Bonn Econon Discussion Papers

Discussion Paper 20/2010

Joint measurement of risk aversion, prudence and temperance

by

Sebastian Ebert and Daniel Wiesen

November 2010

Bonn Graduate School of Economics
Department of Economics
University of Bonn
Kaiserstrasse 1
D-53113 Bonn

Financial support by the
Deutsche Forschungsgemeinschaft (DFG)
through the
Bonn Graduate School of Economics (BGSE)
is gratefully acknowledged.

Deutsche Post World Net is a sponsor of the BGSE.

Joint measurement of risk aversion, prudence and temperance*

Sebastian Ebert[†] and Daniel Wiesen[‡]

November 16, 2010

Abstract

We propose a method to measure the intensity of risk aversion, prudence (downside risk aversion) and temperance (outer risk aversion) in experiments. Higher-order risk compensations are defined within the proper risk apportionment model of Eeckhoudt and Schlesinger [American Economic Review, 96 (2006) 280] that are elicited using a multiple price list format. This approach is not based on expected utility theory. In our experiment we find evidence for risk aversion, prudence and temperance. Women demand higher risk compensations for all orders. The highest compensation is demanded for taking downside risk, not for being (second order) risk-loving. This highlights the importance of prudence when considering economic decisions under risk.

Keywords: Decision making under risk, laboratory experiment, prudence, risk aversion, temperance, gender differences
JEL classification: C91, D81

1 Introduction

The concept of *risk aversion* plays a key role in analyzing decision making under risk. An established characterization is that an individual preferring a payoff with certainty over a risky payoff with the same mean is said to be risk-averse (e.g., Gollier 2001, p.18). Alternatively, Rothschild and Stiglitz (1970) state that a risk averse individual dislikes any mean-preserving spread of the wealth distribution. Within an expected utility (EU) setting, these two characterizations coincide and are equivalent to the utility function being

*We are grateful for valuable comments and suggestions by Louis Eeckhoudt, Thomas Gehrig, Harris Schlesinger, Reinhard Selten, conference participants of the 2010 GfeW Meeting in Luxembourg, seminar participants in Bonn, Freiburg and participants of the SGSS workshop in Bonn in January 2010. We thank Emanuel Castillio for his programming assistance as well as Martin Acht and Javier Sanchez for their help conducting the experiment. Further, we thank Michael Borrs, Mara Ewers, Stefanie Lehmann, Jan Meise and Gert Pönitzsch for their participation in a pilot experiment and their helpful comments on the experiment at that stage. The experiment was financed through the Geneva Association Research Grant 2009. Ebert's research is financed by the Bonn Graduate School of Economics and Wiesen's research is financed by the Konrad-Adenauer-Stiftung e.V.

†Bonn Graduate School of Economics, University of Bonn, Tel: +49 (0)228 73 97 27, e-mail: sebastianebert@uni-bonn.de

‡*B*onn*E*con*L*ab, Laboratory for Experimental Economics, University of Bonn, Tel: +49(0)228 739194, Fax: +49(0)228 739193, e-mail: daniel.wiesen@uni-bonn.de.

concave.

Risk aversion is not a concept to describe an individual's risk preferences exhaustively. It is just one piece in the puzzle, which needs to be complemented by higher-order risk preferences. *Prudence* (third-degree risk-aversion) and *temperance* (fourth degree risk aversion) are lesser known traits affecting behavior towards risk. Although Kimball (1990) coined the term 'prudence', its implications have been used in assessing a precautionary demand for saving much earlier by Leland (1968) and Sandmo (1970). In particular, they show within an EU setting how a risky future income does not guarantee that a consumer increases saving unless the individual exhibited prudence. The notion of 'temperance' was also introduced by Kimball (1992). Temperance refers to the fact that the advent of an unavoidable risk should lead an individual to reduce the exposure to another risk even if the two risks are statistically independent.

Recently a large theoretical literature on the implications of higher-order risk preferences under EU has emerged. Eeckhoudt and Gollier (2005) analyze the impact of prudence on prevention, i.e. the action undertaken to reduce the probability of an adverse effect to occur. This also plays an important role in a medical decision making context (see Courbagé and Rey 2006). Esö and White (2004) show that there can be precautionary bidding in auctions when the value of the object is uncertain and when bidders are prudent. Likewise, White (2008) analyzes prudence in bargaining. Treich (forthcoming) shows that prudence can decrease rent-seeking efforts in a symmetric contest model. Fagart and Sinclair-Desagné (2007) investigate prudence in a principal agent model with applications to monitoring and optimal auditing. Within a standard macroeconomic consumption and labor model, Eeckhoudt and Schlesinger (2008) analyze the impact of prudence and temperance on policy decisions such as changes in the interest rate. Other examples are insurance demand (e.g., Fei and Schlesinger 2008) or life-cycle investment behavior (e.g., Gomes and Michaelides 2005). By necessity this is not a complete list of applications.

Independent of the assumptions of EU, prudence and temperance also play key roles in aversion to negative skewness and kurtosis, respectively. Prudence has been shown to be equivalent to aversion to increases in downside risk as defined by Menezes et al. (1980). A downside risk increase does not change mean and variance of a prospect, but does decrease its skewness. Likewise, an increase in outer risk increases kurtosis but leaves the first three moments of a distribution unchanged. Menezes and Wang (2005) show that temperance is equivalent to outer risk aversion.

More recently, both prudence and temperance have been characterized outside an EU context by Eeckhoudt and Schlesinger (2006) as preferences over 50/50 lottery pairs. Their definition, which is shown to be equivalent to the ones mentioned, is particularly appealing for experimental purposes. Prudence is defined as a preference for disaggregating a zero-mean risk and a sure reduction in wealth across two equally likely states of nature. Analogously, temperance is a preference for the disaggregation of two independent zero-mean risks.[1]

On the empirical side, there is an extensive literature on the measurement of risk

[1] This definition of higher-order risk preferences is generalized in Eeckhoudt et al. (2008) as preference for combining good with bad. This definition also does not rely on EU.

aversion in numerous empirical settings (e.g. Barsky et al. 1997) as well as in various experiments. Focusing on experiments, almost as large as the number of experimental studies is the diversity in procedures. Two well established methods based on binary lottery choices are the multiple price list (e.g., Schubert et al. 1999, Holt and Laury 2002, Barr and Packard 2002) and random lottery pairs technique (e.g., Grether and Plott 1979, Hey and Orme 1994). An alternative approach comprises a selection task from an ordered set of lotteries (e.g., Binswanger 1980, Eckel and Grossman 2008 a). Another prominent method is the Becker-DeGroot-Marschak auction where a certainty equivalent is elicited (Becker et al. 1964, Harrison 1986, Loomes 1988). Related to the latter method Wakker and Deneffe (1996) propose a certainty equivalent technique with endogenous probabilities. In Dohmen et al. (forthcoming) subjects decide between safe and risky options in a variant of the so-called switch multiple price list technique.[2] Another experimental method based on the proper risk apportionment model will be proposed in this paper.

In contrast, there are few empirical studies on higher-order risk attitudes. Dynan (1993), Carrol (1994) and Carroll and Kimball (2008) trace prudence indirectly via the precautionary savings motive. We are not aware of an empirical study intentionally testing for temperance.[3]

Laboratory experiments could be used to investigate prudence and temperance as well as the associated theories and behavioral traits in a more controlled environment. Research in this direction has just started. The first attempt in this direction was made by Tarazona-Gomez (2004) who finds weak evidence for prudence. Her experiment relies on a certainty equivalent approach involving lotteries with several different outcomes. It is based on strong assumptions within EU, in particular, a truncation of the utility function. The only other papers testing for prudence are Deck and Schlesinger (forthcoming) and Ebert and Wiesen (2009) which test for prudence using the lotteries of Eeckhoudt and Schlesinger (2006). Both papers find significant support for prudence (61% and 65% of responses, respectively). Ebert and Wiesen (2009) motivate and show that the choice of the zero-mean risk considered in Eeckhoudt and Schlesinger's proper risk apportionment model significantly influences subjects' decisions. Deck and Schlesinger (forthcoming) also test for temperance and find weak evidence for intemperate behavior.

These studies *test for the direction* of third- or fourth order risk preferences, but do not *measure their intensity*. Subjects make several lottery choices and inference is made on the count of prudent (temperate) choices. In particular, such a design makes it difficult to compare the relative importance of prudence or temperance for a given individual.

Thus the aim of the present paper is, firstly, to present a method to measure the intensity of risk aversion, prudence and temperance. Secondly, this is done jointly so that we can compare their relative importance for a given individual. The approach is not based on EU. We define higher-order risk compensations within the proper risk apportionment model of Eeckhoudt and Schlesinger. More specifically, we measure the smallest amount that must be added to the lottery with more 2nd- (3rd-, 4th-) degree risk that makes an

[2]See Harrison and Rutström (2008) for a comprehensive overview on different experimental methods to elicit risk aversion.

[3]Dittmar (2002) presents weak evidence for kurtosis aversion in asset returns. Also results in Guiso et al. (1996) from an Italian household survey on pension-investment decisions are consistent with temperate behavior.

individual prefer this lottery over the one with less 2nd- (3rd-, 4th-) degree risk. This implies a clear tradeoff between nth degree risk and expected wealth. The lotteries in the experiment are calibrated such that compensations for different degrees of risk are comparable. We also show how these compensations are related to indices of higher-order risk attitudes defined in the literature just recently (Modica and Scarsini Modica and Scarsini, Jindapon and Neilson 2007 and Denuit and Eeckhoudt forthcoming b).

Our experimental method is a combination of the compound lottery display introduced in Ebert and Wiesen (2009) and a multiple price list technique which is popular from the Holt and Laury (2002) experiment. A within-subject design is applied to measure risk compensations of different orders. This design in turn is embedded in a between-subject factorial design used to test our approach for robustness to typical manipulations of the experimental setup.

We find substantial evidence for risk aversion, prudence and temperance. Most interestingly, in our experiment subjects demand a significantly higher downside risk compensation compared to the 2nd-order risk compensation. This highlights the importance of prudence and likewise questions the excessive focus on risk aversion in the economics literature, both theoretical and empirical. In particular, the literature contains numerous different experimental methods to measure risk aversion, but this paper constitutes the first approach to measure prudence. The outer risk compensation is smallest and significantly different from both the downside and second-order risk compensations. However, it is still significantly positive which indicates that most subjects are temperate, contrary to the tendency observed in Deck and Schlesinger (forthcoming). For a given subject, we find a positive correlation between compensations demanded, in particular for prudence and temperance. Thus, given the assumption of EU, our experiment supports the assumption of mixed risk aversion (Caballe and Pomansky 1996) which is exhibited by all the commonly used utility functions (Brockett and Golden 1987).

Moreover, we controlled the number of male and female participants in order to check for possible gender differences. Differences between women and men in risk attitudes are well documented in the experimental economics literature. Most evidence suggests that women perceive risks as greater, engage in less risky behavior, and choose alternatives that involve less risk, see Eckel and Grossman (2008 b) and Croson and Gneezy (2009) for reviews of the relevant literature. We show that this is also the case for higher order risk attitudes. Women are significantly more risk averse, more prudent and more temperate than men.

