambiguity aversion was less pronounced than in many other studies". Binmore et al. (2012) preclude subjects behavior that we dubbed incoherent. However, they report quite a lot of incoherent choices across the two parts of their experiment.

[5]This type of suspicion may be engraved into our psyche or learned. In "The Idyll of Miss Sarah Brown", Damon Ranyon describes the advice given to young Sky Masterson as he is about to leave home, by his father. "Son", the old guy says, "no matter how far you travel, or how smart you get, always remember this: Some day, somewhere", he says, "a guy is going to come to you and show you a nice brand-new deck of cards on which the seal is never broken, and this guy is going to offer to bet you that the jack of spades will jump out of this deck and squirt cider in your ear. But son", the old guy says, "do not bet him, for as sure as you do you are going to get an ear full of cider."

hypothesis seriously and, using fMRI, finds activity in the brain's *amygdala* that signals vigilance about impending threat. They interpret this as evidence that suspicion appears to be a factor with respect to ambiguity aversion.

To alleviate such potential suspicions, in our experiments the subjects were allowed to choose the unambiguous event on which to bet. To control for the "freedom to choose" effect, we conducted a series of experiments in which the subjects were not allowed to choose the ambiguous event to bet on. We found that the prevalence of choices consistent with ambiguity averse attitudes increased significantly, suggesting that our conjecture has merit. We also found that the rate of incoherent ambiguity attitudes is quite significant and is about the same as that for ambiguity averse and ambiguity seeking attitudes combined. It is worth emphasizing that, in contrast to our experimental design, most previous experimental work could not detect incoherent attitudes. It is not unreasonable to think that many observations classified as ambiguity aversion in previous data would end up in the incoherent category had the design allowed for such observation. This may provide an additional explanation to the discrepancy between our finding and earlier findings that report much higher rates of ambiguity averse attitudes.

To address the second question, we ran experiments in which subjects were allowed to interact and discuss their choice before proceeding to place their individual bets on the colors of their choice. Some of the experiments were designed to motivate the participants to make an effort to persuade their fellow subjects of the correctness of their choice, whatever that choice may be. We found that, following the interaction, the ambiguity seeking and ambiguity incoherent subjects tend to change towards ambiguity neutrality, suggesting that ambiguity neutral subjects were better equipped, or able, to persuade their fellow subjects who originally displayed ambiguity seeking and ambiguity incoherent attitudes to adopt ambiguity neutral choice behavior. No clear pattern is apparent when the interaction involved ambiguity averse and ambiguity neutral subjects. These tendencies are apparent whether or not the incentives to persuade were present. However, incentives to engage in persuasion increased the number of attitude changes significantly.

The interest in studying the robustness of ambiguity attitudes to social interaction stems from the fact that most important decisions individuals make are made in a social context. In other words, before making important decisions, decision makers consult other individuals, family members, friends, experts, and discuss their intended course of action. This opens up the possibility of being challenged, forced to rethink, and maybe to reshape their preferences as a result. We investigated the effects of social interactions in different decision contexts (see Charness et al. 2007, 2010) and showed that, when the decision problem has a correct answer, such as an undominated course of action, or a course of action based on correct (as opposed to mistaken) assessment of likelihoods of events, social interaction reduced the occurrence of mistaken choices.[6]

[6]These problems are referred to in the literature as "truth wins" problems (see Cooper and Kagel 2005). In such problems, if one member of a group gets the right answer, she is able to persuade the other members on the correct course of action.

In the case at hand discovering the correct course of action requires some creative thinking. As a result, most individuals are not able to figure it out. Absent this understanding, it is more likely that subjects follow their intuitive inclinations, which seem justifiable, and will not be easily persuaded to act otherwise. Nevertheless, we advance the hypothesis that, when exposed to challenge and forced to deliberate on their choices, not only do individuals change their behavior, but they also tend to adopt the normatively compelling recommended course of action, namely, neutrality toward ambiguity.

This is not the first study to broach the question of social influence on choice behavior in the presence of ambiguity using experimental methods. Recently, Keck et al. (2011) examined similar issues using a different experimental design. To make the discussion of their work and related literature more meaningful, we defer a detailed description of the literature and the comparisons of both methods and results until after we present our work.

In the next section, we describe the experiments and the results. A discussion of our findings, including additional experimental evidence regarding the ambiguity attitudes and a discussion of related literature, appears in Section 2. Section 3 summarizes the main conclusions.

1 Experiments and findings

1.1 The experimental design

The main experiment consists of two stages. In both stages the subjects were asked to choose between betting on an unambiguous event and ambiguous events of their choice in a three-color version of the Ellsberg (1961) experiment similar to the one described in the introduction. The experimental instructions are in Appendix A.

In the first stage, the subjects, acting on their own, were asked to consider envelopes containing red, green and blue slips of paper. They were informed of the total number of slips in each envelope and the corresponding number of red slips. For each of the envelopes the subjects were asked to choose between betting $10 on red, on green, or on blue. For example, if the total number of slips was 36, then the number of red slips in the different envelopes varied between 9 and 14 (in each case the number of red slips is known to the subject).[7] For each envelope they were asked to indicate the color they would like to place the bet on, red, green, or blue. At this stage the subjects were not informed of the existence of a second stage. After the first stage, one of the six envelopes was chosen at random and a ball was drawn from that urn. The subject was paid $10 if she won the bet and nothing otherwise. At the completion of the second stage, again, one of the six envelopes was chosen at

[7] Other than the number of red slips, the composition of the remaining blue and green slips was unknown. The subjects were told that the co-authors picked the composition in each envelope (this was true) and that the experimenter didn't know how this was generated. Also, the subjects were invited to check the envelopes at the end of the experiment.

random and a ball was drawn from that urn. The subjects were paid if they won the bet.

Subjects who chose to bet on red when the number of red slips was 9, 10 or 11 and continue to bet on red all the way to 14 were classified as ambiguity averse. Subjects who always chose another color when the number of red slips was smaller than 12, and chose to bet on red when the number of red slips is 13 and 14, were classified as ambiguity neutral. Subjects who chose to bet on another color when there are from 9 to, at least, 13 red slips were classified as ambiguity seeking.[8] Finally, subjects that display any other pattern of choice were regarded as having ambiguity attitudes that do not fit any of these descriptions and are classified as ambiguity incoherent. Note that if the number of red slips is 12, then betting on any color from that urn is consistent with ambiguity neutral attitudes. One important feature of our design is that we are able to identify inconsistent (or ambiguity incoherent) attitudes. Simply because a subject chooses red when the number of red slips of paper in the envelope is 10 doesn't necessarily imply that the subject is ambiguity averse. For example, the same subject may choose green when the number of red slips in the envelope is 11; these choices are inconsistent with respect to ambiguity preferences.

