Teams Take the Better Risks

by

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Abstract

Many important economic and political decisions are made by teams. In the economic literature, however, the decision units are frequently modeled as individual economic agents. The paper experimentally investigates the question to what extent observed team decisions under risk are actually consistent with the principles of rational choice, specifically the principles of *Expected Utility Theory* (EUT) and of *Portfolio Selection Theory* (PST). The experiment is performed with individuals and teams. We find almost no evidence for the greater compliance of team decisions than of individual decisions with the principles of EUT. However, there is substantial evidence for the consistency of team decisions with the PST. Compared to individuals, teams accumulate significantly more expected value at a significantly lower total risk (measured in SD). We introduce a team decision algorithm, *excess-risk vetoing*, that combines simple majority voting with the right to veto alternatives providing additional risk that is not compensated by additional expected value. We find that the results of our experiment are well explained by the excess-risk vetoing.

Keywords Decision under Risk, Group Decision, Expected Utility, Portfolio Selection

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1. Introduction

Most important decisions are made by teams such as managerial boards, production units, faculties, or families. In the economic literature, however, the decision units are frequently modeled as individual economic agents such as "the firm", "the department", "the union", or "the political party". An important reason why the within team decision process is often not modeled, is to avoid conflicts between economic rationality and the aggregation of preferences in a group. As the seminal papers by Arrow (1951) and Black (1958) have shown, the *aggregation problem* may lead to situations in which the economic rationality underlying the decisions of every single team member contradict the compliance of the team's decisions with the same type of rationality principles. This inherent difficulty with the principles of rationality is often bypassed by assuming that the team decisions (directly) conform to the principles of rational decision making[1].

The goal of our study is to experimentally investigate the compliance of team decisions with the principles of rational choice. We have chosen to focus on decision making under risk, because it provides an elementary but integral economic setting. Observed team decisions are compared to two very influential theoretic benchmarks: the *Expected Utility Theory* (EUT) of von Neumann and Morgenstern (1944) and the *Portfolio Selection Theory* (PST) of Markowitz (1952).[2] However, since in many experiments with individual decision makers systematic deviations both from the principles of EUT and of PST were observed,[3] we compare the team decisions not only to the theoretical benchmarks, but also to the choices made by individual subjects in a control treatment. Finding that team decisions are in line with the principles of EUT and/or of PST, perhaps even when individual decisions typically are not, will be a strong support for many of the results derived from applications of EUT and/or PST.

The novelty of our research lies in introducing an experimental framework that is specifically tailored to

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1 Apart from the extensive literature on social choice theory, some effort has been made to model the within team situation and, thus, to cope with the aggregation problem theoretically. Most papers follow Harsanyi's cardinal utility approach (1955). See for example Eliashberg and Winkler (1981), Keeney (1976), and Keeney and Kirkwood (1975). A different line of research, originally due to Marschak and Radner (1972), is concerned with the process of information exchange and decision making rules when all team members share the same preferences.

2 Although the two models are based on very different foundations, they have nevertheless been shown to be compatible for certain ranges of specifications. Starting with Schneeweiß (1966), a number of papers have described the types of utility functions and the types of risk and return measures that lead to a compatibility of the two approaches (Bell 1995, Levy and Markowitz 1979, Markowitz 1991, Sarin and M. Weber 1993).

3 See Camerer (1995), Kahneman and Tversky (1979), and Schoemaker (1993) for surveys on the experimental work in the case of EUT. See Kroll, Levy, and Rapoport (1988a/1988b), Rapoport, Zwick, and Funk (1988), and Weber and Camerer (1992) for experimental work in the case of PST.

test for the compliance of team decisions with the principles of EUT and/or PST. Our experimental protocol is simple. A number of pairwise lottery choice tasks and lottery evaluation tasks are presented to individual subjects as well as to teams of three in an across-subject design. Drawing on the experimental individual choice literature, we have constructed the tasks such that detecting inconsistencies of observed choice patterns with the principles of EUT and/or PST is not only technically possible, but also quite likely - at least in the control treatment with individual decision makers. Specifically, we test for three patterns of choices that are inconsistent with EUT and have regularly been reported in the literature, namely the *common ratio effect*, the *preference reversal effect*[4], and the *reference point effect*. Detailed descriptions of the effects are given in section 4. At the same time, the lottery pairs are parameterized such that in half of the cases the lottery with the lower expected value has the higher variance (*gambler lottery pairs*), while in the other half of the cases the constellation is reversed (*investor lottery pairs*).[5] Obviously, choosing the lottery with the lower expected value in a gambler lottery pair contradicts the risk-value principle of PST.[6]

From the experimental data we draw two main conclusions. On the one hand, we find almost no evidence for the compliance of team decisions with the principles of EUT. The observed team decisions are not distinguishable from the individual decisions in the cases of the common ratio effect and the preference reversal effect. Only concerning the reference point effect, do we find significantly less inconsistent choice patterns in team decisions than in individual decisions. On the other hand, we find substantial evidence for the consistency of team decisions with the risk-value principle of PST. Compared to individual decision makers, teams accumulate significantly more expected value at a significantly lower total risk. In view of these results, we conjecture that team decision making may be adequately represented by a risk-value model based on the principles of PST. This result falls completely in line with the observation by Gooding (1975, p. 1301), that "while investor groups' average stock perceptions are highly related to relevant risk and return measures, significant differences may exist between portfolio managers' and nonprofessional investors' average multidimensional perceptions."

Inspired by the video taped discussions, we introduce a team decision algorithm, the *excess-risk*

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4 Note that preference reversals are neither in line with EUT nor with PST nor with any other theory that assumes preference orderings that are independent of the presentation of the task. In the literature, however, this effect is usually related to EUT.