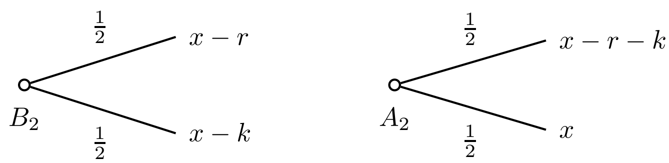
The remainder of this paper is as follows. In Section 2 we review the proper risk apportionment model and define risk compensations of higher-orders. In Section 3 we explain our experimental approach to elicit these compensations. In Section 4 we give the results of the experiment and in Section 5 we conclude.

2 Proper risk apportionment approach to elicit demanded higher-order risk compensations

Within the expected utility (EU) framework, assuming differentiability of a utility function u, risk aversion, prudence and temperance are defined as $u'' < 0$, $u''' > 0$ and $u^{(4)} < 0$, respectively. However, our experimental methodology is not based on EU but on the proper risk apportionment model of Eeckhoudt and Schlesinger (2006). Therefore, risk aversion, prudence and temperance are defined as a preference over lottery pairs.

We first define (2nd-degree) risk aversion. Let x be the individual's wealth and $k, r > 0$ are fixed monetary amounts. With $B_2 = [x - r, x - k]$, for example, we denote the 50/50 gamble B_2 that has equally likely payoffs $x - r$ and $x - k$. An individual is called risk averse if she prefers B_2 to $A_2 = [x - r - k, x]$ for arbitrary parameter values x, r and k. The lotteries are displayed in Figure 1. Thus, a risk averse individual prefers to disaggregate

Figure 1: Risk aversion lottery pair (A_2, B_2)



This figure shows lotteries of the type used to measure risk aversion in the experiment. x is the subject's endowment and $-r$ and $-k$ denote sure reductions in wealth. To imagine a prudence lottery pair (A_3, B_3), simply replace the $-r$ with a zero-mean risk $\tilde{\epsilon}_1$. To imagine a temperance lottery pair (A_4, B_4), additionally replace $-k$ with a second independent zero-mean risk $\tilde{\epsilon}_2$.

unavoidable losses $-r$ and $-k$ across states of nature. This preference is equivalent under EU to $u'' < 0$, as shown in Appendix A.[4] The preference is also equivalent to a preference for decreases in risk in the sense of Rothschild and Stiglitz (1970).

In order to define prudence (3rd-degree risk aversion, downside risk aversion), the sure reduction in wealth $-r$ in the definition for risk aversion (also illustrated in Figure 1) is replaced with a zero-mean risk $\tilde{\epsilon}$. That is, an individual is called prudent if she prefers $B_3 = [x - k, x + \tilde{\epsilon}]$ over $A_3 = [x, x - k + \tilde{\epsilon}]$ for all wealth levels x, sure wealth reductions $-k$ and zero-mean risks $\tilde{\epsilon}$. That is, a prudent individual prefers to disaggregate an unavoidable risk and a loss across different states of nature. Equivalently, an unavoidable risk is preferred when wealth is higher. Eeckhoudt and Schlesinger (2006) show that this preference is equivalent to $u''' > 0$ in EU or to a preference for decreases in downside risk as defined by Menezes et al. (1980).

Finally, temperance (4th-degree risk aversion, outer risk aversion) is defined as a preference of $B_4 = [x + \tilde{\epsilon}_1, x + \tilde{\epsilon}_2]$ over $A_4 = [x, x + \tilde{\epsilon}_1 + \tilde{\epsilon}_2]$ where $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ are two independent zero-mean risks. Under EU, this preference is equivalent to $u^{(4)} < 0$ and it is also equivalent to a preference for decreases in outer risk as defined by Menezes and Wang (2005).

Eeckhoudt and Schlesinger (2006) define a nesting process to construct lotteries B_n and A_n from the lotteries B_{n-2} and A_{n-2}. Then they show that the preference B_n over A_n is equivalent to $(-1)^{(n)} u^{(n)} < 0$ under EU which was labeled nth-degree risk aversion by Ekern (1980). An individual might be, for example, risk-loving and prudent (imprudent)

[4]Eeckhoudt and Schlesinger (2006) originally considered the lotteries $\tilde{B}_2 \equiv 0$ and $\tilde{A}_2 = [0, \tilde{\epsilon}]$, where $\tilde{\epsilon}$ is a zero-mean risk, and show that preferring $\tilde{B}_2$ over $\tilde{A}_2$ for all $\tilde{\epsilon}$ is equivalent to $u'' < 0$. We use the lotteries B_2 and A_2 instead because a certainty effect could distort experimental results when using $\tilde{B}_2$ and $\tilde{A}_2$.

just as he might be risk-averse and prudent (imprudent). If an individual prefers B_n over A_n for all n she is called *mixed risk averse*, see Caballe and Pomansky (1996). Under EU this means that her utility function is increasing with derivatives of alternating sign. It is interesting to note that all the commonly used utility functions imply mixed risk aversion, see Brockett and Golden (1987). Ebert (2010) showed that the utility of the proper risk apportionment of left-skewed risks is maximal if and only if the EU decision maker is mixed risk averse. By measuring three different degrees of risk aversion, we obtain a testable hypothesis for mixed risk aversion.

Our experiment aims to elicit compensations for nth-degree risk aversion for $n = 2, 3, 4$, i.e. a (2nd-degree) risk compensation m^{RA}, a downside risk (imprudence) compensation m^{PR} and an outer risk (intemperance) compensation m^{TE}. For example, in the case of risk aversion, for every individual we aim to elicit m^{RA} where she is indifferent between $B_2 = [x - r, x - k]$ and $A_2 + m^{\mathrm{RA}} = [x + m^{\mathrm{RA}}, x - r - k + m^{\mathrm{RA}}]$.[5] For a (2nd-degree) risk-loving individual, m^{RA} will be negative. Unlike in the experiments of Deck and Schlesinger (forthcoming) and Ebert and Wiesen (2009) we thus obtain a measure of the intensity of the risk attitude rather than only a test of preference direction.

Before explaining the procedure to implement our higher-order risk compensation approach to measure higher-order risk preferences in a laboratory experiment, it is interesting to relate it to the very recent theoretical literature on higher-order intensity measures. Generally, this literature is concerned with generalizing the measures introduced in Arrow (1965), Pratt (1964) and Ross (1981) to higher orders. Thus the following interpretations are subject to the EU paradigm. However, keep in mind that our approach is based on the proper risk apportionment model of Eeckhoudt and Schlesinger which does not rely on EU and, in particular, does not rely on any of the assumptions or approximations frequently observed in that literature.

Kimball (1990, 1992) established a link between $\frac{u'''}{u''}$ and the intensity of precautionary savings. Chiu (2005) gave a choice-theoretic foundation of this measure paralleling that of Arrow and Pratt being generalized to nth order by Denuit and Eeckhoudt (forthcoming a). Modica and Scarsini (2005) show that $\frac{u'''}{u'}$ is a natural extension of the Ross measure of stronger risk aversion and suggest that it is also locally a good measure for the intensity of downside risk aversion. In particular, the difference in compensations of random variables with equal mean and variance can approximately be written as the product of $\frac{u'''}{u'}$ and the difference in their third moments. This holds locally at any wealth level x. Jindapon and Neilson (2007) and Denuit and Eeckhoudt (forthcoming b) generalize their results and conclude that $(-1)^{n+1}\frac{u^{(n)}}{u'}$ is also locally an appropriate index of nth order risk attitude. For example, $-\frac{u^{(4)}}{u'}$ is an appropriate measure for kurtosis aversion. Crainich and Eeckhoudt (2008) more specifically consider a compensation for Eeckhoudt and Schlesinger's prudence lotteries and relate it to $\frac{u'''}{u'}$. In derivations similar

[5]Many different forms of compensations are possible. For example, the (second-order) risk premium defined in Ross (1981) in our setting corresponds to a compensation subtracted from B_2 for sure. We chose the compensation we think is most convenient for experimentation, see section 3.3 for a discussion. It has been considered in LaValle (1968).

to theirs, in Appendix A we show that for the lotteries in our experiment we have

$$-\frac{u''(x)}{u'(x)} \approx \frac{2m^{\mathrm{RA}}}{r(k-m^{\mathrm{RA}})} \tag{1}$$

$$\frac{u'''(x)}{u'(x)} \approx \frac{4m^{\mathrm{PR}}}{\sigma^2(k-m^{\mathrm{PR}})} \tag{2}$$

$$-\frac{u^{(4)}(x)}{u'(x)} \approx \frac{8m^{\mathrm{TE}}}{\sigma_1^2\sigma_2^2} \tag{3}$$

where $\sigma^2 = E[\tilde{\epsilon}^2]$, $\sigma_1^2 = E[\tilde{\epsilon}_1^2]$ and $\sigma_2^2 = E[\tilde{\epsilon}_2^2]$ denote the variances of the zero-mean risks.

Each intensity measure is increasing in the corresponding compensation $m^{\bullet}$. If we further assume that $m^{\mathrm{RA}}r$ and $m^{\mathrm{PR}}\sigma^2$ are small compared to rk and $\sigma^2 k$, respectively, we can add some more interpretation. The difference in variance of the risk aversion lotteries is $-rk$, the difference in the unstandardized central third moment of the prudence lotteries is $0.75\sigma^2 k$ and the difference in the unstandardized central fourth moment is $-1.5\sigma_1^2\sigma_2^2$.[6] Thus in this case each compensation of order n that we measure is proportional to the corresponding intensity measure of order n and to the difference in moments of order n.

3 Experimental design and procedure

In this section we first present the general set up of the experiment. Then we describe the decision situation in-depth. We further discuss our experimental methodology and the choice of parameters. Finally, we describe the experimental procedure.

3.1 General design

In our experiment, we present subjects with a menu of pairwise lottery choices that permits us to identify subjects' degree of risk aversion, prudence and temperance. Thereby we extend the methodology of Deck and Schlesinger (forthcoming) and Ebert and Wiesen (2009) who test for higher-order risk attitudes in a yes-or-no fashion. Further, because we use a within-subject design, we can compare the intensity of risk attitudes of orders 2,3 and 4 at an individual level. That is, we can investigate their relative importance to subjects. The main idea of the method is to combine a multiple price list format[7] with the ballot box representation of compound lotteries introduced in Ebert and Wiesen (2009).

Overall subjects make 120 decisions. After the experiment one decision is randomly selected to determine that subject's payoff.[8] The 120 decisions divide into 20 decisions

[6]Because of centralization this holds for the lotteries with or without a compensation. See e.g. Ebert (2010) for the computations.

[7]Besides the studies mentioned in the Introduction prominent examples of studies employing a multiple price list method to elicit risk attitudes are Murnighan et al. (1988) and Gonzalez and Wu (1999).

[8]It has become increasingly common in economics experiments to elicit a series of choices from participants and then to pay for only one selected at random; see Baltussen et al. (2010) for a fine overview. The random choice payment technique enables the researcher to observe a large number of individual decisions for a given research budget. However, the important question arises whether subjects behave as if each of these choices involves the stated payoffs. This issue has been analyzed, among various other setups, in experiments with pairwise lottery choice problems similar to our experiment. For example, Starmer and Sugden (1991) found clear evidence that under random payment subjects isolate choices as if paid for each task. Similar evidence was reported by Beattie and Loomes (1997) and Cubitt et al. (1998). In a lottery experiment with a multiple price list format Laury (2005) reports no significant difference in choices between paying for 1 or all 10 decision.