Once the subjects filled out the questionnaires, they entered the second stage of the experiment.[9] In this stage, the subjects were matched in pairs. In each pair there was almost always at least one ambiguity neutral subject. The subjects were allowed to discuss their choices before placing their personal bets on the colors of their choice. In one version of the second stage, following their discussion, the subjects were asked to indicate again their betting preferences by filling out the same questionnaire as in the first stage. In this version, there was no incentive for the subject to try to reach an agreement about the way they should choose. In another version of the second stage, the subjects were motivated to make an effort to persuade their counterparts to choose the same bet. This was done by increasing the payoff to subjects whose choices, following the discussion, agreed. The extra payoff was chosen in a way that makes it worthwhile to switch only if the subject is actually persuaded that his original choice was wrong. In other words, *the increased payoff in itself was not sufficient to induce a subject to choose differently from her preferences unless she is convinced that her original preferences were in some sense mistaken.*

There are three essential aspects to the second version of the design. First, there is a conflict of interests between subjects exhibiting distinct ambiguity attitudes. Second, the extra payoff creates an incentive for the subjects to reach an agreement. Third, when the subjects in a pair exhibit distinct ambiguity attitudes, to reach an agreement

[8] Implicit in this classification is the presumption that subjects do not firmly believe that, in each envelope, one of the colors, say green, is present in number larger than red. If this were the case then the subject should choose this color thoughout and will be classified as ambiguity seeking even though he may well be ambiguity neutral.

[9] The subjects were not informed of the second stage of the experiment while engaged in the first stage, so there was no concern that an ambiguity neutral subject might employ a strategy of displaying ambiguity averse attitudes in order to be matched with other ambiguity neutral subjects in the second stage. And of course they were also unaware of the matching process.

one of the subjects in the pair has to persuade the other that the latter's preferences are misguided, and that it is in her best interest to change her choice. We intended this part of the experiment to reveal whether there is a tendency for one type of ambiguity attitude to be more "persuasive" in the sense of attracting the other attitudes toward it rather than being attracted by them. It is also intended to discover to what extent incentives play a role in making subjects change their attitudes. Our hypothesis is that significantly more switches will occur from ambiguity averse, ambiguity seeking and ambiguity incoherent attitudes to ambiguity neutral attitudes than vice versa, and that these tendencies are more pronounced when the incentives are built into the payoffs.

A tricky element of the design involves the calculation of the extra payoff (premium) to be paid to subjects who, after discussing their choices with their pair-mates, come to an agreement on the best way to place their bets. The issue here is to choose the extra payoff so as to motivate subjects with distinct ambiguity attitudes to engage in a discussion trying to persuade each other to accept their respective positions, but not enough that any of them is ready to accept the other's position for the extra payoff without being persuaded of the correctness of the position.

The following example will show how the extra payoff can be set in the case of envelopes containing 36 slips. Consider an ambiguity averse subject who chooses one of the "other colors" when the number of reds is 1–9 and switches to red when the number of reds is 10 and up. Her choice indicated that

$$\left(x, \frac{11}{36}\right) \succ \left(x, \frac{10}{36}\right) \succ \left(x, \frac{k(36-10)}{36}\right),$$

where x is the money payoff and $\frac{11}{36}$ and $\frac{10}{36}$ are the objective probabilities of red in line with 11 and 10 red slips, respectively, and $\frac{k(36-10)}{36}$, is the probability of the "other color". Hence,

$$\frac{10}{36} > \frac{k(36-10)}{36}.$$

Thus

$$k < \frac{10}{26} = \frac{5}{13}$$

What does it mean for this subject to be persuaded by the ambiguity neutral subject? It requires that she stays with the "other color" when the number of reds is 10 and 11 and switch to red at 12. However, she should not be induced to do so just because of the increased payoff. This puts an upper limit on what the extra payoff can be. This upper bound is calculated below:

Let $y > x$ be the payoff if there is an agreement and suppose that the subjects are risk averse. Normalize the utility function so that $u(0) = 0$, and let $k = 5/13$, then y must satisfy the following:

$$\left(x, \frac{11}{36}\right) \succ \left(y, \frac{5(36-11)}{13 \times 36}\right).$$

Under expected utility this implies

$$u(x)\frac{11}{36} > \frac{y}{x}u(x)\frac{5 \times 25}{13 \times 36} > u(y)\frac{5 \times 25}{13 \times 36}.$$

Hence, choosing y such that

$$\frac{y}{x} < \frac{11 \times 13 \times 36}{36 \times 5 \times 25} = \frac{143}{125} = 1.144$$

is not going to make the ambiguity averse type change her switch point.

Consider next an ambiguity neutral subject. She prefers betting on another color when the number of reds slips is 11 or below, she may switch at 12 red slips, and she will definitely choose to bet on red when the number of red slips is 13 and above. What does it mean for this subject to be persuaded by the ambiguity averse subject? It requires that she chooses betting on red when the number of reds is 11 or below. However, she should not be induced to do so just because of the increased payoff. In other words, if the ambiguity averse person is unwilling to accept the choices of the ambiguity neutral person, it should not be the case that the ambiguity neutral subject rather would accept the choices of the ambiguity averse person in order to collect the "agreement premium" rather than avoid an agreement. This puts an upper limit on what the extra payoff can be. This upper bound is calculated below:

For an ambiguity neutral subject, y must satisfy

$$\left(y, \frac{11}{36}\right) \prec \left(x, \frac{12}{36}\right)$$

which under expected utility (the utility function is normalized so that $u(0) = 0$) implies

$$u\,(y)\,\frac{11}{36} < u\,(x)\,\frac{12.5}{36}.$$

It is reasonable to assume that, for the small stakes involved, the utility function is approximately linear.[10] Hence,

$$\frac{y}{x} < \frac{12}{11} = 1.09$$

Thus, $y < 1.09x$.

1.2 The experiments

Our experiments were conducted in a spacious classroom at the University of California, Santa Barbara (UCSB). The 404 participants were recruited using the ORSEE software (Greiner 2004) from the general student population that had expressed interest in participating in such experiments. No participant could be in more than one session. Participants were seated at some distance from each other, so that people did not observe one another's choices.

