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Working Papers

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No. 1712 | June 2011

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JEL classification: C91, D81

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Paradoxes and Mechanisms for Choice under Risk

By James C. Cox, Vjollca Sadiraj, and Ulrich Schmidt[1]

Abstract: Experiments on choice under risk typically involve multiple decisions by individual subjects. The choice of mechanism for selecting decision(s) for payoff is an essential design feature that is often driven by appeal to the isolation hypothesis or the independence axiom. We report two experiments with 710 subjects. Experiment 1 provides the first simple test of the isolation hypothesis. Experiment 2 is a crossed design with six payoff mechanisms and five lottery pairs that can elicit four paradoxes for the independence axiom and dual independence axiom. The crossed design discriminates between: (a) behavioral deviations from postulated properties of payoff mechanisms; and (b) behavioral deviations from theoretical implications of alternative decision theories. Experiment 2 provides tests of the isolation hypothesis and four paradoxes. It also provides data for tests for portfolio effect, wealth effect, reduction, adding up, and cross-task contamination. Data from Experiment 2 suggest that a new mechanism introduced herein may be less biased than random selection of one decision for payoff.

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1. INTRODUCTION

Most experiments on individual choice under risk involve multiple decisions by individual subjects and random selection of one choice for payoff. Such random selection is intended to avoid possible: (a) wealth effects from paying all choices sequentially during the experiment; and (b) portfolio effects from paying all choices at the end of the experiment. Random selection, however, also has a serious disadvantage first discussed by Holt (1986): In case that the reduction of compound lotteries axiom holds, random selection provides incentives for truthfully reporting preferences only if the independence axiom of expected utility theory is satisfied. This means that random selection is theoretically appropriate for testing expected utility theory (EU) but not for testing numerous prominent alternatives to EU such as rank-

[1] Financial support was provided by the National Science Foundation (grant number SES-0849590) and the Fritz Thyssen Stiftung. Glenn W. Harrison provided helpful comments and suggestions.

dependent utility theory (Quiggin, 1981, 1982; Luce 1991, 2000; Luce and Fishburn 1991), cumulative prospect theory (Starmer and Sugden, 1989; Tversky and Kahneman, 1992; Wakker and Tversky, 1993), or utility theories with the betweenness property (Chew, 1983; Gul, 1991). These theories – which all satisfy the reduction of compound lotteries axiom – can only be tested in modified variants by additionally assuming some kind of narrow bracketing similar to the isolation hypothesis in original prospect theory (Kahneman and Tversky, 1979).[2] In case of violations of theoretical predictions under random selection, however, one cannot discriminate between inconsistencies with (non-EU) decision theories and inconsistencies with the isolation hypothesis.

Isolation is an extreme hypothesis that supposes that a subject views each decision task independently of all other tasks in an experiment. Our Experiment 1 provides what we believe to be the first simple test of the isolation hypothesis. Experiment 1 data imply rejection of the isolation hypothesis. A "simple test" is distinguished from a joint test of a compound hypothesis consisting of the isolation hypothesis and one or more hypotheses from decision theory. Our Experiment 2 provides data that, like previous literature, support joint tests of compound hypotheses that include isolation. Data from Experiment 2 imply rejection of joint hypotheses that include isolation.

Unless isolation holds as a behavioral phenomenon, there is no generally-applicable payoff mechanism for use in conducting multi-decision experiments. In that case questions about the behavioral properties of alternative mechanisms become central to critical evaluation of experimental methods for studying alternative theories of decision under risk. We experiment with the properties of six mechanisms; some of them are commonly used, some rarely used, and two of which are new. The six mechanisms are: (i) "pay one decision randomly" at the end of the experiment; (ii) "pay all decisions sequentially" during the experiment; (iii) "pay all decisions independently" at the end of the experiment; (iv) "pay all decisions correlated" at the end of the experiment; (v) "pay 1/n (of the amount) of all decisions correlated" at the end of the experiment, where n is the number of tasks; and (vi) the "one task" design in which each subject makes only one decision (and is paid for the outcome). Mechanisms (iv) and (v) are the new ones. As we show below, they are incentive compatible if preferences satisfy the dual independence axiom (Yaari, 1987).

Use of six different payoff mechanisms with the same five lottery pairs yields insight into relative effectiveness of alternative mechanisms in solving the problems that are inherent

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[2] For comparison, note that in his Nobel Prize lecture Kahneman (2002) advocates use of between-subjects designs, in which each subject makes one choice, rather than within-subjects designs with multiple decisions. Our one task design (or "OT mechanism") implements this approach to experiments on decision under risk.

in experiments involving multiple decisions under risk. We use data from Experiment 2 to provide an empirical assessment of experimental methods including tests for the isolation effect, reduction, portfolio effect, wealth effect, and cross-task contamination.

While isolation is one extreme hypothesis, reduction of compound lotteries is an opposing extreme hypothesis that supposes that a subject views a whole experiment as one compound lottery. For Experiment 2, the reduction hypothesis implies that the proportion of risky choices in two of our lottery pairs should be the same. This implication of reduction is rejected by the data.

Another extreme hypothesis in opposition to isolation is the hypothesis that a subject would consider the whole experiment as one lottery and construct a portfolio using the choice pairs. The data are consistent with existence of a portfolio effect. Yet another extreme hypothesis in opposition to isolation is adding-up, that subjects consider all choice tasks of the experiment simultaneously and add up outcomes for each state of the world. The data are consistent with adding-up. Wealth changes during an experiment if earlier choices are paid before subsequent choices are made. This is exactly what happens with the pay all sequentially mechanism. This opens the possibility that changes in wealth can affect choices with this mechanism. The data provide support for a wealth effect.

Our data reveal that a portfolio effect and a wealth effect can occur with mechanisms that pay all decisions. Random selection of one decision for payoff was introduced to eliminate biases in risk preference elicitation experiments with multiple decisions by individual subjects. But our data reveal that random selection of one decision for payoff is not unbiased; instead, data from the treatment that uses this mechanism reveal two types of cross-task contamination.

The design of Experiment 2 "crosses" the six preference elicitation mechanisms with five pairs of lotteries that can elicit four paradoxes: the common ratio effect; the common consequence effect; the dual common ratio effect; and the dual common consequence effect. The common ratio effect and common consequence effect have been researched with many experiments testing expected utility theory. They provide direct tests of the independence axiom of that theory. In contrast, there are few if any experiments with the dual common ratio effect and dual common consequence effect that provide direct tests of the dual independence axiom. We report experiment treatments on all four of these paradoxes.

Most previous experiments with the common ratio effect (CRE) and common consequence effect (CCE) have been conducted either with hypothetical payoffs or with multiple-choice experiments in which one choice was randomly selected for money payoff.

Random selection of one out of many choices for payoff raises issues of weak incentives (Harrison, 1994) and possible cross-task contamination (section 6 below). Only one previous experiment avoided both weak incentives and all possible types of cross-task contamination by having each subject make *only one* decision that paid non-trivial money payoff (Cubitt, Starmer, and Sugden, 1998b). In their “classic test” (p. 1376), the Cubitt, et al. data do *not* show a CRE. We ask whether the finding that CRE is insignificant is robust to our experimental design and procedures.

The crossed design of our Experiment 2 provides insight into ways in which elicitations of risk preferences can be contaminated by payoff mechanisms. This approach allows us to (partly) disentangle (a) behavioral deviations from postulated properties of elicitation mechanisms from (b) behavioral deviations from theoretical implications of alternative decision theories.

The paper is organized as follows. In the next section we review some of the related literature on payoff mechanisms and experiments on paradoxes. Section 3 reports Experiment 1, the simple test of the isolation hypothesis. In section 4 we present six payoff mechanisms and relate their properties to alternative decision theories. Section 5 explains the design of Experiment 2. Section 6 summarizes hypotheses we test. The results from Experiment 2 are reported in section 7. Section 8 summarizes implications for experimental methods, paradoxes of choice under risk, and subjects’ revealed risk preferences.

2. MECHANISMS AND EXPERIMENTS ON PARADOXES

The pay one decision randomly (POR) mechanism previously has been given several names including random lottery incentive mechanism. POR is a standard procedure in much literature involving multiple decisions under risk. It gets its theoretical justification from the independence axiom of expected utility theory and is therefore theoretically justified for experiments on the common ratio effect and common consequence effect.

The literature contains a large number of papers that report experiments on theories, such as cumulative prospect theory, that do not assume the independence axiom. Many of these experiments involve multiple decisions and use POR for determining salient payoffs to the subjects. Although there is no theoretical justification for use of this payoff mechanism in such experiments, many authors invoke the isolation hypothesis to justify the procedure. Many prominent experimental studies relied upon POR (e.g. Smith, 1976; Grether and Plott, 1979; Reilly, 1982; Hey and Orme, 1994; Harrison, List, and Towe, 2007). In some studies (e.g. Camerer, 1989) subjects were allowed to change their choices after the question played out for real was determined by POR. Although this design may be fruitful in some cases, it can be used only once because initial choices become cheap talk if subjects know that there is a chance to change choices afterwards. Moreover, it should be noted that in the case of violation of independence people will possibly not change their choice even though they would have revealed a preference for the other alternative in a single-choice decision task not embedded in the POR mechanism. More precisely, only "naïve" decision makers would change their choices whereas "resolute" ones would not do so (see Machina, 1989).

In view of the above mentioned problems and our negative empirical results on isolation (reported in sections 3 and 7), it is unclear whether POR is the best of the available payment mechanisms for experiments with decisions under risk. We discuss five alternatives to POR and experiment with the properties of all six mechanisms. First we consider two new mechanisms that have not previously been discussed in the literature. In one of these mechanisms – referred to as the pay all correlated (PAC) mechanism – at the end of the experiment one state of nature is randomly drawn and then all (comonotonic) lotteries chosen in the experiment are paid out for this state of nature. We show that this mechanism is incentive compatible if the utility functional representing risk preferences is linear in payoffs, as in the dual theory of expected utility (Yaari, 1987) or linear cumulative prospect theory (Schmidt and Zank, 2009). The same is true for the PAC/n mechanism where the payoff of PAC is divided by the number of tasks (so that subjects face the same expected value of payoff incentives as in POR).

It turns out that simple tests of hypotheses that use within-subjects data can only be conducted for utility theories with functionals that are linear in probabilities (expected utility theory with POR) or linear in outcomes (dual theory or linear cumulative prospect theory with PAC and PAC/n). If utility is nonlinear in both probabilities and outcomes (e.g. rank-dependent utility theory and cumulative prospect theory), there exists no known incentive compatible mechanism for multiple-decision experiments and, hence, joint hypotheses including isolation are what are actually tested. It is, however, an empirical question which of the mechanisms, POR, PAC, or PAC/n, will minimize distortions coming from cross-task contamination when isolation fails.

There is quite some evidence that people are risk averse even for small stakes (Holt and Laury 2002, 2005; Harrison et al. 2005). A central question for decision theory is whether such risk aversion can be modeled with nonlinear utility or nonlinear probability weighting or both. Some experimental studies have reported observations of nonlinear probability weighting and some have also reported data consistent with linear utility for small stakes

(Lopes, 1995; Fox, Rogers, and Tversky, 1996; Kilka and Weber, 2001). Recent econometric analysis of risky decision data from experiments using POR yields a reported conclusion that the data are characterized by nonlinearity in both payoffs and probabilities (Harrison and Rutström, 2008). But such empirical analysis seems dissonant because: *if* (a) risk preferences are actually characterized by nonlinearity in both payoffs and probabilities *then* (b) POR is not theoretically incentive compatible for use in experiments to generate data for use in the econometric analysis. Validity of the seemingly-dissonant data analysis depends on POR being behaviorally unbiased even though it is not theoretically incentive compatible.