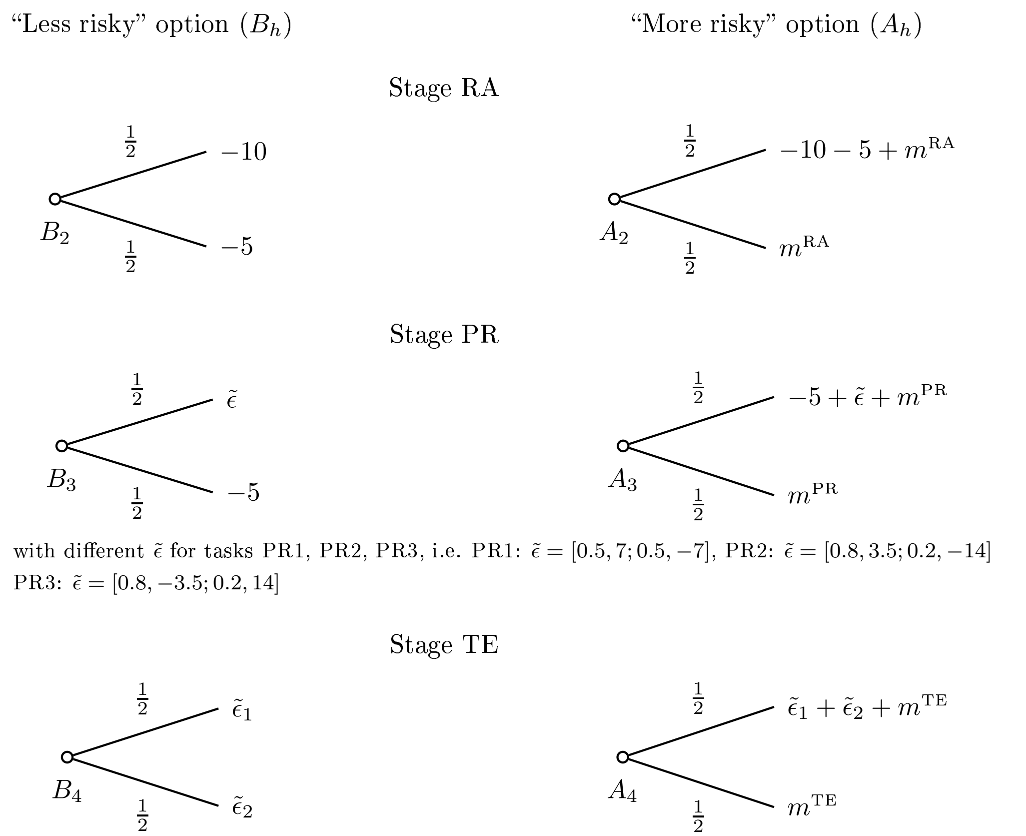
on each out of 6 different decision screens. One screen is for risk aversion (stage RA), three screens are for prudence (stage PR, tasks PR1, PR2, PR3) and two screens are for temperance (stage TE, tasks TE1, TE2). On each screen, subjects make 20 choices over a lottery pair as introduced in Section 2, where each decision is for a different value of the compensation. For example, in stage RA subjects decide between B_2 and $A_2 + m^{\mathrm{RA}}$ for $k = 5$ and $r = 10$ where m^{RA} takes the 20 values in EUR[9]

$$-2.50, -2.25, \ldots, -0.25, 0.00, 0.25, \ldots, 2.00, 2.25.$$

The values for m^{PR} and m^{TE} follow the same grid within one experimental session.[10] Figure 2 schematically illustrates the lottery pairs used in the stages of the experiment.

Because outcomes of lotteries could be negative subjects received an endowment per

Figure 2: Lottery pairs in the stages of the experiment



with different $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ for tasks TE1 and TE2, i.e. TE1: $\tilde{\epsilon}_1 = [0.5, 7; 0.5, -7]$, $\tilde{\epsilon}_2 = [0.5, 3.5; 0.5, -3.5]$
TE2: $\tilde{\epsilon}_1 = [0.8, -2.8; 0.2, 11.1]$, $\tilde{\epsilon}_2 = [0.8, 2.8; 0.2, -11.1]$

This figure illustrates the lotteries used in the experiment including the compensations. For risk aversion we measure one compensation m^{RA}, for prudence temperance we measure three compensations $m^{\mathrm{PR1}}, m^{\mathrm{PR2}}$ and m^{PR3} and for temperance we measure two compensations m^{TE1} and m^{TE2}.

decision. Endowments vary across stages being 25.00 EUR in stage RA, 20.00 EUR in stage PR and 17.50 EUR in stage TE. The endowment is shown on subjects decision screens

[9]Notice that all monetary values in the experiment are indicated in EUR.
[10]In Subsection 3.4 we explain how we test for robustness to variations of the compensations grid and to sequencing effects.

and, additionally, subjects are handed coupons illustrating the endowment right before each stage is started.

3.2 Decision screens

We use a computerized experiment programmed with z-Tree (Fischbacher 2007) to make use of appropriate randomization techniques explained later. While it is somewhat cumbersome to explain the decision screen in writing, it is conveniently explained to subjects in a presentation prior to the experiment. In the following we will describe the decision situation in the experimental stages in more detail. We begin with stage PR and afterwards contrast it with stages RA and TE.

An example of a decision task in stage PR (task PR3) is given in Figure 3. It must be understood as follows: On the upper left the number of the current decision is displayed ('Decision 35'). Below follows a statement indicating subjects' endowment which is constant for all decisions in that stage. By clicking the "OK" button on the lower right corner the subject can leave the decision screen if all 20 decisions have been made. Otherwise the subject is reminded through a pop-up window that she first has to complete all 20 decisions on that screen. The rest of the screen is divided into three panels that are displayed in darker greys than the background. From left to right, the first panel displays one possible lottery choice (Option A), the second displays the alternative lottery choice (Option B) and the far right, dark grey panel is the "decision panel."

We start with explaining the representation of the lottery displayed in the *first* panel (Option A). It consists of three items. Left is a ballot box containing two (blue) balls, labeled "Up" and "Down", respectively. Note that the panel itself is horizontally separated. The upper part contains a second ballot box that contains eight (yellow) balls labeled "-3.50" and two (white) balls labeled "14.00" and represents a gamble that yields -3.50 with probability $8/10$ and 14.00 with probability $2/10$. The lower part of the panel contains the entry -5.00 which represents a fixed reduction in wealth of 5.00. In total, the lottery displayed in Option A must be understood as follows. To determine its outcome, first, a ball is drawn from the ballot box containing two balls. If "Up" is realized, this means that the outcome will be determined as depicted in the upper part of the panel. That is, a draw is made from the second ballot box. Recall that the individual's endowment in this stage is 20.00. If a ball labeled -3.50 is drawn, the outcome of the lottery in Option A would be $20.00 - 3.50 = 16.50$. If a ball labeled 14.00 is drawn, the outcome would be $20.00 + 14.00 = 34.00$. Now suppose, in the first gamble "Down" is drawn. Then the individual faces a sure reduction in wealth of -5.00 and the outcome of the lottery in Option A would be $20.00 - 5.00 = 15.00$. The ballot boxes in the screen shot aim to mimic the real world ballot boxes used to determine subjects' payoffs that are depicted in Figure 4.

Now consider the *second* panel in Figure 3, i.e. Option B. Like the first panel it is horizontally separated and contains the same two ballot boxes and the same fixed reduction in wealth -5.00. However, for Option B the -5.00 now occurs in the upper rather than in the lower part of the panel. The second difference is that both parts of the panel contain a bill labeled 1.00. To determine the outcome of the lottery in Option B, like in Option A, first a ball is drawn from the first ballot box. If "Up" is drawn, a draw is made from the second ballot box. If -3.50 is drawn, the outcome of the lottery in Option B would be

Figure 3: Sample decision screen in stage PR (task PR3)

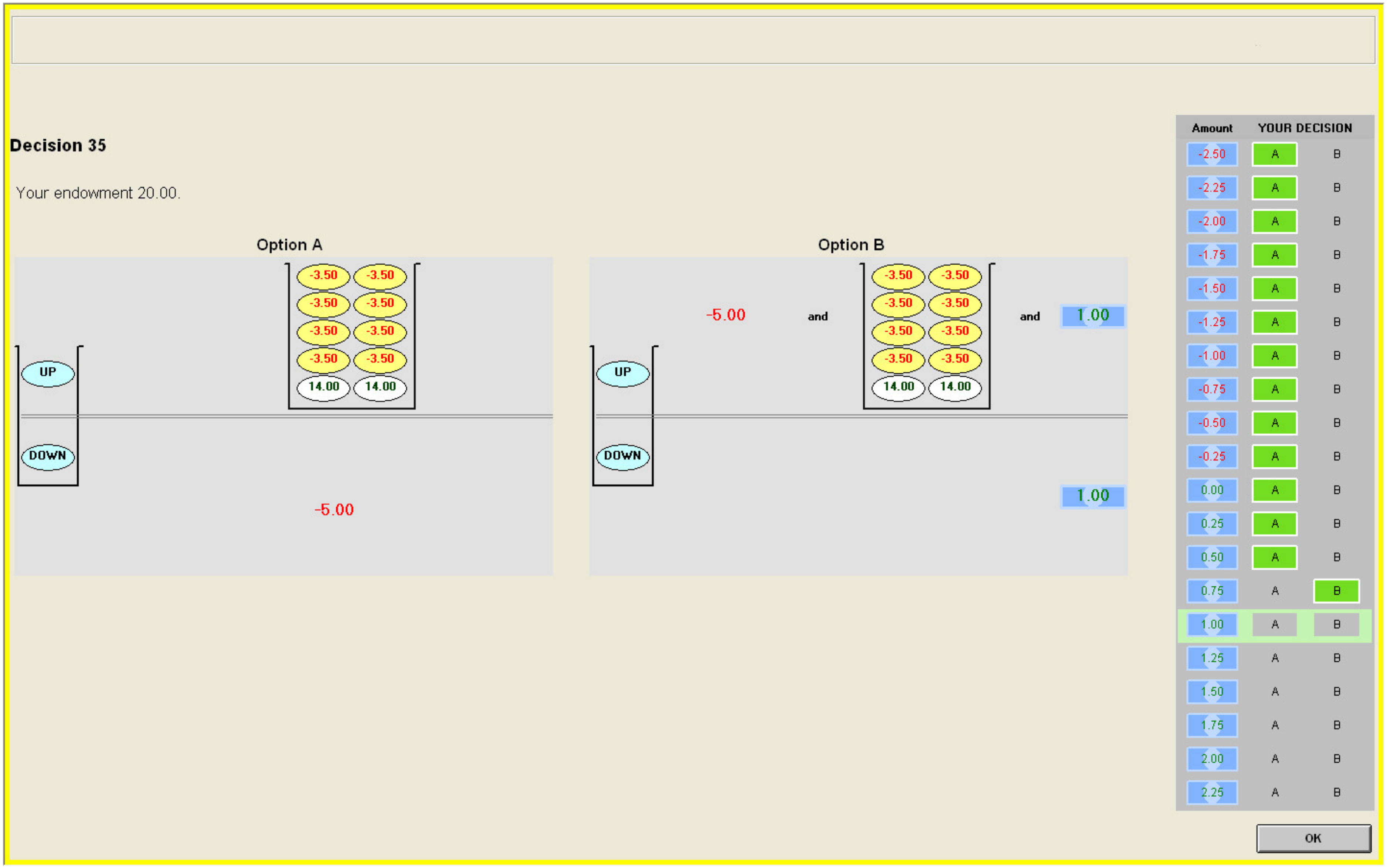


Figure 4: Real world ballot boxes to determine individual payoffs

$20.00 - 5.00 - 3.50 + 1.00 = 19.50$. If 14.00 is drawn, the outcome of the lottery in Option B would be $20.00 - 5.00 + 14.00 + 1.00 = 30.00$. If in the first draw "Down" is drawn, the outcome of the lottery in Option B would be $20.00 + 1.00 = 21.00$.

