Axiom of Monotonicity: An Experimental Test

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Abstract

The Axiom of Monotonicity (AM) is a necessary condition for a number of expected utility representations, including those obtained by de Finetti (1930), von Neumann and Morgenstern (1944), Savage (1954), and Anscombe and Auman (1963). The paper reports on experiments that directly test AM by eliminating strategic uncertainty, context, and peer effects. In one treatment, the state space is simple to formulate. Here we do not observe violations of AM. When the state space is a bit more obscure, we find significant violations of AM.
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1 Introduction

An intuitively appealing postulate in decision theory is the axiom of monotonicity (AM). It stipulates that if for each state of nature, the consequence of some act f is preferred to that of another act g, then f is preferred to g. The axioms of von Neumann and Morgenstern (1944), and Savage (1954) imply AM. The axiom is explicitly taken into consideration in the representations provided by de Finetti (1930), Anscombe and Aumann (1963), Schmeidler (1989), Gilboa and Schmeidler (1995) and others (see Gilboa, 2009). AM also has broader implications that go beyond decision theory. In strategic settings, for example, AM provides an epistemic foundation for the choice of dominant strategies. In one way or another, the axiom of monotonicity is central to the way we understand individual decision making today.

In recent years experimental methods have been instrumental in putting important axioms to rigorous testing. This is probably best exemplified by Ellsberg (1961) who constructed an intuitive scenario for choice under ambiguity in which people violate Savage's Sure Thing Principle (postulate P2 in Savage) over acts.[1] Ellsberg's experiment motivated much of the theoretical[2] and experimental[3] work on ambiguity aversion. In the same spirit, a recent experiment by Charness, Karni and Levin (2010) explores the robustness of what Khaneman and Tversky (1983) called a "conjunction fallacy" – an observed violation of first-order stochastic dominance which implies a violation of Svage's postulate P3. This particular violation was found to be not robust to certain perturbations. Violations diminished in salient decisions and practically vanished when subjects decided in teams.

[1] To be precise, subjects violated P2 or completeness or transitivity.

[2] This typically involves relaxing Savage's axioms to derive, amongst others, the Choquet Expected Utility representation in Schmeidler (1989), the Maxmin Expected Utility representation in Gilboa and Schmeidler (1989) and the representation of Klibanoff, Marinacci and Mukerji (2005). It is appropriate to add here that AM is a necessary condition for all of these approaches.

[3] A horse-race testing of various theoretical explanations for ambiguity aversion has been done by Halevy (2007) and Ahn, Choi, Gale, and Kariv (2010).

Our focus is on the axiom of monotonicity. This axiom is so intuitive that there would be no reason for doubting it, had it not been for a series of intriguing studies that jointly establish the empirical relevance of what is known as the "disjunction fallacy" (Shafir and Tversky 1992a,b; and Croson 1999). These experiments suggest that substantial number of individuals (in the order of 30-35%) make choices that are inconsistent with AM. If true, this would have at least three important implications: (i) much of the current decision theory would have limited applicability; (ii) because the violation of AM is so non-intuitive it would pose a serious challenge for theoretical modeling; (iii) our understanding of subjects' choices of dominated strategies in games (e.g., prisoner's dilemma) would have to be re-evaluated.

The purpose of our experiment is to understand, in as clean a manner as possible, what causes violations of AM to emerge. Toward this end, we subject *violations* of AM to the toughest experimental test yet. To our knowledge this is the first test of AM in a salient, non-strategic and context-free setting. We have two treatments. First, we imposed sufficient experimental controls to create an environment as *simple* and transparent as possible. We hoped to create an environment where reasons for AM violations did not exist. Second, we perturbed the setting by reducing transparency. The objective was to determine if there is an increase in violations of AM. Each of our two treatment used a bingo cage as a randomizing device. A ball drawn randomly from the cage, resolved the lottery chosen by a subject. In the transparent treatment subjects got to see and count the total number of balls in the bingo cage. Here, only 0-5% of the subjects made choices inconsistent with AM. In the other treatment subjects did not know the total number of balls in the bingo cage. In this simple scenario, a little amount of deliberation would have convinced an astute subject that this lack of knowledge does not really matter. Yet, about 18-25% of the subjects made choices inconsistent with AM. Taking state-dependent decision theoretic framework as a good description of human behavior, we conclude that behavior is consistent with AM when subjects are able to formulate the relevant state space. However, the inability to correctly formulate the relevant state space could lead to choices inconsistent with AM.

Even when a decision maker finds it hard to describe the relevant state space, she may still be able to rationally rank acts (or lotteries). This could be done by deliberating directly on the likelihood of consequences without considering the state space. The Bolker-Jeffrey approach to decision making under uncertainty provides a relevant framework (Bolker 1966, 1967; and Jeffrey 1965). A similar, but conceptually different framework is provided in Ahn (2008). In Ahn's paper, the set of consequences is infinite. In Gravel, Marchant and Sen (2009), the decision maker decides over finite sets of consequences by providing equal weight to the elements in each set. Thus, as of now, there is no theory wherein a "rational" decision maker could potentially violate AM when consequences are finite. So from a theoretical perspective we do not know what leads to the emergence of AM violations in simple environments. However, Gilboa (1995, 2009) provides a criterion for deliberations that does not directly take into account the state space and where AM could be violated. For a given act (lottery) that is available to the decision maker, she simply evaluates the relevant frequency of each consequence from historical data.

We find Gilboa's intuition appropriate for interpreting our result. Consider a decision maker (DM) who has to decide between advertising her products and not advertising.[4] If she were to advertise, then depending on market conditions she could either get high profits worth \$75 or low profits worth \$25. If she were not to advertise, she could get either \$85 or \$35. DM finds it difficult to figure out the relevant market conditions and how they translate into profits. So she carries out a *small* market survey which informs her that three-fifths of those who advertised got high profits while only one-fifth of those who did not advertise got high profits. Being an expected profit maximizer she chooses to advertise. As time passes, she is happy to note that she is making high profits around three fifths of the time. Now, along with the

[4]This example is a modified version of that in Kreps (1988).

growth of her business, her circle of friends in the business community also grows. She notices that those who sell similar products, but do not advertise, also make high profits around three fifths of the time. Her deliberations lead her to figure out that high and low profits, in her business, have more to do with the state of the economy than advertisement. Accordingly, she changes her strategy to not advertise, and still makes high profits three fifths of the time. An economist, knowledgeable about the *relevant* state space would conclude: in her early days DM violated AM, but as she got to learn about the circumstances affecting the consequences, she stopped violating AM.

In our experiment the mechanics of the bingo cage is much simpler than that of the "market." Yet, it seems that a significant minority of subjects are still unable to figure out the relevant state space and go on to violate AM. When all the possible outcomes of the bingo cage are laid bare to the subject, violations almost vanish. Of course, with a very large number of repetitions, a subject could possibly be able to figure out the relevant state space by herself. Instead of letting her collect this large sample herself, in our simpler treatment she is just told about the number of balls. Thus, our simpler treatment could be viewed as the culmination of a process where the subject has got to learn enough about the relevant state space.

2 The Axiom of Monotonicity

In the world of Savage a decision maker is aware of a set of states of nature S and a set of consequences C. An act is a function from S to C and A is the set of all such functions. The decision maker has complete and transitive preference, $\succeq$ $(\succ)$, over all acts in A. The decision maker also has a preference relation over the elements of C. Let us call this relation R. Anscome and Aumann (1963), and others, derive R (P) from $\succeq$ $(\succ)$. Let us denote the so derived preference as $R^{(\succeq)}$. Let an act which gives the same consequence x in all states of nature be denoted f^x.

Definition: For any two consequences x and y in C, if $f^x \succeq (\succ) f^y$ then

$xR^{(\succeq)}(P^{(\succeq)})y$.