PAC is also not theoretically incentive compatible for experiments on theories with utility that is nonlinear in both payoffs and probabilities. But there is no theoretical basis for thinking that POR is a better mechanism than PAC for use in experiments on such theories. Our Experiment 2 produces data that can be used to compare the empirical performance of POR and PAC. Since the expected payoff of subjects is larger in PAC than in POR we also experiment with PAC/n: here subjects get the payoff of PAC divided by the number of tasks, which makes the expected payoff equal to that of POR.

Many experiments with market institutions and game theory use the pay all sequentially (PAS) mechanism in which subjects accrue changes in their earnings from the experiment after each decision is made and before undertaking the subsequent decision tasks. The main problem with PAS is the possibility of wealth effects, i.e. earnings on previous rounds may influence behavior in later rounds. However, studies using PAS in experiments with decisions under risk that tested for wealth effects reported they were insignificant (Cox and Epstein, 1989; Cox and Grether, 1996; Laury, 2006).

An obvious alternative to PAS is to pay subjects independently for each task at the end of the experiment, which we will call the pay all independently (PAI) mechanism. PAI has recently been used in experiments with role reversal in trust games that involve risks from defection (Burks, Carpenter, and Verhoogen 2003; Chaudhuri and Gangadharan, 2007). An obvious disadvantage of PAI is the possibility of portfolio effects: playing out several lotteries independently and paying subjects for all of them reduces the risk involved in the single lotteries and, thus, should induce less risk averse behavior. Laury (2006) did not find a significant difference between PAI and POR for the same payoff scale.

An alternative protocol that eliminates all potential distortions of risk preferences by the payoff mechanism is to ask each subject to make only one decision. Use of this one task (OT) "mechanism" requires that hypothesis tests be conducted with a between-subjects approach. Data from Experiment 2 reported below allow us to compare the implications of between-subjects tests of hypotheses using data elicited with OT with implications of both between-subjects and within-subjects tests of hypotheses using data elicited with POR, PAC, PAC/n, PAI, and PAS.

There is previous literature that addresses some of our questions. Cubitt, Starmer, and Sugden (1998b) investigate whether OT yields different risk preferences than POR in a treatment with pre-commitment. This joint test for isolation implies rejection at 10% but not at 5% significance. Cubitt, et al. (1998b) also report a test for ("classic") CRE using OT data that is insignificant; that is, CRE is not observed. Three other studies compare an impure form of OT to POR. Starmer and Sugden (1991), Beattie and Loomes (1997), and Cubitt, Starmer, and Sugden (1998a, 2001) integrated OT into a series of hypothetical choices, i.e. there were first hypothetical choice questions and at the end of the experiment one question appeared which was played out for real. This procedure could be behaviorally unbiased; however if cross-task contamination effects exist (see section 6 below) then hypothetical questions may also contaminate the responses to the real question. Along with many treatments with hypothetical payoffs, Conlisk (1989) also reported a pilot experiment with hypothetical practice rounds followed by one choice task with real payoffs. He reported Allais paradox behavior for the hypothetical treatments but that, with the real payoff OT choices, "Allais behavior disappeared" (Conlisk, 1989, p. 401).

Other studies focus on whether experiments with POR generate data that are significantly different from data generated from PAS or PAI. Laury (2006) reports a payoff scale effect but for small payoffs no significant differences between POR data and PAI data. Lee (2008) looks at PAS versus POR and concludes that POR does better than PAS in controlling for wealth effects. Isolation under PAS implies myopic behavior, which has previously been reported in experimental studies (Thaler et al., 1997; Gneezy and Potters, 1997; Gneezy, et al., 2003; Haigh and List, 2005; Langer and Weber 2005; Bellemare et al., 2005; Fellner and Sutter, 2008).[3]

3. EXPERIMENT 1: A SIMPLE TEST OF THE ISOLATION HYPOTHESIS

As explained above, consideration of alternative mechanisms becomes central if the isolation hypothesis fails in simple tests. In this section we report (what we believe to be) the first *simple* test of the isolation hypothesis.

[3] For studies analyzing the POR or analogous mechanisms in other fields than risky decision making see Bolle (1990), Sefton (1992), Harrison, Lau, and Williams (2002), Stahl and Haruvy (2006), and Armantier (2006).

3.1 *Experimental Design*

In this experiment 284 subjects were randomly assigned to five groups, referred to below as Groups 1, 2.1, 2.2, 3.1, and 3.2. Payoffs in this experiment were in Euros. The choice options received by all groups are reported in Table 1. No group of subjects was shown Table 1; instead, they were given only their own decision tasks as follows. Group 1 subjects had a one-stage decision task in which they were asked to choose either Option A or Option B. Group 2.1 subjects had a two-stage decision task in which they were asked to choose between Options C and D in the first stage and between Options A and B in the second stage. Group 3.1 subjects were asked to choose between Options E and F in the first stage and between Options A and B in the second stage. Groups 2.2 and 3.2 differed from Groups 2.1 and 3.1, respectively, only by the order in which the choices were presented, i.e. the choice between Options A and B was presented in the first stage for Groups 2.2 and 3.2.

Table 1. Experiment 1 Lotteries

	Group 1	Group 2.1	Group 3.1
First Stage	Option A: 4 € with 100% Option B: 10 € with 50% 0 € with 50%	Option C: 3 € with 100% Option D: 12 € with 50% 0 € with 50%	Option E: 5 € with 100% Option F: 8 € with 50% 0 € with 50%
Second Stage	none	Option A: 4 € with 100% Option B: 10 € with 50% 0 € with 50%	Option A: 4 € with 100% Option B: 10 € with 50% 0 € with 50%

Group 1 is an OT treatment where subjects had to just choose between Options A and B. They were told that each subject would receive the payoff from their chosen option in cash directly after the experiment and that, if they chose Option B, their payoff would be determined by a coin flip. In Groups 2.1, 2.2, 3.1, and 3.2 there were two choice tasks and a POR mechanism was employed, i.e. there was a first coin flip which determined whether the first or the second choice problem was played out for real and a second coin flip which determined the payoff if one of the risky options (B, D, or F) was chosen. In all groups the top or bottom position of the two payoffs of a first stage lottery and the two payoffs of a second stage lottery (if not Group 1) was randomly determined for individual subjects.

The aim of the Group 1 treatment is to elicit true preferences of subjects between Options A and B in that an OT design played out for real offers perfect incentives to state true preferences (see Cubitt et al., 2001). The Group 2 and Group 3 treatments elicit preferences between Options A and B which could however be biased as the design here involves an additional choice problem. In Groups 2.1 and 2.2 the safe option of the additional choice problem (Option C) is dominated by Option A whereas the risky one (Option D) dominates Option B. The opposite is true in Groups 3.1 and 3.2. If the isolation hypothesis holds, the proportion of subjects choosing Option A should be the same in Groups 1, 2, and 3. If isolation is violated, the additional choice problem in Groups 2 and 3 may influence the choice between Options A and B. Recall that Option A dominates Option C whereas Option B is dominated by Option D in the Group 2 treatment. Analogous to the evidence of asymmetrically dominated alternatives in context-dependent choice experiments (see e.g. Huber et al., 1982; Simonson and Tversky, 1992; Hsee and Lecrerc, 1998; Bhargava et al., 2000), this could increase attractiveness of Option A and decrease attractiveness of Option B, leading to a higher proportion of A choices compared to Group 1.[4]

Experiment 1 was run at the University of Kiel. In each group subjects received one page of paper which contained instructions and all tasks; details are shown in Appendix 2. The way in which lotteries were presented to the subjects is illustrated in Figure 1, using one of the lottery pairs as an example.

Which of the following options do you choose?	
Option A:	*Option B:*
4 Euro with probability 100%	*10 Euro with probability 50%*
	0 Euro with probability 50%

Figure 1. Presentation of Lotteries in Experiment 1

3.2 *Results*

The results of Experiment 1 are presented in Table 2, which shows for all groups and both choices (when applicable) the percentage of subjects who chose the risky lottery. First, we can see that in Group 2 almost all subjects chose Option D. In Group 3, as expected, very few subjects chose Option F. While 82.8% of subjects chose Option B in Group 1, this

Table 2. Results from Experiment 1

Group	1	2.1	2.2	3.1	3.2
N	58	54	54	62	56
% Choice of B	82.8	51.9**	59.3**	80.6	78.6

[4] The opposite could be expected for Group 3 as here Option A is dominated by Option E whereas Option B dominates Option F.

% Choice of D (F)	88.9	96.3	12.9	3.6*

percentage decreases to 51.9% and 59.3% in Groups 2.1 and 2.2, respectively. Both differences are significant at the 1%-level (1-sided test according to the statistic of Conlisk, 1989). As expected, Option A turns out to be more attractive (Option B less attractive) in Group 2 than in Group 1, leading to a significant violation of isolation and, therefore, to a failure of the POR mechanism to elicit true preferences.

There are order effects in Groups 2.1 and 2.2 as well as Groups 3.1 and 3.2 which are all in the expected direction. However, only one of these effects (the difference between choice of F in Groups 3.1 and 3.2) is significant at the 5% level. The relatively small order effects can be explained by the fact that all alternatives were presented prior to elicitation of any responses from the subjects.

We conclude from this experiment that isolation can be significantly violated. This questions the suitability of using POR for testing theories that do not include the independence axiom. Hence it may be fruitful to consider alternative mechanisms and explore their properties.

4. THEORETICAL PROPERTIES OF MECHANISMS

For convenience, we restrict attention to experiments involving binary choices between lotteries. Lotteries will often be represented by $(X_1, p_1; \ldots; X_m, p_m)$, indicating that outcome X_s is obtained with probability p_s, for $s = 1,2, \ldots, m$. Outcome X_s can be a monetary amount or a lottery. Consider experiments that include n questions in which the subject has to choose between options A_i and B_i, for $i = 1,\ldots,n$. The choice of the subject in question i will be denoted by C_i.

4.1 *The Pay One Randomly (POR) Mechanism*

Here each question usually has a 1/n chance of being played out for real. Suppose a subject has made all her choices apart from question i. Then her choice between A_i and B_i determines whether she will receive $(1/n)A_i + (1-1/n)C$ or $(1/n)B_i + (1-1/n)C$, where $C = (C_1, 1/(n-1); \ldots; C_{i-1}, 1/(n-1); C_{i+1}, 1/(n-1); \ldots; C_n, 1/(n-1))$ is the lottery for which the subject receives all her previous choices with equal probability 1/(n-1). Consequently, a subject whose preferences satisfy the independence axiom has an incentive to reveal her preferences truthfully because under that axiom $A_i \succ B_i$ if and only if $(1/n)A_i + (1-1/n)C \succ (1/n)B_i + (1-1/n)C$.