Before we explain the decision panel, note that Option A depicts a prudent lottery choice of type B_3 defined in Section 2 and depicted in Figure 2. The ballot box containing the "Up" and "Down" balls represents the 50/50 gamble. The second ballot box containing ten balls represents the zero-mean risk $\tilde{\epsilon}$. Likewise, Option B depicts the corresponding imprudent lottery A_3. The bill labeled 1.00 is the downside risk compensation m^{PR} for the current decision. Whether the prudent or imprudent Option is displayed as "Option A", i.e. in the first panel, is randomized for every subject individually, and so is the association of payoffs with the "up" or "down"-state of the lottery.

We now explain how subjects actually indicate their decisions in the *decision panel.* By clicking one of the 20 amounts of the m^{PR}-grid that is displayed in the first column ("Amount"), the amounts m^{PR} displayed in the first panel adjust accordingly. Also the decision number in the upper left of the screen will adjust. In Figure 3 the subject currently has selected to make her decision for $m^{\mathrm{PR}} = 1.00$, which is why the corresponding row in the decision panel is framed in light green. To decide for Option A or Option B, respectively, she can click either "A" in the second column of the decision panel or "B" in the third column of the decision panel. The selected button then turns dark green. The subject can continue to make another decision by clicking another fixed amount in column "Amount" and click "A" or "B" in the corresponding row. In Figure 3, the subject chose Option A for $m^{\mathrm{PR}} = -2.50, \ldots, 0.50$, chose Option B for $m^{\mathrm{PR}} = 0.75$ and is about to make her choice for $m^{PR} = 1.00$. She can also make another choice by clicking another value of m^{PR}. This way, she can also go back to a previous decision and change it. Further, the subject is free to answer the questions in a different order as suggested in the screenshot. After having made all 20 decisions, she can leave the decision screen by clicking the "OK" button. A pop-up window will appear, asking the subject to confirm or cancel. The subject is reminded that if she confirms, her decisions in this task will be final.

The decision screens for tasks in stages RA and TE are analogous to the one just explained. A lottery of type A_2 or B_2 in stage RA is displayed like A_3 or B_3 in Figure 3, except that the ballot box representing the zero-mean risk is replaced by the fixed amount $r = -10$. Likewise, in stage TE, the fixed amount $k = -5$ is replaced by another ballot box with ten balls that represents the other zero-mean risk in the definitions of A_4 and B_4. See the instructions in the Appendix B for explicit screenshots of these stages.

3.3 Discussion of experimental method and parameter choices

In a theoretical paper, Ebert (2010) analyzes the statistical properties of the proper risk apportionment lotteries of Eeckhoudt and Schlesinger (2006) and shows that they are mostly driven by the skewness of the zero-mean risks that have to be apportioned. As a consequence, he shows that no binary lottery can capture the essential features of the proper risk apportionment lotteries of 3rd order and higher sufficiently well. This is also observed in the experiment of Ebert and Wiesen (2009) who show that the skewness of the zero-mean risk indeed influences subjects' decisions significantly. Thus we need at least trinomial lotteries. The temperance lotteries of Eeckhoudt and Schlesinger with binary zero-mean risks involve up to 5 states. Comparison between two such lotteries would pose a significant challenge in comprehensiveness to subjects. Thus we use the representation as a compound lottery introduced in Ebert and Wiesen (2009) that they also test for experimental robustness. This representation also fits well the intuition of proper risk apportionment (disaggregation of harms across states of nature, "putting risk in its proper place") as defined by Eeckhoudt and Schlesinger (2006).

Probabilities do not vary within one decision screen and, generally, the only probabilities used are 50/50 and 80/20. Unlike the probabilities, the outcomes of the "more risky" option of a lottery pair are varied in our procedure. That it is meaningful to vary outcomes rather than probabilities to change the expected value of a risky prospect has recently been shown by Bruner (2009). The probabilities of our lottery pairs are visualized using ballot boxes similar to the ones actually used to determine subjects' payoffs (see Figure 4). They were shown to subjects prior to the experiment while explaining the decision screens.

The multiple price list procedure is one of the most established methods to measure individual risk attitudes. As already described in Subsection 3.2 the variant applied in our experiment confronts a subject with an array of ordered prices (here m^{RA}, m^{PR} and m^{TE}) and asks the subject to make a decision between Option A and Option B for each price. For a detailed discussion of the advantages and drawbacks of this method see Andersen et al. (2006) and Abdellaoui et al. (forthcoming). In general, the procedure is very attractive as it easy to implement and the task involved can be easily accessed by the subjects. Moreover, truthful revelation is in subjects' best interest. However, one frequently raised concern is that the multiple price list method is prone to a framing effect. Subjects might be drawn to the middle row of the ordered list irrespective of their true values. To account for this possible effect we devise a test by shifting the cardinal scale of the multiple price list as will be explained in Subsection 3.4. Notice however that our qualitative results are unaffected by this framing issue.[11]

Our approach is largely inspired by the theoretical paper of Crainich and Eeckhoudt (2008). However, the downside risk compensation m^{PR} they define is added to A_3 in the "good" state only, while we define it as being added to both states of the 50/50 gamble. That is, we consider $A_h + m_h$ ($h = 2, 3, 4$). A compensation for sure seems to be more comprehensive for experimental purposes than a compensation "with probability". Further, crucial to our approach is that this simplifies the calibration of the lotteries significantly because A_h differs from $A_h + m_h$ only by its mean while all higher central moments are unaffected by the size of the compensation. This allows for a "clean" tradeoff between increased mean and 2nd-degree risk, downside risk or outer risk, respectively. Furthermore, this is why we will be able to reasonably compare the compensations of various orders obtained in each stage. Note that, although the compensations are added for sure, there is no experimental certainty effect because both Option A and Option B are always risky.

Moreover, our approach is not based on moments. It is, rather, insightful to look at the

Table 1: Statistical features of lottery pairs employed in the experiment

	Stage RA	Stage PR			Stage TE	
		PR1	PR2	PR3	TE1	TE2
$E[B_h] - (E[A_h] + m_h^{\cdot})$	0.00	0.00	0.00	0.00	0.00	0.00
$V(B_h) - V(A_h)$	-50.00	0.00	0.00	0.00	0.00	0.00
$Skew(B_h) - Skew(A_h)$	0.00	2.16	2.16	2.16	0.00	0.00
$Kurt(B_h) - Kurt(A_h)$	0.00	0.00	-5.44	5.44	-1.92	-3.00

This table shows differences in the first four standardized central moments between the lottery pairs in each of the six tasks of the experiment. The compensations $m_i^{\bullet}$ only influence expectation and thus do not distort higher-order risk features of the lotteries. The risk averse lottery choice has a smaller variance than the risk-loving lottery choice. The prudent lottery choice has a higher skewness than the imprudent choice but can have a smaller or higher kurtosis, depending on the skewness of the zero-mean risk that has to be apportioned. The kurtosis is smaller if and only if the zero-mean risk is left-skewed. The temperate lottery choice has a smaller kurtosis.

moments of the particular lotteries employed in our experiment to supplement our intuition for the different orders of risk. Table 1 illustrates in what moments the lotteries to test for different risk orders differ. For more on higher-order risk preferences, nth-degree risk and moments see Ekern (1980), Roger (forthcoming) and Ebert (2010). The latter paper shows that, for prudence and temperance, the intuition provided by considering the first four moments only essentially generalizes to more general notions of skewness and kurtosis as defined by all odd and even moments, respectively. For example, prudence is shown to be a preference for high odd moments (skewness) irrespective of the even moments (kurto-

[11] Abdellaoui et al. (forthcoming) mention three possible drawbacks of the multiple price list method. One is the framing effect just explained. The second drawback concerns the variation of probabilities which does not apply to our method as we manipulate outcomes instead. The remaining third drawback they mention is that measurement takes place on an interval scale determined by the price list. At worst, this could result in a small loss of accuracy which will not affect qualitative results. Further, we test for an effect of different sizes of these intervals, see Subsection 3.4.

sis). Ebert and Wiesen (2009) observe a significant effect of kurtosis on prudent decision behavior and thus the present experiment comprises three tasks for prudence to respect that effect.

To facilitate comparisons *between* the compensations measured in each task, all lottery pairs are calibrated according to their moments up to the third order. That is, for equal values of the compensation, the six lotteries with less (more) nth-degree risk have expectation 17.5 ($17.5 + m_i^\bullet$). Because we choose the compensations to be added for sure, they do not distort higher-order moments of the lotteries. Naturally, the risk averse lotteries differ by their variance. Independent of the value of m^{RA}, for the lotteries in task RA we have $0.5\,(V(B_2) + V(A_2)) = 31.25$. The prudence and temperance lotteries in our experiment are constructed such that $V(A_3) = V(B_3) = V(A_4) = V(B_4) \approx 31$ with an error of less than 0.25. Similarly the risk aversion and temperance lotteries have a skewness of approximately 0 which is the average skewness of the six prudence lotteries used in tasks PR1 to PR3. Thus we test for risk aversion, prudence and temperance not only in the same "wealth region", but also in the same "risk region" in terms of variance and skewness. Together with the consistent decision framing as proper risk apportionment in all three stages with the same type of decision screen, this should make the compensations of different order we elicit reasonably comparable.

3.4 Robustness tests and factorial design

To account for possible disadvantages associated with our method to elicit subjects risk preferences, like order effects and framing, we employ a between subjects 2^4-factorial design, i.e. four factors (A, B, C, D) with two levels each. For all $2^4 = 16$ possible combinations of factor levels 8 subjects make their choices in the experimental stages (see Table 2). This explains why our experiment was outlined for $16 \cdot 8 = 128$ subjects in total in the experiment. The sequence of sessions (with their particular factor constellations) was randomized. See Montgomery (2005) for an overview of the factorial design technique.

Within our factorial design we test for *order effects* (factors A and B) that potentially can distort results (see Harrison et al. 2005 and Andersen et al. 2006). As shown in Table 2, Factor A implies that stage TE is either the first or last stage a subject enters and Factor B is either "stage RA precedes stage PR" or "stage PR precedes stage RA". Thus we consider four out of six possible stage sequences: TE-PR-RA, TE-RA-PR, PR-RA-TE, RA-PR-TE. Note that the sequences of tasks in stages PR and TE is randomized individually.