5 Also from a perception point of view it seems adequate to classify the lotteries in this way, since March and Shapira (1987) report that managers actually "make a sharp distinction between taking risks and gambling."

6 We use variance as a measure of risk in the risk-value model, mainly because it is free of personalized parameters and easily accessible in the context of lottery choices. However, it should be mentioned that a number of experimental papers report other better suited measures of risk that typically require the assessment of an personalized parameter. For a survey of the risk measures literature see Brachinger and M. Weber (1997). An overview of the risk-value models is contained in Sarin and M. Weber (1993).

vetoing, that combines simple majority voting with the right to veto alternatives providing additional risk that is not compensated by additional expected value. Without implying general validity of this rule for the team decision process, we find that the results of our experiment are well explained by the excess-risk vetoing.

Although a large number of experimental studies in social psychology have investigated group decision behavior under uncertainty, we know of no study that addresses the discussed issues. Recently, interest in studying the effects of the social dynamics of informal discussions on group decision making has also been growing in experimental economics. Most of this research, however, is focused on topics other than the concern of this paper.[7] In section 2 we give a short overview of those aspects of the group decision making literature that are of interest for our topic. In section 3 the experimental setup is presented, before the results are discussed in sections 4 and 5. In section 6 the excess-risk vetoing rule is introduced and compared to the experimental data. Finally, in section 7 we summarize and draw conclusions.

2. Related Research on Group Decision Making

In social psychology a great amount of research has been centered on the effect of the social dynamics of informal discussions on group decision making (Kerr, MacCoun, and Kramer 1996). In the framework of decision situations with uncertain outcomes, an early finding, called the *risky shift* phenomenon, caused much turmoil (Stoner 1961; Wallach, Kogan, and Bem 1962). The finding was that groups confronted with a *choice dilemma* task[8] tended to make a riskier decision than the average group members, to whom the same task was presented individually.[9] The phenomenon was first explained with a presumed tendency of group members to use the group for "hiding" from their responsibility and taking exaggerated risks (Wallach, Kogan, and Bem 1964).

After both *risky* and *cautious shifts* were observed (Stoner 1968), the *social comparison theory* (Brown 1965; Myers, Bruggink, Kersting, and Schlosser 1980; Stoner 1968) emerged as the leading explanation for the general *choice shift* phenomena. From the point of view of the social comparison

7 Cason and Mui (1997) and Bornstein and Yaniv (1998), for example, are both concerned with the effect of informal group interaction on the extent of other-regarding behavior. Cox and Hayne (1998) investigate group decision making in the setting of common value auctions.

8 These tasks consisted of a social context frame that included a risky action with superior outcome and a cautious action with inferior outcome (e.g. a student choosing between a "risky" and a "safe" major in college or a trainer choosing between a "risky" and a "safe" game strategy for a football team).

9 Evidence of this kind was subsequently also reported in marketing papers, e.g. Woodside (1972 and 1974).

theory, the direction of the choice shift depends on the *social value* of risk-taking or risk-avoidance in the given situation: A risky (cautious) shift is observed, because group members discover and adapt to the risky (cautious) alternative that is more highly valued in their group. The theory was criticized almost from the start. Using a simple binary choice task, Zajonc, R. Wolosin, M. Wolosin, and Sherman (1968) found a significant cautious shift. They interpreted their result as evidence against the social comparison theory, since the task had been presented and run in a completely context free setting. More studies with context free decision situations followed, almost all finding choice shifts.[10]

In the mean time, Moscovici and Zavallini (1969) made the observation that group members often reported more extreme judgements after group discussion than before. This effect, later called *group polarization* (Myers and Lamm 1976), was suggested as an explanation for the choice shift phenomenon. The concept was criticized (e.g. Davis 1992), however, because it left a puzzle unsolved: if choice shifts are caused by group polarization, what causes the latter; if the causal chain is reversed, what causes the former. Burnstein, Vinokur, and Trope (1973) offered a partial explanation with the *persuasive argument theory*. They suggested that the extent and the direction in which the group members actually adjust to the group, i.e. to each other, depends on the persuasiveness and the number of the arguments related to the available alternatives.

Finally, another answer to the question of choice shifts emerged after Zajonc et al. (1968) and other authors suggested that the aggregation of the group members' preferences will lead to a risky shift (cautious shift), if majority rule is used and the median voter's preference is riskier (more cautious) than the average preference of the group. Davis (1973) formalized this argument and introduced the *theory of social decision schemes*.[11]

As this brief outline and the extensive overview by Davis (1992) of the social psychology literature on group decision making under risk show, the field has mainly been interested in analyzing and describing the relationship between the individual team member's preference and the team's decision. The notion of consistency in this literature is usually a self-referential evaluation of the team members' choices in different situations. Comparisons to rational economic or decision theoretic models are extremely rare.

The only experiment we know of, that is on group decision making under risk and has its main focus on

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10 Davis, Kerr, Sussmann, and Rissman (1974) , for example, present an extremely elaborate experiment, in which subjects had to evaluate "duplex bets", lotteries that were split up into a "lose" and a "win" component, on a 10-point scale. They observed risky shifts for lotteries with positive expected values and cautious shifts for lotteries with negative expected values. Crott, Zuber, and Schermer (1986) also find risky shifts for ranking tasks of lotteries with positive expected values.

11 See the overviews by Davis 1992 and Davis, Kameda, and Stasson 1992.

testing economic theory is reported in Bone, Hey, and Suckling (1997). As in our experiment, individual subjects and subject groups are presented with lottery choice tasks. Bone et al., however, use a within-subject design, where subjects first make individual choices, then decide in groups, before returning for a second round of individual decision making. Corresponding to their specific research goal, their setup only allows testing for the common ratio effect pertaining to EUT and is not designed for testing the compliance of choices with the principles of PST.