It is easy to see that $R^{(\succeq)}$ is complete and transitive.

The axiom of monotonicity (AM): We say that preference $\succeq$ satisfies the axiom of monotonicity in B, where $B \subseteq A$, if for any pair of acts f and g in B, such that $f(s)R^{(\succeq)}g(s)$ for all s in Ω, we have $f \succeq g$.

As mentioned earlier, AM is a fundamental axiom for most of decision theory and has natural implications in game theoretic settings as well. In a game, player i's pure strategy can be thought of as an act which maps from opponents' pure strategy profiles (the state space) to her own payoffs. If for all such profiles (states), the payoff from strategy s_i is strictly greater than that from any other strategy then s_i is said to be a dominant strategy. When i knows the game, and knows that strategy choice is independent across players, she knows that she can never be better off by choosing a strategy different from s_i.

Our main objective was to design a simple and direct test of AM. In our experiment, subjects first made a sequence of two choices, each between two different monetary amounts. These choices were very simple. Each boiled down to essentially choosing between a higher and a lower amount of money. In the process, we assume that, $R^{(\succeq)}$ is revealed. Then, we presented each subject with a choice between two lotteries. The first, dominant lottery, used prizes that were revealed preferred, i.e., equal to the amounts chosen earlier, and the dominated lottery used prizes that were revealed inferior. With this structure a violation of AM would appear as the choice of the dominated lottery.

The nature of uncertainty was at the heart of our experiment. To obtain the most direct test of AM we first implemented choice under full transparency. We were very explicit about all the details of the randomization process, used a physical randomization device - a bingo cage, and set the probability for resolving the chosen lottery at 50%. In the second treatment, subjects were given no information about the number of balls in the bingo cage.

In Shafir and Tversky (1992b), subjects played a sequence of various prisoner's dilemma games with randomly chosen opponents. At times, they saw their opponents move before choosing their own actions and at times they did not. Again, more than 30% of subjects who defected after observing the opponent's choice, cooperated when the opponent's choice was unobservable. Croson (1999) used across-subject design to support the disjunction effect hypothesis. In her experiment, subjects often cooperated in the simple prisoner's dilemma. But when asked to state their belief about the opponent's play before choosing their own strategy, they defected at much higher rate.

Because our experiment uses within-subject design it can also be viewed as a screening procedure for subjects' behavioral types. We identify each subject as being behaviorally consistent or inconsistent with AM. This property allows us to ask how inconsistency with AM translates into play in the prisoner's dilemma (PD) game. After we screened the subjects for their types we had them play a one-shot prisoner's dilemma with a randomly chosen opponent. A naive conjecture could be that those who have violated AM should cooperate at higher rate than the rest. We do not see this in the data. But this should not be too surprising because the strategic aspect of PD makes it a much more complicated environment. Subjects have to form conjectures about opponents' behavior and other-regarding preferences (e.g., Rabin 1993, Bolton and Ockenfels 1999, Fehr and Schmidt 2000, Dufwenberg and Kirchsteiger 2004, Andreoni and Samuelson 2006) that are typically hard to measure or control[5]. In the so formulated unobserved state space, the antecedent of AM may or may not hold. This is why games are not an ideal environment for testing AM.

[5] With the exception of PD game in the last task all these considerations are absent in our experiment.

3 The experiment and hypotheses

3.1 The experiment

The objective was to create a simple, nonstrategic environment in which violation of AM can be observed directly. For this purpose we designed an experiment in which each treatment had two parts and each part consisted of two tasks. The first part was intended to elicit the antecedent of AM and the second to verify its implication. The first part was very simple. In task 1 the subject was asked to choose between two options R (Right) and L (Left). If she chose R she got \$85 and if she chose L she got \$75. In task 2, she again had to choose between two options R and L. But now if she chose R she received \$35 and if she chooses L she received \$25.

In task 3 a subject was asked to choose between the "dominant" lottery R and a the "dominated" lottery L as shown in the Figure 1, panel (a). AM implies that if the subject chose the higher amount in both tasks 1 and 2 then the same subject should prefer the dominant lottery R, with prizes \$85 and \$35, to the dominated lottery L with prizes \$75 and \$25[6].

Figure 1: Task 3

Fixed Columns

	Left	Right
B-ball Num. > 20	75	85
B-ball Num. ≤ 20	25	35

(a)

Switched Columns

	Left	Right
B-ball Num. > 20	85	75
B-ball Num. ≤ 20	25	35

(b)

Note: "B-ball Num." refers the number on the ball chosen from the bingo cage.

Interesting situation occurs when the subject takes the lower amount in one of the tasks 1 or 2. Then, Fixed Columns (FC) version of task 3, as shown

[6]Our payoffs are very similar to those used by Shafir and Tversky (1992b) and Croson (1999) who have both found a large amount of disjunct behavior in the prisoner's dilemma game with almost identical payoffs. The only difference is that in our case the lower payoffs of L and R are 25 and 35 instead of 30 and 35.

in the Figure 1 panel (a), is a test of AM *only* if we are willing to believe that the subject had made a mistake in tasks 1 or 2. But if say the lower amount were truly preferred to the higher amount in task 1, then the appropriate test of AM is the Switched Columns (SC) formulation of task 3 as shown in panel (b). Similar SC formulation is needed for a choice of the lower amount in task 2. We ran one of our treatments (the "Transparent" treatment) under both conditions FC and SC[7]. The other treatment ("Non-transparent") was run only under SC condition.

The lotteries R and L in task 3 were resolved with the same randomizations device - a bingo cage. The balls in the bingo cage were uniquely labeled with numbers between 1-40. The higher prize of the chosen lottery was paid out whenever the number on the ball drawn from the bingo cage exceeded 20. Otherwise, the subject earned the lower prize. In the Transparent treatment we gave the subjects all the details about the bingo cage. Subjects were told that there were exactly 40 uniquely labeled balls in the bingo cage. Then, they were all invited come to the front of the room[8] where all the balls from the bingo-cage were lined up and ordered in the ascending order so they could easily inspect that all we told them was true. In the second Non-transparent treatment subjects were told that the balls were uniquely labeled from 1-40 but we did not reveal anything about how many balls were in the bingo cage. The bingo-cage contained 35 balls. Subjects did see the bingo cage placed in the front of the room but were not invited to come and inspect the contents.

The final task of the experiment was the prisoner's dilemma game with payoffs we've been using all along. Subjects were told that in this task (and

[7]Only one treatment was run under both conditions because in the experiment only a few subjects had chosen the lower amount in tasks 1 or 2. It would have been very costly to run both treatments under both conditions. The Transparent treatment was deemed more appropriate because there the behavior of subjects who had chosen the higher amount in both tasks 1 and 2 was very convincing: they committed virtually zero violations in task 3. Therefore, for example under the assumption that subject's choice of the lower amount in one of the tasks 1 or 2 was due to a mistake and mistakes are not correlated across tasks, we would have had a clear prediction of no violation of AM under FC condition even for this group of subjects. We refer the reader to the results section for further discussion.

[8]This was done row-by-row.

only in this task) they are matched with one randomly chosen participant. The frame of the PD is presented in Figure 2

Figure 2: Task 4

	Left	Right
The person who you are matched with chose: Left	75 , 75	25 , 85
The person who you are matched with chose: Right	25 , 85	35 , 35

To minimize the chance of distortions due to possible peer and experimenter effects[9] we minimized social distance by adopting a double-blind protocol. Subjects were separated from each other by blinders that fully surrounded each of them and provided complete privacy. In the experiment each subject was identified by a number that was inscribed on a card randomly drawn from a hat. This number was entered by the subject on the opening

[9]Tasks 1 and 2 are so simple and transparent that they may seem unnecessary. After all, who would ever take less money if more is available? We can think of at least two reasons why this could happen. For instance, subjects may try to avoid the shame from appearing greedy in front of their peers or the experimenter (who might become their future professor). There is an established literature on the importance of double-blind protocol in preventing these peer-effects in experiments (Hoffman *et al.* 1996, Eckel and Grossman 1996).