The multiple price list instrument might suggest a frame that encourages subjects to select the middle row of the m-list to switch from one lottery to the other, contrary to their unframed risk preferences (Andersen et al. 2006 and Harrison et al. 2007). To account for this potential problem we devise a *shifted grid* (Factor C) in which the middle row implies different risk attitudes. More specifically, the levels of Factor C are either a shift in the scale of the m-list (2.00 EUR are added to each value) or no shift. We also deliberately changed the grid distances of the m-list in order to detect behavioral influences of *grid increments* (Factor D), i.e. we used a fine and a coarser grid. Factor D considers the distance between two values on the grid being either 0.25 EUR (such as described in the previous subsections) or 0.50 EUR. Consequently, depending on the levels for factors C

Table 2: Factorial design

Ses.	Level of Factor A	Level of Factor B	Level of Factor C	Level of Factor D	Number of subjects (female, male)
1	TE last	PR-RA	no Shift	Grid 0.50	8 (4,4)
2	TE last	RA-PR	no Shift	Grid 0.25	8 (4,4)
3	TE last	RA-PR	no Shift	Grid 0.50	8 (4,4)
4	TE last	PR-RA	no Shift	Grid 0.25	8 (4,4)
5	TE first	PR-RA	Shift	Grid 0.50	8 (4,4)
6	TE last	RA-PR	Shift	Grid 0.50	8 (4,4)
7	TE first	RA-PR	Shift	Grid 0.50	7 (4,3)
8	TE last	RA-PR	Shift	Grid 0.25	8 (4,4)
9	TE first	RA-PR	no Shift	Grid 0.25	8 (4,4)
10	TE first	PR-RA	no Shift	Grid 0.50	8 (4,4)
11	TE first	PR-RA	Shift	Grid 0.25	8 (4,4)
12	TE first	RA-PR	Shift	Grid 0.25	8 (4,4)
13	TE first	PR-RA	no Shift	Grid 0.25	8 (4,4)
14	TE last	PR-RA	Shift	Grid 0.50	8 (4,4)
15	TE first	RA-PR	no Shift	Grid 0.50	8 (4,4)
16	TE last	PR-RA	Shift	Grid 0.25	8 (4,4)

This table illustrates the run-order of the sixteen sessions we conducted, the factor constellation for every session and the number of participants and their gender. In every session we collected responses of 4 men and 4 women, except in session 7 where only 3 women (including the invited substitutes) showed up.

and D the m-list adapts four different ranges: (i) $[-2.50, 2.25]$ and (ii) $[-0.50, 4.25]$ both with a gird of 0.25 EUR as well as (iii) $[-5.00, 4.50]$ and (iv) $[-3.00, 6.50]$ with a grid of 0.50 EUR.

Gender differences in risk preferences, i.e. risk aversion, is a well documented phenomenon in the experimental economics literature (Croson and Gneezy, 2009). To consider possible gender effects in the decision tasks of our experiment the number of male and female participants is well balanced for each session.

3.5 Experimental procedure

The experimental sessions were conducted at Bonn$E$con$L$ab in January and February 2010. Overall 127 students from various disciplines, e.g. mathematics, economics, law, business administration, history and linguistics, participated in our 16 experimental sessions. Subjects were recruited by the online recruiting system ORSEE (**?** **?**). As already shown in Table 2 the number of male and female participants was well balanced in each session. The experimental sessions lasted for about 1.5 to 2 hours. Subjects earned on average 24.00 EUR.

The procedure of the experiment was as follows: Firstly, experimenters extensively introduced the decision task and the procedure of the experiment to the subjects. Before each experimental stage started, subjects were asked to answer control questions testing their understanding of the decision task. In particular, they were familiarized with the illustration of lotteries and their outcomes as well as probabilities. Only when subjects had answered the questions correctly they were allowed to proceed to the experimental decisions. Then subjects made the decisions in the experimental stages. Fourthly, subjects answered the questionnaire comprising demographic questions. For answering the questionnaire subjects received 4.00 EUR in addition to their earnings from the experiment.

Finally, each subject's payoff was determined by a random-choice payment technique. As already mentioned, subjects made a series of 120 choices, each with substantial monetary consequences, and final payoff are based on just *one* of these choices selected at random after all have been completed. The random choice was made by drawing one card out of a set of cards numbered between 1 and 120 from a ballot box. The randomly drawn choice could either be from stage RA, PR or TE. Moreover, the lottery of the randomly chosen question determined by a subject's choice is actually played out. Corresponding to the question randomly chosen a coupon was allocated to the lottery outcome. Afterwards the experimenters gave the resulting payoff to the subjects.

4 Behavioral results

In this section, we present the results from our experimental sessions. Firstly, we report risk taking behavior on the aggregate for each risk type. Secondly, we explore the relationship between the different risk types. Thirdly, the robustness of our experimental method is checked and, finally, we analyze risk taking behavior across gender.

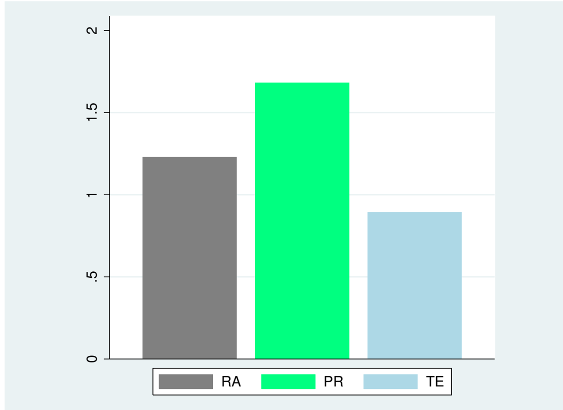
4.1 Premia for different risk types

In all questions, the vast majority of subjects chose the "less risky option" when compensation was small, and then crossed over to the "more risky option" without ever going back to the less risky option. Aggregated over six tasks, 85% of individuals switched once and 8% did not switch. For 3% we observe two switches and in about 4% of responses subjects switch back and forth more than two times. This latter fraction is slightly lower than reported in other multiple price list experiments to elicit risk preferences, e.g. Holt and Laury (2002) who report between 5 to 6% of multiple switches. We included subjects in our analysis with one switching point or no switch at all. Further, we include subjects with two switching points. We dropped subjects from our analysis who had more than two switching points for more than *one* out of the six decision screens. This was the case for eight out of 127 subjects.

In the following, for a given task an individual's *response* or *(demanded) compensation* refers to the first compensation for which an individual switched to the more risky lottery choice in that task. For a given *stage*, a subject's response or (demanded) compensation is the average of the subject's responses to the tasks of that stage. Formally, let $\hat{m}_i^{\mathrm{RA}}$ denote individual i's response in stage RA (which consisted of one task only). Further, let $\hat{m}_i^{\overline{\mathrm{PR}}} := \frac{1}{3}\left(\hat{m}_i^{\mathrm{PR1}} + \hat{m}_i^{\mathrm{PR2}} + \hat{m}_i^{\mathrm{PR3}}\right)$ and $\hat{m}_i^{\overline{\mathrm{TE}}} := \frac{1}{2}\left(\hat{m}_i^{\mathrm{TE1}} + \hat{m}_i^{\mathrm{TE2}}\right)$ denote individual i's average response to the three prudence and two temperance tasks, respectively. The corresponding averages over all individuals are denoted by $\overline{\hat{m}}^{\mathrm{RA}}$, $\overline{\hat{m}}^{\overline{\mathrm{PR}}}$ and $\overline{\hat{m}}^{\overline{\mathrm{TE}}}$, respectively. These overall averages are depicted in Figure 5. We clearly observe that subjects demand a higher compensation to make the imprudent compared to the risk loving and intemperate choice.

In particular, as shown in Table 3 subjects on average demand a higher compensation to make an imprudent choice ($\overline{\hat{m}}^{\overline{\mathrm{PR}}} = 1.6817$; s.d. 1.3427) compared to the risk loving

Figure 5: Average compensation by risk type



This figure shows the average demanded compensations of 119 subjects by risk type, $\overline{\hat{m}}^{\text{RA}}$, $\overline{\hat{m}}^{\text{PR}}$ and $\overline{\hat{m}}^{\text{TE}}$.

($\overline{\hat{m}}^{\text{RA}} = 1.2290$; s.d. 1.8012) and the intemperate choice ($\overline{\hat{m}}^{\text{TE}} = 0.8929$, s.d. 1.2175).[12] This behavioral pattern implies that subjects attach, on average, more weight to third-order risks than to second-order and fourth-order risks. We also observe this pattern for subjects' responses per task. Table 3 shows that a higher compensation is demanded for all three tasks in stage PR compared to stage RA and the tasks in stage TE. Further, the average compensation for taking the risk loving choice is larger than that for the two temperance items.

To test these differences for significance, we first conduct a Page-Test for ordered

Table 3: Descriptive statistics on subjects' demanded compensations

	$\hat{m}_i^{\text{RA}}$	$\hat{m}_i^{\text{PR1}}$	$\hat{m}_i^{\text{PR2}}$	$\hat{m}_i^{\text{PR3}}$	$(\hat{m}_i^{\overline{\text{PR}}})$	$\hat{m}_i^{\text{TE1}}$	$\hat{m}_i^{\text{TE1}}$	$(\hat{m}_i^{\overline{\text{TE}}})$
Mean	1.2290	1.8361	1.6940	1.5192	1.6817	0.9916	0.8098	0.8929
s.d.	1.8012	1.7837	1.6142	1.6325	1.3427	1.4287	1.4221	1.2175
Median	1.00	2.00	1.50	1.50	1.5	0.5	0.5	0.5
N	119	119	116	117	359	119	117	227

This table shows descriptive statistics on demanded compensations for each tasks and averages over tasks for stages PR and TE.

alternatives. The null hypothesis is that on average subject's responses were the same in every stage and the alternative hypothesis is that they are ordered in a *specific* way.[13] We suppose $\hat{m}_i^{\overline{\text{PR}}} \geq \hat{m}_i^{\text{RA}} \geq \hat{m}_i^{\overline{\text{TE}}}$ to be the *specific order*. The null hypothesis of equality of

[12] Analyzing the medians for m_i^{RA}, $\hat{m}_i^{\overline{\text{PR}}}$ and $\hat{m}_i^{\overline{\text{TE}}}$ clearly indicates a tendency towards risk averse, prudent and temperate behavior, as subjects' responses differ substantially from the risk neutral choice, i.e. a demanded compensation of 0 (or put differently, crossing over from the less risky to the more risky choice when the expected value of more risky choice is larger for the first time). The median responses for the risk loving, imprudent and intemperate choice are 1.00, 1.50 and 0.50, respectively. Note that responses for all risks differ significantly from the risk neutral choice ($p < 0.0001$, Wilcoxon signed rank test, two-sided).

[13] To specify the null hypothesis and its alternative more explicitly, let $\theta(\cdot)$ be the population median of subjects' responses. Then the null hypothesis that the medians are the same may be written as $H_0 : \theta(\hat{m}_i^{\text{RA}}) = \theta(\hat{m}^i_{\text{PR}}) = \theta(\hat{m}_i^{\text{TE}})$ and the alternative hypothesis may be written as $H_0 : \theta(\hat{m}_i^{\overline{\text{TE}}}) \leq \theta(\hat{m}_i^{\text{RA}}) \leq \theta(\hat{m}_i^{\overline{\text{PR}}})$ where at least one of the differences is a strict inequality. That is, the medians are ordered in magnitude. Notice that, we corrected for ties.

responses can be rejected and, thus, it follows that *at least one* of the differences is a strict inequality ($p = 0.0004$, $L = 1480$, Page-test).[14]

Pairwise comparisons were conducted using a two-sided Wilcoxon signed rank (WSR) test and a t-test for paired samples (t). The normality assumption of the t-tests should be well satisfied given our sample size. The null hypothesis that the demanded compensations for risk aversion and prudence, $\hat{m}_i^{\text{RA}}$ and $\hat{m}_i^{\text{PR}}$, have the same mean, i.e. $\overline{\hat{m}}^{\text{RA}} = \overline{\hat{m}}^{\text{PR}}$ is rejected ($p = 0.0057$, t and $p = 0.0101$, WSR). Likewise, the average demanded compensation for the imprudent choice ($\overline{\hat{m}}^{\text{PR}}$) differs significantly from the average compensation for the intemperate choice $\overline{\hat{m}}^{\text{TE}}$ ($p = 0.0000$, t and WSR). The p-values for the null hypothesis that the means of the 2nd-degree risk compensations $\overline{\hat{m}}^{\text{RA}}$ and the outer risk compensations $\overline{\hat{m}}^{\text{TE}}$ are $p = 0.0527$ (t) and $p = 0.2024$ (WSR). As application of the stronger t-test seems justified, we conclude that there is weak evidence that 2nd-order demanded compensations are higher than for outer risk.