The main interest of the investigation by Bone et al. lies not in the groups' decisions, but in the effect of the group interaction on the individuals' decision making. The question is whether the individuals are affected towards more compliance with the axioms of EUT through the informal group discussions. Bone et al. find that neither group discussion nor task repetition lead to a rise in the number of EUT-consistent choices. In fact, the rate of consistent choices even drops slightly from the pre- to the post-discussion round of individual decision making. Typically, the rate of consistent choices by groups is closer to the lower of the two individual rates. Our results seem compatible with the results of Bone et al., because we also find almost no difference when comparing team and individual decisions in the case of the common ratio effect. We do, however, find significant differences between team and individual decision making with respect to other effects.

3. The Experimental Setup

In each session of the experiment, sixteen lottery choices and eight lottery evaluations were preformed by either a single subject (*individuals treatment*) or a team of three subjects (*teams treatment*). The lottery choice tasks were all pairwise choices. For the lottery evaluations the method introduced by Becker, DeGroot, and Marschak (1964) was used.[12]

Table 1 contains all lottery pairs used in the choice tasks. Each of the lotteries in the pairs 9 to 12 was also evaluated in the evaluation task. In Table 1, the lottery pairs are presented in an order corresponding to the behavioral regularities they were designed to test for (see below). The sequence in which the choice tasks were presented to the subjects is indicated in the column *Task* of Table 1. The evaluation tasks followed the choice tasks.

At the beginning of each session, the instruction sheet (see appendix A) was read aloud to the subject

12 In the selling price elicitation procedure used, the subject reported a minimum price $\hat{p}$ at which he/she was willing to sell the lottery. Next a price p was randomly drawn from the range of zero to the highest payoff of the lottery. The subject received p, if $p \$ \hat{p}$. If $p < \hat{p}$, the subject played the lottery. It is dominant to report the certainty equivalent of the lottery as $\hat{p}$. The dominance argument was presented to the subjects in the instructions.

or the subject group. The instruction sheets for both treatments were identical except for the parts that were concerned with the treatment variable, i.e. individual or team decision. After the instructions were read, the subjects - alone or as a team - were seated in front of a computer screen on which the lottery choice and evaluation tasks were displayed. The subjects viewed the screen, but did not operate the computer. In both treatments, the computer was operated by a student monitor, who was instructed in using the experimental software[13]. The student monitors were told not to interfere with the decision process.

The subjects had to record their decision on the *decision sheet* (see appendix A). In the individuals treatment, the decision sheet was signed by the single subject. In the teams treatment, the decision sheet was only accepted if all three team members had signed it. Apart from this *all-signatures rule,* the mode of team decision making was not restricted. The signed decision sheet was handed to the student monitor, who entered the decision to the computer.

All sessions were video taped. The subjects in the individuals treatment had been asked to make comments on their decisions. The subjects in the teams treatment discussed their decisions freely. No explicit time limit was given in either treatment, but the posters for subject recruitment had announced a duration of one-and-one-half hours. The actual duration of the sessions, including instructions, varied between a minimum of ca. 30 minutes to a maximum of ca. 50 minutes. The sessions in the teams treatment usually took a little longer.

All decisions were paid. By default, each team member received a payoff equal to the amount the team had earned. The possibility of an internal reallocation of the team earnings had neither been pointed out nor excluded, but redistribution was not discussed in any team.[14] Thus, in every team, each team member received the same payoff. No subject earned less than DM 20 or more than DM 26.[15] All 32 sessions - 16 individuals and 16 teams - were run at the *Laboratorium für experimentelle Wirtschaftsforschung* of the University of Bonn. Each subject was only permitted to participate in a single session only. A total of 64 subjects took part in the experiment, most of which were undergradu-

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13 The software was programmed using *RatImage* (Abbink and Sadrieh 1995). Each lottery was presented numerically and graphically, with the probabilities of outcomes as portions of a *wheel of fortune*. Once a lottery was chosen, the corresponding wheel of fortune was *turned* and the outcome was determined by the stopping point of the wheel. After a selling price was reported in an evaluation task, a random number between zero and the highest outcome of the lottery was drawn in an on-screen slot machine style device. If the randomly drawn number was greater than the chosen price, the number was the payoff for the task. If it was smaller than the price, the lottery was played out with a wheel of fortune. (The random number generator of the computer software determined the draws.)

14 The absence of payoff re-allocations amongst group members is also reported by Bone et al. (1997).

15 At the time the experiment was conducted, the wage paid to student teaching aids at German universities was roughly DM 15 an hour and the exchange rate US$ to DM was ca. US$ .60 for DM 1.00.

ate students of law or economics. None of the subjects had taken part in a lottery choice or evaluation experiment before.