We have had our own share of experience. In our early pilots that were run pen-and-paper in a nonanonymous classroom setting we found as much as 50% of subjects taking the lower amount in tasks 1 and 2. This stands in stark contrast with the data we obtained in the actual experiment in which we used (i) double-blind procedure and (ii) we stated clearly in the instructions that the experiment was funded by an external grant in order to mitigate the possibility that subjects think they are taking money out of our own pocket.

The second explanation for taking the lower amount could be that some subjects are simply more prone to making mistakes than others. Their behavior might be qualitatively different form those who do not make mistakes. In either case, whether the lower amount is taken due to preferences or mistakes, our initial two tasks 1 and 2 are able to detect such person and allow us to analyze these types separately from the rest.

screen of the software. At the end of the experiment the experimenter put all payments in the respective envelopes with the corresponding numbers written on the top of them. One of the subjects was again randomly selected to hand out the envelopes to everyone else in the room[10,11].

To get at our questions we used a within subject design in which tasks come in sequence. Since under SC, payoffs in task three were contingent on task 1 and 2 choices, tasks were unfolded to the subject one at a time. A computer which observed choices in tasks 1 and 2, constructed and presented the subject with task three.

Sequencing of tasks could cause order effects. We control for order effects by randomizing the order of tasks. To preserve the natural structure of the AM implication we only randomized the order of the tasks 1 and 2 and the order of tasks 3 and 4. Furthermore, we were worried that responding to tasks may become automatic if the same column with the higher amount(s) is always associated with the same button, e.g., Right. For this reason we also randomized the assignment of columns to buttons for each task and each subject.

The experiment was run at ITAM in the computer laboratory. The software was written in Visual Basic 6.0. Together 162 subjects participated in the experiment. The Non-transparent and Transparent treatments consisted of 3 and 6 sessions respectively with 12 - 20 students per session. The students were recruited form the 1st year introductory courses offered at ITAM, i.e., they had only minimal exposure to economics. The experiment was

[10] In exchange for the envelope she collected the card with the number that matched the envelope. The cards were then handed back to the experimenter.

[11] One of the major difficulties with double blind procedure is with having subjects sign the payment receipts. At that point a name and face is clearly related to the amount (and decisions) made in the experiment. We by-passed this problem by having each subject sign a payment form with the average amount earned by a subject in the experiment. This procedure was explained to subjects verbally.

run in Spanish[12,13]. Our assistant who is a native Spanish speaker has read the instructions aloud for the whole class. This was followed by a round of privately answering subjects' individual questions. The opening screen of the software contained a page of comprehension questions that had to be answered correctly by everyone before the experiment could begin. The experiment lasted for about 45 minutes. Subjects were paid 50 Pesos as a show fee and half of their total point earnings in the experiment. The average payment was 155 Pesos.

3.2 Hypotheses

In the experiment we observe choices and not preferences nor the subjects' construct of the state space. Therefore, before we state our hypotheses it is necessary to define an observational equivalent of the AM for our experiment. This we call the monotonicity principle:

Monotonicity Principle: Choice satisfies the principle of monotonicity if the dominant lottery is chosen in task three.

Recall that in the Transparent treatment we carefully explained to subjects all details of the randomization device in task 3. If this was understood by them, then the state space can be represented by the numbers inscribed in the balls. So, $S = \{1, 2, ..., 39, 40\}$. Let c_t denote choice in task t and let a_t denote the alternative which was not chosen. Task 1 can be viewed as a choice such that the chosen amount is preferred to the alternative, i.e., $c_1 P^{(\succeq)} a_1$. Similarly for task 2 we have, $c_2 P^{(\succeq)} a_2$. For all $s \in \{1, ...20\}$ the dominant lottery gives c_1 and the dominated lottery gives a_1. For $s \in \{21, ..., 40\}$, the dominant lottery gives c_2 and the dominated lottery gives a_2. Then, by

[12] The instructions and the software were initially written in English, then translated to Spanish by our assistant, and consequently translated back to English by our second assistant to ensure the accuracy of the translation.

[13] The English version of the instructions can be found in the Appendix C.

AM,[14] the dominant lottery must be preferred to the dominated lottery. This stronger version of AM implies our first hypothesis.

H1: If AM holds under transparency, then we will observe no (or negligible number of) dominated lottery choices in the Transparent treatment.

In the Non-transparent treatment the randomization process is bit more obscure. The hypothetical state space is still $S = \{1, 2, ..., 39, 40\}$, because the subject knows that a ball in the bingo cage has a unique number between 1 and 40. However, if she were to start deliberating on what the actual state space could be she would be overwhelmed. For there could potentially be $2^{40} - 1$ sets of potential states. Maybe less, for she could still see some balls in the cage. But the point remains that *if* she were to start her process of deliberation by trying to figure the number of balls in the cage, she would probably be overwhelmed. In such a scenario, she could well resort to Gilboa's process as highlighted in the introduction. Alternately, our decision maker could start her process of deliberation by starting from the hypothetical state space with forty elements and continue as previously stated. Under the latter scenario, we obtain the following hypothesis.

H2: If AM holds, then under both transparency and non-transparency, then we will observe no (negligible number of) dominated lottery choices in both treatments.

Our next question of interest is how does a violation of AM affect play in the prisoner's dilemma. To choose a strategy in a game the player has to form a belief about the opponent's strategy and type (in terms of the opponent's other regarding payoffs). This necessarily puts the player in the situation

[14] To test AM through revealed preferences, in a simple setting as ours, we need a stronger version of AM. This version would read as follows:

We say that preference $\succeq$ satisfies the strong axiom of monotonicity in B, where $B \subseteq A$, if for any pair of acts f and g in B, such that $f(s)P^{(\succeq)}g(s)$ for all s in Ω, we have $f \succ g$.

with reduced transparency, i.e., akin to the Non-transparent treatment. We speculate that the same factors that are responsible for the violation of AM in the decision theoretic setting will also contribute to the choice of the dominated strategy (cooperation) in the PD game.

H3: Subjects who violated AM will cooperate in the prisoner's dilemma at higher rate than subjects who did not violate AM.

4 Results

As the first step we check the consistency of behavior in tasks (1, 2, and 4) that were unaffected by treatment variations.

Table 1: Choice frequencies in tasks 1, 2 and 4

	Treatments	
	Non-transp.	Transp.
Tasks 1 and 2: took the higher amount	85%	82.4%
Task 4: chose the dominated strategy	45%	47.1%
No. of observations	60	102

Note: Task 3 is left out intentionally and is analyzed in detail in Table 2.

The Table 1 shows that there are indeed no differences. In addition, there is nothing irregular about the behavior in three tasks 1, 2 and 4. In tasks 1 and 2 most of the subjects revealed preferences for money and took the higher amount. Somewhat surprisingly, however, a minority (about 15-20%) took the lower amount at least once. We will return to this subgroup in the later section. Task 4 was the PD game. The observed cooperation rates are 45-47% and this is consistent with the previous findings in the literature[15]. Next we turn to our main result - the evidence on the violation of monotonicity.

[15] Fisher's exact test shows no significant differences between frequencies for Tasks 1 and 2 (p-value = 0.687) and also for Task 4 (p-value = 0.429).

4.1 Violation of the Monotonicity Axiom

Task 3 presented the subjects with a choice between two lotteries. The dominant lottery, in which the prizes were the chosen amounts in the initial two tasks, and the dominated lottery, with prizes equal to the amounts left unchosen.