Result 1. *On average, subjects demand significantly higher (third-order) downside risk compensations than second-order and outer risk compensations. We further find weak evidence that second-order compensations are higher than outer risk compensations.*

Result 1 is a major result of this paper. It shows that in a direct comparison, prudence can be relatively more important to subjects than risk aversion. This is meant in the sense that they demand a larger compensation to take a lottery with more downside risk compared to taking a lottery with more 2nd-degree risk. This shows that generally the importance of risk preferences does not decrease with their order. Thus the result also questions the extensive focus on risk aversion in the economics literature, both theoretical and empirical (experimental), and highlights the importance of prudence. In particular, the experimental economic literature contains numerous different methods to measure risk aversion, but this paper constitutes the first approach to measure prudence. As shown here, a variance-increasing 2nd-order risk increase which is addressed by risk aversion might not be the most important one to subjects. A skewness-decreasing downside risk increase can be more harmful and this will be reflected by an individual's preferences if and only if prudence is assumed.[15]

The only significant difference for average compensations *within stages PR and TE,* respectively, is observed for PR1 and PR3 ($p = 0.0269$, t and $p = 0.0561$, WSR). This confirms that subjects indeed should respond to several prudence tasks as the choice of the zero-mean risk influences decision behavior (see also Ebert and Wiesen 2009). In particular, if we had only employed stage PR3 we would not have observed a significant difference in compensations to stage RA (0.1331, t and 0.3013, WSR). The observation that the downside risk compensation is smallest for a right-skewed zero-mean risk as employed in task PR3 seems reasonable as such a risk constitutes less of a harm to a prudent individual. It can further be shown that in this case prudence implies choosing higher kurtosis (as defined by *all* even moments being higher) what might make the prudent option less

[14]Notice that if we assume the ordering $\hat{m}_i^{\text{RA}} \geq m_i^{\text{PR}} \geq \hat{m}_i^{\text{TE}}$ the null hypothesis can not be rejected ($p = 0.4364$).

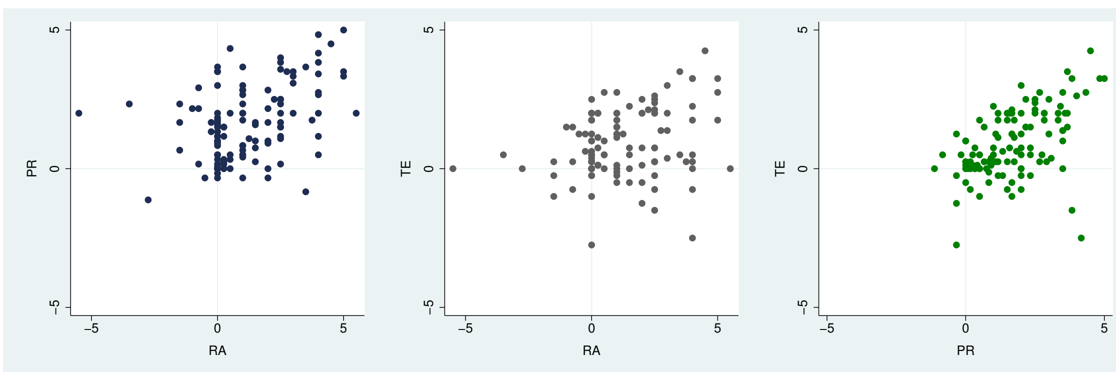
[15]Also note that, under EU, 1 is not equivalent to decreasing absolute risk aversion. This is because our compensation is not directly related to Kimball's measure of absolute prudence but to that of Modica and Scarsini.

attractive to a temperate individual, see Ebert (2010). Further, according to that paper, a mixed risk averse decision maker should demand higher compensations for left-skewed zero-mean risk. We find some significant support for this in the comparison of PR1 to PR3. Further, the compensation in PR2 is higher than in PR3, but not significantly. Contradictory to mixed risk aversion is that the compensation in PR1 is higher than in PR2 (but not significantly). Let us finally also note that Maxmin preferences (e.g. Gilboa 2009, chapter 17) cannot explain our behavioral result as the temperance lotteries involve the highest losses but the corresponding outer risk compensations are smallest.

4.2 Relationship between risk aversion, prudence and temperance

Theoretically, risk aversion, prudence and temperance are complementary in describing individuals' risk attitudes. But what is the relationship empirically? In the following we explore this question by analyzing each individual's demanded compensation for the three different risk types. Figure 6 shows three scatter plots contrasting individuals' demanded compensation for risk types in a pairwise manner. For all three comparisons the plots suggest a positive correlation. Test statistics of a Spearman rank correlation test confirm

Figure 6: Pairwise comparison of compensations for different risk types



The left graph plots jointly the compensations demanded for prudence (vertical axis) and risk aversion (horizontal axis) by each of 119 individuals. The centered (right) graph plots the demanded compensations for temperance and risk aversion (temperance and prudence).

this tendency. There is a significant positive relationship between the second-order risk compensation $\hat{m}_i^{\mathrm{RA}}$ and the downside risk compensation $\hat{m}_i^{\mathrm{PR}}$ ($r_s = 0.3896$, $p = 0.0000$). Moreover, the correlation between $\hat{m}_i^{\mathrm{RA}}$ and $\hat{m}_i^{\mathrm{TE}}$ is also positive ($r_s = 0.2681$) and significant ($p = 0.0032$). The strongest positive relationship can be observed between responses in stage PR ($\hat{m}_i^{\mathrm{PR}}$) and stage TE ($\hat{m}_i^{\mathrm{TE}}$), as $r_s = 0.5805$ at a 1% significance level.[16] This supports the assumption of mixed risk aversion which is common in the economic literature.

Result 2. *Behavioral data evidence a positive relationship between demanded compensations for second-order risk, downside risk and outer risk. This implies that risk aversion, prudence and temperance often occur jointly (but with different intensity, see Result 1). ~~The highest positive correlation can~~ be observed between prudence and temperance.*

[16]The relationships are qualitatively the same when considering compensations for the tasks in stages PR and TE separately, i.e. $\hat{m}_i^{\mathrm{PR1}}, \hat{m}_i^{\mathrm{PR2}}, \hat{m}_i^{\mathrm{PR3}}$ and $\hat{m}_i^{\mathrm{TE1}}, \hat{m}_i^{\mathrm{TE2}}$.

4.3 Robustness and factor analysis

In this section we analyze the factorial design described in Section 3.4. We test robustness of our experiment towards stage order effects (Factors A and B) and manipulations of the compensations grid. For Factor C the levels are either "the compensations grid is shifted by 2.00 EUR" or "the compensations grid is not shifted". Depending on Factor D the grid size was either 0.25 EUR or 0.50 EUR.

At first we analyze whether subjects' average compensations over all six tasks, $\overline{m}_i := \frac{1}{6}(\hat{m}_i^{\mathrm{RA}} + \hat{m}_i^{\mathrm{PR1}} + \hat{m}_i^{\mathrm{PR2}} + \hat{m}_i^{\mathrm{PR3}} + \hat{m}_i^{\mathrm{TE1}} + \hat{m}_i^{\mathrm{TE2}})$, varies for different factor levels. Table 4.3 shows descriptive statistics by factor levels and provides p-values of a two-sided Fisher-Pitman permutation test.

The order in which stages occur does not significantly influence subjects' responses (A: $p = 0.4126$, B: $p = 0.1271$). However, shifting the scale of the compensations grid by +2.00 EUR does significantly influence subjects responses. When there is no shift compensations are lower than when there is a shift. This difference is significant at a 1% level (C: $p = 0.0077$). Although the average responses are slightly larger for a grid of 0.50 EUR on the compensation scale than for a grid of 0.25 EUR, the change in grid size did not exert a significant influence on subjects' decisions (D: $p = 0.6104$).[17]

Are the same factors still influential for subjects' behavior when we distinguish between

Table 4: Factor analysis

Factor (level)		$\overline{m}_i$	m_i^{RA}	$\hat{m}_i^{\mathrm{PR}}$	$\hat{m}_i^{\mathrm{TE}}$
A (TE first)	Mean	1.4244	1.4831	1.5367	0.7288
	s.d.	1.1202	1.9208	1.3310	1.2834
A (TE last)	Mean	1.2579	1.6534	1.8243	1.0542
	s.d.	1.0834	0.9792	1.3499	1.1367
	p	0.4126	0.1311	0.2439	0.1482
B (PR-RA)	Mean	1.5004	1.1353	1.5731	0.6455
	s.d.	0.9959	1.9146	1.4049	1.3410
B (RA-PR)	Mean	1.1911	1.3276	1.7960	1.1530
	s.d.	1.1802	1.6847	1.2761	1.0206
	p	0.1271	0.5742	0.3672	0.0226
C (no Shift)	Mean	1.0794	0.9713	1.3805	0.6742
	s.d.	1.0207	1.6552	1.2604	1.2540
C (Shift)	Mean	1.6180	1.5000	1.9987	1.1228
	s.d.	1.0207	1.9200	1.3641	1.1439
	p	0.0077	0.1126	0.0122	0.0443
D (Grid 0.25)	Mean	1.3926	1.2629	1.5611	0.8966
	s.d.	1.2170	1.3990	1.1441	0.9954
D (Grid 0.50)	Mean	1.2885	1.1967	1.7965	0.8893
	s.d.	0.9712	2.1258	1.5082	1.4050
	p	0.6104	0.8538	0.3437	0.9828

This table shows descriptive statistics on compensations averaged over risk types $\overline{m}_i$ and on compensations per risk type for each factor level. Further it shows p-values of a two-sided Fisher-Pitman permutation test for independent samples.

responses for individual the stages RA, PR and TE, i.e. $\hat{m}_i^{\mathrm{RA}}$, $\hat{m}_i^{\overline{\mathrm{PR}}}$ and $\hat{m}_i^{\overline{\mathrm{TE}}}$? Different levels of Factors A and D have no significant influence on the compensations for all three

[17] p-values from a parametric t-test for unpaired samples are very similar; i.e. A: $p = 0.4425$, B: $p = 0.1260$, C: $p = 0.0071$ and D: $p = 0.6081$.

risk types. For Factor B the temperance compensation is significantly larger when stage RA precedes PR. Subjects demand a substantially higher compensation for all types of risk when there is a shift in the scale of compensations (Factor C). This difference is significant for $\hat{m}_i^{\mathrm{PR}}$ and $\hat{m}_i^{\mathrm{TE}}$. However, for $\hat{m}_i^{\mathrm{RA}}$ the difference is substantial but not significant ($p = 0.11263$). To sum up, as is typical for experiments employing a multiple price list format, shifts in the compensations grid can potentially distort measurements such that one should control for this effect.