TABLE 1
Lottery pairs used in the 16 choice tasks

No.	Task	Type	Endow-ment	Lottery A						Lottery B					
				A1	P(A1)	A2	P(A2)	EV	SD	B1	P(B1)	B2	P(B2)	EV	SD
Common Ratio Tasks															
1	1	I	0	600	60%	0	40%	360	293.9	320	90%	0	10%	288	96.0
2	15	I	0	320	45%	0	55%	144	159.2	600	30%	0	70%	180	275.0
3	9	I	0	320	30%	0	70%	96	146.6	600	20%	0	80%	120	240.0
4	5	I	0	600	10%	0	90%	60	180.0	320	15%	0	85%	48	114.3
5	6	G	0	640	60%	0	40%	384	313.5	500	80%	0	20%	400	200.0
6	16	G	0	500	60%	0	40%	300	245.0	640	45%	0	55%	288	318.4
7	11	G	0	640	30%	0	70%	192	293.3	500	40%	0	60%	200	245.0
8	2	G	0	500	20%	0	80%	100	200.0	640	15%	0	85%	96	228.5
Preference Reversal Tasks															
9	3	I	0	200	80%	50	20%	170	60.0	650	30%	0	70%	195	297.9
10	7	I	0	200	90%	50	10%	185	45.0	450	20%	150	80%	210	120.0
11	10	G	0	250	90%	0	10%	225	75.0	500	20%	100	80%	180	160.0
12	13	G	0	150	90%	50	10%	140	30.0	600	20%	0	80%	120	240.0
Reference Point Tasks															
13	4	I	0	300	100%	0	0%	300	0.0	500	40%	250	60%	350	122.5
14	8	I	500	-200	100%	0	0%	-200	0.0	0	40%	-250	60%	-150	122.5
15	12	G	0	600	20%	100	80%	200	200.0	250	100%	0	0%	250	0.0
16	14	G	500	-250	100%	0	0%	-250	0.0	-400	80%	100	20%	-300	200.0

Note: The lotteries A and B of the pairs 9 - 12 were used in the 8 evaluation tasks, that followed the choice tasks.

4. Are Team Decisions Consistent with the Axioms of EUT?

The lottery pairs of the choice tasks (see Table 1) were selected to test for three typical patterns of choice that are not consistent with axioms of EUT. All three *behavioral regularities* are well-known and have often been reported in the literature on individual decision making under risk.[16] The lottery pair sequences 1 to 4 and 5 to 8 were designed to test for the *common ratio effect*, which is due to Allais (1953). Each of the lotteries in the pairs 9 to 12 was presented in both in a choice and in an evaluation task. The combination of decisions was used to check for the *preference reversal effect*, a phenomenon first reported by Lichtenstein and Slovic (1971) and separately by Lindman (1971). Finally, the pairs 13 to 16 were devised to check for the *reference point effect* (Kahneman and

16 See Camerer 1995, Kahneman and Tversky 1979, and Schoemaker 1993.

Tversky 1979), which is sometimes referred to as *loss aversion* or *reflection effect* and which was already informally mentioned much earlier by Markowitz (1952).

The Common Ratio Effect

In each of the two *common ratio sequences* (pairs 1 - 4 and 5 - 8), each lottery pair consists of a lottery with a high and a lottery with a medium prize. The other outcome of each lottery, the low prize, is always equal to zero. The probabilities of winning the high and the medium prize fall from pair to pair in the sequence, but the ratio of the high prize probability to the medium prize probability remains unchanged throughout the sequence. It can easily be shown that a subject following the EUT axioms should either choose the lottery with the high prize or choose the lottery with the medium prize in every one of the four tasks of a sequence. The common ratio effect, however, predicts that subjects are more likely to choose the medium prize lottery, in those pairs in which the winning probabilities are perceived high, but less likely to do so, if the probabilities of winning are perceived low. The explanation often given for such behavior is that the perceived difference between the probabilities of winning declines as the probabilities of winning decline in absolute value. Hence, in pairs with high winning probabilities this difference is decisive, while in pairs with low winning probabilities the difference in prizes is decisive. For overviews see Kahneman and Tversky (1979) and Camerer (1995).

The Preference Reversal Effect

Each pair in the four preference reversal tasks (pairs 9 - 12) consists of a *dollar bet* ($-bet), in which a large prize can be won with a small probability, and a *probability bet* (P-bet), in which a medium prize can be won with a high probability. A *predicted* preference reversal refers to the phenomenon that subjects willing to opt for the P-bet in the choice task, tend to evaluate the $-bet with a higher selling price than the P-bet in the evaluation task. The most prominent explanation for this type of switch in preferences is that subjects' information processing varies with the framing of the task: choices among pairs of lotteries are influenced more by the probabilities of winning, while evaluations of lotteries are strongly correlated to the amounts that can be won. Obviously, any switch in the preferences that is only due to the framing of the task is inconsistent with EUT, PST, and any other theory that assumes framing independent preferences.[17] The literature on preference reversals is abundant. See Slovic and Lichtenstein (1983) and Camerer (1995) for overviews. In their rigorous examination of the phenomenon, Grether and Plott (1979) found strong support for the cognitive hypothesis, especially since they observed predicted preference reversals significantly more often than unpredicted ones (when

17 In a recent experimental study, however, E. Weber and Milliman (1997) find support for a risk-value model that employs *perceived risk* (a measure reported by the subjects themselves), instead of employing an objective risk measure. The concept is interesting, because it allows for situational dependency of preferences. This opens the door for certain preference reversals that can then be accounted for in the framework of a risk-value model.

the $-bet is chosen, but the P-bet is evaluated with a higher price) in a variety of settings.

The Reference Point Effect

The reference point effect, tested with the lottery pairs 13 - 14 and 15 - 16, refers to the inclination of subjects to accept risks in losses, which they avoid in gains. Here the terms "losses" and "gains" are used in the sense of Kahneman and Tversky's (1979) *prospect theory*, in which preferences are assumed to be sensitive to the variations of wealth from an initial reference point instead of to the variations of total wealth. As indicated in Table 1, the subjects were paid an initial endowment, before choosing from the lottery pairs 14 and 16. It can be easily seen that the lottery pair 14 is constructed by subtracting this endowment from all outcomes of the lotteries in the pair 13. The pair 16 is constructed analogously from the pair 15. Since the tasks 13 and 14, as well as 15 and 16, are equivalent concerning changes of total wealth, subjects complying with the EUT axioms should be consistent in their choices across each pair, i.e. should choose the lottery with the higher expected value in either both or in neither of the tasks. In contrast, the reference point effect predicts that subjects will select the less risky alternative, when the choice is presented in the domain of positive payoffs (pairs 13 and 15), but will choose the more risky alternative, when choice is presented in the domain of negative payoffs (pairs 14 and 16). This inconsistency in preferences seems to stem from the subjects' affinity for (almost) sure gains and their aversion against (almost) certain losses. The reference point effect has been reported in a large number of studies (for example see Bazerman 1983 or Hershey and Shoemaker 1980).