The above result, discussed by Holt (1986), shows that POR is not appropriate for testing alternatives to expected utility theory (which do not include the independence axiom) if subjects consider all choice problems simultaneously and employ the reduction of compound lotteries axiom. A simple example – referred to as Example 1 in the subsequent analysis – illustrates this for rank dependent utility theory. Consider a rank dependent expected utility maximizer with utility function u(x) = $\sqrt{x}$ and f(p) = $p^{0.9}$ choosing between Option A ($30 for sure) and Option B (a coin-flip between $100 and $0); she would choose Option A. Now suppose that the choice task would be offered twice. Under POR and the reduction of compound lotteries axiom, Option A would be chosen in one task and Option B would be chosen in the other task because the resulting lottery ($100, 0.25; $30, 0.5; $0, 0.25) has a higher utility than $30 for sure. It has been argued that it is quite unlikely that subjects behave according to this reduction hypothesis as it requires too much mental effort. The opposite extreme is the isolation hypothesis: here, subjects evaluate each choice problem independently of the other choice problems in the experiment. Under this isolation hypothesis, POR is incentive compatible also for preferences violating the independence axiom. In between these two extremes is the hypothesis of cross-task contamination where responses to one choice problem may be influenced by the other choice problems in an experiment but not to such an extent as the reduction hypothesis would imply. A psychological foundation for such contamination effects is range-frequency theory (Parducci, 1965). As in the case of reduction, POR is not incentive compatible for non-expected utility preferences if contamination effects exist. In the following we will discuss four incentive mechanisms where, unlike POR, all chosen options are played out for real.

4.2 *The Pay All Independently (PAI) Mechanism*

In the PAI mechanism, at the end of the experiment all tasks are played out independently which seems to be the most obvious alternative to POR. However, PAI has a serious problem, well known as portfolio effect in the finance literature: the risk of a mixture of two independent random variables is less than the risk of each variable in isolation. Due to this risk reduction effect, PAI is incentive compatible only in the case of risk neutrality. To illustrate this fact consider again Example 1 in the previous section. An expected utility maximizer with utility function u(x) = $\sqrt{x}$ prefers Option A ($30 for sure) to Option B (a coin-flip between $100 and $0). Obviously she would choose Option A. Now suppose that the choice would be presented twice. Under POR, she would respond truthfully by choosing Option A both times whereas under PAI Option B would be chosen both times since the resulting lottery (\$200, 0.25; \$100, 0.5; \$0, 0.25) has a higher utility than \$60 for sure. So, POR is superior to PAI for theories that assume the independence axiom. However, as illustrated in the previous section, POR might not be incentive compatible if the independence axiom is violated; therefore POR is not necessarily superior to PAI. Assuming isolation, revealed preferences with the PAI and POR mechanisms should be the same.

4.3 *The Pay All Sequentially (PAS) Mechanism*

The PAS mechanism could be superior to PAI if portfolio diversification effects significantly distort single choice preference revelation. However, it is easy to see that PAS is not incentive compatible in the case of expected utility of terminal wealth. If we would play the lotteries of Example 1 under PAS two times, the optimal strategy for the given utility function would be to choose Option B in the first choice and Option B (resp. Option A) in the second choice if the outcome of the first choice was 100 (resp. 0). Things could be different, however, if we assume expected utility of income, linear utility, or reference dependent preferences for which the reference point adjusts immediately after paying out the first choice (this case will be referred to as utility of income model). In all these cases the second choice is independent of the payoff received from the first choice. But is this sufficient to yield incentive compatibility? Consider again the choice between Option A and Option B as in Example 1 and a second choice between Option B and \$1 for sure. Assume that the utility function is the same as in Example 1 but now defined on gains and losses relative to a reference point equal to 0 such that $A \succ B \succ \$1$. Since it is clear that Option B is chosen in the second choice, the first choice in terms of gains and losses at the end of the experiment would yield (130, 0.5; 30, 0.5) if Option A is chosen and (200, 0.25; 100, 0.5; 0, 0.25) if Option B is chosen. Since the latter alternative has the higher utility, PAS would not elicit true preferences. However, since each choice is paid out directly, assuming isolation seems to be particularly intuitive in the case of PAS. Isolation under PAS would imply myopic behavior, as for instance discussed in the literature on myopic loss aversion (Benartzi and Thaler, 1995).

4.4 *The Pay All Correlated (PAC) and PAC/n Mechanisms*

If the independence axiom is violated, the mechanisms discussed above incentivize revelation of true preferences only under additional assumptions such as narrow bracketing. In contrast, the preference revelation properties of PAC and PAC/n depend on the *dual* independence axiom. With these mechanisms, preferences are revealed truthfully if dual independence is satisfied, otherwise additional assumptions are required.

For the PAC and PAC/n mechanism, states of the world need to be defined (e.g. tickets numbered from 1 to 100) and all lotteries need to be arranged in the same order such that they are comonotonic. More formally, there are m states indexed by s = 1, 2, …, m and lotteries are identified by $A_i = (a_{i1}, p_1; \ldots; a_{im}, p_m)$ and $B_i = (b_{i1}, p_1; \ldots; b_{im}, p_m)$ where a_{is} (b_{is}) is the outcome of lottery A_i (B_i) in state s and p_s is probability of that state. We arrange lotteries such that $a_{is} \geq a_{is+1}$ and $b_{is} \geq b_{is+1}$ for all s = 1, …, m-1 and all i = 1, …, n. At the end of the experiment one state is randomly drawn and the outcomes of all choices in this state are paid out under PAC. Suppose as above that a subject made all choices apart from choice i. Then her choice between A_i and B_i will determine whether she will receive either $A_i^* = (a_{i1} + \sum_{j\neq i}c_{j1}, p_1; \ldots; a_{im} + \sum_{j\neq i}c_{jm}, p_m)$ or $B_i^* = (b_{i1} + \sum_{j\neq i}c_{j1}, p_1; \ldots; b_{im} + \sum_{j\neq i}c_{jm}, p_m)$ as reward before the state of nature is determined. This shows that PAC is incentive compatible under Yaari´s (1987) dual theory; a subject whose preferences satisfy the dual independence axiom has an incentive to reveal her preferences truthfully because under that axiom $A_i \succ B_i$ if and only if $A_i^* \succ B_i^*$. Moreover, if lotteries are cosigned – i.e. the outcomes in a given state are all gains or all losses – PAC is also incentive compatible under linear cumulative prospect theory (Schmidt and Zank, 2009) since in this case the independence condition of that model has the same implications as the dual independence axiom.

When we wish to compare PAC with POR we have to keep in mind that the expected total payoff from the experiment is n times higher under PAC. This may have significant effects on behavior. In particular one can expect lower error rates under PAC as wrong decisions are more costly (see Laury and Holt, 2008). Therefore, we also include PAC/n in our experimental study where the payoff of PAC is divided by the number of tasks. PAC/n has the same theoretical properties as PAC and is incentive compatible under the dual theory and linear cumulative prospect theory.

4.5 *The One Task (OT) Mechanism*

So far we can conclude that payment mechanisms for binary choice are incentive compatible only under narrow bracketing or if utility is linear in probabilities or in outcomes. This is not true for the OT mechanism. In this mechanism each subject has to respond to only one choice problem which is played out for real. Besides being rather costly, this mechanism has one obvious disadvantage in the context of decision making under risk: since a test of independence conditions requires at least two binary choice questions, OT allows only for between-subjects tests of these conditions. OT is nevertheless very interesting because it is the only mechanism that is always (i.e. for all possible preferences) incentive compatible. Given this fact it is somewhat surprising that OT in its pure form has been used to test the independence axiom in only one study (Cubitt, Starmer, and Sugden, 1998b).

4.6 *Summary of Incentive Compatibility Conditions*

Table 3 gives an overview of the discussion in the present section. Under our definition of isolation all mechanisms are incentive compatible. If isolation does not hold, POR or PAC (and PAC/n) are incentive compatible if the relevant independence condition holds.

Table 3. Incentive Compatibility of Payoff Mechanisms

Preference condition	**Incentive compatible mechanisms**
All preferences	OT
Independence	OT, POR
Dual independence	OT, PAC, PAC/n
Isolation	OT, POR, PAI, PAS, PAC, PAC/n

5. DESIGN OF EXPERIMENT 2

5.1 *Lottery Pairs*

Experiment 2 includes the five lottery pairs that are presented in Table 4. Payoffs in Experiment 2 are in dollars. Each lottery pair consists of a relatively safe and a relatively risky lottery. There is a bingo cage with twenty numbered balls out of which one ball is drawn in the presence of the subjects to determine the payoff of a lottery. The five lottery pairs contain a common ratio effect (CRE, Pairs 2 and 3), a common consequence effect (CCE, Pairs 3 and 4), a dual common ratio effect (DCRE, Pairs 1 and 3), a dual common consequence effect (DCCE, Pairs 2 and 5), a dominated pair (Pair 1), and a dominating pair (Pair 5).

A CRE consists of two lottery pairs where the lotteries in the second pair (Pair 3 in our design) are constructed from the lotteries in the first pair (Pair 2 here) by multiplying all probabilities by a common factor (1/4 in our study) and assigning the remaining probability to a common outcome (in our study $0). It is easy to see that according to EU either the safe lottery should be chosen in both pairs or the risky lottery should be chosen in both pairs. Many empirical studies report evidence that subjects tend to violate the independence axiom of EU in CREs by choosing the safe lottery in the high EV pair (Pair 2 in our study) but the risky lottery in the low EV pair. A prominent explanation of this effect is the fanning out hypothesis (Machina, 1982) which states that the degree of risk aversion is increasing with the attractiveness of lotteries (measured in terms of stochastic dominance).

Table 4. Experiment 2 Lottery Pairs

Pair	Safe		Risky		
1	Balls 1-15	Balls 16-20	Balls 1-16	Balls 17-20	
	\$0	\$3	\$0	\$5	
2	Balls 1-20		Balls 1-4	Balls 5-20	
	\$6		\$0	\$10	
3	Balls 1-15	Balls 16-20	Balls 1-16	Balls 17-20	
	\$0	\$6	\$0	\$10	
4	Balls 1-5	Balls 6-20	Ball 1	Balls 2-5	Balls 6-20
	\$6	\$12	\$0	\$10	\$12
5	Balls 1-20		Balls 1-4	Balls 5-20	
	\$18		\$12	\$22	

A CCE consists of two lottery pairs. Here, the lotteries in the second pair (Pair 4 in our design) are constructed from the lotteries in the first pair (Pair 3 here) by shifting probability mass (75% in our study) from one common outcome (\$0 in our study) to a different common outcome (\$12 in our study). EU again implies that the subjects will either choose the safe lottery in both pairs or the risky lottery in both pairs. While the empirical evidence against EU reported in studies relying on CCEs is as extensive as for CREs the direction of violations is less clear cut. Some studies involving a sure outcome mostly reported violations in the direction of fanning out which means in our example choosing the risky lottery in Pair 3 and the safe one in Pair 4. There exist, however, also several studies observing the majority of violations in the opposite direction (termed fanning in): see Conlisk (1989), Prelec (1990), Camerer (1992), Wu and Gonzalez (1998), Birnbaum (2004), Birnbaum and Schmidt (2010), and Schmidt and Trautman (2010).

DCRE and DCCE play the same role for dual theory of expected utility (Yaari, 1987) as CRE and CCE for EU. As utility is linear under dual theory, it exhibits constant absolute and constant relative risk aversion. Consequently, neither multiplying all outcomes in a lottery pair by a constant (DCRE, see Pairs 1 and 3 where the constant equals 2) nor adding a constant to all outcomes in a lottery pair (DCCE, see Pairs 2 and 5 where the constant equals \$12) should change preferences. Yaari (1987) stated that the dual paradoxes could be used to refute his theory analogously to the way in which CRE and CCE had been used to refute EU. As far as we know, however, the dual paradoxes have never been investigated in a systematic empirical test with a theoretically correct incentive mechanism.