The more important point with respect to the application of the factorial design is the following. The factorial design introduced a lot of variation into our measurements, but still we obtain significance for our results. That is, these results are robust towards caveats of the experimental method.

Result 3. *The order of stages does not significantly influence average compensations. Also the grid increments do not influence subjects' choices. A shift in the compensations grid influences subjects' behavior for all orders of risk significantly. It is important to note that the other results of the experiment are significant despite of being challenged by the factorial design.*

4.4 Is there a male-female difference?

Differences between women and men in risk attitudes are well documented in the experimental economics literature. Most evidence suggests that women perceive risks as greater, engage in less risky behavior, and choose alternatives that involve less risk. In their literature reviews Eckel and Grossman (2008 b) and Croson and Gneezy (2009) conclude that it is a robust finding from (economic) experiments that women are more risk averse than men. In this section we show that this observation also applies to the higher-order risk preferences prudence and temperance.

Figure 7 illustrates average compensations for the different types of risk for 58 women and 61 men. The finding that a higher compensation is desired for the imprudent choice than for the risk loving and intemperate choice is robust for both males and females.

In line with the literature on gender differences in risk taking behavior we find that female (F) subjects are more risk averse than male (M) subjects. To accept the risk loving choice women demand, on average, a higher compensation than men ($\overline{\hat{m}}^{\text{RA-F}} = 1.5690$; $\overline{\hat{m}}^{\text{RA-M}} = 0.9057$). This difference is significant ($p = 0.04474$, two-sided Fisher-Pitman permutation test).[18]

Moreover, our data show that women are both more prudent and temperate than men. That is, women demand a higher compensation for the imprudent ($\overline{\hat{m}}^{\text{PR-F}} = 1.8829$; $\overline{\hat{m}}^{\text{PR-M}} = 1.4904$) and the intemperate choices ($\overline{\hat{m}}^{\text{TE-F}} = 1.1504$; $\overline{\hat{m}}^{\text{TE-M}} = 0.7350$). Both differences are significant at a 5% level ($p = 0.0448$; $p = 0.0432$). This puts the robust finding that "men are more risk prone than women" (Croson and Gneezy 2009, p.449) on a broader basis.

Result 4. *Women not only are more risk averse than men, but also are more prudent and more temperate.*

[18] Notice that we employ a permutation test for *paired samples* as session averages are compared by gender.

Figure 7: Average compensation by gender

This figure shows the average compensations of 119 subjects for risk types for female and male subjects, i.e. $\overline{\hat{m}}^{\text{RA-F}}$, $\overline{\hat{m}}^{\text{PR-F}}$ and $\overline{\hat{m}}^{\text{TE-F}}$ and $\overline{\hat{m}}^{\text{RA-M}}$, $\overline{\hat{m}}^{\text{PR-M}}$ and $\overline{\hat{m}}^{\text{TE-M}}$.

5 Conclusion

In this paper we propose an experimental method to measure risk aversion, prudence and temperance at an individual level. Within the scarce empirical literature on higher-order risk preferences, this constitutes the first attempt to measure the *intensity* of risk preferences rather than only their *direction.* Further, it is the first attempt to *compare* the intensity of the preferences within subjects.

The theoretical fundament of our experimental method is the proper risk apportionment model of Eeckhoudt and Schlesinger. Within this model we define risk compensations of higher orders and show that they are related to higher-order intensity measures in the spirit of Arrow-Pratt. By definition, the compensations imply a clear tradeoff between mean and 2nd-degree risk (downside risk and outer risk, respectively) for the lottery choices in the experiment. Lotteries are calibrated so that these compensations are comparable not only between but also within subjects.

In the experiment we measure these compensations using a multiple price list technique. The lotteries employed in the experiment are presented as compound rather than trinomial (quadri- or pentanomial) and match the intuition of proper risk apportionment. The only probabilities used are 50/50 and 80/20. These probabilities are visualized using ballot boxes similar to the ones actually used to determine subjects' payoffs. This experimental design is tested for robustness to typical manipulations using a between subject factorial design.

A major result is that, on average, the downside risk compensation demanded is significantly higher than the second-order risk compensation. This highlights the importance of prudence and questions the extensive focus in the economics literature on risk aversion. In particular, the literature contains numerous different experimental methods to measure risk aversion, but this paper constitutes the first approach to measure prudence.

Behavioral data imply that the outer risk compensation is smallest. It is smaller than the second degree compensation with weak significance and smaller than the downside risk compensation with strong significance. We also observe that the stylized fact that women are more risk averse than men extends to risks of higher orders. That means, women are significantly more prudent and more temperate than men.

Further research on the measurement of higher-order risk preferences seems to be desirable in order to close the significant gap to the experimental literature on risk aversion. Given the observation that the intensity of downside risk aversion can be higher than that for risk aversion, this seems to be even more justified. Moreover, our method could find application in further experiments to test the predictions of numerous theoretical papers on higher-order risk preferences.

References

Abdellaoui, M., A. Driouchi, and O. L'Haridon (forthcoming): "Risk Aversion Elicitation: Reconciling Tractability and Bias Minimization," *Theory and Decision*.

Andersen, S., G. W. Harrison, M. I. Lau, and E. E. Rutström (2006): "Elicitation Using Multiple Price List Formats," *Experimental Economics*, 9, 383–405.

Arrow, K. J. (1965): *Aspects in the Theory of Risk-bearing*, Yrjö Jahnssonin Saeaetioe, Helsinki.

Baltussen, G., T. Post, M. J. van den Assem, and P. P. Wakker (2010): "Random Incentive Systems in a Dynamic Choice Experiment," Working Paper, University of Rotterdam.

Barr, A. M. and T. G. Packard (2002): "Revealed Preference and Self-Insurance: Can We Learn from the Self-Employed in Chile?" World Bank Policy Research Working Paper No. 2754.

Barsky, R. B., M. S. Kimball, F. T. Juster, and M. D. Shapiro (1997): "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study," *Quarterly Journal of Economics*, 112, 537–579.

Beattie, J. and G. Loomes (1997): "The Impact of Incentives upon Risky Choice Experiments," *Journal of Risk and Uncertainty*, 14, 155–168.

Becker, G., M. DeGroote, and J. Marschak (1964): "Measuring Utility by a Single-Response Sequential Method," *Behavioral Science*, 9, 226–232.

Binswanger, H. P. (1980): "Attitudes Towards Risk: Experimental Measurement in Rural India," *American Journal of Agricultural Economics*, 62, 395–407.

Brockett, P. L. and L. L. Golden (1987): "A Class of Utility Functions Containing All the Common Utility Functions," *Management Science*, 33, 955–964.

Bruner, D. (2009): "Changing the Probability versus Changing the Reward," *Experimental Economics*, 12, 367–385.

Caballe, J. and A. Pomansky (1996): "Mixed Risk Aversion," *Journal of Economic Theory*, 71, 485–513.

Carrol, C. D. (1994): "How does Future Income Affect Current Consumption?" *Quarterly Journal of Economics*, 109, 111–147.

Carroll, C. D. and M. S. Kimball (2008): "Precautionary Savings and Precautionary Wealth," in *The New Palgrave Dictionary of Economics*, ed. by S. Durlauf and L. Blume, MacMillan, London.

Chiu, H. (2005): "Skewness Preference, Risk Aversion and the Precedence Relations on Stochastic Changes," *Management Science*, 51, 1816–28.

Courbagé, C. and B. Rey (2006): "Prudence and Optimal Prevention for Health Risks," *Health Economics*, 15, 1323–1327.

Crainich, D. and L. Eeckhoudt (2008): "On the Intensity of Downside Risk Aversion," *Journal of Risk and Uncertainty*, 36, 267–276.

Croson, R. T. A. and U. Gneezy (2009): "Gender Differences in Preferences," *Journal of Economic Literature*, 47, 448–474.

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

Deck, C. A. and H. Schlesinger (forthcoming): "Exploring Higher Order Risk Effects," *Review of Economic Studies*.

Denuit, M. M. and L. Eeckhoudt (forthcoming a): "Stronger Measures of Higher-order Risk Attitudes," *Journal of Economic Theory*.

——— (forthcoming b): "A General Index of Absolute Risk Attitude," *Management Science*.

Dittmar, R. F. (2002): "Nonlinear Pricing Kernels, Kurtosis Preference, and Evidence from a Cross Section of Equity Returns," *Journal of Finance*, 57, 369–403.

Dohmen, T., A. Falk, D. Huffman, and U. Sunde (forthcoming): "Are Risk Aversion and Impatience Related to Cognitive Ability?" *American Economic Review*.

Dynan, K. E. (1993): "How Prudent are Consumers," *Journal of Political Economy*, 101, 1104–1013.

Ebert, S. (2010): "On higher-order Risk Preferences, Moments and the Diversification of Skewed Risks," Working Paper, University of Bonn.

Ebert, S. and D. Wiesen (2009): "An Experimental Methodology Testing for Prudence and Third-order Preferences," University of Bonn, Bonn Econ Discussion Papers, No. 21/2009.

Eckel, C. C. and P. J. Grossman (2008 a): "Differences in the Economic Decisions of Men and Women: Experimental Evidence," in *Handbook of Experimental Economics Results Vol. 1*, ed. by C. Plott and V. Smith, Elsevier, New York, 1061–1073.

——— (2008 b): "Forecasting Risk Attitudes: An Experimental Study Using Actual and Forecast Gamble Choices," *Journal of Economic Behavior and Organization*, 68, 1–17.

Eeckhoudt, L. and C. Gollier (2005): "The Impact of Prudence on Optimal Prevention," *Economic Theory*, 26, 989–994.

Eeckhoudt, L. and H. Schlesinger (2006): "Putting Risk in Its Proper Place," *American Economic Review*, 96, 280–289.

——— (2008): "Changes in Risk and the Demand for Saving," *Journal of Monetary Economics*, 55, 1329–1336.

Eeckhoudt, L., H. Schlesinger, and I. Tsetlin (2008): "Risk Apportionment and Stochastic Dominance," INSEAD Business School Research Paper No. 2007/45/DS.

Ekern, S. (1980): "Increasing Nth Degree Risk," *Economics Letters*, 6, 329–333.

Esö, P. and L. White (2004): "Precautionary Bidding in Auctions," *Econometrica*, 72, 77–92.

Fagart, M. and B. Sinclair-Desagné (2007): "Ranking Contingent Monitoring Systems," *Management Science*, 53, 1501–1509.

Fei, W. and H. Schlesinger (2008): "Precautionary Insurance Demand with State-dependent Background Risk," *Journal of Risk and Insurance*, 75, 1–16.

Fischbacher, U. (2007): "Z-tree: Zurich Toolboox for Readymade Economic Experiments," *Experimental Economics*, 10, 171–178.

Gilboa, I. (2009): *Theory of Decision under Uncertainty*, Econometric Society Monographs ESM 45, Cambridge University Press, New York.

Gollier, C. (2001): *The Economics of Risk and Time*, MIT Press, Cambridge (MA).

Gomes, F. and A. Michaelides (2005): "Optimal Life-Cycle Asset Allocation: Understanding the Empirical Evidence," *Journal of Finance*, 60, 869–904.

Gonzalez, R. and G. Wu (1999): "On the Shape of the Probability Weighting Function," *Cognitive Psychology*, 38, 129–166.

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

Guiso, L., T. Jappelli, and D. Terlizzese (1996): "Income Risk, Borrowing Constraints and Portfolio Choice," *American Economic Review*, 86, 158–172.