Frequency of Predicted and Unpredicted Inconsistencies

All three behavioral regularities have a *direction*, i.e. predict a specific structural constellation of the choices that is inconsistent with the axioms of EUT. These are the *predicted inconsistencies*. In all three cases, however, a different pattern of choices can also evolve that is not only inconsistent with the axioms of EUT, but also with the behavioral explanation of the predicted inconsistencies. This type of choice pattern is call an *unpredicted inconsistency*. The relationship between the frequency with which predicted and unpredicted patterns of behavior are observed seems to be a sensible measure for the explanatory power of the behavioral hypotheses discussed above. On the level of individual decision making, there is plenty of experimental evidence showing that predicted inconsistencies are observed significantly more often than unpredicted ones.

Since in our setup observing both multiple predicted and multiple unpredicted inconsistencies in preferences is possible, we classify each individual and each group in one of the following four categories: *no inconsistencies*, *more predicted inconsistencies*, *equally many predicted and unpredicted inconsistencies*, and *more unpredicted inconsistencies*. Table 2 contains the corresponding data. (The tables B.2a and B.2b in the appendix B present the data in detail.)

The distribution of individuals over the four categories in Table 2 clearly supports the case for the behavioral explanations of the common ratio and the preference reversal effects: Not only do most subjects violate expected utility theory, but a large majority of them falls in the category with more predicted than unpredicted inconsistencies. The binomial test significantly rejects the null hypothesis that individuals are equally likely to exhibit more predicted than unpredicted patterns of choice and vice versa at the 1% level (one-sided) for the common ratio effect and at the 5% level (one-sided) for the preference reversal effect. Thus, concerning these effects, our experimental results from the individuals treatment support earlier findings.

The comparison of the individuals to the teams in Table 2 reveals that the treatment variable seems to have practically no influence on the emergence of the common ratio and preference reversal effects. All in all, teams exhibit patterns of inconsistencies that seem very similar to those of individuals. The impression of similarity is supported by the fact that team and individual behavior cannot be proven to be significantly different - neither concerning the total number of, nor the number of predicted, nor the number of unpredicted inconsistencies. (We checked the differences using the U-test on the distribution of individuals and teams across each of these different dimensions.) Finally, teams - just like individuals - exhibit significantly more predicted than unpredicted inconsistencies in the common ratio and preference reversal tasks (binomial test is significant at the 2% level, one-sided).

TABLE 2
Individuals (teams) classified by the relationship of exhibited predicted to unpredicted inconsistencies

Set of Tasks	Common Ratio		Preference Reversal		Reference Point	
Treatment	individuals	teams	individuals	teams	individuals	teams
no inconsistencies	4	2	5	1	4	12
more predicted inconsistencies	10	10	9	12	6	2
equally many predicted and unpredicted inconsistencies	1	2	0	1	1	0
more unpredicted inconsistencies	1	2	2	2	5	2

Note: Individuals (teams) exhibiting no inconsistencies are counted only in the first, but not in the third category.

In the tasks concerning the reference point effect, the picture is different. Here, significantly less teams than individuals made choices that were not consistent with the axioms of EUT (Fisher's exact test at the 1% level, one-sided). In fact, all teams exhibited EUT-consistent choice patterns in the lottery pair combination (13 - 14), while 2 predicted and 2 unpredicted inconsistencies were observed in the (15 - 16)-combination. In contrast, many choices made in the individuals treatment were inconsistent with EUT: We observed 7 predicted and no unpredicted inconsistencies in the (13 - 14)-combination, but 2 predicted and 6 unpredicted inconsistencies in the (15 - 16)-combination. Especially the latter result is astonishing, since many of the exhibited patterns of choice not only contradict the axioms of EUT, but also the behavioral explanation of the reference point effect. It seems that the (15 - 16)-combination has some unusual feature that induces such a large number of unpredicted choices in the individuals treatment, but does not affect the choices of the teams.

Summarizing the results on the behavioral regularities in choices under risk, we find the common ratio and the preference reversal effects are strongly present both in the individual and the team decision data. In addition no differences are detectable between the individual and the team decision data relating to these effects. The results concerning the reference point effect are somewhat different, because teams exhibit significantly less inconsistencies in these tasks than individuals. All in all, we must negate the question whether team decisions are consistent with the axioms of EUT. Even the positive evidence from the reference point lottery pairs, should only be cautiously interpreted as revealing a tendency of team decisions to be more compliant with the axioms of EUT than individual decisions.

5. Are Team Decisions Consistent with the Principles of PST?

To test for choice behavior with respect to different risk-value constellations, we designed two different types of lottery pairs: the *investor lottery pairs* and the *gambler lottery pairs*. The classification is based on the comparison of the expected values (EV) and standard deviation (SD) of the two lotteries contained in the pair. Of the 16 lottery pairs that were used in the experiment, 8 were investor lottery pairs and 8 gambler lottery pairs. Table 2 contains an entry for the type of each lottery pair: investor lottery pairs are marked with an I and gambler lottery pairs are marked with a G.

An investor lottery pair resembles a *typical* investment decision: the lottery with the higher EV also features the higher risk (the higher SD), whereas the other lottery has both the lower EV and the lower risk (the lower SD). So the lottery with the greater EV (*EVmax lottery*) can be interpreted as a risky investment, such as an investment in stocks, whereas the lottery with the smaller EV (*EVmin lottery*) is comparable to low risk asset, such as a bond. Thus, choosing from an investor lottery pair means facing the trade-off between risk and value (EV).