5.2 *Protocol*

Experiment 2 was run in the laboratory of the Experimental Economics Center at Georgia State University. Subjects in groups OT_i, i = 1, 2, …, 5, just had to perform one binary choice between the lotteries of Pair i which was played out for real. Subjects in other (payoff-mechanism) treatments saw all five lottery pairs in advance on five separate, randomly-ordered (small) sheets of paper. Each subject could display his or her five sheets of paper in any way desired on his or her private decision table. Subjects entered their decisions in computers. In all treatments, including OT, the top or bottom positioning of the two lotteries in any pair was randomized by the decision software. In all treatments other than OT, the five lottery pairs were presented to individual subjects by the decision software in randomly-drawn orders.

Subjects in group POR had to make choices for all five lottery pairs and at the end one pair was randomly selected (by drawing a ball from a bingo cage) and the chosen lottery in that pair was played out for real (by drawing a ball from another bingo cage). Also in groups PAI, PAC, PAC/5, and PAS subjects had to make choices for all five pairs but here the choice from each pair was played out for real by drawing ball(s) from a bingo cage. In group PAI the five choices were played out independently at the end of the experiment whereas in groups PAC and PAC/n the five choices were played out correlated at the end of the experiment (i.e. one ball was drawn from the bingo cage which determined the payoff of all five choices). In group PAS the chosen lotteries were played immediately after each choice was made (by drawing a ball from a bingo cage after each decision).

Before any ball was drawn from a bingo cage, subjects were permitted to inspect the cage and the balls. Each ball drawn from a bingo cage was done in the presence of the subjects. Lotteries were presented in a format illustrated by the example in Figure 2 which shows one of the two ways in which the lotteries of Pair 4 were presented to subjects. As explained above, some subjects would see the Pair 4 lotteries as shown in Figure 2 while others would see them presented with inversed top and bottom positioning and reversed A and B labeling.

Ball nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Option A	$6					$12														
Option B	$0	$10				$12														

Figure 2. Presentation of Lotteries in Experiment 2

Altogether, 426 subjects participated in Experiment 2. In treatment OT, 231 subjects each made a single choice. In each of the other treatments, 38 - 40 subjects each made five choices. No subject participated in more than one treatment. Subject instructions for Experiment 2 are contained in Appendix 3.[5]

6. HYPOTHESES

6.1 *Risk Preferences Hypotheses*

We presuppose that the OT groups elicit true preferences whereas choices in the other groups could be biased by the incentive mechanism. First we can use the responses of the OT groups to analyze behavior with respect to CRE and CCE. The null hypothesis that follows from the independence axiom is that the proportion of choices of the risky option in Pair 3 should be the same as the proportions of choices of the risky options in Pairs 2 and 4. An alternative hypothesis that follows from fanning out (Machina, 1982) is:

Hypothesis 1 (fanning out): The proportion of choices of the risky option is higher in group OT_3 than in OT_2 (CRE) and also higher in group OT_3 than in OT_4 (CCE).

All payoff amounts in Pair 3 are two times corresponding payoff amounts in Pair 1. All payoff amounts in Pair 5 are $12 higher than corresponding payoffs in Pair 2. Responses of the OT groups can be used to analyze behavior with respect to DCRE and DCCE. The null hypothesis that follows from the dual independence axiom (which implies linearity in payoffs) is that the proportion of choices of the risky option should be: (a) the same in Pairs 1 and 3; and (b) the same in Pairs 2 and 5. The null hypothesis of choices in Pairs 1 and 3 coming from the same distribution also follows from a power function for payoffs, with or without linearity in probabilities. On the other hand, the null hypothesis of choices in Pairs 2

[5] An individual subject was given only the instructions for the treatment he or she was participating in, not the several pages of instructions for all treatments shown together in Appendix 3.

and 5 revealing the same distribution is consistent with an exponential function for payoffs. Alternative hypotheses are that choices correspond to DRRA or DARA.

Hypothesis 2 (DRRA): The proportion of choices of the risky option is higher in group OT_3 *than in* OT_1.

Hypothesis 3 (DARA): The proportion of choices of the risky option is higher in group OT_5 *than in* OT_2.

6.2 *Elicitation Mechanism Hypotheses*

We now compare data from the OT treatment to data from five multi-decision treatments. The first hypothesis in this context is isolation. If isolation holds, subjects tackle each choice task independently of the other choice tasks. In that case, data from all treatments should reveal the same distribution and thus conform to the following null hypothesis.

Hypothesis 4 (isolation): For each lottery pair the proportion of choices of the risky option is the same in treatments OT, POR, PAI, PAS, PAC, and PAC/n.

Isolation is one extreme hypothesis. In the following we consider some other hypotheses that are important to assessing the empirical properties of payoff mechanisms when isolation does not hold in general. Let us first consider POR, which in the absence of isolation is incentive compatible only for testing expected utility theory. Suppose that subjects treat the whole experiment as a compound lottery and obey the reduction of compound lotteries axiom. It can be easily shown that choosing the risky option in Pair 3 and the safe option in Pair 4 leads to the same reduced lottery as choosing the safe option in Pair 3 and the risky option in Pair 4 (see Starmer and Sugden, 1991). Let S_i denote choice of the safe option in pair i and R_j choice of the risky option in pair j. Under the reduction hypothesis the proportion of choices of (S_3,R_4) should not differ from the proportion of choices of (R_3,S_4) even if the proportions of sure choices in Pairs 3 and 4 differ according to true preferences in the OT groups (i.e., EU is violated). Thus, we have the following null hypothesis that follows from the reduction of compound lotteries axiom.

Hypothesis 5 (reduction): In the POR treatment, the proportions of patterns (R_3,S_4) *and* (S_3,R_4) *are the same.*

Let us now consider treatment PAI. Since the five chosen lotteries are played out independently it is possible for a subject to construct a risk-reducing portfolio. In an extreme case analogous to reduction, the subject would consider the whole experiment as one lottery and construct an optimal portfolio from all five choices. Now consider Pairs 2 and 5. It is easily verified that choosing the safe option in Pair 2 and the risky option in Pair 5 leads to the same portfolio as choosing the risky option in Pair 2 and the safe option in Pair 5 (both cases lead to a portfolio where you win $18 for balls 1-4 and $28 otherwise). This implies similar proportions of patterns (R_2,S_5) and (S_2,R_5) even if the proportions of risky choices in Pairs 2 and 5 differ according to true preferences in the OT groups (i.e., DCCE is violated). Therefore, if subjects indeed form a portfolio of options then choices should conform to the following null hypothesis.

Hypothesis 6 (portfolio effect): In the PAI treatment the proportions of patterns (R_2,S_5) and (S_2,R_5) are the same.

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Possible portfolio effects from paying all decisions at the end of an experiment is one of the cross-task contaminations that POR is designed to avoid. An important empirical question for experimental methods is whether POR actually does avoid portfolio effects in multi-decision experiments. If subjects reveal similar proportions of *(R_2,S_5) and (S_2,R_5)* in choices with POR but different proportions of safe choices in Pairs 2 and 5 with OT then the data would be consistent with type 1 cross-task contamination with POR.

Hypothesis 7 (type 1 cross-task contamination): In the POR treatment the proportions of patterns (R_2, S_5) and (S_2, R_5) are the same when the proportions of safe choices in Pairs 2 and 5 *are different in the OT treatment.*

Type 1 cross-task contamination by POR is narrowly defined and specific to lottery Pairs 2 and 5. In contrast, type 2 cross-task contamination reflects the straightforward view that if POR is unbiased then it should elicit the same preferences for safe vs. risky lotteries as does OT. Hypothesis 8 addresses type 2 contamination.

Hypothesis 8 (type 2 cross-task contamination): In the POR treatment the proportions of choices of the risky options are the same as in the OT treatment.

The new mechanism, PAC is incentive compatible for utility that is linear in outcomes, i.e. DEU, the model of Yaari (1987), and since we only have gains as outcomes, also for linear cumulative prospect theory (Schmidt and Zank, 2009). Suppose now that utility is not linear as we can infer from responses to DCRE and DCCE in the OT groups (see Hypotheses 2 and 3). In the extreme case, subjects could again consider all choice tasks of the experiment simultaneously and add up outcomes for each state of the world. In this case choosing the safe option in Pair 2 and the risky option in Pair 5 leads to the same state-dependent sums of payoffs as choosing the risky option in Pair 2 and the safe option in Pair 5. Similarly to the above (in case of the reduction and portfolio hypotheses), this implies similar proportions of patterns (R_2,S_5) and (S_2,R_5) even if the proportions of safe option choices in Pairs 2 and 5 differ according to true preferences in the OT groups (i.e., DCCE is violated). .

Hypothesis 9 (adding-up): In the PAC and PAC/n treatments the proportions of patterns (R_2,S_5) and (S_2,R_5) are the same.

Finally, recall that in PAS subjects accrue earnings between decisions during the experiment and that different subjects face different randomly-generated orders of lottery pairs across rounds. If there is a wealth effect on risk preferences, subjects' payoffs between rounds are expected to induce less risk averse behavior (given DARA).

Hypothesis 10 (wealth effect): The proportion of choices of safe options is lower in the PAS treatment than in the OT treatment.

7. RESULTS

A first overview of our results can be taken from the left panel in Table 5 which presents for each choice problem i (=1,…,5) and each elicitation mechanism the percentage of subjects who chose the less risky (or "safe") lottery denoted by S_i. There are some striking differences across mechanisms. For example, only 15.5% of subjects chose S_2 with OT whereas 50%, 52.6%, and 52.6% of choices were S_2 with POR, PAC, and PAI respectively. With OT, 28.95% and 38.5% of choices were S_4 and S_5 whereas the S_4 and S_5 choice figures were 10.26% and 17.95% with PAS. Figures for the root mean-squared deviations between figures in rows 2-6 and row 1 (the OT row) in Table 5 are: 18.6, 10.2, 17.2, 14.5, and 18.4 for POR, PAC/5, PAC, PAS, and PAI respectively. PAC/5 has the smallest root mean-squared error whereas POR has the largest one (which is 1.8 times the figure for PAC/5).[6] By this measure, PAC/5 introduces less bias in risk preference elicitation than POR (or any of the other mechanisms). Statistical tests of differences among risk preferences elicited by the six mechanisms are presented below in tests of the isolation hypothesis.

Table 5. Between-Subjects Data Analysis*

	Observed frequencies (in %) of the less risky option across pairs					Two-sample test of proportions: z-value (p-value) $H_0 : S_i - S_j = 0; \quad i, j \in \{1,...,5\}$			
	S_1	S_2	S_3	S_4	S_5	CRE	CCE	DCRE	DCCE
OT	39.47	15.52	27.59	28.95	38.46	**-1.581 (0.114)**	**-0.257 (0.798)**	**1.221 (0.222)**	**-2.843*** (0.005)**
POR	27.50	50.00	42.50	22.50	50.00	**0.673 (0.501)**	**1.910* (0.056)**	-1.406 (0.160)	0.000 (1.000)
PAC/5	37.50	35.00	35.00	22.50	45.00	0.000 (1.000)	1.235 (0.217)	**0.233 (0.816)**	**-0.913 (0.361)**
PAC	36.84	52.63	23.68	21.05	42.11	2.598*** (0.009)	0.275 (0.783)	**1.249 (0.212)**	**0.919 (0.358)**
PAS	25.64	23.08	33.33	10.26	17.95	-1.007 (0.314)	2.468** (0.014)	-0.745 (0.456)	0.561 (0.575)
PAI	36.84	52.63	36.84	34.21	52.63	1.384 (0.166)	0.240 (0.811)	0.000 (1.000)	0.000 (1.000)

* Bold entries denote results for theoretically "correct" mechanisms. P-values are in parentheses

We next report results concerning the paradoxes for expected utility theory (CRE and CCE) and dual theory of expected utility (DCRE and DCCE). After that we report tests of hypotheses on risk preferences and elicitation mechanisms.