Table 2: Dominated lottery choices in Task 3

	Treatments			
	Non-transp.	Transp.		
		Pooled	SC	FC
Higher amount in both task 1 and 2	17.7%	2.4%	4.4%	0%
	(9/51)	(2/82)	(2/45)	(0/39)
Lower amount in task 1 or task 2	66.7%	-	72.7%	28.6%
	(6/9)	-	(8/11)	(2/7)
Combined	25%	-	17.9%	4.4%
	(15/60)	-	(10/56)	(2/46)

Note: The ratios in parenthesis give the actual number of observations.

The top row presents number of violations for the sub-sample (82-85%) of subjects who have chosen the higher amount in both initial two tasks. This gives the cleanest test of AM because for these subjects we are confident that the antecedent of AM is satisfied. Furthermore, for this subgroup there was no difference between SC and FC conditions. All four tasks were exactly the same. Therefore, we present a test based on the pooled data. The incidence of dominated lottery choices in the Non transparent treatment was as high as 17.7% and in the Transparent treatment only 2.4%. The difference is significant on 1% level with the p-value of one-sided (two-sided) Fisher's exact test[16] being 0.006 (0.008)[17]. Based on this evidence we reject H2 but cannot reject H1.

[16] The p-values in the reminder of this paper are based on this test.

[17] The difference between Non transparency and and individual Transparency conditions is also significant. One-sided (two-sided) p-values for the Non transparency vs. SC condition are 0.064 (0.108) and for the Non transparency vs. FC condition are 0.009 (0.011).

Result 1: AM holds in the most basic decision-theoretic setting. Under transparency only 2.4% of subjects violate AM. Under non-transparency a significant 17.7% of subjects violate AM.

The subjects who chose the lower amount in at least one of the tasks 1 or 2 account for about 15-20% of the data. This makes them less important but nonetheless a quite interesting group. Their dominated lottery choices are shown in the second row of Table 2[18]. For these subjects we have much less confidence that the antecedent of AM is satisfied because the choice of the lower amount in task 1 or 2 seems somewhat strange. It could be that this choice is preference driven but it could also be that it is a product of a mistake.

We cannot and would not want to rule out either of the explanations. Under the assumption that all choices in our experiment are preference driven the appropriate test of AM is the formulation of task 3 with switched columns, i.e., condition SC. On the other hand, if the choice of the lower amount occurred due to a mistake, then the appropriate test of AM is task 3 with the fixed columns, i.e., condition FC.

The data in Table 2 show that under preference assumption it would be that majority of subjects, 72.7%, violate AM. Under the mistakes assumption the proportion of would-be violators drops down to 28.8% but it is still far from negligible.[19] From our experiment we cannot determine whether choices are preference- or mistake-driven. But irrespective of which one it is the data indicate that the number of AM violators is likely to be higher for this group then for the previous group[20].

[18] Additional tables allowing a deeper look in the data can be found in the Appendix B.

[19] The test of the hypotheses that the proportions AM violators in the subsample of those who always took the higher amount (2/82) and those who did not under FC condition (2/7) is rejected on the 5% level (p-value is 0.045)

[20] The power of this conclusion is limited by the small sample-size that it's based on.

4.2 Play in the Prisoner's Dilemma

In the previous sections we have shown that a significant proportion of subjects violate AM. This brings up a question about the implications of this finding for the dominance play in games. Recall from our previous discussion that both Shafir and Tversky (1992, 1993) and Croson (1999) have found a large proportion of what appeared to be AM violations (in the order of 30%) in the prisoner's dilemma game. They called this the disjunction effect. However, PD game arguably involves more complex state space where each element signifies a strategy and payoff type. Cooperation can occur for other reasons that are unrelated to the monotonicity of choice. For instance, in the PD game players split the payoffs between the two of them which can bring in social preferences to play a role in their decisions[21]; secondly, in the PD game players face strategic uncertainty which requires that they form beliefs about the others' preferences and strategy choices. This is certainly a great leap from simple bingo-cage-type uncertainty with 50/50 chances. However, here we are only interested in a very simple question: is the violation of AM one of the drivers of cooperation in the PD game. Our experiment allows us to screen each subject for her type, either she is an AM violator or not, and then relate her type to her behavior in the PD game.

We only look at the data for subjects who chose the higher amount in both tasks 1 and 2. Only for this subgroup we have sufficient confidence that a choice of dominated lottery in task 3 is a violation of AM. It is natural to suppose that those subjects who violate AM in our simple setting would also tend to violate AM in more complex settings. Based on this we could, under the additional assumption that the antecedent of AM is satisfied in the PD game, expect AM violators to cooperate in the PD game at higher rate than non-violators. But not surprisingly we cannot quite conclude this from the data. The proportion of cooperators amongst those who took the higher amount in tasks 1 and 2 and did not violate AM is 42.8% (18/42).

[21] For example due to distribution-based (e.g., see Bolton and Ockenfels, 2000 or Fehr and Schmidt, 1999) or belief-based (Rabin 1993) preferences.

Amongst those who did violate AM the proportion is higher, 55.6% (5/9), but the difference is not significant (the p-value is 0.45).

Result 2: Violation of AM does not imply cooperative behavior in the prisoner's dilemma game.

Thus, we can reject the H3 hypothesis. This suggests that there may be a fundamental disconnect between violation of AM and what is known in the literature as the disjunction effect.

4.3 Discussion

Several points should be noted.

1. The reader may have two concerns. First, the individual tasks were very simple. One may wonder whether "simplicity" of the initial two tasks could have led, via some experimenter demand effect, to violations of AM (see footnote 9). But, such "simplicity", and hence the possible experimenter demand effects, do not vary between our treatments. However, AM violations do differ.

The second concern has to do with the "small" proportion of subjects who violated AM in the Non-transparent treatment. We believe that "size" is an important issue when one is concerned about the empirical validity of an axiom. We are far from such a concern. Our experiment simply suggests that AM is not violated in the environment that makes it easy for subjects to formulate state space correctly. When formulation of the state space is more difficult, then (what can at worst be called statistically *traceable)* violations of AM emerge. Does this mean that AM violations would increase if the relevant state space is more complex? Perhaps, yes. But before we even try to answer the question we would have to have a better understanding of what complexity is and how it could be measured. Without such understanding, the best one could do is to run experiments in various different contexts and see if AM holds. One has to be cautious though. In complex situations, like say in a game, the antecedent of AM may be hard to verify.

2. Our experiment suggests that if and when subjects learn enough about the state space, there would be no violation of AM. Indeed in almost all expected utility representations, the decision maker is assumed to be "aware" of the state space. Of course, there is an issue about what this awareness means. Leaving aside such concerns, one would ideally like to see if AM violations decrease as subjects learn more in the laboratory. Such experiments would, however, be more complex than what we present in this paper. Especially if beliefs are to be elicited through incentive compatible mechanisms, some amount of clarity may have to be sacrificed. Our paper provides a motivation for such kinds of more complex experiments in the future.

3. Though we assert that AM would vanish with learning, we provide no evidence for the assertion. Such learning could take time. In the meantime, we agree that, violators of AM could have important consequences for others. Shiller (1998) observes that AM violators could be causing higher volatility in financial markets. In the same vein, asset market bubbles may be fueled by AM violators and more importantly by those who pretend to be AM violators. Informed and rational traders could take advantage by mimicking such types, leading to a market bubble and then jumping the gun just before the crash. This is the main idea behind the "greater fool theory," see for example Kindelberger (2000) and Allen and Gorton (1993).

4. In our Transparent treatment, subjects could perhaps agree with each other on the probabilities to be assigned to each ball. In the Non-transparent treatment, where the total number of balls is not known, this is not necessarily the case. Hence one could perhaps call the choice in the Non-transparent treatment, "choice under ambiguity." If so, then what is the relationship between our experiment and that of Ellsberg? A basic difference is that, in the case of Ellsberg, subjects could avoid to choose ambiguous lotteries whereas in our experiment subjects could not.