There were 272 participants in our first experiment. We first passed around an opaque bag that contained index cards with a number for each participant. We then presented the subjects with instructions (which were also read aloud) and decision sheets with six rows. These rows displayed the number of red slips of paper (ranging

[10] But if the subject is risk averse then $u\,(y) < u\,(x)\,\frac{y}{x}$, which reinforces the argument.

from 9–14) present in an envelope in which there were 36 slips of paper; the remaining slips of paper were either green or blue and no information was given about the numbers of green or blue slips of paper. There was an envelope corresponding to each row in the decision sheet, so that one envelope contained nine red slips, one contained 10 red slips, etc.

In the first stage of the experiment, the participants were asked to choose among betting on red, blue, or green in each row. They were informed that a die would be rolled to select which row would be used to determine the actual payoff. After the participants selected rows, the decision sheets were collected. The die was rolled, and a slip of paper was drawn from the corresponding envelope. If the color drawn matched the color chosen, the chooser received $10.

In the second stage of the experiment, there was a sufficient number of ambiguity neutral subjects so that almost every person who was not ambiguity neutral in the first stage was paired with an ambiguity neutral subject. This pairing was done quickly (less than 30 sec) by the experimenter from behind a lectern, while making sure that there was no conversation. The decision sheets were then passed back to the participants, with the ID number of the person with whom one was paired also written on the sheet. Subjects then formed pairs (if the number of participants was odd, one subject was asked to choose individually; we didn't count this decision in our data). Pairs were told that they could (quietly) discuss the scenario with their partner before making their choices; it was not required that responses be the same for the two members in the pair. After the consultation, each subject chose his bets. Pairs were seated apart, so that they did not observe the choices of others or hear other discussions. Once again, a die was rolled to select the row and a colored slip of paper was drawn from the corresponding envelope to determine the winning color.

There were two variants of this experiment, which differed across sessions. In the first, we paid a premium of $1.25 to each subject in the pair if the correct color was guessed and both subjects made the same choices in all six rows. In the second variant, we did not pay any premium. Note that the premium is below what it would take to make an ambiguity averse subject act against her preferences and accept the choice of an ambiguity neutral subject, and enough to incentivize a (weakly) risk-averse, ambiguity neutral subject to accept the choice of an ambiguity averse subject. Hence, except when the ambiguity neutral subject is risk inclined, if an ambiguity averse subject and an ambiguity neutral subject are to reach an agreement in order to collect the premium, the former subject is in an advantageous position. In other words, if the ambiguity averse person is unwilling to change his choice, the ambiguity neutral person would rather accept the choice of the ambiguity averse person rather than stick to his original choice and forego the premium.

1.3 The findings

A. Individual choice in isolation Our first finding is that the large majority of subjects display ambiguity neutral attitudes.[11] Of the 272 subjects that participated in

[11] Complete individual choice profiles for both versions of the experiment can be found in Appendix B.

the experiment, 164 subjects (60.3%) displayed ambiguity neutral choices.[12] Only 22 subjects (8.1%) displayed ambiguity averse choice and 32 subjects, (11.8%) displayed ambiguity seeking attitudes. The rest, 54 subjects (19.9%), displayed choices that were incoherent (see Appendix B Table 1).[13]

The next question is how ambiguity averse are the ambiguity averse subjects? As with risk aversion the degree of ambiguity aversion could, in principle, be measured by the premium they are willing to pay to avoid the ambiguous bets. In the preceding subsection we demonstrated how we may estimate this premium. The maximal premium for an ambiguity averse subject who (hypothetically) chooses to bet on one of the "other colors" when the number of reds is 1–9 and switches to red when the number of reds is 10 and up was shown to be 14.4% of the payoff of the bet. The same premium for an ambiguity averse subject who (hypothetically) chooses one of the "other colors" when the number of reds is 1–8 and switches to red when the number of reds is 9 and up is 15.4% of the payoff of the bet.[14] Clearly, if an ambiguity averse

[12]This figure should be interpreted with some care. When there are fewer than 12 red slips the probability of red is smaller than 0.31, and when there are more than 12 red slips, the corresponding probability is at least 0.36. A subject that was classified as ambiguity neutral assigns a probability higher than 0.31 to one of the other colors in the former case and a probability lower than 0.36 in the latter case. When there are 12 red slips, so that the probability of red is 1/3, there is room for a subject to entertain beliefs that one of the other colors has a probability higher than 1/3 and yet chooses to bet on red. Consequently, our set of ambiguity neutral subjects might include some (slightly) ambiguity averse types. Further investigation of this issue, by refining the partition (e.g., using 90 slips) or using our design with a total of 37 instead of 36 slips is a subject for future research. We thank Luca Rigotti for raising this issue.

[13]The full set of decisions for each individual can be found in Appendix B to this paper.

[14]Consider an ambiguity averse subject who chooses one of the "other colors" when the number of reds is 1–9 and switches to red when the number of reds is 10 and up. Her choice indicated that

$$\left(x, \frac{10}{36}\right) \succ \left(x, \frac{9}{36}\right) \succ \left(x, \frac{k(36-9)}{36}\right),$$

where x is the money payoff and $\frac{10}{36}$ and $\frac{9}{36}$ are the objective probabilities of red in line with 10 and 9 red balls, respectively, and $\frac{k(36-9)}{36}$, is the probability of the "other color". Thus,

$$\frac{9}{36} > \frac{k(36-9)}{36}.$$

Thus

$$k < \frac{9}{27}$$

Let $y > x$ be the payoff if there is an agreement and suppose that the subjects are risk averse. Normalize the utility function so that $u(0) = 0$, and let $k = 9/25$, then y must satisfy the following:

$$\left(x, \frac{10}{36}\right) \succ \left(y, \frac{9(36-10)}{27 \times 36}\right).$$

Under expected utility this implies

$$u(x)\frac{10}{36} > \frac{y}{x}u(x)\frac{9 \times 26}{27 \times 36} > u(y)\frac{9 \times 26}{27 \times 36}.$$

Hence, choosing y such that

$$\frac{y}{x} < \frac{10 \times 27 \times 36}{36 \times 9 \times 26} = \frac{270}{234} = 1.154$$

is not going to make the AA type change her switch point.