7.1 *Tests for Paradoxes*

The right panel of Table 5 presents tests for the four paradoxes on a between-subjects basis. The reported tests use the statistics of Conlisk (1989) unless otherwise indicated.[7] These test results are discussed along with across-subjects test results in the following subsections.

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[6] Let $s_t(i)$ be the percentage of the safer choices in treatment t and task i; then the root mean squared error is

$$d(t, OT) = \sqrt{\frac{1}{5}\sum_{i=1..5}(s_t(i) - s_{ot}(i))^2}, t \in \{POR, PAC/5, PAC, PAS, PAI\}.$$

[7] P-values reported by Fisher's exact tests are consistent with the ones reported by proportion tests (shown in Table 5.)

7.1.a *Tests for a Common Ratio Effect (CRE)*

The first test of the independence axiom of EU involves two pairs of binary lottery choices that preserve all payoffs and the ratio of the probabilities of the outcomes. In our experiment design, Pairs 2 and 3 have these properties. Using notation S and R for the less risky and the riskier lotteries within a pair, EU predicts only patterns SS and RR for choice in Pairs 2 and 3.

The CRE is a paradox for EU theory, so we focus on data from the OT (one task) and POR (many-tasks, pay one randomly at the end) treatments, which are the theoretically-correct elicitation mechanisms for EU. Results from between-subjects tests are reported in Table 5. Recall that the fanning-out hypothesis predicts the safer option will be chosen less often in Pair 3 than in Pair 2. In the OT treatment the safe option is observed in 15.52% (9 subjects out of a total of 58 subjects) of choices in Pair 2 and 27.59% (16 subjects out of a total of 58 subjects) of choices in Pair 3. Figures for the safer option in the POR treatment are 50% and 42.5%, respectively, in Pairs 2 and 3. The null hypothesis of lottery choices in Pairs 2 and 3 being drawn from the same distribution is not rejected for OT data (two-sided p-value is 0.114) nor for POR data (two-sided p-value is 0.501).

Figures for within-subjects data are reported in Table 6; these figures are the total number of subjects for each multi-choice treatment and the percentages of subjects who chose all relevant choice patterns. From previous literature, we expect to observe more SR pattern than any other pattern. This is not what we observe. The percentages of subjects whose choices exhibit S_2S_3, R_2R_3, R_2S_3 and S_2R_3 patterns are 27.5, 35.0, 15.0 and 22.5 in the POR treatment. Hence, 62.5% of the subjects in the POR treatment made choices consistent with EU (i.e. S_2S_3 and R_2R_3). In addition, the difference between the frequencies of the S_2R_3 and

Table 6. Within-Subjects Data Patterns (in %) for EU Paradox Tests

Treatment	nobs	Common Ratio				Common Consequence			
		S_2S_3	R_2R_3	R_2S_3	S_2R_3	S_3S_4	R_3R_4	R_3S_4	S_3R_4
POR	40	27.50	35.00	15.00	22.50	10.00	45.00	12.50	32.50
PAC/5	40	10.00	40.00	25.00	25.00	17.50	60.00	5.00	17.50
PAC	38	15.79	39.47	7.89	36.84	5.26	60.53	15.79	18.42
PAS	39	10.26	53.85	23.08	12.82	7.69	64.10	2.56	25.64
PAI	38	28.95	39.47	7.89	23.68	15.79	44.74	18.42	21.05

R_2S_3 patterns is not significant; the p-value is 0.446 as shown in Table A1 in Appendix 1 (the right-most column, first POR row). We conclude that the common ratio implication of EU theory is not rejected by the OT treatment data nor by the POR treatment data.

7.1.b *Tests for a Common Consequence Effect (CCE)*

The second test of the independence axiom of EU involves two pairs of binary lottery choices that differ only with respect to a common consequence. Lotteries in Pair 3 differ from lotteries in Pair 4 with respect to a common consequence: a payoff of $12 with likelihood 3/4 replaces $0 in both lotteries.

The CCE is a paradox for EU theory, so here we focus again on OT and POR treatments. Results from between-subjects tests are reported in Table 5. In the OT and POR treatments the safer option is observed in 27.59% and 42.50% of the choices in Pair 3. Pair 4 figures are similar for the OT treatment but not for the POR treatment: 28.95% (11 out of 38) and 22.50% (9 out of 40) of the subjects in the OT and POR treatments chose the less risky option. The null hypothesis of lottery choices in Pairs 3 and 4 being drawn from the same distribution is not rejected by the OT data ($p = 0.798$). However, the POR data reject the null hypothesis ($p = 0.056$) at 10% significance level.

Data for within-subjects tests for CCE are reported in Table 6. In terms of pattern notation, EU theory permits only patterns SS and RR for choice in Pairs 3 and 4. The percentages of subjects with S_3S_4, R_3R_4, R_3S_4 and S_3R_4 preferences are 10.0, 45.0, 12.5 and 32.5 in the POR treatment. Consistent with previous evidence, there are more SR than RS patterns; Choices made by violators (45% of the subjects) reveal systematic violations that are significant at the 10% level ($p = 0.058$, see Table A1, second POR row, the right-most column). We conclude that the common consequence implication of EU theory is rejected by the POR treatment data but not by the OT treatment data.

7.1.c *Tests for a Dual Common Ratio Effect (DCRE)*

This test of the dual independence axiom of DEU involves two pairs of binary lottery choices that preserve ratios of payoffs. Note that Pairs 1 and 3 provide an example of the dual common ratio problem since the ratio of (nonzero) payoffs in lotteries is the same for Pair 1 (3/5) and Pair 3 (6/10). DEU predicts that the safer option is chosen in Pair 1 if and only if the safer option is chosen in Pair 3.[8]

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[8] EU and RDU with a power or logarithmic utility of money payoff function make the same prediction. OT data are informative with respect to testing these functional specifications and data are consistent with them.

The DCRE is constructed to test DEU theory, so we focus on OT, PAC, and PAC/5 treatments. (Recall that PAC and PAC/n are incentive compatible mechanisms for DEU). Results from between-subjects tests are reported in Table 5. In the OT treatment, the safer option is observed in 39.47% (15 subjects out of a total of 38 subjects) of choices in Pair 1 and 27.59% (16 subjects out of a total of 58 subjects) of choices in Pair 3. Corresponding figures are 36.84% and 23.68% for the PAC treatment and 37.50 and 35.00 for the PAC/5 treatment. The null hypothesis of lottery choices in Pairs 1 and 3 being drawn from the same distribution is not rejected for all three treatments (p-values are 0.222, 0.816, and 0.212).

Table 7. Within-Subjects Data Patterns (in %) for DEU Paradox Tests

Treatment	nobs	Dual Common Ratio				Dual Common Consequence			
		S_1S_3	R_1R_3	R_1S_3	S_1R_3	S_2S_5	R_2R_5	R_2S_5	S_2R_5
PAC	38	21.05	60.53	2.63	15.79	28.95	34.21	13.16	23.68
PAC/5	40	25.00	52.50	10.00	12.50	22.50	42.50	22.50	12.50
POR	40	22.50	52.50	20.00	5.00	37.50	37.50	12.50	12.50
PAS	39	15.38	56.41	17.95	10.26	12.82	71.79	5.13	10.26
PAI	38	23.68	50.00	13.16	13.16	39.47	34.21	13.16	13.16

Data for within-subjects tests for DCRE are reported in Table 7, which shows the total number of subjects for each multi-choice treatment and the numbers of subjects that exhibited relevant choice patterns. The observed percentages of subjects with S_1S_3, R_1R_3, R_1S_3 and S_1R_3 preferences are 21.05, 60.53, 2.63, and 15.79 in the PAC treatment and 25.0, 52.5, 10.0, and 12.5 in the PAC/5 treatment. So, we observe that 81.58% and 77.50% of patterns in the PAC and PAC/5 treatments are consistent with DEU predicted patterns.[9] We conclude that the dual common ratio implication of DEU theory is not rejected by the OT treatment data nor by the PAC and PAC/5 treatment data.

7.1.d *Tests for a Dual Common Consequence Effect (DCCE)*

This test of the dual independence axiom of DEU involves two pairs of binary lottery choices that preserve differences of payoffs. Recall that the dual common consequence

[9] Note however that those few violations (about 1/5 of subjects) are systematic in the PAC data (p-value is 0.058; see Table A2 in Appendix 1) but not in PAC5 (p-value is 0.744; Table A.2 in Appendix 1).

problem in our experiment design consists of Pairs 2 and 5; DEU predicts that the risky option is chosen in Pair 2 if and only if the risky option is chosen in Pair 5.[10]

The DCCE is constructed to test DEU theory, so we focus on OT, PAC, and PAC/5 treatments. Results from between-subjects tests are reported in Table 5. In the OT treatment, the safe option is observed in 15.52% (9 subjects out of a total of 58 subjects) of choices in Pair 2 and 38.46% (24 subjects out of a total of 39 subjects) of choices in Pair 5. For the PAC treatment data these figures are 52.63% and 42.11% while they are 35.00% and 45.00% in the PAC/5 treatment. The null hypothesis of lottery choices in Pairs 2 and 5 being drawn from the same distribution is rejected by the OT treatment data (p-value is 0.005); however, neither the PAC data nor the PAC/5 data reject the null hypothesis (p-values are 0.358 and 0.361, respectively).

Data for within-subjects tests for DCCE are reported in Table 7. The observed percentages of subjects with S_2S_5, R_2R_5, R_2S_5 and S_2R_5 choice patterns are 28.95, 34.21, 13.16, and 23.68 in the PAC treatment and 22.5, 42.5, 22.5, and 12.5 for the PAC/5 treatment. Hence, the majority of subjects in PAC and PAC/5 treatments are making choices that are consistent with DEU predictions. Table A2 in Appendix 1 shows that data from violators (37% and 35% of the subjects) from both treatments, PAC and PAC5, do not reveal systematic violations of the dual common consequence implication of DEU theory (testing for systematic violations, both p-values are 0.291).

7.2 Tests of Risk Preferences Hypotheses

Our results for the risk preferences hypotheses follow from the analysis of paradoxes in the preceding subsection. According to Hypothesis 1 (fanning out) the riskier choice should be observed more often in Pair 3 than in either Pair 2 (CRE) or in Pair 4 (CCE). On the contrary, the riskier choice is observed more often in Pair 2 than in Pair 3: 84.48% and 72.41% respectively. Percentages of the riskier option being chosen are almost the same in Pairs 4 and 3: 71% and 72.41% respectively. Looking at Table 5, Hypothesis 1 requires positive z-values in the CRE column and negative z-values in the CCE column. The sign is correct for the CCE column (as is expected from the above figures) but the one-sided p-value is too high (0.399). Thus, we conclude that the OT data are not consistent with fanning out preferences.

[10] EU and RDU with an exponential function for money make the same prediction. OT data are not consistent with this specification; p-value is 0.005 (see Table 5, the right-most column, OT row).