5. One may wonder whether our findings cannot be interpreted as (or driven by) ambiguity aversion found in numerous Ellsberg-type experiments, e.g., Halevy (2007), Ahn et al. (2011). In the Ellsberg experiment, subjects violated axiom P2 of Savage (or completeness or transitivity). P2 is also known as the "sure thing principle." We explicitly define P2 in the Appendix. How is P2 related to AM? We deal with this question in the Appendix C. We show that, in general, when the state space has three or more elements, P2 is neither necessary nor sufficient for AM. A reader may assert that in our experiment, the relevant state space has cardinality two. We show that, when there are just two acts available for choice and the state space has two elements, P2 can never be violated but AM can. So our point of view is that one should not invoke P2 to interpret violations of AM.

6. There is one way, however, to relate P2 to AM. If one were to consider the set of all possible acts and the cardinality of the state space were to be two. Then, we show that, AM implies P2. In this scenario, one could say that a subject who violates P2 in some subset of A would surely violate AM over some pair of acts in A. We do not like this interpretation. If one were to indeed talk in terms of the hypothetical then with four consequences, as in our experiment, we do not know how to justify the claim that the "relevant" cardinality of the state space is two. We deal with this issue explicitly in the Appendix.

7. Another axiom of Savage that is similar to AM is P3. Again, in the Appendix, we show that P3 is neither necessary not sufficient for AM. In a sense P3 is a restriction which makes some set of dynamic preferences (as uncertainty lessens) compatible with static preferences. AM is a restriction which makes static preferences compatible with preferences over consequences, in a different sense.

5 Conclusion

The disjunction effect literature reports on data that is inconsistent with AM. A reason for such violations is provided by the Bolker-Jeffrey approach to decision making. Here a decision maker deliberates on the probability of consequences. Such deliberations make sense when the state space is difficult to formulate. This motivated a careful test where violations of AM was recorded over two treatments. In one treatment, the state space was made transparent. In the other, the state space was less transparent. We found that in the simple environment, that allowed the decision maker to formulate the state space relatively easily, AM is not violated. When the nature of uncertainty is more obscure, we find significant violations.

References

[1] Ahn, S. D. (2008): "Ambiguity without a state space," *Review of Economic Studies*, 75(1), 3–28.

[2] Ahn, S. D., S. Choi, D. Gale, and S. Kariv (2011): "Estimating Ambiguity Aversion in a Portfolio Choice Experiment," Working Paper, University of California at Berkeley.

[3] Allen, F., and G. Gorton (1993): "Churning Bubbles," *Review of Economic Studies*, 60(4), 813–836.

[4] Andreoni, J., and L. Samuelson (2006): "Building rational cooperation," *Journal of Economic Theory*, 127, 117–154.

[5] Anscombe, F. J., and R. J. Aumann (1963): "A definition of subjective probability," *The Annals of Mathematics and Statistics*, 34, 199–205.

[6] Bolker, E. D. (1966): "Functions resembling quotients of measures," *Transaction of the American Mathematical Society*, 124, 292–312.

[7] Bolker, E. D. (1967): “A simultaneous axiomatization of utility and subjective probability,” *Philosophy of Sciences*, 333-340.

[8] Bolton, G., and A. Ockenfels (2000): “ERC—A theory of equity, reciprocity and competition,” *American Economic Review*, 90, 166–193.

[9] Charness G., E. Karni, and D. Levin (2010): “On The Conjunction Fallacy in Probability Judgment: New Experimental Evidence Regarding Linda,” *Games and Economic Behavior*, 68, 551-556.

[10] Croson, R. T. A. (1999): “The disjunction effect and reason-based choice in games,” *Organizational Behavior and Human Decision Processes*, 80, 118–133.

[11] de Finetti, B. (1930): “Funzione caratteristica di un fenomeno aleatorio,” *Atti Accad. Naz. Lincei Rend. Cl. Sci. Fis. Mat. Nat.*, 4, 86–133.

[12] Dufwenberg, M., and G. Kirchsteiger (2004): “A Theory of Sequential Reciprocity,” *Games and Economic Behavior* 47, 268-98.

[13] Eckel, C. C., and P. Grossman (1996): “Altruism in anonymous dictator games,” *Games and Economic Behavior* 16, 181–191.

[14] Ellsberg, D. (1961): “Risk, Ambiguity and the savage axioms,” *Quarterly Journal of Economics*, 75, 643–669.

[15] Fehr, E., and K. Schmidt (1999): “A theory of fairness, competition, and cooperation,” *Quarterly Journal of Economics*, 114, 817–868.

[16] Gächter, S. (2007): “Conditional cooperation, behavioral regularities from the lab and the field and their policy implications,” in Bruno S. Frey and Alois Stutzer (eds): Economics and Psychology. A Promising New Cross-Disciplinary Field. CESifo Seminar Series. The MIT Press.

[17] Gilboa, I. (2009): “Theory of decision under uncertainty,” Cambridge University Press.

[18] Gilboa, I., and D. Schmeidler (1989): "Maxmin expected utility with a non-unique prior," *Journal of Mathematical Economics*, 18, 141–153.

[19] Gilboa, I., and D. Schmeidler (1995): "Case-based decision theory," *Quarterly Journal of Economics*, 110, 605–639.

[20] Graval, N., T. Marchant and A. Sen (2009): "Uniform expected utility criterion for decision making under ignorance or objective ambiguity," working paper, Indian Statistical Institute, Delhi.

[21] Halevy, Y. (2007): "Ellsberg revisited: an experimental study," *Econometrica* (2007), 75, 503–536.

[22] Hoffman, E., K. McCabe, K. Shachat, and V. Smith (1996): "Social distance and other-regarding behavior in dictator games," *American Economic Review* 86, 653–660.

[23] Jeffrey, R. (1965): *The Logic of Decisions*. University of Chicago Press, Chicago, reprint 1983.

[24] Kindleberger, C. P. (2000): "Manias, Panics and Crashes: A History of Financial Crises," Macmillan, London, 5th edition.

[25] Klibanoff, P., M. Marinacci, and S. Mukerji (2005): "A smooth model of decision making under ambiguity," *Econometrica* 73(6) 1849–1892.

[26] Kreps, D. (1988): "Notes on the theory of choice," Westview Press: Underground Classics in Economics.

[27] Kreps, D. M., P. R. Milgrom, J. Roberts, and R. J.Wilson (1982): "Rational Cooperation in the Finitely Repeated Prisoners' Dilemma," *Journal of Economic Theory*, 27(2), 245–252.

[28] Savage, L. J. (1954): "The foundations of statistics," New York: Wiley.

[29] Schmeidler, D. (1989): "Subjective probability and expected utility without additivity," *Econometrica*, 57, 571–587.

[30] Shafir, E. (1994): "Uncertainty and the difficulty of thinking through disjunctions," *Cognition*, 50, 403–430.

[31] Shafir, E., and A. Tversky, (1992): "Thinking through uncertainty: Nonconsequential reasoning and choice," *Cognitive Psychology*, 24, 449–474.

[32] Shafir, E., I. Simonson, and A. Tversky (1993): "Reason-based choice," *Cognition*, 49, 11–36.

[33] Shiller, R. J. (1998): "Human Behavior and the Efficiency of the Financial System," Working Paper, The National Bureau of Economic Research, No. 6375.

[34] von Neumann, J., and O. Morgenstern (1944): "Theory of games and economic behavior," Princeton University Press.

Appendix

A Relationship between axioms

Here we discuss the relationship between two axioms of Savage, respectively P2 and P3, and the Axiom of Monotonicity (see below for definitions).