subject chooses one of the "other colors" when the number of reds is 1 to 10 and switches to red when the number of reds is 11 and up, the premium is smaller than 14.4%. Among the 22 subjects in our study who displayed ambiguity aversion, 16 subjects switched at a number smaller or equal to 9, two subjects switched at 10, and five subjects switched at 11. Thus, for the majority of subjects displaying ambiguity averse attitudes, the degree of ambiguity aversion exceeds the 15% premium mark.[15]

B. Individual behavior following consultation (aggregate data) Our session-level data and summary for pair behavior is shown below in Appendix B Table 2. Persuading another person to change his mind, especially when the issue is regarded as a matter of taste, takes effort. Participants in the study should be more inclined to make the necessary effort if motivated by an incentive scheme. If these presumptions are correct and important, we expect to see more agreements when the subjects are motivated by an agreement premium than without it. Our findings lend support to this hypothesis. Incentives to reach an agreement dramatically increase the agreements rate, from 30.5% to 84.0% ($Z = 6.28$, $p = 0.000$).[16] Based on these findings we conclude that incentives, in this context, are very significant.

In so far as the "direction" that the persuasion took, the finding shows the following tendencies: First, there is a slight increase in ambiguity averse choice behavior (from 8.1% in individual choices to 10.4% following consultations).[17] Second, there is a considerable increase in ambiguity neutral attitudes (from 60.3% in individual choices to 75.2% following consultations).[18] Third, there is a substantial decline in ambiguity seeking attitudes (from 11.8% in individual choices to 6.7% following consultations).[19] Fourth, there is a decline in ambiguity incoherent attitudes (from 19.9% in individual choices to 15.7% following consultations).[20] These results suggest that the ambiguity averse and ambiguity neutral subjects had a "persuasive edge" over the ambiguity seeking and ambiguity incoherent subjects. Moreover, the ambiguity neutral subjects turned out to be more persuasive than ambiguity

[15] However, there may be some evidence of ambiguity aversion when the number of red slips in the envelope is 12, so that this is costless; however, this is a matter of interpretation regarding what one considers the base rate. We find that 50% of choices (82 of 164) in this case are to bet are on red. If everyone is ambiguity neutral, they might randomize amongst the three colors (although it could be argued that red is more focal, in terms of there being red and non-red categories) who are indifferent in this case. However, there are many ambiguity averse people and even with the tiniest degree of ambiguity aversion an individual will choose red. Of course, if there is more than the tiniest amount of ambiguity aversion we should expect to see this when the number of red slips in the envelope is 11.

[16] See Appendix B, Table 2.

[17] See Appendix B, Tables 1 and 2. Following consultations, the rate of ambiguity averse subjects increases to 9.3% when no incentives were present and 11.3% when incentives were built in.

[18] See Appendix B, Tables 1 and 2. Following consultations, the rate of ambiguity neutral subjects increases to 65.2% when no incentives were present and 68.7% when incentives were built in.

[19] See Appendix B, Tables 1 and 2. Following consultations, the rate of ambiguity seeking subjects falls slightly, to 9.3%, when no incentives were present and more significantly, to 4.7%, when incentives were built in.

[20] See Appendix B, Tables 1 and 2. Following consultations, the rate of ambiguity incoherent subjects declines to 16.1% when no incentives were present and 15.3% when incentives were built in.

averse subjects. In addition, these tendencies are more pronounced in the presence of incentives.

C. Individual behavior following consultation (individual data) The analysis of individual choices suggests the following general tendencies: (a) In pairs involving ambiguity averse and ambiguity neutral types, there is no clear direction of influence. Roughly as many subjects displayed ambiguity aversion before the interaction and ambiguity neutrality after the interaction (7 with incentives and 2 without incentives) as the number of subjects who displayed ambiguity neutral attitudes before the interaction (8 with incentives and 2 without incentives) and ambiguity aversion following the interaction. This is true despite the "bargaining" advantage that the agreement premia gives the ambiguity averse individuals.[21] (b) In pairs involving ambiguity seeking and ambiguity neutral types, the direction of influence is clear. Again, the ambiguity neutral subjects had a persuasive edge over the ambiguity seeking subjects. Roughly speaking, twice as many subjects displayed ambiguity seeking attitudes before the interaction and ambiguity neutral choice patterns after the interaction (11 with incentives and 11 without incentives) as the number of subjects who displayed ambiguity neutral attitudes before the interaction (4 with incentives and 5 without incentives) and ambiguity seeking attitudes following the interaction. This is true with and without incentives.[22] (c) In pairs involving ambiguity incoherent and ambiguity neutral types, the direction of influence is clear. The ambiguity neutral subjects had a persuasive edge over the ambiguity incoherent subjects. Roughly speaking, one and a half times as many subjects displayed ambiguity incoherent attitudes before the interaction and ambiguity neutral choice patterns after the interaction (18 with incentives and 10 without incentives) as the number of subjects who displayed ambiguity neutral attitudes before the interaction (12 with incentives and 6 without incentives) and ambiguity incoherent attitudes following the interaction. This is true with and without incentives.[23] (d) No clear pattern can be ascribed to other pairs as the number of changes is too small to indicate a tendency.

It is conceivable that subjects are more "open to persuasion" following a failure than following a success. If this is indeed so, then in pairs consisting of a "winner" (that is, a subject that won in the first round) and a "loser" (that is, a subject that lost

[21] The simple binomial test indicates no significant overall tendency for the subsamples with and without premium. For the full sample, $Z = 0.23$, with no premium $Z = 0.00$ and with premium $Z = 0.26$.

[22] For the full sample the simple binomial test shows that the tendency to switch from ambiguity seeking to ambiguity neutrality as opposed to switching in the other direction is significant ($Z = 2.33$, $p = 0.010$, one-tailed test, $p = 0.019$, two-tailed test). The same test for the subsample with no premium, $Z = 1.50$, $p = 0.067$, one-tailed test, $p = 0.134$, two-tailed test. For the subsample with a premium, $Z = 1.81$, $p = 0.035$, one-tailed test, $p = 0.070$, two-tailed test.