In a gambler lottery pair one of the two lotteries contained has both the higher EV and the lower risk (the lower SD), whereas the other lottery yields less EV at a higher risk. Gambling of any kind resembles this type of choice. For example, choosing to participate in a national lottery instead of keeping the price of the lottery ticket, means choosing a lower EV at a much higher risk. This may be attractive, simply because the lottery promises extremely high prizes, even if the chances of winning are extremely low. In a gambler lottery pair there obviously is no trade-off between risk and value, since the EVmax lottery has the lower risk.

The first question to ask is, whether individuals and teams differ in the amount of expected value and the amount of risk (measured in SD) they *collect* in the course of the experiment. To compare the data, we calculated the accumulated expected values and the accumulated standard deviations of the 16 lotteries chosen by each individual and by each team. The result is that the teams collect significantly more expected value with their choices than individuals (U-test 1% level, one-sided) and this at a significantly lower risk (U-test 5% level, one-sided).

Obviously, the teams are closer both to expected value maximization and risk minimization with their choices than are the individuals. But, if teams are doing better in both the risk and the value dimension, we can infer that a number choices by individuals are not on the *efficient frontier* of the risk-value curve. To check for this, we break down the total accumulated expected value into the part accumulated in investor lottery pairs and the part accumulated in gambler lottery pairs. We split up the accumulated standard deviations similarly.

In the investor lottery pairs, the difference between the choices of the teams and of the individuals corresponds to the overall direction, but is relatively small: teams accumulate significantly more expected value than individuals (U-test, 10% one-sided), however, at an accumulated risk that is not significantly different from that of individuals (U-test with $p > 20\%$, one-sided). The results for the gambler lottery pairs are not only in the overall direction, but even much more extreme: with their lottery choices, teams accumulate significantly more expected value than individuals (U-test, 1% level, one-sided) at a significantly lower risk (U-test, 1% level, one-sided).

To analyze the extend to which team and individual decisions differ, normalized expected value and standard deviation measures are studied. For each lottery choice task, we calculate the difference between the expected value of the chosen lottery and the minimum of the two lotteries' expected values. These values are summed up over all tasks and normalized over the maximal possible difference. The measure has the advantage of focussing on the rate of expected value accumulation that exceeds the default minimum. The standard deviation measure is derived in an analogous manner. Note that applying the U-test to these normalized measures leads to the same statistical inferences as reported above. Table 3 shows the averages of the observed normalized expected value and standard deviation measures.

TABLE 3
Average normalized expected value (EV) and standard deviation (SD) measures

	average normalized EV measure		average normalized SD measure	
	individuals	teams	individuals	teams
Investor lottery pairs	0.96	0.98	0.88	0.91
Gambler lottery pairs	0.5	0.75	0.46	0.23
All lottery pairs	0.91	0.96	0.75	0.69

Table 3 shows that individual and team choices in investor lottery pairs are similar: in both cases slightly less than the maximum expected value is accumulated at about 90% of the additional risk. The picture is different in the gambler lottery pairs, in which 100% EV accumulation could have been achieved at minimal risk. In these tasks, teams on average collect 25% more of the additional EV than individuals (75% to 50%). At the same time, teams on average only accumulate 23% of the risk that exceeds default minimum risk, while individuals accumulate double as much (46%).

Thus, we find that teams and individuals tend to make similar choices when there is a trade-off between the lottery with the higher expected value and the lottery with the lower risk, i.e. in a investor lottery pair. When it comes to *gambling*, i.e. when it comes to choosing the lottery with the lower expected value at a higher risk, however, teams tend to be significantly less risk seeking. This means that the lotteries chosen by teams tend to be on the efficient frontier of the risk-value curve more often than the lotteries chosen by individuals. Hence, the choices made by individuals are inconsistent with the principles of PST more often than the decisions by teams. It seems that the informal group discussions do increase the frequency of decisions that are consistent with PST, although teams choices do violate the principles of PST in about 25% of the possible cases.

6. Excess-Risk Vetoing

From the video protocols it was quite apparent, that decision making in teams was most frequently based on the majority vote. It seems, however, that some teams added a special type of veto to the majority rule in order to hinder unreasonable gambling: the selection of a risky choice could be vetoed, if the risk was not compensated by a substantial gain in expected payoff. The notion underlying such a rule is in the spirit of the risk-value principle of PST.

On the basis of this observation, we define the *excess-risk vetoing* algorithm as follows:

1. the team decides by majority vote, unless one team member raises an *excess-risk veto*;
2. an *excess-risk veto* is the proposal by a team member to select an alternative lottery that has a higher expected value, but is not riskier than the one nominated;
3. once an *excess-risk veto* is raised, the alternative proposed with the veto is chosen.

It can immediately be seen, that in the context of our experimental setup, teams deciding in accordance with the excess-risk vetoing rule will chose the high risk, low expected value lottery of a gambler lottery pair only if there is a unanimous vote for that lottery. The same team, however, can select either lottery of an investor lottery pair with a simple majority vote.

It is important to point out, that we are not suggesting that teams explicitly used such a rule. We rather believe that excess-risk vetoing implicitly arises from the positions in the debate. The vetoing team member needs a strong argument to prevail. Evidently, a substantial gain in expected payoff at a no greater risk is such a strong argument. In the *Persuasive Argument Theory* (PAT), proposed by Burnstein, Vinokur, and Trope (1973), the group decision is influenced by the strength and number of persuasive arguments for the competing alternatives. Thus, if dominance in the risk-value space is a persuasive argument, then a team member pointing out the existence of a risk-value dominant alternative, will easily convince the other team members to avoid the excess risk pertaining to the dominated alternative.