Let there be a finite set of consequences C with two or more elements, a finite set of states of nature Ω. Acts, which are functions $f : \Omega \longrightarrow C$. Let the set of all acts be A. Let E denote a non-null, strict subset of Ω and E^c it's complement in Ω.

Savage's P2: We say that P2 is satisfied in B, where $B \subseteq A$, if for any four acts f, g, f' and g' in B and any $E \subsetneq \Omega$ such that: (i) $f(s) = f'(s)$ and $g(s) = g'(s)$ for all s in E; (ii) $f(s) = g(s)$ and $f'(s) = g'(s)$ for all s in E^c; and (iii) $f \succeq g$, we have $f' \succeq g'$.

Ellsberg's experiments showed that a sizeable proportion of people violate the behavior stated in P2. Could it be the case that AM is violated by only those who violate P2? Note from the definition that if f, g, f' and g' are not distinct acts, then P2 is trivially satisfied. Thus, if the cardinality of B is equal to 2, as in our experiment, P2 can never be violated whereas AM can. So, in a rather narrow sense, one can say that AM is not necessarily violated by only those who violate P2. The point, however, is to understand the relationship between P2 and AM in a broader sense. That is, when we take the set B to be equal to A.

Individual who violate P2 in A, need not violate AM in A. This fact is known in the literature. For example, the motivation behind most expected utility representations under ambiguity is that P2 does not hold. Yet, all these representations assume that AM holds. So it must be that a violation of P2 does not imply a violation of AM, or equivalently, AM does not imply P2. Actually, neither is it the case that P2 implies AM. Examples 1 and 2 illustrate this fact. In Example 1, P2 is violated but AM is not. In Example 2, AM is violated but P2 is not.

Example 1: Let $\Omega = \{s_1, s_2, s_3\}$; $C = \{1, 0\}$; $A = \{p, q, r, s, t, u, v, w\}$; acts map to consequences as follows (e.g. $p(s_1) = 1$):

	s_1	s_2	s_3
p	1	1	1
q	1	1	0
r	1	0	1
s	0	1	1
t	0	0	1
u	0	1	0
v	1	0	0
w	0	0	0

Preferences over acts are as follows: $p \succ q \succ r \succ s \succ t \succ u \succ v \succ w$.

By transitivity, $p \succ w$ and hence, $1 \; P^{(\succeq)} \; 0$. AM is satisfied in A, by the given preferences. The way to check it is as follows. Consider q, we have $q(s_3) = 0$, otherwise $q(s) = 1$. Note that q is strictly preferred over all other acts which result in 0 in state s_3. There are no other acts listed below q which has consequence 1 in states s_1 and s_2. Similarly for other acts.

To see that P2 is violated in A, consider $E = \{s_1, s_3\}$, $E^c = \{s_2\}$. Note that: (i) $q(s) = v(s)$ and $s(s) = t(s)$ in E; (ii) $q(s) = s(s)$ and $v(s) = t(s)$; (iii) $q \succ s$. However, $t \succ v$.

This example shows that when the cardinality of Ω is greater than two, then it is not the case that (in A) AM implies P2. We now show, by example, that neither is it the case that P2 implies AM. In the example below, AM is violated in A, but P2 is not.

Example 2: As before, let $\Omega = \{s_1, s_2, s_3\}$; $C = \{1, 0\}$; $A = \{p, q, r, s, t, u, v, w\}$; acts map to consequences as follows:

	s_1	s_2	s_3
p	1	1	0
q	1	1	1
r	1	0	1
s	0	1	1
t	0	0	1
u	0	1	0
v	1	0	0
w	0	0	0

Preferences over acts are as follows: $p \succ q \succ r \sim s \sim t \sim u \sim v \succ w$.

By transitivity, $q \succ w$. Hence, $1 \ P^{(\succeq)} \ 0$. Now note that AM is violated in A as $q(s) \succeq p(s)$ for all s, but $p \succ q$. We now come to the tedious part of showing that P2 is not violated. Because of our earlier observation, we shall consider only distinct acts.

Let $E = \{s_1, s_2\}$. Note that the set $\{p, q, s, u\}$ satisfies the antecedent of P2. To see this, rename $f \equiv p$, $f' \equiv q$, $g' \equiv s$, $g \equiv u$. Check that: (i) $f(s) = f'(s)$ and $g(s) = g'(s)$ for s in E; (ii) $f(s) = g(s)$ and $f'(s) = g'(s)$ in E^c; (iii) $f \succ g$. Since $f' \succ g'$, P2 is satisfied.

Let $\{p, q, t, w\} \equiv \{f, f', g', g\}$ (i.e. p is renamed f etc.). Check that: (i) $f(s) = f'(s)$ and $g(s) = g'(s)$ for s in E; (ii) $f(s) = g(s)$ and $f'(s) = g'(s)$ in E^c; (iii) $f \succ g$. Since $f' \succ g'$, P2 is satisfied. From now, we simply state the set of acts and rename them. The "check" remains the same as above.

$\{p, q, r, v\} \equiv \{f, f', g', g\}$; $\{r, s, u, v\} \equiv \{f, g, g', f'\}$; $\{r, t, v, w\} \equiv \{f, g, f', g'\}$ (in (iii) we get $f \sim g$, while $f' \succ g'$, which does not violate P2); $\{s, t, u, w\} \equiv \{f, g, f', g'\}$ (here in (iii) of the antecedent we get $f \sim g$, while $f' \succ g'$, which does not violate P2).

Given $E = \{s_1, s_2\}$, there are no more sets of acts which satisfy P2.

Let $E = \{s_2, s_3\}$. Check: $\{p, u, q, s\} \equiv \{f, f', g, g'\}$ (here in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{p, u, r, t\} \equiv \{f, f', g, g'\}$ (here again in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{p, u, v, w\} \equiv \{f, f', g, g'\}$; $\{q, s, r, t\} \equiv \{f, f', g, g'\}$ (again in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{q, s, v, w\} \equiv \{f, f', g, g'\}$; $\{r, t, v, w\} \equiv \{f, f', g, g'\}$.

Let $E = \{s_1, s_3\}$. Check: $\{p, v, u, w\} \equiv \{f, f', g, g'\}$; $\{p, v, s, t\} \equiv \{f, f', g, g'\}$ (here in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{p, v, q, r\} \equiv \{f, f', g, g'\}$ (here in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{q, r, s, t\} \equiv \{f, f', g, g'\}$ (in (iii) of the antecedent we get $f \succ g$, while $f' \sim g'$); $\{q, r, u, w\} \equiv \{f, f', g, g'\}$; $\{s, t, u, w\} \equiv \{f, f', g, g'\}$ (here in (iii) of the antecedent we get $f \sim g$, while $f' \succ g'$).

This ends the example.

Note that the structure of both the examples is such that it is easy to extend them to cases where the cardinality of Ω is strictly greater than three.

The reader may assert that in our experiment, the relevant state space is of cardinality two. This is because, in both lotteries, all consequences are the same for balls drawn with numbers greater than 20 and similarly, all consequences are the same for balls drawn with numbers less than or equal to 20. But this is so only for the narrow sense, i.e. when comparisons are made over B (the subset of acts) which has only two elements. And we have already seen that in such cases, P2 always holds. On the other hand, in our experiment C (the set of consequences) has four elements. So in the the set A (the set of all acts) we have acts for which the set of all states cannot be meaningfully partitioned into two. For example, the act which has consequences \$25, \$35, \$75 and \$85, when the ball drawn has numbers belonging to sets $\{1, .., 10\}$, $\{11, .., 20\}$, $\{21, .., 30\}$, and $\{31, .., 40\}$ respectively.

The reader may still want to know about the relationship between AM and P2 when the cardinality of Ω is two. Here, the surprising result is that AM implies P2.