[23] For the full sample the simple binomial test shows that the tendency to switch from ambiguity incoherence to ambiguity neutrality as opposed to switching in the other direction is significant. For the full sample ($Z = 1.73$, $p = 0.042$, one-tailed test, $p = 0.083$, two-tailed test). For the subsample with no premium, $Z = 1.41$, $p = 0.079$, one-tailed test, $p = 0.157$, two-tailed test. For the subsample with a premium, $Z = 1.10$, $p = 0.136$, one-tailed test, $p = 0.272$, two-tailed test.

in the first round) the latter subject is more open to persuasion, which may tilt the results towards the choice of the winners independently of their ambiguity attitude. To neutralize this effect, we also looked at "homogenous" pairs (that is, pairs of subjects that had the same experience in the first round, consisting of either two winners or two losers). Our data include 16 such pairs. Here the results are more striking. Among these, only one ambiguity neutral subject switched to the ambiguity averse choice, while all the other 15 subjects who displayed ambiguity non-neutral attitudes in the first round switched their choice to that of ambiguity neutrality. These include three ambiguity averse subjects, seven ambiguity seeking subjects and five subjects that displayed ambiguity incoherent choice behavior in the first round.[24] These results are suggestive. Teasing out more fully the effect of the normative appeal as opposed to the effect of past performance is beyond the scope of the current study.

These findings suggest that ambiguity neutral subjects possess a persuasive edge over ambiguity seeking and ambiguity incoherent subjects, and to a lesser degree over ambiguity averse subjects. They also indicate that, while the presence of incentives leads to more changes following the interactions, incentives do not influence the direction of the changes.

2 Discussion

The results concerning individual choice in isolation, reported in Section 1, agree with the findings of relatively few ambiguity averse attitudes, which, if correct, cast serious doubt on the significance of ambiguity aversion even from the psychological point of view.[25]

One aspect of our experimental design which is different from the original Ellsberg experiments and later replications is that, in our experiments, the subjects were asked to choose between betting on the unambiguous event, red, and betting on the ambiguous events of their choice. To examine whether the freedom to choose is a possible explanation of our findings, we conducted another set of experiments trying to replicate the existing results.

The new experiments were confined to individual choice in isolation. This time the subjects were asked to choose between betting on red and betting on a given other color, blue or green. The subjects were asked to bet on a color of a chip drawn from an a sack containing 36 chips. The questionnaires contained three rows. In each row the number of red chips is indicated, the remaining chips are either blue or green, and

[24] The binomial test gives $Z = 3.50$, $p = 0.000$, one-tail or two-tail test.

[25] Low rates of ambiguity averse attitudes were recently reported in Binmore et al. (2012) which led them to conclude that "ambiguity aversion is not always as powerful and robust a phenomenon as it is sometimes said to be". (p. 21). Wakker (2010) provides supporting evidence to this conclusion in the context of cumulative prospect theory. According to Wakker, there is more ambiguity seeking than ambiguity aversion for losses. Similarly, there is more ambiguity seeking than ambiguity aversion for gains and unlikely events.

the number of either of these colors is not specified. The number of red chips varied between 11, 12 and 13.

The number of participants in this experiment was 132. In the first round of the experiment, for each row the subjects were asked to indicate whether they prefer betting on red or betting on blue. After the first round, a row was chosen at random and a chip was drawn from an urn containing the number of red chips as in the chosen row. The color is observed and the subjects were paid $10 if it is the color they bet on and nothing otherwise.

In the second round the same subjects were faced with the same choices except that this time they were asked to choose between betting on red or betting on green. After the second round, a row was chosen at random and a chip was drawn from an urn containing the number of red chips as in the chosen row. The color is observed and the subjects were paid $10 if it is the color they bet on and nothing otherwise.

In the first round, a subject is said to display an ambiguity averse attitude if she chooses red in all three rows. A subject is said to display an ambiguity neutral attitude if she chooses blue in the row indicating that the number of red chips is 11 and chooses red in the row indicating that the number of red chips is 13. (In the row indicating that the number of red chips is 12, she can choose either color.) A subject is said to display an ambiguity seeking attitude if she chooses blue in the rows indicating that the number of red chips is 11 and continues to choose blue in all the rows thereafter. All other subjects are said to display incoherent attitudes. Similar definitions apply to the second round with green replacing blue.

Our session-level data and summary for first-round and second-round behavior is shown below in Tables 3 and 4 in Appendix B. The percentage of ambiguity averse subjects increased significantly, to slightly less than 25% (to be exact, 23.5% (31/132) in the first round and 24.2% (32/132) in the second round). Although still relatively low, it is much closer to the results of Ellsberg and other studies than when the subjects were allowed to choose the other color to bet on. These results suggest that the observed ambiguity averse choice behavior might be due, in part, to the experimental design reflecting the concern that the deck may have been stacked, rather than genuine aversion to ambiguity.

Other than ambiguity aversion, the distribution of displayed ambiguity attitudes in the first round is as follows: 50.0% (66/132) of the subjects displayed an ambiguity neutral attitude, 7.6% (10/132) of the subjects displayed an ambiguity seeking attitude and the rest, 18.9% (25/132), displayed an ambiguity incoherent attitude. The corresponding numbers in the second round are: 52.3% (69/132); 9.1% (12/132); and 14.4% (19/132).

The distribution of the displayed aggregate ambiguity attitudes in the subject population is stable between the first and second rounds of choices. The question is whether this stability also characterizes the individual choices. To answer this question we reclassified the subjects into two groups, those who display the same ambiguity attitudes in the two rounds of choice, and those who didn't. Subjects

belonging to the latter group are said to display inconsistent ambiguity attitudes. According to this classification, 18.9% (25/132) of the subjects displayed consistent ambiguity aversion, 40.2% (53/132) of the subjects displayed consistent ambiguity neutral attitudes, 5.3% (7/132) of the subjects displayed consistent ambiguity seeking attitudes, and 35.6% (47/132) of the subjects displayed incoherent and/or inconsistent ambiguity attitudes.[26]

In some respects these results are consistent with the results of the two rounds, namely, the percentage of subjects displaying ambiguity neutral attitudes is twice that of subjects displaying ambiguity averse attitudes, and ambiguity seeking attitudes are much less prevalent than the other attitudes. There is one aspect of these results, however, that is quite different than the results of the two rounds, namely, the significant increase in the rate of ambiguity incoherent attitudes. This much higher rate is a reflection of inconsistency between the ambiguity attitudes displayed in the first and second rounds. This finding raises concern that attributing ambiguity attitudes to individuals on the basis of observing one set of choices is premature and might contain a large element of chance.