Hypothesis 2 (DRRA) requires that the riskier option should be observed more often in Pair 3 than in Pair 1. We observe that the riskier option was indeed chosen more often in Pair 3 than in Pair 1: exact figures are 72.41% and 60.53% for Pairs 3 and 1, respectively. However, the difference is not statistically significant (one-sided p-value is 0.111); see Table 5, OT row and DCRE column). We conclude that the OT data are not characterized by the DRRA property. Finally, OT data are not consistent with Hypothesis 3 (DARA). Contrary to the hypothesis, the proportion of risky choices is not higher in group OT_5 than in OT_2: we observe the riskier option being chosen in 61.54% of the decisions in Pair 5 but 84.48% in Pair 2. Referring to Table 5, Hypothesis 3 requires a positive z-value in the DCCE column; this is not what we find. Thus, we conclude that the OT data are not characterized by the DARA property either.

7.3 *Tests of Elicitation Mechanism Hypotheses*

7.3.a *Isolation*

According to Hypothesis 4 (isolation) the overall proportion of risky choices should be the same in treatments OT, POR, PAI, PAS, PAC, and PAC/5. This is not what the data show. The proportion of risky choices in lowest under PAI (57.37%) and highest under PAS (77.95). The risky choice proportions for the other mechanisms are 71.43%, 64.73%, 65% and 61.50% for OT, PAC, PAC/5 and POR respectively.

Sample proportions tests comparing safe option choices in different payoff mechanism treatments show that there are significant differences between OT data and: (a) POR data (two-sided p-values are 0.029 according to the proportions test and 0.032 according to Fisher's exact test); and (b) PAI data (two-sided p-value is 0.003 by both tests). Other two-sided tests are insignificant.[11]

Tests for differences in sample proportions between pairs of multi-choice mechanisms yield the following. There are significant differences between PAS data and: (a) POR data (two-sided p-values are 0.0004 for the proportions test and 0.000 for Fisher's exact test); (b) PAC data (two-sided p-values are 0.004 and 0.005 for the proportions test and Fisher's test); (c) PAC/5 data (two-sided p-values are 0.004 and 0.005 for the proportions test and Fisher's

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[11] According to one-sided sample proportions tests, POR and PAI data are biased towards significantly more risk aversion compared to OT data (p-values are ½ of above). At 10% significance with one-sided tests, PAS data show less risk aversion (one-sided Fisher's exact p-value is 0.077) and both PAC and PAC/5 data show more risk aversion (one-sided p-values are 0.086 and 0.092) than OT data.

test); (d) PAI data (two-sided p-values are 0.000 for both tests). Other differences between sample proportions are insignificant.

An alternative test for bias in the multi-choice mechanism data can be based on probit analysis with subject-ID clustered errors. The left hand variable is probability of choosing the risky option. Right hand variables are: a constant; differences between expected values, standard deviations and skewness of payoffs for the risky and safe options; and a dummy variable with value 1 for data from a multi-task mechanism and value zero for OT data. Estimated coefficients for the dummy variable are negative and significantly different from 0 in the probit for POR (p-value is 0.046) and in the probit for PAI (p-value is 0.013). By this test only POR and PAI significantly bias risk preferences compared to OT.

Another comparison of data from different mechanisms can be based on the percentages reported in Table 5 for each of the five lottery pairs. Pair 2 leads to a very large percentage of risky option choices in the OT treatment (84.5%) which differs significantly from responses observed in POR, PAC, and PAI at the 1% level and at the 3% level in case of PAC/5 data.[12] Subjects are less risk averse under PAS compared to other mechanisms. For Pair 2, responses in PAS are significantly different (at the 1% level) from those obtained under POR, PAC, and PAI. For Pair 5, responses under PAS differ from OT (at 5%), POR (at 1%), PAI (at 1%), and PAC (at 2%). Additionally, there is a significant difference between PAS and OT data (at the 5% level) and PAI (at 1%) for Pair 4. Summarizing, all multi-decision protocols except PAS generate different choices than OT for Pair 2. PAS on the other hand generates data that are statistically different from other protocols for Pairs 2 and 5.

All of the above tests support a central conclusion. Data from Experiment 2 support rejection of the isolation hypothesis. As explained in section 3, data from Experiment 1 also support rejection of isolation.

7.3.b *Reduction, Portfolio Effect, Wealth Effect, and Adding-Up*

According to Hypothesis 5 (reduction) the safer-riskier mixed patterns for choices in Pairs 3 and 4 should be the same in the POR group. The POR data are not consistent with reduction; the p-value is 0.057 (see Table A.1, the most right column, fifth row from the bottom).

[12] Probit regressions with fixed effects report a significant positive effect of a many-task treatment dummy on the likelihood of the less risky option in Pair 2 for POR, PAC, PAC/5 and PAI. For the PAS treatment, estimated coefficients of the dummy variable are significantly negative for Pairs 4 and 5, suggesting that PAS induces more risky behavior than OT.

According to Hypothesis 6 (portfolio effect), the safer-riskier mixed patterns for choices in Pairs 2 and 5 should be the same in the PAI treatment. Data are consistent with this hypothesis (see Table 5; DCCE column, the bottom row). This result together with the observation that OT data reject the null hypothesis of equal choice distributions in Pairs 2 and 5 suggest that subjects' choices with PAI reveal a portfolio effect. Such an effect is consistent with EU under the PAI mechanism; indeed it is just such a possible effect that POR is supposed to eliminate. The empirical question for experimental methods is whether the POR mechanism successfully eliminates possible portfolio effects.

As predicted by Hypothesis 9 (adding-up), we do not observe significant differences in responses to Pairs 2 and 5 for PAC, and PAC/5 data (p-values are 0.291; see Table A.2, the right-most column, PAC and PAC/5 rows). We conclude that this hypothesis is not rejected.
As reported above, we observe the riskier options more often in PAS than in OT; PAS data are statistically less risk averse in Pairs 4 and 5. We conclude that the data are consistent with Hypothesis 10 on existence of a wealth effect in the PAS treatment.

7.3.c *Cross-Task Contamination with POR*

According to Hypothesis 7 (type 1 cross-task contamination): if the safer-riskier mixed patterns for choices in Pairs 2 and 5 are equally observed in the POR treatment but not in the OT treatment then POR exhibits type 1 cross-task contamination. Data are consistent with the hypothesis that the proportions of patterns (R_2,S_5) and (S_2,R_5) are the same in the POR treatment (see Table 5; DCCE column, the POR row). This result, combined with the observation that OT data reject the null hypothesis of equal proportions of choices of the safe option in Pairs 2 and 5, support the conclusion that subjects' choices in POR exhibit type 1 cross-task contamination. Hypothesis 8 (type 2 cross-task contamination) states that if POR is unbiased then it should elicit the same proportions of choices of safe lotteries as OT. A sample proportions test with OT and POR data rejects this hypothesis with two-sided p-value of 0.029 (alternatively, Fisher's exact test p-value is 0.032). In this way, POR exhibits type 2 cross-task contamination.

8. SUMMARY

Experiments on choice under risk typically involve multiple decisions by individual subjects and random selection of one decision for payoff. If the isolation hypothesis has empirical validity – i.e. if subjects make each decision independently of other decision opportunities – then random selection for payoff is appropriate for testing all theories of decision under risk with data from multi-decision experiments. Experiment 1 provides (what we believe to be) the first simple test of the isolation hypothesis and the data are inconsistent with isolation, as noted in the first row of Table 8.

Empirical failure of the isolation hypothesis is especially a problem for design of experiments to test theories such as rank dependent utility theory, cumulative prospect theory, and betweenness theories that do not include either the independence axiom or the dual independence axiom. There is no known theoretically correct payoff mechanism to use in multi-decision experiments designed to test such theories.

The finding that the data are inconsistent with the isolation hypothesis makes clear the importance of systematic study of the properties of alternative payoff mechanisms and the relationship of those properties to validity of conclusions about theory that can be drawn from data. Experiment 2 is a step in the direction of such study.

8.1 *Isolation, Reduction, Portfolio Effect, Adding-up, Wealth Effect, and Cross-Task Contamination*

Table 8 summarizes test results using data from Experiment 2. This experiment supports a different type of test of the isolation hypothesis than Experiment 1; in this case we compare data from the one task (OT) treatment with data from five multi-decision treatments. If isolation holds in general then data from OT and the treatments that use other mechanisms should come from the same distribution. Isolation is rejected by Experiment 2 data.

Table 8. Summary Test Results for Experimental Methods

	Isola.	Reduc.	Port. Eff.	Add. Up	Wlth. Eff.	Type 1 Cont.	Type 2 Cont.
Exp. 1	no	…	…	…	…	…	…
Exp. 2	no	no	yes	yes	yes	yes	yes

Isolation is an extreme hypothesis that supposes that a subject views each decision task independently of all other tasks in an experiment. Reduction of compound lotteries is an opposing extreme hypothesis that supposes that a subject views a whole experiment as one compound lottery. For Experiment 2, the reduction hypothesis implies that the proportion of risky choices in Pairs 3 and 4 should be the same. This implication of reduction is rejected by the data at a conventional level of 10% significance.

Another extreme hypothesis in opposition to isolation is the hypothesis that a subject would consider the whole experiment as one lottery and construct a portfolio using the choice pairs. The data are consistent with existence of a portfolio effect. Yet another extreme hypothesis in opposition to isolation is adding-up, that subjects consider all choice tasks of the experiment simultaneously and add up outcomes for each state of the world. The data are consistent with adding-up. Wealth changes during an experiment if earlier choices are paid before subsequent choices are made, which is exactly what happens with the pay all sequentially (PAS) mechanism. This opens the possibility that changes in wealth can affect choices with PAS. The data provide some support for a wealth effect.

Our data reveal that a portfolio effect and a wealth effect can occur with mechanisms that pay all decisions. Random selection of one decision for payoff was introduced to eliminate biases in risk preference elicitation experiments involving multiple decisions by individual subjects. But our data reveal that random selection, as with the pay one randomly (POR) mechanism, is not unbiased; instead data from the POR treatment reveal two types of cross-task contamination.

8.2 *Paradoxes and Mechanisms*

All our test results for paradoxes are summarized in Table 9. Bold entries denote tests that use theoretically “right” mechanisms. The common ratio effect (CRE) and common consequence effect (CCE) are paradoxes for expected utility theory; hence the OT and POR mechanisms are theoretically right for testing for the presence of these effects. Data from treatments that use the OT and POR mechanisms do not show CRE. Data from the OT treatment do not show CCE either. In contrast, POR data reveal CCE patterns. PAS data also show CCE (but the mechanism is not theoretically right). The PAC data are the only ones to show CRE (but the mechanism is not theoretically right).

Table 9. Summary Test Results for Paradoxes*

	OT	POR	PAI	PAS	PAC	PAC/5
CRE	**no**	**no**	no	no	yes	no
CCE	**no**	**yes**	no	yes	no	no
DCRE	**no**	no	no	no	**no**	**no**
DCCE	**yes**	no	no	no	**no**	**no**

* Bold entries denote results for theoretically “correct” mechanisms.

The dual common ratio effect (DCRE) and dual common consequence effect (DCCE) are paradoxes for the dual theory of expected utility; hence the OT, PAC, and PAC/5 mechanisms are theoretically right for testing for the presence of these effects. Data from the

OT treatment do not show DCRE but they do show DCCE. In contrast, PAC and PAC/5 data do not show either effect.