Proposition 1 *Let $\Omega = \{s_1, s_2\}$. AM implies P2.*

Proof. Let c_1, c_2, c_3, c_4 be consequences in C. P2 is trivially satisfied unless (i) $f(s_1) = f'(s_1) = c_1$ and $g(s_1) = g'(s_1) = c_2$; (ii) $f(s_2) = g(s_2) = c_3$ and $f'(s_2) = g'(s_2) = c_4$. So suppose (i) and (ii). By completeness, either $c_1 R c_2$ or $c_2 R c_1$. Without loss of generality, let $c_1 R c_2$. Since, $f(s_1) = c_1$, $g(s_1) = c_2$ and $f(s_2) = g(s_2) = c_3$, then, by AM, we have $f \succeq g$. Now, $f'(s_1) = c_1$, $g'(s_1) = c_2$ and $f'(s_2) = g'(s_2) = c_4$. Therefore, by AM, we have $f' \succeq g'$. ■

This result says that all those who violate P2 also violate AM. The other way around is not necessarily true. So the number of people who violate AM cannot be greater than the number who violate P2. In this sense, the number of people who violate AM provides a lower bound for the number who violate P2.

We now state P3:

Savage's P3: Let f, g, f' and g' be four acts in B, where $B \subseteq A$, such that $f'(s) = x$ and $g'(s) = y$ for all s in Ω and $f(s) = f'(s)$ and $g(s) = g'(s)$ for all s in E. We say that P3 is satisfied in B when: $f' \succeq g'$ iff $f \succeq_E g$.

The fact that AM is neither necessary nor sufficient for P3 should be clear. Nevertheless, we provide two examples. In example 3, P3 is violated but AM is not. In example 4, AM is violated but P3 is not.

Example 3: $\Omega = \{s_1, s_2, s_3\}$; $C = \{1, 0\}$; $B = \{p, q, r\}$, where $B \subset A$.

	s_1	s_2	s_3
p	1	1	1
q	0	0	1
r	0	0	0

Preferences over acts: $p \succ q \succ r$.

A conditional preference: $q \sim_E r \succ_E p$, where $E = \{s_1, s_2\}$.

Here $p \succ r$ implies $1 \; P^{(\succeq)} \; 0$. It is easy to see that AM is satisfied by the given preference over acts. P3 is violated due to $q \succ_E p$.

P3 is violated because of "event dependent preferences." To see this, let s_1 and s_2 stand for heavy and medium showers and s_3 stand for a sunny day. Let 0 stand for an umbrella and 1 for a hat. A decision maker wants to go out for a walk the next day. Today, he has to choose between a hat and an umbrella (or a lottery which gives him a hat tomorrow irrespective of the state, and a lottery which gives him an umbrella tomorrow irrespective of the state). Suppose the decision maker believes that it is unlikely to rain tomorrow. It makes sense for him to choose a hat. Next day she finds out that it is raining, though she still does not know whether rains would be heavy or medium when she goes out for the walk. She might now prefer an umbrella over a hat. The point here is that preferences conditional on some event may be quite at odds with unconditional preferences. P3 is a way to relate conditional and unconditional preferences. AM is a way to relate unconditional preference over acts to preference over consequences (or prizes). These are quite different restrictions.

The next example violates AM but not P3.

Example 4: $\Omega = \{s_1, s_2, s_3\}$; $C = \{1, 0\}$; $B = \{p, q, r\}$, where $B \subset A$.

	s_1	s_2	s_3
p	1	1	1
q	0	0	1
r	0	0	0

Preferences over acts: $q \succ p \succ r$.

Conditional preference with $E = \{s_1, s_2\}$, $E = \{s_1\}$, $E = \{s_2\}$: $p \succ_E q \sim_E r$.

Conditional preference with $E = \{s_2, s_3\}$, $E = \{s_1, s_3\}$, $E = \{s_3\}$: $p \succ_E q \succ_E r$.

P3 is not violated here because it puts no restrictions on the unconditional preference between p and q, while AM does. The only unconditional preference on which P3 puts a restriction on is that between p and r.

B Additional tables

Table 3: Dominated lottery choices in Task 3

	Took lower amount in tasks 1 or 2			
	Order		Payoffs	
	First task encountered	Second task	Task 1 75 vs. 85	Task2 25 vs. 35
Non-transp.	75%	0%	60%	66%
	(6/8)	(0/1)	(3/5)	(4/6)
Transp. SC	66.7%	80%	75%	66.7%
	(4/6)	(4/5)	(6/8)	(2/3)
Transp. FC	50%	0%	0%	40%
	(2/4)	(0/3)	(0/2)	(2/5)
Total	66.7%	44.4%	60%	57.1%
	(12/18)	(4/9)	(9/15)	(8/14)

Note: The ratios in parenthesis give the actual number of observations.

C Instructions

Below is the English version of the instructions. The instructions below are those used in the Transparency treatment. In the Non transparency treatment the changes were that the text in [] was added and the text in { } was deleted.

Table 4: Cooperation in PD by groups

	Treatments			
	Non-transp.	Transp.		
		Pooled	SC	FC
Task 3: Satisfied AM				
T1&2: Both high	18/42	35/82	20/43	15/39
	42.9%	42.7%	46.5%	38.5%
T1&2: One low	2/3	7/8	2/3	5/5
	66.7%	87.5%	66.7%	50%
Task 3: Violated AM				
T1&2: Both high	5/9	0/2	0/2	0/0
	55.6%	0%	0%	-
T1&2: One low	2/6	6/10	4/8	2/2
	33.3%	60%	50%	100%
Total	45%	47.1%	46.4%	47.8%
	27/60	48/102	26/56	22/46

Instructions

Welcome to the experiment. From this moment on no talking is allowed. If you have a question after we finish reading the instructions, please raise your hand and the experimenter will approach you and answer your question in privacy.

The experiment consists of 4 tasks that will be presented to you in sequence (one after another). In each task you will be asked to make a single decision.

Earnings

The amount you earn in this experiment will be paid to you in cash at the end of the experiment. The funding for this experiment was provided by an external grant from Asociation Mexicana de Cultura.

You will be paid according to the following rule:

50 pesos for coming on time to the experiment + $\frac{1}{2}$ * (the points that you earn in each of the four tasks of the experiment).

Privacy

In this experiment you are completely anonymous. The experimental procedure that will be described to you in detail insures that NO ONE including the experimenters will be able to know which decision was made by you.

Tasks and Decisions

You will be seated at the computer terminal which is shielded by blinders to insure your complete privacy. In front of you there is a folded card with a number which will identify you throughout the experiment. You will use this number to make your decisions and also to redeem your payment.

After we finish reading these instructions and answer any questions that you may have, you will be asked to follow the instructions on the computer screen. The software will guide you through the tasks of the experiment.

When we start the experiment you will see the following screen:

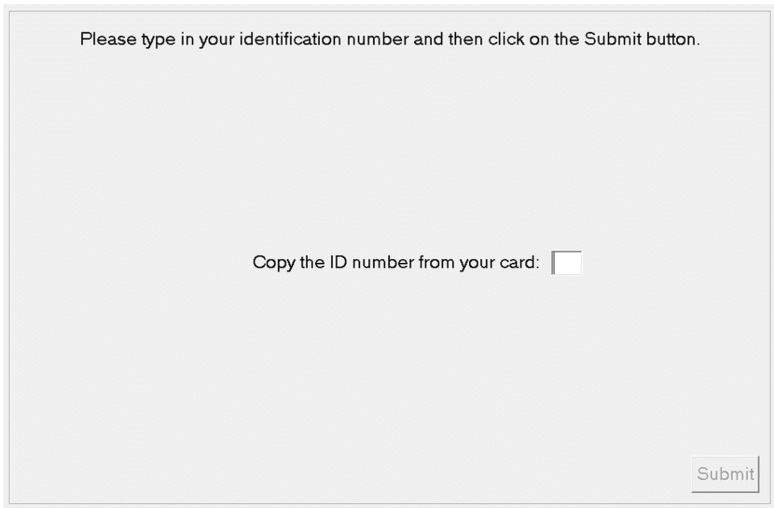

Figure 1

Please enter your identification number which is written on the card in front of you. Make sure that you copy the number correctly. If you make a mistake we will not be able to pay you your earnings.