2.1 Related literature

A. Ambiguity attitudes: individual choice in isolation

Camerer and Weber (1992) provide an extensive survey of the experimental work regarding ambiguity attitudes up to that time. According to this survey, the results regarding the percentage of ambiguity averse subjects and the intensity of ambiguity aversion, measured by the (relative) size of the premium subjects were willing to pay to avoid the ambiguous bets, varied substantially across studies. In the first such study, by Becker and Brownson (1964), subjects were screened for ambiguity aversion, before the experiment began, using the two-color Ellsberg problem. About half the subjects displayed ambiguity aversion and were selected to participate in the experiment. During the experiment the subjects were presented with pairs of envelopes and asked to choose one urn from each pair and bet on the color from that urn. In each pair there was always an unambiguous urn, containing 50 (out of 100) red slips, and in the ambiguous urn the number of red slips varied. The actual payoffs were small as only one of ten choices was picked and then paid $1.00 if the right color was drawn. The subjects were willing to pay substantive premia to avoid an ambiguous urn. For example, they paid an average of 72% of expected value when the number of red slips in the ambiguous urn was in the range 0–100, and 28%

[26] Note that if a subject thought that there were many more blue than green slips he would choose blue when blue is one of the choices and green if green is the alternative to red. Such a subject would be classified as ambiguity incoherent while, in fact he might be ambiguity neutral. If such subjects were present, this would partially explain the very high (35.6%) rate of ambiguity incoherent attitudes observed in version 2.

when the number of red slips was in the range 40–60.[27] By contrast, in MacCrimmon (1968) only 10% of the subjects exhibited the Ellsberg ambiguity averse choice pattern. MacCrimmon and Larsson (1979) found that 15 of their 19 subjects displayed ambiguity eversion in the three-color version of the Ellsberg experiment. However, when the known probability was lowered from 1/3 to 1/4 that number fell to 6 out of 19. [28]

More recently, Chew et al. (2012) found that 49.4% of the 325 Beijing subjects in their study, chose to bet on the color of a card pulled from a deck containing the same number of red and black cards as opposed to betting on a color from a deck containing an unknown composition of red and black cards, even though the latter bet paid 20% more than the former.

Halevy (2007) reports that 15% to 20% of the subjects in his experiments exhibit ambiguity neutral attitudes; this is closely associated with abiding by the axiom of reduction of compound lotteries and 70% of the subjects exhibit non-neutral ambiguity attitudes.

Charness and Gneezy (2010) examine ambiguity aversion in an investment task in which one has 100 units and can invest as many as desired in a risky asset that has a 50% chance of success; whatever is not invested is kept. The risky asset pays 2.5 to 1 if successful and the investment is lost if it fails. Subjects are asked how much they would invest. There is one treatment in which they know there is one urn that is 50/50 black/red and another urn has 100 balls of unknown distribution; they could freely choose from which urn to draw. In the companion treatment, they had a choice of these urns, but had to pay 5% of their endowment to draw from the one with the known distribution. When it was free to draw from either, 72% (18 of 25) chose the known distribution; the difference from 50% is significant ($Z = 2.20$, $p = 0.028$, one-tailed binomial test), suggesting the overall presence of ambiguity aversion when it is costless in expectation.[29] Moreover, when it cost 5% to draw from the known distribution, 65% chose the known distribution. The difference in rates according to whether payment was required is not significant ($Z = 0.51$).

Ahn et al. (2011) estimated parametric models of ambiguity (and risk) aversion in portfolio-choice problems. Subjects are endowed with a budget and have to choose among three Arrow securities, corresponding to three states of nature $s = 1, 2, 3$. The probability of the second state, $\pi(s_2)$, is known to be $1/3$, and the probabilities of the remaining two states are not known. Each subject is given the prices of the three Arrow securities. Ambiguity can be avoided by picking $x_1 = x_3$, where x_s denotes the quantity of Arrow securities of type s. Ambiguity aversion can be inferred

[27] These ambiguity premiums are much higher than those observed in other studies. Recall, however, that Becker and Brownson (1964) only allowed subjects who were ambiguity averse to participate in their experiment.

[28] Camerer and Weber (1992) do not report which studies controlled for what we consider a possible explanation for the preference of risky over ambiguous bets, namely subjects' suspicion of the ambiguous urns being rigged.

[29] Note that this result is in line with our results suggesting the presence of ambiguity aversion in the knife-edge case when all actions give the same expected value.

from choices under the different prices. The study finds significant heterogeneity in subjects' attitudes to risk, loss, and ambiguity. Over 60.4% of the subjects displayed choice behavior consistent with subjective expected utility preferences (that is, that displaying neither ambiguity nor loss aversion). Moreover, 78.5% of the subjects displayed ambiguity neutral attitudes (that is, the 60.4% mentioned above and additional 18.1% of the subjects who displayed neutrality to ambiguity and loss aversion). Only 21.5% of the subjects displayed ambiguity aversion.

Bossaerts et al. (2010) found significant presence and effects of ambiguity aversion in financial markets in which Arrow securities of the type described above are traded. Even though this work is different in several respects, these findings are consistent with those of Ahn et al. (2011). In particular, Bossaerts et al. (2010) report that the presence of ambiguity averse traders exert significant effect on the end-of-period wealth distribution and that agents who are sufficiently ambiguity averse refrain from holding ambiguous securities for an (open) set of prices. Unlike Ahn et al. (2011), the experimental design of Bossaerts et al. (2010) included a market setting, but not learning.

Trautmann et al. (2011) shows that elicitation methods matter a lot under ambiguity. For example, in the two-color problem with willingness-to-pay, virtually 100% of subjects are ambiguity averse, but much less so under direct choice. Our paper supports this view. Moreover, our results suggest that the three-color format is quite different from the two-color format. This relates to the notion in Abdellaoui et al. (2011) that in the two-color problem there are clearly identified, different sources (risky and ambiguous), whereas in the three-color problem there is only one gamble that comes from a mixed source. A possible implication of our paper is that if the generalization from two-color to a three-color urn does not work well, then the distinction by source may well be important.

Regarding the studies mentioned above, we are not familiar with any previous work that both controlled for experimental suspicion and permitted the researchers to identify (or accounted for) incoherence. The combination of these omissions may explain those studies with a much higher rate of ambiguity aversion than our findings.