8.3 *Implications for Experimental Methods for Choice under Risk*

Data from our experiments revive dormant questions about experimental methods. Use of PAS as the payoff mechanism in multi-choice experiments is theoretically problematic for tests of some hypotheses because an agent's wealth changes between decisions. Use of PAI is theoretically objectionable for tests of many hypotheses because it involves an incentive to diversify risks through biased responses to individual choice opportunities. POR was first introduced to solve both problems in tests of hypotheses from expected utility theory because, as a consequence of the independence axiom, POR provides a theoretical solution to both wealth effects and portfolio effects. Subsequently, use of POR became conventional in much of the literature on elicitation of individuals' risk preferences in multi-choice experiments, including experiments intended for purposes other than testing EU hypotheses. PAS has often been used in market experiments and some many-round experiments on game theory. PAI has been used occasionally. OT has been used occasionally, especially in experiments on paradoxes of theories of decision under risk. PAC and PAC/n are new mechanisms.

Two distinct types of questions arise in evaluating payoff mechanisms: (a) Are any of the mechanisms behaviorally unbiased under conditions in which they are theoretically incentive compatible? (b) Do they provide usable data under conditions in which they are not theoretically incentive compatible? Our experiments contribute to the literature on both types of questions. The results provide some answers and raise related questions for future research.

Data from different mechanisms imply different conclusions about the classic (Allais paradox) question about behavioral observation of a CCE. The effect is observed in POR data but not in OT data although POR is a theoretically right mechanism for testing for CCE. Perhaps the observation of CCE with POR data is a false positive coming from the cross-task contamination we observe with POR. DCCE is observed with OT data but not with PAC or PAC/n data even though PAC and PAC/n are theoretically right mechanisms for this test.

POR has been commonly used in multi-decision experiments designed to test hypotheses from non-EU theories for which there exists no known theoretically-incentive-compatible mechanism. And POR has been used to generate data used in econometric estimation of non-EU utility functionals. In both types of research, the conclusion that POR-generated data support non-EU theories is dissonant because non-EU theories do not imply that POR is unbiased. It may be the case that biases introduced into data by POR are insignificant in some (or most) contexts but the question needs systematic exploration. One good candidate for comparison with POR is OT because the latter is incentive compatible for all theories. But OT has two problems: high cost of subject payments and limitation to between-subjects tests of hypotheses. Another good candidate for comparison with POR is the PAC/n mechanism introduced in this paper. These two mechanisms have the same expected cost to the experimenter's research budget. And the theoretical duality between the mechanisms makes them good candidates for robustness checks on conclusions from empirical applications of non-EU theories. Data from our Experiment 2 reveal much higher bias for POR than for PAC/n. It is currently unknown whether this finding is robust.

REFERENCES

Armantier, O. (2006), "Do Wealth Differences Affect Fairness Considerations?", *International Economic Review*, 47, 391–429.

Beattie, J. and Loomes, G. (1997), "The Impact of Incentives upon Risky Choice Experiments", *Journal of Risk and Uncertainty*, 14, 149-62.

Bellemare, C., Krause, M., Kroger, S., and Zhang, C. (2005), "Myopic Loss Aversion: Information Feedback vs. Investment Flexibility", *Economic Letters*, 87, 319–324.

Benartzi, S., and Thaler, R. (1995), "Myopic Loss Aversion and the Equity Premium Puzzle", *Quarterly Journal of Economics*, 110, 73–92.

Bhargava, I., Kim, J., and Srivastava, R. (2000), "Explaining Context Effects on Choice Using a Model of Comparative Judgement," *Journal of Consumer Psychology*, 9, 167–177.

Birnbaum, M. (2004), "Causes of Allais Common Consequence Paradoxes: An Experimental Dissection," *Journal of Mathematical Psychology*, 48, 87-106.

Birnbaum, M.H. and Schmidt, U. (2010), "Allais Paradoxes Can be Reversed by Presenting Choices in Canonical Split Form," Kiel Working Papers 1615, Kiel Institute for the World Economy.

Bolle, F. (1990), "High Reward Experiments without High Expenditure for the Experimenter", *Journal of Economic Psychology*, 11, 157–167.

Burks, S. V., Carpenter, J. P. and Verhoogen, E. (2003), "Playing Both Roles in the Trust Game", *Journal of Economic Behavior and Organization*, 51, 195-216.

Camerer, C. F. (1989), "An Experimental Test of Several Generalized Utility Theories," *Journal of Risk and Uncertainty*, 2, 61-104.

Camerer, C. F. (1992), "Recent Tests of Generalizations of Expected Utility Theory," in: W. Edwards (ed.) Utility: Theories, Measurement, and Applications, Norwell, MA: Kluwer, 207–251.

Chaudhuri, A. and Gangadharan, L. (2007), "An Experimental Analysis of Trust and Trustworthiness", *Southern Economic Journal*, 73, 959-985.

Chew, S.H. (1983), "A Generalization of the Quasilinear Mean with Application to the Measurement of Income Inequality and Decision Theory Resolving the Allais Paradox," *Econometrica,* 51, 1065-1092.

Conlisk, J. (1989), "Three Variants on the Allais Example", *American Economic Review*, 79, 392-407.

Cox, J. C. and Epstein, S. (1989), "Preference Reversals without the Independence Axiom", *American Economic Review*, 79, 408-426.

Cox, J. C. and Grether, D. M. (1996), "The Preference Reversal Phenomenon: Response Mode, Markets and Incentives", *Economic Theory,* 7, 381-405.

Cubitt, R. P., Starmer, C. and Sugden, R. (1998a), "On the Validity of the Random Lottery Incentive System", *Experimental Economics*, 1, 115-131.

Cubitt, R. P., Starmer, C. and Sugden, R. (1998b), "Dynamic Choice and the Common Ratio Effect: An Experimental Investigation", *Economic Journal*, 108, 1362-80.

Cubitt, R. P., Starmer, C., & Sugden, R. (2001), "Discovered Preferences and the Experimental Evidence of Violations of Expected Utility Theory," *Journal of Economic Methodology*, 8(3), 385-414.

Fellner, G. and Sutter, M. (2008), "Causes, Consequences, and Cures of Myopic Loss Aversion - An Experimental Investigation", Universität Innsbruck, Working Paper, No.01.

Fox, C. R., Rogers, B. A., and Tversky, A. (1996), "Options Traders Exhibit Subadditive Decision Weights", *Journal of Risk and Uncertainty*, 13, 5-17.

Gneezy, U., Kapteyn A. and Potters J. (2003), "Evaluation Periods and Asset Prices in a Market Experiment", *Journal of Finance*, 65, 821-38.

Gneezy, U. and Potters J. (1997), "An Experiment on Risk Taking and Evaluation Periods", *Quarterly Journal of Economics*, 112, 631-45.

Grether, D. M. and Plott, C. R. (1979), "Economic Theory of Choice and the Preference Reversal Phenomenon," *American Economic Review*, 69, 623-638.

Gul, F. (1991), "Theory of Disappointment Aversion," *Econometrica,*59(3), 667-686.

Haigh, M. and List, J. (2005), "Do Professional Traders Exhibit Myopic Loss Aversion? An Experimental Analysis", *Journal of Finance*, 60, 523-34.

Harrison, G.W. (1994). "Expected Utility Theory and the Experimentalists." *Empirical Economics*. 19, 223–253.

Harrison, G. W., Johnson, E., McInnes, M. M. and Rutström, E. E. (2005), "Risk Aversion and Incentive Effects: Comment", *American Economic Review*, 95, 897–901.

Harrison, G., Lau, M., and Williams, M. (2002), "Estimating Individual Discount Rates for Denmark: A Field Experiment", *American Economic Review*, 92, 1606–1617.

Harrison, G. W., List, J. A., and Towe, C. (2007), "Naturally Occurring Preferences and Exogenous Laboratory Experiments: A Case Study of Risk Aversion," *Econometrica*, 75, 433-458.

Harrison, G. W. and Rutström, E. E. (2008). "Risk Aversion in the Laboratory", in J. C. Cox and G. W. Harrison (eds.), *Risk Aversion in Experiments*, Bingley, UK: Emerald, Research in Experimental Economics, Volume 12.

Hey, J. D. and Orme, C. (1994), "Investigating Generalizations of Expected Utility Theory Using Experimental Data", *Econometrica*, 62, 1291-1326.

Holt, C. A. (1986), "Preference Reversals and the Independence Axiom", *American Economic Review*, 76, 508-515.

Holt, C. A. and Laury, S. K. (2002), "Risk Aversion and Incentive Effects", *American Economic Review*, 92, 1644-1655.

Holt, C., and Laury, S. (2005), "Risk Aversion and Incentive Effects: New Data without Order Effects", *American Economic Review,* 95, 902–904.

Hsee, C. K. and Leclerc, F. (1998), "Will Products Look More Attractive when Evaluated Jointly or When Evaluated Separately?" *Journal of Consumer Research*, 25, 175-186.

Huber, J., Payne, J. W. and Puto, C. (1982), "Adding Asymmetrically Dominated Alternatives: Violations of Regularity and the Similarity Hypothesis," *Journal of Consumer Research,* 9, 90–98.

Kahneman, D. (2002), "Maps of Bounded Rationality: A Perspective on Intuitive Judgment and Choice", Prize lecture for the Nobel Foundation, http://nobelprize.org/nobel_prizes/economics/laureates/2002/kahneman-lecture.html

Kahneman, D. and Tversky, A. (1979), "Prospect Theory: An Analysis of Decision under Risk", *Econometrica*, 47, 263-291.

Kilka, M. and Weber, M. (2001), "What Determines the Shape of the Probability Weighting Function under Uncertainty", *Management Science*, 47, 1712-1726.

Langer, T. and Weber, M. (2005), "Myopic Prospect Theory vs. Myopic Loss Aversion: How General is the Phenomenon?", *Journal of Economic Behavior and Organization*, 56, 25-38.

Laury, S. K. (2006), "Pay One or Pay All: Random Selection of One Choice for Payment", Experimental Economics Center Working Paper 2006-24, Georgia State University.

Laury, S. K. and Holt, C. A. (2008), "Payoff Scale Effects and Risk Preference Under Real and Hypothetical Conditions", in C. Plott and V. Smith (eds.) *Handbook of Experimental Economic Results*, Vol. 1, New York, Elsevier Press.

Lee, J. (2008), "The Effect of the Background Risk in a Simple Chance Improving Decision Model", *Journal of Risk and Uncertainty*, 36, 19–41.

Lopes, L. L. (1995), “Algebra and Process in the Modeling of Risky Choice”, *The Psychology of Learning and Motivation*, 32, 177-220.

Luce, R. D. (1991). "Rank- and Sign-Dependent Linear Utility Models for Binary Gambles," *Journal of Economic Theory* 53, 75-100.

Luce, R. D. (2000). *Utility of gains and losses: measurement-theoretical, and experimental approaches*. NJ: Lawrence Erlbaum.

Luce, R. D., and P. C. Fishburn. (1991). "Rank- and Sign-Dependent Linear Utility Models for Finite First-Order Gambles," *Journal of Risk and Uncertainty* 4, 29-59.

Machina, M. J. (1982), “‘Expected Utility’ Analysis without the Independence Axiom”, *Econometrica*, 50, 277-323.

Machina, Mark J, 1989. "Dynamic Consistency and Non-expected Utility Models of Choice under Uncertainty," *Journal of Economic Literature, American Economic Association*, vol. 27(4), pages 1622-68, December.