Next you will be asked to complete a series of comprehension questions. These questions ensure that you have properly understood the instructions. You will not be allowed to proceed with the experiment unless you have answered all questions correctly. Once you have answered the instructions the Task 1 of the experiment begins.

TASK 1: The task is very simple. On the screen (Figure 2) you see two boxes each containing a single number.

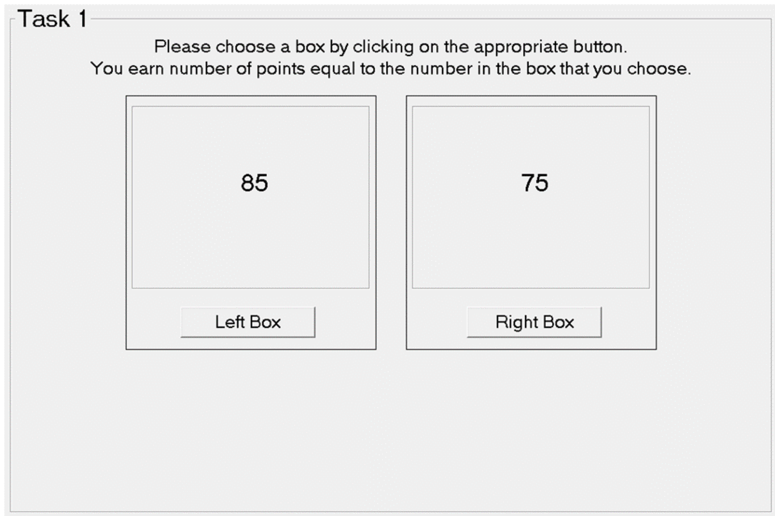

Figure 2

This screen is just an example. In the experiment the numbers in boxes may be switched.

All you have to do is to choose a box (left or right) by clicking on the appropriate button labeled either "Left" or "Right." The number inside of the box that you choose represents the number of points that you earn in this task.

TASK 2: The instructions for task 2 are exactly the same as for task 1. The only difference between tasks 1 and 2 is the numbers in the two boxes.

TASK 3:

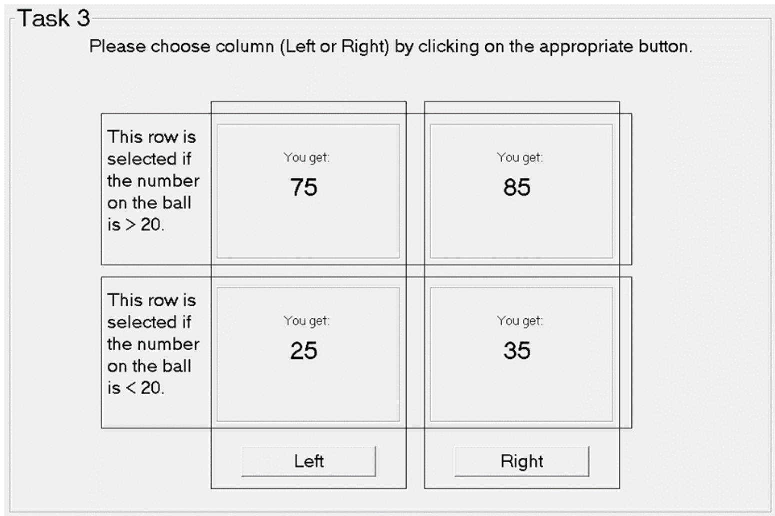

Figure 3

This screen is just an example. In the experiment the numbers in boxes may be switched.

In this task (Figure 3) you see 4 boxes. The boxes are grouped horizontally into two rows and also vertically into two columns.

You are asked to choose a column (left or right) by clicking on the appropriate button labeled either "Left" or "Right."

The number of points you earn is equal to the number in box which is

(i) inside of the column that you have selected and also

(ii) inside of the row which will be decided randomly at the end of the experiment by a draw of a single ball from a bingo cage. This is done in the following way:

The bingo cage in front of the room contains [forty] balls that are labeled with numbers between 1 and 40. No two balls have the same number. {The number of balls in the bingo cage is decided by the experimenter.} After everyone has completed the experiment one of the participants will be randomly selected to spin the bingo cage and draw a single ball. If the number on the ball is 20 then the top row is chosen. If the number on the ball is different from 20 then the bottom row is chosen.

TASK 4:

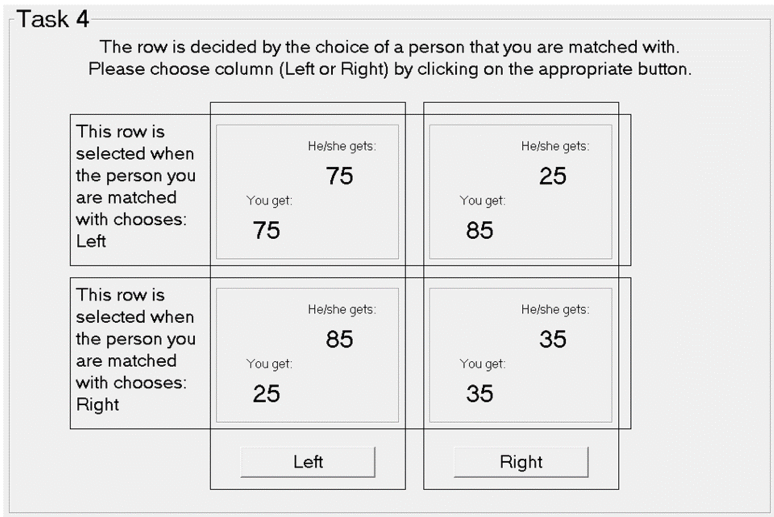

Figure 4

This task is similar to task 3. The difference is that now you are randomly matched with one other person in this room. In Figure 4 you see 4 boxes. The boxes are grouped horizontally into two rows and also vertically into two columns. Each box contains two numbers. The number labeled "You earn:" represents the number of points that you earn when that box is selected. Similarly, the number labeled "He/she earns:" represents the number of points that the person you are matched with earns when that box is selected.

Which box is selected depends on your decision as well as on the decision of the other person that you are matched with. Both you and the other person simultaneously choose a column (left or right) by clicking on the appropriate button labeled either "Left" or "Right." The box which is selected for payment lies

(i) inside of the column that you have chosen and also

(ii) it is inside of the row which depends on what the other person has done: if he/she chose left, then the top row is selected; and if he/she chose right, the bottom row is selected.

The order of tasks

In the experiment you will first complete tasks 1 and 2 but the order in which they appear is decided randomly. This means that you may encounter task 2 as first and task 1 as second. Then you complete tasks 3 and 4. Again their order is decided randomly and you may complete task 4 before you complete task 3. When everyone is finished with all four tasks you will be asked to fill out a short questionnaire. After that one randomly chosen participant will draw a ball from the bingo cage to determine which row is played in the Task 3.

Payment

When everyone is finished with the experiment the experimenter will put earnings of each student into a separate envelope and write the student's identification number on the top of the envelope. Then, one of the students in the room will be randomly selected to distribute the envelopes to everyone else in the room. To receive your earnings you will be asked to exchange the card with your identification number for the envelope which contains your earnings and has the same number written on the top of it. When you get your envelope you may leave the room.