B. Ambiguity attitudes: individual choice following social interactions

In a recent paper Keck et al. (2011) report the results of experiments designed to study, among others, some of the issues addressed in this work. These include individual ambiguity attitudes and the effect of group deliberations on these attitudes.[30] The work of Keck, Diecidue and Budescu is different from ours in the experimental design and the findings. More specifically, they elicited the certainty equivalents for 15 risky (that is, unambiguous) or vague (that is, ambiguous) two-outcome gambles. Their subjects made their decisions in different social settings, two of which are the same as ours. The first is individual choice without prior social interactions and the

[30]They refer to ambiguity as vagueness.

second is individual choices after discussions with other participants.[31] We consider each of these in turn.

As in this paper, some of the experiments of Keck, Diecidue and Budescu consisted of two stages. In the first stage the certainty equivalent of the gambles were elicited by asking the subjects to fill out a "decision sheet" that consisted of binary choices between gambles and sure amounts. For each line the subjects were to indicate their preference between the gamble and the sure amount on that line. Since the sure amounts were arranged in increasing order, the point at which the individual switched from a preference for the gamble to a preference for the sure amount is an estimate of the certainty equivalent.

For the risky (precise) gambles the certainty equivalents are measures of risk aversion. Similarly, the subjects' certainty equivalents were elicited for the vague gambles. The vagueness premia were computed as the differences between the certainty equivalents of the vague and the risky gambles. Ambiguity aversion is equivalent to a negative vagueness premium, ambiguity neutral attitude is equivalent to a zero vagueness premium and ambiguity seeking is equivalent to a positive vagueness premium. The size of the premium is a measure of the degree of ambiguity aversion or ambiguity seeking.

Keck et al. (2011) report that, depending on the gambles under consideration, between 35 and 39% of the subjects displayed ambiguity averse attitudes; between 28 and 34% of the subjects displayed ambiguity neutral attitudes; and between 25 and 31 percent of the subjects displayed ambiguity seeking attitudes. These numbers are quite different from ours. It is interesting to speculate on the possible reasons.

One possible explanation has to do with the method used to elicit the attitudes toward ambiguity. Keck, Diecidue and Budescu use the difference in the certainty equivalents of the precise and vague gambles. By contrast we use direct comparisons between the precise and vague gambles (to use their terminology). Hence the tasks of the subjects are quite different, and it is known from the literature on the 'preference reversal' phenomenon that the indirect comparisons, via the certainty equivalents, and the direct comparisons lead to conflicting results.[32] In view of this, it seems to us that it is not unreasonable to hold that the direct comparison method is more compelling. In this respect, we also find it troubling that Keck, Diecidue and Budescu indicate no instances in which the subjects display incoherent ambiguity attitudes. This is in contrast to the relatively large number of incoherent responses in our study.[33]

[31] Keck et al. also studied group decision making in which decisions were taken by majority vote of the group and the payoff shared among the membership. This is an issue that is outside the scope of our work.

[32] See Lichtenstein and Slovic (1971), Grether and Plott (1979).

[33] One possible explanation for this is that they offered their subjects the option of letting the computer assist in the decision making process. This assistance allows the computer to automatically fill in all the choices located on the decision sheet above the choice for which a participant preferred the sure amount of money over the gamble. Using this procedure may rule out what would have been inconsistent choices.

A second noteworthy difference between this study and that of Keck, Diecidue and Budescu is the level of ambiguity. They controlled and varied the level of ambiguity and, except in one case, they only considered narrower levels of ambiguity than the one we used, which is full ambiguity (that is, no information whatsoever was given regarding the composition of the envelopes as between the green and blue colors).

In their study of individual decisions following consultations with other participants Keck et al. (2011) report a tendency for ambiguity seeking and ambiguity averse attitudes to decline and that of ambiguity neutral attitudes to increase. That tendency is statistically significant. They regard this as confirming the hypothesis that neutral ambiguity attitudes act as a persuasive argument during group discussions. Nevertheless, even following group interaction, the pattern of individual decision without group interaction is preserved. The reported proportion of ambiguity averse attitudes is between 30 and 50% while ambiguity neutral attitudes is between 25 and 35% (the rest being ambiguity seeking).

Most importantly, however, unlike our study, Keck, Diecidue and Budescu didn't provide incentives to motivate the participants to engage in persuasion. In view of the fact that we found the incentive effect to be significant, it would have been interesting to test whether the tendency to shift towards an ambiguity neutral attitude would have been significantly enhanced in the presence of incentives.

3 Concluding remarks

The main conclusions of this work pertain to subjects' behavior in the context of the Ellsberg experiments. The conclusions can be divided into those pertaining to individual choice in isolation, and those pertaining to individual choice and change of attitude following consultations.

Regarding individual choice in isolation, the main conclusions are:

1. Ambiguity aversion is much less prevalent than neutrality, and is as common as ambiguity seeking. Moreover, many more subjects exhibit incoherent ambiguity attitudes than ambiguity aversion.
2. To a certain extent choices between betting on unambiguous and ambiguous events, interpreted as ambiguity aversion, may be potentially attributed to the subjects being suspicious that the deck is stacked against them.

Regarding individual choice following interaction with one other subject, the main conclusions are:

1. The presence of incentives significantly increased the number of subjects who changed their attitude following consultation.
2. Ambiguity neutral attitude becomes more prevalent following social interaction. The increased number of subjects displaying ambiguity neutral attitudes is at the expense of ambiguity seeking and ambiguity incoherent attitudes, suggesting that the ambiguity neutral attitudes possess a persuasive edge over these

other types of attitudes. This persuasive edge exists, to a smaller degree, between ambiguity neutral and ambiguity averse subjects. It is more pronounced, however, when the subjects in the pairs had the same experience (winning or losing) in the first round.

3. The tendencies described above are the same whether or not the subjects were paid a premium if they reached an agreement, suggesting that the presence of incentives does not have a significant effect on these tendencies.

In closing, our results indicate that concerns about ambiguity aversion may in fact be exaggerated. While there is no doubt that there are some people who are susceptible, ambiguity aversion by no means seems as prevalent as some studies have suggested. Our design enables us to create a richer classification, one that finds a substantial degree of internally-inconsistent choices. In previous designs, these choices may well have been interpreted as ambiguity aversion, but not with the richer classification made feasible with multiple decisions. In addition, our results suggest that previous interpretations of data as being indicative of ambiguity aversion may have reflected suspicion that the experimenter was trying to "game" the subjects. Ambiguity attitudes move towards ambiguity neutrality when there is consultation between parties, which we feel means that ambiguity preferences that seem less sensible are only evanescent. Since our evidence may seem controversial to some, we feel strongly that more tests should be conducted with a richer design such as ours.