Parducci, A. (1965), “Category Judgment: A Range-Frequency Model”, *Psychological Review*, 72, 407-418.

Prelec, D. (1990), “A ‘Pseudo-Endowment’ Effect, and Its Implications for Some Recent Nonexpected Utility Models”, *Journal of Risk and Uncertainty*, 3, 247-259.

Quiggin, John, 1981. "Risk Perception And The Analysis Of Risk Attitudes," *Australian Journal of Agricultural Economics*, Australian Agricultural and Resource Economics Society, vol. 25(02), August.

Quiggin, John, 1982. "A theory of anticipated utility," *Journal of Economic Behavior & Organization*, Elsevier, vol. 3(4), pages 323-343, December.

Reilly, R. J. (1982). “Preference Reversal: Further Evidence and Some Suggested Modifications in Experimental Design. *American Economic Review*, 72, 576-584.

Schmidt, U. and Trautmann, S.T. (2010),"Common Consequence Effects with Pricing Data," Kiel Working Papers 1610, Kiel Institute for the World Economy.

Schmidt, U., and Zank, H. (2009), “A Simple Model of Cumulative Prospect Theory”, *Journal of Mathematical Economics,* 45, 308–319.

Sefton, M. (1992), “Incentives in Simple Bargaining Games”, *Journal of Economic Psychology*, 13, 263–276.

Appendix 1: Tests of Paradoxes

Table A1: Tests of EU Paradoxes

Treatment	N nobs	Proportions of EU violators $V = \frac{SR+RS}{N}$	EU violations D-value (p-value) $Ho: V_{POR} = V_{tr}$, $tr \in \{PAC, PAS, PAE\}$	Systematic EU violations $SV = \frac{SR}{SR+RS}$	Systematic Violations Z-value (p-value) $Ho: SV = 0.5$
		Common Ratio			
POR	40	**0.375**		**0.600**	**0.771 (0.446)**
PAC5	40	0.500	-1.123 (0.260)	0.500	0.000 (1.000)
PAC	38	0.447	-0.650 (0.516)	0.824	2.920*** (0.006)
PAS	39	0.359	0.148 (0.883)	0.357	-1.071 (0.390)
PAI	38	0.316	0.550 (0.583)	0.750	1.781* (0.084)
		Common Consequence			
POR	40	**0.450**		**0.722**	**1.951* (0.057)**
PAC5	40	0.225	2.128** (0.033)	0.778	1.706* (0.096)
PAC	38	0.342	0.973 (0.330)	0.539	0.274 (0.786)
PAS	39	0.282	1.548 (0.122)	0.909	2.974*** (0.005)
PAI	38	0.395	0.494 (0.622)	0.533	0.255 (0.800)

Figures for the “right” mechanisms are in bold.

Table A2: Tests of DEU Paradoxes

Treatment	N	Proportions of DEU violators $V = \frac{SR+RS}{N}$	DEU violations D-value (p-value) $H_0: V_{PAC} = V_{tr}$, $tr \in \{POR, PAS, PAE\}$	Systematic DEU violations $SV = \frac{SR}{SR+RS}$	Systematic Violations Z-value (p-value) $H_0: SV = 0.5$
		Dual Common Ratio			
PAC	38	**0.18**		**0.857**	**1.960* (0.058)**
PAC5	40	**0.225**	-0.446 (0.656)	**0.556**	**0.330 (0.744)**
POR	40	0.25	-0.704 (0.482)	0.200	-1.964* (0.057)
PAS	39	0.28	-1.014 (0.311)	0.364	- 0.902 (0.373)
PAI	38	0.27	-0.826 (0.409)	0.500	0.000 (1.000)
		Dual Common Consequence			
PAC	38	**0.368**		**0.643**	**1.071 (0.291)**
PAC5	40	**0.350**	0.170 (0.865)	**0.357**	**-1.071(0.291)**
POR	40	0.250	1.133 (0.257)	0.500	0.000 (1.000)
PAS	39	0.154	2.147** (0.032)	0.667	0.813 (0.421)
PAI	38	0.263	0.987 (0.324)	0.500	0.000 (1.000)

Figures for the “right” mechanisms are in bold.

Appendix 2: Subject Instructions for Experiment 1

Subject Instructions (Group 1):

In the following you have the choice between two options. In one option (Option A) you get a certain payoff for sure, the other option (Option B) is risky. Here a coinflip will determine which of the two possible payoffs you get. All payoffs will be paid out in cash directly after the experiment.

Which of the following options do you choose?

Option A:	*Option B:*
4 Euro with probability 100%	*10 Euro with probability 50%*
	0 Euro with probability 50%

Subject Instructions (Group 2.1):

In the following you have to make two choices, each consisting of two options. At the end of the experiment a coinflip will determine whether the first or the second choice problem will be paid out for real. In both choice problems there are two options. In one option (Option A in Choice Problem 1 and Option C in Choice Problem 2) you get a certain payoff for sure, the other option (Option B in Choice Problem 1 and Option D in Choice Problem 2) is risky. Here a coinflip will determine which of the two possible payoffs you get. All payoffs will be paid out in cash directly after the experiment.

Choice Problem 1: Which of the following options do you choose?

Option A:	*Option B:*
3 Euro with probability 100%	*12 Euro with probability 50%*
	0 Euro with probability 50%

Choice Problem 2: Which of the following options do you choose?

Option C:	*Option D:*
4 Euro with probability 100%	*10 Euro with probability 50%*
	0 Euro with probability 50%

Subject Instructions (all other groups):

For all other groups instructions were the same as those for Group 2.1 except the option was changed.

Appendix 3: Subject Instructions for Experiment 2

Subject Instructions (OT)

In this experiment, you are asked to choose between two options. The example below shows two options that are similar to ones on the decision page.

In Option A you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In Option B you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

Ball nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Option A	$3				$10															
Option B	$5			$7				$8												

Making Choices Please make your choice by clicking on Option A or Option B

Payoffs After you make a decision, your chosen option will be played. Your payoff in the option you selected will be determined by drawing a ball from a bingo cage that contains balls numbered 1,2,3,…,20.

Subject Instructions (PAC)

In this experiment, you are asked to choose between two options on each of five decision pages. On each decision page you will choose between a different pair of options. The example below shows two options that are similar to ones on decision pages.

In Option A you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In Option B you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

<table>
<tr><th>Ball nr</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th></tr>
<tr><td>Option A</td><td colspan="4">$3</td><td colspan="16">$10</td></tr>
<tr><td>Option B</td><td colspan="3">$5</td><td colspan="4">$7</td><td colspan="13">$8</td></tr>
</table>

Making Choices Please make your choice on each of the five decision pages by clicking on Option A or Option B

Payoffs After you make a decision on each of the five decision pages, all your chosen options will be played as follows. One numbered ball will be drawn from a bingo cage that contains balls numbered 1,2,3,…,20. The ball drawn determines your payoff from the option you chose on all five decision pages.

Your total payoff is the sum of your payoffs from all five decision pages; all payoffs are determined by the one ball drawn.

Subject Instructions (POR)

In this experiment, you are asked to choose between two options on each of five decision pages. On each decision page you will choose between a different pair of options. The example below shows two options that are similar to ones on decision pages.

In Option A you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In Option B you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

<table>
<tr><td>Ball nr</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr>
<tr><td>Option A</td><td colspan="4">$3</td><td colspan="16">$10</td></tr>
<tr><td>Option B</td><td colspan="3">$5</td><td colspan="4">$7</td><td colspan="13">$8</td></tr>
</table>

Making Choices Please make your choice on each of the five decision pages by clicking on Option A or Option B

Payoffs After you make a decision on each of the five decision pages, one of the pages will be randomly selected and your chosen option on that page will be played. The selection of the page is carried out by drawing a ball from a bingo cage that contains five balls numbered 1,2,3,4,5. The number on the drawn ball determines the decision page that is selected.

After the one page is randomly selected, your money payoff will be determined by playing the lottery in the option you selected on that page. Your payoff in the option you selected will be determined by drawing a ball from a bingo cage that contains balls numbered 1,2,3,…,20.

Subject Instructions (PAS)

In this experiment, you are asked to choose between two options on each of five decision pages. On each decision page you will choose between a different pair of options. The example below shows two options that are similar to ones on decision pages.

In Option A you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In Option B you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

Ball nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Option A	$3				$10															
Option B	$5			$7				$8												

Making your First Page Choice Please make your choice on the first decision page by clicking on Option A or Option B

First Page Payoff A numbered ball is drawn from a bingo cage that contains balls numbered 1,2,3…,20. The ball drawn determines your payoff from the option you chose on the first page. The drawn ball is returned to the bingo cage. Then you turn to the next decision page.

Making your Choices and Determining Payoffs on Subsequent Pages

Make your choice on page 2. Then a ball is drawn to determine your payoff. The ball is returned to the bingo cage. Next, you make your choice on page 3. Another ball is drawn and then returned to the bingo cage. This process continues until your choices and payoffs have been determined for all five decision pages. Your total payoff is the sum of your payoffs from all five decision pages that are determined by the sequence of choices and independently drawn balls.

Subject Instructions (PAI)

In this experiment, you are asked to choose between two options on each of five decision pages. On each decision page you will choose between a different pair of options. The example below shows two options that are similar to ones on decision pages.

In Option A you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In Option B you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

Ball nr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Option A	$3				$10															
Option B	$5			$7				$8												

Making Choices Please make your choices on all five decision pages by clicking on Option A or Option B

Payoffs After you make decisions on all five decision pages, **all** of your chosen options will be played as follows.

A numbered ball will be drawn from a bingo cage that contains balls numbered 1,2,3,…,20. The ball drawn determines your payoff from the option you chose on the first page. The drawn ball is returned to the bingo cage. Next, a second ball is drawn, which determines your payoff from the option you chose on the second page. That ball is returned to the bingo cage. This sequential procedure is continued until your payoffs are determined for all five decision pages.

Your total payoff is the sum of your payoffs from all five decision pages, each of which is determined by an independently drawn ball.

Subject Instructions (PAC/5)

In this experiment, you are asked to choose between two options on each of five decision pages. On each decision page you will choose between a different pair of options. The example below shows two options that are similar to ones on decision pages.

In <u>Option A</u> you receive either $3 or $10. Your payoff is determined by drawing one ball from a bingo cage containing 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 4 is drawn then you receive $3. If a ball with number 5 to 20 is drawn then you receive $10.

In <u>Option B</u> you receive either $5 or $7 or $8. Your payoff is determined by drawing one ball from a bingo cage that contains 20 balls numbered 1, 2, 3, …, 20. If a ball with number 1 to 3 is drawn then you receive $5. If a ball with number 4 to 7 is drawn then you receive $7. If a ball with numbers 8 to 20 is drawn then you receive $8.

<table>
<tr><th>Ball nr</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th></tr>
<tr><td>Option A</td><td colspan="4">$3</td><td colspan="16">$10</td></tr>
<tr><td>Option B</td><td colspan="3">$5</td><td colspan="4">$7</td><td colspan="13">$8</td></tr>
</table>

Making Choices

Please make your choice on each of the five decision pages by clicking on Option A or Option B

Payoffs

After you make a decision on each of the five decision pages, **all** your chosen options will be played as follows. One numbered ball will be drawn from a bingo cage that contains balls numbered 1, 2, 3,…,20. The ball drawn determines your payoff from the option you chose on all five decision pages.

Your total payoff is one fifth of the sum of your payoffs from all five decision pages; all payoffs are determined by the one ball drawn.