We test the explanatory power of the excess-risk vetoing rule in comparison to the three standard voting schemes, *Minority for EVmax*, *Majority for EVmax*, and *Unanimity for EVmax*. For the test, we form all possible 3360 hypothetical groups of three subjects from the 16 subjects who participated in our individuals treatment. In each of these hypothetical "teams", we let the three members "vote" for a lottery choice, where each "vote" is determined by the observed decision of the corresponding subject in that task of the experiment. The decision of the hypothetical team is calculated by combining the individual votes with one of the following voting schemes:

Minority for EVmax: If at least one vote is cast for the high EV lottery, then it is selected; otherwise the low EV lottery is selected.

Majority for EVmax: If at least two votes are cast for the high EV lottery, then it is selected; otherwise the low EV lottery is selected.

Unanimity for EVmax: If all three votes are cast for the high EV lottery, then it is selected; otherwise the low EV lottery is selected.

In the investor lottery pairs, the excess-risk vetoing rule coincides with the *Majority for EVmax*, because an excess-risk veto is not possible. In the gambler lottery pairs, however, excess-risk vetoing is possible, since any team member can veto the EVmin lottery and propose the alternative low risk lottery with the higher expected value instead. Hence, the low EV lottery is only selected, if none of the team member casts a vote against it. Thus, in the gambler lottery pairs the excess-risk vetoing rule coincides with the *Minority for EVmax* rule.

To check whether the excess-risk vetoing rule explains our experimental data well, we compare the relative frequencies of observed and hypothetical EVmax lottery choices. Table 4 contains the observed relative frequencies of individuals and teams choosing the EVmax lottery. The frequencies are given for investor and for gambler lottery pairs separately, as well as over all pairs. The lower part of the table contains the relative frequencies of EVmax choices that would follow from each of the four voting rules in the hypothetical teams.[18]

18 Obviously, if all 16 subjects in the individuals treatment had chosen the EVmax lottery (as in the pairs 4 and 14), 100% of the hypothetical teams select the EVmax lottery under all three voting rules. Conversely, if no individual had chosen the EVmax lottery - which never occurred -, 0% of the hypothetical teams select the EVmax lottery.

As Table 4 clearly show, there is no substantial difference between the number of teams and the number of individuals choosing the EVmax lottery in the investor lottery pairs. The main difference between the choice behavior of individuals and teams is evidently due to the divergence of behavior in the gambler lottery pairs. On average about 17% more teams choose the EVmax lottery in these tasks than individuals do.

TABLE 4
Relative frequencies of observed and hypothetical EVmax lottery choices

	investor lottery pairs	gambler lottery pairs	all pairs
Observed individuals	0.81	0.56	0.69
Observed teams	0.88	0.73	0.8
Hypothetical teams, if ...			
... minority for EVmax	0.98	0.88	0.93
... majority for EVmax	0.86	0.57	0.72
... unanimity for EVmax	0.59	0.23	0.41
... excess-risk vetoing	0.86	0.88	0.87

The comparison of the observed team decisions and the hypothetical team decisions in Table 4 seems to provide support for the excess-risk vetoing rule. The number of teams choosing the EVmax lottery in the investor lottery pairs tends to be closer to the number of the hypothetical teams using the *Majority for EVmax* rule. But, in the gambler lottery pairs, the actual number of teams choosing the EVmax lottery tends to be closer to the number of the hypothetical teams using the *Minority for EVmax* rule. This observation is confirmed by the following Table 5, which contains the sum of the squared deviations of the relative frequency of EVmax choices by the observed teams from relative frequency of EVmax choices by the hypothetical teams. The deviation measure is smallest for the excess-risk vetoing rule.

TABLE 5
Sum of the squared deviations of observed teams' from hypothetical teams' EVmax choice frequencies

Decision rule	' (rel. freq. EVmax choices by observed - by hypothetical teams)^2		
	investor lottery pairs	gambler lottery pairs	all pairs
Minority for EVmax	0.33	0.29	0.63
Majority for EVmax	0.23	0.53	0.76
Unanimity for EVmax	1.25	2.25	3.5
Excess-risk vetoing	0.23	0.29	0.52

More rigorous statistical tests of the excess-risk vetoing hypothesis cannot by applied using this method, since the results of the hypothetical groups, which were formed from the observed 16 subjects' decisions in the individuals treatment, are statistically interdependent. But, the effect of the *excess risk*, i.e. the difference between the SD of the EVmin lottery and the SD of the EVmax lottery, on team decisions can be tested in a different way.

The difference between the number of teams and the number of individuals choosing the lottery with the higher EV is quite large for some lottery pairs (e.g. the pairs 11, 12, and 15), whereas this difference is rather small for other lottery pairs. An explanation for this variability can be that the persuasiveness of the excess-risk vetoing argument grows with the magnitude of the excess risk. If this conjecture is true, then we should observe a positive correlation between the excess risk and the difference in EVmax choice frequencies between teams and individual. Calculating Spearman's rank correlation coefficient for the two measures, over the 8 gambler lottery pairs, indeed yields a positive correlation coefficient of .679, that is significantly unequal to zero on a 5% level, one-sided. Thus, we can conclude that the magnitude of excess risk in a lottery pair positively influences the degree to which more team decisions than individual decisions comply with the risk-value principle.