Appendix A

A.1 Instructions 1

Thank you for participating in our experiment. This experiment is conducted as a part of a research project on people's preferences. The whole session will last between 30 minutes and one hour. After we read the instructions and you understand the task, we shall proceed.

Consider six containers that have 36 chips in each. Each container will have a different (but known) number of Red chips, with the remaining chips in the container being either Blue or Green; you will not be told how many chips are Blue and how many chips are Green.

You'll be faced with a table with six rows, with each row representing one container. The first row will ask you to make a choice when there are 9 Red chips in the container (container 9), and so 27 Blue or Green chips; the second row to consider has 10 Red chips in the container (container 10), and so 26 Blue or Green chips; and so on up to 14 Red chips (and 22 Blue or Green chips) in the container (container 14). For each row your task is to choose one of the three colors to bet on.

After people make their choices, we will randomly draw a number from 9–14 to determine which line in the table is to be implemented (played). Once a line is selected it determines which container will be used. We will draw one chip from that container and pay $10.00 to each person who picked that color.

A.1.1 Decision sheet

In the table below, please circle R or G or B in each row. If you have any questions, please raise your hand, and we will come to assist you. Please do not speak to any other person.

Red numbers	Blue or Green numbers	Bet on Red [R], bet on Green [G] or bet on Blue [B]		
9	27	R	G	B
10	26	R	G	B
11	25	R	G	B
12	24	R	G	B
13	23	R	G	B
14	22	R	G	B

A.2 Instructions (2) *[Premium]*

We now proceed to pair each person with another person amongst the participants. Look for the person who has the same ID number as you. You will now have the opportunity to consult directly with this other person regarding the selections made on the second decision sheet that follows. The same rules apply in terms of selecting a color and the amount of the prize.

You may speak (quietly) with the person with whom you are paired and you'll have 5 minutes to deliberate about the decisions to be made. Afterwards each person is free to make his or her own decision. [These decisions need not be the same; however, if these decisions are indeed the same, *then an additional $1.25 will be added to the potential prize upon winning for each person (so that it becomes $10.00 + $1.25 = $11.25, rather than $10.00).*] If all of the decisions are not the same, the potential prize for each person remains $10.00.

A.2.1 Decision sheet 2

In the table below, please circle R or G or B in each row. If you have any questions, please raise your hand, and we will come to assist you. Please do not speak to any other person besides the person with whom you have been paired.

Red numbers	Blue or Green numbers	Bet on Red [R], bet on Green [G] or bet on Blue [B]		
9	27	R	G	B
10	26	R	G	B
11	25	R	G	B
12	24	R	G	B
13	23	R	G	B
14	22	R	G	B

A.3 Instructions (2) *[No Premium]*

We now proceed to pair each person with another person amongst the participants. Look for the person who has the same ID number as you. You will now have the opportunity to consult directly with this other person regarding the selections made on the second decision sheet that follows. The same rules apply in terms of selecting a color and the amount of the prize.

You may speak (quietly) with the person with whom you are paired and you'll have 5 minutes to deliberate about the decisions to be made. Afterwards each person is free to make his or her own decision.

A.3.1 Decision sheet 2

In the table below, please circle R or G or B in each row. If you have any questions, please raise your hand, and we will come to assist you. Please do not speak to any other person besides the person with whom you have been paired.

Red Numbers	Blue or Green Numbers	Bet on Red [R], bet on Green [G] or bet on Blue [B]		
9	27	R	G	B
10	26	R	G	B
11	25	R	G	B
12	24	R	G	B
13	23	R	G	B
14	22	R	G	B

Appendix B

B.1 Summary of Ellsberg results

Table 1 Single behavior in version 1

	Ambiguity averse	Ambiguity neutral	Ambiguity seeking	Ambiguity incoherent
Session 1	2	17	1	4
Session 2	1	14	4	3
Session 3	0	10	2	4
Session 4	3	10	2	2
Session 5	1	13	1	3
Session 6	1	16	2	4
Session 7	1	10	1	0
Session 8	2	13	8	12
Session 9	6	19	3	10
Session 10	5	19	3	6
Session 11	0	23	5	6
Total	22 (8.1%)	164 (60.3%)	32 (11.8%)	54 (19.9%)

Table 2 Pair behavior in version 1

	Ambiguity averse	Ambiguity neutral	Ambiguity seeking	Ambiguity incoherent	Match (y/n)
S1 (P*)	0	22	0	2	12/0
S2 (NP)	0	14	3	5	1/10
S3 (P)	0	14	0	2	7/1
S4 (NP)	7	8	1	0	3/5
S5 (P)	2	14	0	2	8/1
S6 (P)	0	19	0	3	9/2
S7 (NP)	2	6	2	2	0/6
S8 (NP)	0	23	4	7	3/14
S9 (P)	6	19	5	8	14/5
S10 (P)	9	15	2	6	13/3
S11 (NP)	2	26	1	5	11/6
Total (NP)	11 (9.3%)	77 (65.3%)	11 (9.3%)	19 (16.1%)	18/41 (30.5%)
Total (P)	17 (11.3%)	103 (68.7%)	7 (4.7%)	23 (15.3%)	63/12 (84.0%)
Grand total	28 (10.4%)	180 (67.2%)	18 (6.7%)	42 (15.7%)	81/53 (60.4%)

P (NP) indicates premium paid (not paid) for agreement

* $2.50 paid as premium in Session 1. The premium was $1.25 in Sessions 3, 5, 6, 9, and 11

Table 3 First-round behavior in version 2

	Ambiguity averse	Ambiguity neutral	Ambiguity seeking	Ambiguity incoherent
Session 1	5	16	2	8
Session 2	8	17	1	5
Session 3	7	15	2	7
Session 4	11	18	5	5
Total	31 (23.5%)	66 (50.0%)	10 (7.6%)	25 (18.9%)

Table 4 Second-round behavior in version 2

	Ambiguity averse	Ambiguity neutral	Ambiguity seeking	Ambiguity incoherent
Session 1	6	19	2	4
Session 2	9	17	1	4
Session 3	6	16	3	6
Session 4	11	17	6	5
Total	32 (24.2%)	69 (52.2%)	12 (9.1%)	19 (14.4%)

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