7. Summary and Conclusions

The present paper reports an experiment designed to test for the compliance of team decisions under risk with the principles of two influential theoretic benchmarks: Expected Utility Theory (EUT) and Portfolio Selection Theory (PST). The experiment relies on an across-subject design. A series of lottery choice and evaluation tasks was presented to 16 individual subjects and to 16 teams, each consisting of 3 subjects. The tasks were designed to allow for three typical patterns of behavior that are inconsistent with the axioms of EUT and are all well-known from the literature on individual decision taking under risk: the common ratio effect, the preference reversal effect, and the reference point effect. Furthermore, the lottery pairs were chosen such that in half of the cases the lottery with the lower expected value had the higher variance (gambler lottery pairs), while in the other half of the cases the constellation was reversed (investor lottery pairs). This allows a test of the risk-value principle of PST, because choosing the low expected value, high risk lottery of a gambler lottery pair means selecting a portfolio that is not on the efficient frontier of risk and return.

The first result of the experiment is that the number of team decisions inconsistent with the axioms of EUT is only slightly lower than the number of such individual decisions. We observed both the common ratio effect and the preference reversal effect in the team decisions to the same extent as in the individuals' choices. The two effects were robust, in the sense that predicted inconsistencies were significantly more frequent than unpredicted inconsistencies. In one of the two lottery pairs testing for the reference point effect, however, the individual subjects exhibited an unexpectedly high number of unpredicted inconsistencies, although many predicted inconsistencies were exhibited by them in the other pair. It is remarkable that in these two tasks, the teams exhibited significantly fewer inconsistencies than the individuals.

The second result of the experiment is that the teams accumulated significantly more expected value (EV) than the individuals and this at a significantly lower total risk (SD). The effect was mainly driven by the difference between the team and the individual decisions in the gambler lottery pairs. By choosing the high EV, low risk lottery significantly more often in these pairs, the teams exhibited a greater compliance with the risk-return principle of PST than the individuals. In the light of this evidence, it seems that team decision making can adequately be represented by a risk-value model, of which many have been suggested for individual decision makers in the literature (see Sarin and M. Weber 1993).

The last result of the paper pertains to the process of decision making within the team. Our experimental setup had avoided imposing a formal decision protocol on the group interaction. Based on clues from the video taped team discussions, we constructed a decision rule, called excess-risk vetoing, and compared its predictions to the observed team decisions. Excess-risk vetoing is an enhanced majority rule, which allows each team member to veto a nominated prospect, by naming a different prospect with a higher EV at a lower risk (lower SD). Since the latter prospect dominates the former prospect in the risk-value space, the vetoing team member has a persuasive argument, by pointing out that the old candidate entailed an excess-risk, i.e. a risk that can be reduced without a sacrifice of EV. Comparing the predictions of the excess-risk vetoing rule as well as the predictions of the minority, the majority, and the unanimity rules, to the observed team decisions, we find that the excess-risk vetoing rule organizes our data best.

Two aspects of the results point at directions for future research. We conjectured that excess-risk vetoing is driven by the persuasiveness of the argument that one prospect dominates the other in the risk-value space. A different hypothesis, however, can also serve as a plausible explanation of the phenomenon. Team members may have preference orderings that not only depend on the features of the lotteries, but also on features of the decision environment, e.g. on being alone or in a team. A family mother, for example, may have different preferences for the driving speed of her car, depending on whether she is driving alone or accompanied by her children. Separating these different explanations remains to be examined by future research.

Another open question is directed towards the method of risk measurement. In our study, we have taken the conventional position of measuring risk only on the basis of objective characteristics of the lotteries, specifically by employing the standard deviation measure. Some authors, however, have argued that measures of *perceived* risk are better suited to explain decision making under risk[19]. Unlike the objective measures of risk, it seems plausible to conjecture that the perception of risk is influenced by the team discussions. The difference in risk perception could possibly account for the differences between individual and team decisions. For future research in this direction, however, the problem of establishing an accurate and meaningful measurement of risk perception, especially in the context of teams, has to be mastered.

19 See E. Weber and Milliman (1997) for an excellent recent paper on the topic.

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Appendix A: Handouts

INSTRUCTION SHEET

Your are asked to make 24 decisions on lotteries:
16 choices between two lotteries each
and 8 decisions on selling prices of lotteries

LOTTERY CHOICES

- In each round, you will be asked to choose between two different lotteries, labeled lottery A and lottery B
- the lottery you have chosen is then played
- the realized prize is you round payoff

SELLING LOTTERIES

- In each round one lottery will be presented
- you have to specify a minimal price, which you would accept for selling this lottery
- a random price is determined in the range of 0 and the maximal prize of the lottery
- in the case that the random price is equal to or exceeds you specified minimal price, you "sell" the lottery for the random price
- in the case that the random price is below your specified minimal selling price, you do not sell the lottery and it is instead played for you

PAYOFFS

- Your total payoff is the sum of all points you gained in the different tasks
- every 10 point are converted into 4 Pfennigs

FIGURE A.1 English Translation of the Instruction Sheet

LOTTERY CHOICE TASKS		
Round	Lottery Choice	Signature of the Player
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		

FIGURE A.2 English Translation of the Decision Sheet for Lottery Choice Task (Individuals)

SELLING LOTTERIES		
Round	Lottery Price	Signature of the Player
1		
2		
3		
4		
5		
6		
7		
8		

FIGURE A.2B English Translation of the Decision Sheet for Lottery Evaluation Task (Individuals)

LOTTERY CHOICE TASKS				
Round	Lottery Choice	Signature of player		
		left	middle	right
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				

FIGURE A.2A English Translation of the Decision Sheet for Lottery Choice Task (Teams)

SELLING LOTTERIES				
Round	Lottery Price	Signature of player		
		left	middle	right
1				
2				
3				
4				
5				
6				
7				
8				

FIGURE A.2B English Translation of the Decision Sheet for Lottery Evaluation Task (Teams)