Harrison, G. W. (1986): "An Experimental Test for Risk Aversion," *Economics Letters*, 21, 7–11.

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

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

Harrison, G. W. and E. E. Rutström (2008): "Risk Aversion in the Laboratory," in *Research in Experimental Economics*, ed. by G. Harrison and J. Cox, JAI Press, Greenwich (CT).

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

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

Jindapon, P. and W. Neilson (2007): "Higher-order Generalizations of Arrow-Pratt and Ross Risk Aversion: A Comparative Statics Approach," *Journal of Economic Theory*, 136, 719–728.

Kimball, M. S. (1990): "Precautionary Savings in the Small and in the Large," *Econometrica*, 58, 53–73.

——— (1992): "Precautionary Motives for Holding Assets," in *The New Palgrave Dictionary of Money and Finance*, ed. by P. Newman, M. Milgate, and e. John Eatwell, Stockton Press, New York, 158–161.

Laury, S. K. (2005): "Pay One or Pay All: Random Selection of One Choice for Payment," Working Paper, Andrew Young School of Policy Studies Research Paper Series 06-13.

LaValle, I. H. (1968): "On Cash Equivalents and Information Evaluation in Decisions under Uncertainty: Part I: Basic Theory," *Journal of the American Statistical Association*, 63, 252–276.

Leland, H. E. (1968): "Saving and Uncertainty: The Precautionary Demand for Saving," *Quarterly Journal of Ecoomics*, 82, 465–473.

Loomes, G. (1988): "Different Experimental Procedures for Obtaining Valuations of Risky Actions: Implications for Utility Theory," *Theory and Decision*, 25, 1–23.

Menezes, C. F., C. Geiss, and J. Tressler (1980): "Increasing Downside Risk," *American Economic Review*, 70, 921–932.

Menezes, C. F. and X. H. Wang (2005): "Increasing Outer Risk," *Journal of Mathematical Economics*, 41, 875–886.

Modica, S. and M. Scarsini (2005): "A Note on Comparative Downside Risk Aversion," *Journal of Economic Theory*, 122, 267–271.

Montgomery, D. C. (2005): *Design and Analysis of Experiments*, John Wiley & Sons, New York.

Murnighan, J. K., A. Roth, and F. Schoumaker (1988): "Risk Aversion in Bargaining: An Experimental Study," *Journal of Risk and Uncertainty*, 1, 101–24.

Pratt, J. W. (1964): "Risk Aversion in the Small and in the Large," *Econometrica*, 32, 122–136.

Roger, P. (forthcoming): "Mixed Risk Aversion and Preference for Risk Disaggregation: A Story of Moments," *Theory and Decision*.

Ross, S. A. (1981): "Some Stronger Measures of Risk Aversion in the Small and in the Large with Applications," *Econometrica*, 49, 621–663.

Rothschild, M. D. and J. E. Stiglitz (1970): "Increasing Risk: I. A Definition," *Journal of Economic Theory*, 2(3), 225–243.

Sandmo, A. (1970): "The Effect of Uncertainty on Saving Decisions," *Review of Economic Studies*, 37, 353–360.

Schubert, R., M. Brown, M. Gysler, and H. W. Brachinger (1999): "Financial Decision-Making: Are Women Really More Risk-Averse?" *American Economic Review*, 89, 381–385.

Starmer, C. and R. Sugden (1991): "Does the Random-Lottery Incentive System Elicit True Preferences? An Experimental Investigation," *American Economic Review*, 81, 971–78.

Tarazona-Gomez, M. (2004): "Are Individuals Prudent? An Experimental Approach Using Lottery Choices," Working Paper, Copenhagen Business School.

Treich, N. (forthcoming): "Risk-aversion and Prudence in Rent-seeking Games," *Public Choice*.

Wakker, P. P. and D. Deneffe (1996): "Eliciting von Neumann-Morgenstern Utilities when Probabilities are Distorted or Unknown," *Management Science*, 42, 1131–1150.

White, L. (2008): "Prudence in Bargaining: The Effect of Uncertainty on Bargaining Outcomes," *Games Economomic Behavior*, 62, 211–231.

A Derivations

We first show that our lottery preference B_2 over A_2 implies risk aversion in the differentiable EU framework, i.e. $u'' < 0$. B_2 is preferred to A_2 by an EU maximizer implies that

$$\begin{aligned} \frac{1}{2}u(x-k) + \frac{1}{2}u(x-r) &> \frac{1}{2}u(x-r-k) + \frac{1}{2}u(x) \\ \iff u(x) - u(x-k) &< u(x-r) - U(x-r-k). \end{aligned}$$

Now we divide by k and since the preference holds for all positive k we can let k go to zero to obtain

$$u'(x) < u'(x-r).$$

Since this holds for all r (and for all x) the latter equation implies that $u'(x)$ is strictly decreasing, i.e. $u''(x) < 0$, what we wanted to show. That the preferences B_3 over A_3 and B_4 over A_4, respectively, are equivalent to prudence and temperance within the differentiable EU framework is proven by use of similar arguments in Eeckhoudt and Schlesinger (2006).

We now present the approximations that relate individuals' indices of absolute risk attitude to the compensations measured in our experiment.[19] The 2nd-degree risk compensation that makes the individual indifferent between the risk-loving and risk-averse lottery choice is defined as

$$\frac{1}{2}u(x-k) + \frac{1}{2}u(x-r) = \frac{1}{2}u(x+m^{\mathrm{RA}}) + \frac{1}{2}u(x-r-k+m^{\mathrm{RA}}). \tag{4}$$

We approximate

$$\begin{aligned} u(x-k-r+m^{\mathrm{RA}}) &\approx u(x-r) + (m^{\mathrm{RA}}-k)u'(x-r) \\ &\approx u(x-r) + (m^{\mathrm{RA}}-k)\left(u'(x) - ru''(x)\right) \end{aligned}$$

so that equation (4) approximately becomes

$$\begin{aligned} u(x) - ku'(x) + u(x-r) &= u(x) + m^{\mathrm{RA}}u'(x) + u(x-r) + (m^{\mathrm{RA}}-k)\left(u'(x) - ru''(x)\right) \\ \iff 0 &= m^{\mathrm{RA}}u'(x) + m^{\mathrm{RA}}\left(u'(x) - ru''(x)\right) + rku''(x) \\ \iff 0 &= 2m^{\mathrm{RA}}u'(x) + u''(x)\left((r(k-m^{\mathrm{RA}})\right) \\ \iff -\frac{u''(x)}{u'(x)} &= \frac{2m^{\mathrm{RA}}}{r(k-m^{\mathrm{RA}})}. \end{aligned}$$

For prudence consider

$$\frac{1}{2}u(x-k) + \frac{1}{2}E[u(x+\tilde{\epsilon})] = \frac{1}{2}u(x+m^{\mathrm{PR}}) + \frac{1}{2}E[u(x-k+\tilde{\epsilon}+m^{\mathrm{PR}})]. \tag{5}$$

[19] These approximations are similar to those in Crainich and Eeckhoudt (2008) who note that they are à la Arrow-Pratt.

We approximate

$$\begin{aligned} E[u(x-k+\tilde{\epsilon}+m^{\mathrm{PR}})] &\approx u(x-k+m^{\mathrm{PR}})+\frac{1}{2}u''(x-k+m^{\mathrm{PR}})\sigma^2 \\ &\approx u(x)+(m^{\mathrm{PR}}-k)u'(x)+\frac{\sigma^2}{2}(u''(x)+(m^{\mathrm{PR}}-k)u'''(x)) \end{aligned}$$

such that equation (5) approximately becomes

$$\begin{aligned} 2u(x)-ku'(x)+\frac{1}{2}\sigma^2u''(x) &= 2u(x)+m^{\mathrm{PR}}u'(x)+(m^{\mathrm{PR}}-k)u'(x) \\ &\quad +\frac{\sigma^2}{2}\left(u''(x)+(m^{\mathrm{PR}}-k)u'''(x)\right) \\ \Longleftrightarrow 0 &= 2m^{\mathrm{PR}}u'(x)+\frac{\sigma^2}{2}(m^{\mathrm{PR}}-k)u'''(x) \\ \Longleftrightarrow \frac{u'''(x)}{u'(x)} &= \frac{4m^{\mathrm{PR}}}{\sigma^2(k-m^{\mathrm{PR}})}. \end{aligned}$$

Finally, for temperance first consider

$$E[u(x+m^{\mathrm{TE}}+\tilde{\epsilon}_1+\tilde{\epsilon}_2)]$$

which is approximated as

$$\begin{aligned} & E[u(x+\tilde{\epsilon}_1+\tilde{\epsilon}_2)]+m^{\mathrm{TE}}E[u'(x+\tilde{\epsilon}_1+\tilde{\epsilon}_2)] \\ &= E[u(x+\tilde{\epsilon}_1+\tilde{\epsilon}_2)]+m^{\mathrm{TE}}(u'(x)+u''(x)E[(\tilde{\epsilon}_1+\tilde{\epsilon}_2)] \\ &= E[u(x+\tilde{\epsilon}_1+\tilde{\epsilon}_2)]+m^{\mathrm{TE}}u'(x) \\ &= E[u(x+\tilde{\epsilon}_1)]+\frac{1}{2}E[u''(x+\tilde{\epsilon}_1)]\sigma_2^2 \\ &= u(x)+\frac{1}{2}u''(x)\sigma_1^2+\frac{\sigma_2^2}{2}\left(u''(x)+\frac{1}{2}u^{(4)}(x)\sigma_1^2\right) \\ &= u(x)+\frac{1}{2}u''(x)\sigma_1^2+\frac{1}{2}u''(x)\sigma_2^2+\frac{1}{4}u^{(4)}(x)\sigma_1^2\sigma_2^2 \end{aligned}$$

Thus we can approximate

$$E[u(x+\tilde{\epsilon}_1)]+E[u(x+\tilde{\epsilon}_2)] = u(x+m^{\mathrm{TE}})+E[u(x+m^{\mathrm{TE}}+\tilde{\epsilon}_1+\tilde{\epsilon}_2)] \tag{6}$$

as

$$u(x)+u''(x)\sigma_1^2+u(x)+u''(x)\sigma_2^2 = u(x)+m^{\mathrm{TE}}u'(x)+u(x)+\frac{1}{2}u''(x)\sigma_1^2+\frac{1}{2}u''(x)\sigma_2^2+\frac{1}{4}u^{(4)}(x)\sigma_1^2\sigma_2^2.$$

Collecting terms and rearranging yields

$$\begin{aligned} 0 &= 2m^{\mathrm{TE}}u'(x)+\frac{1}{4}u^{(4)}(x)\sigma_1^2\sigma_2^2 \\ \Longleftrightarrow m^{\mathrm{TE}} &= -\frac{u^{(4)}(x)}{u'(x)}\cdot\left(\frac{1}{8}\sigma_1^2\sigma_2^2\right). \end{aligned}$$

B Instructions

[*translated from German*]

Thank you very much for participating in this decision experiment!

General Information

In the following experiment, you will make a couple of decisions. Following the instructions and depending on your decisions, you can earn money. It is therefore very important that you read the instructions carefully.

You will make your decisions anonymously on your computer screen in your cubicle. During the experiment you are not allowed to talk to the other participants. Whenever you have a question, please raise your hand. The experimenter will answer your question in private in your cubicle. If you disregard these rules you can be excluded from the experiment. Then you receive no payment.

During the experiment **all amounts are stated in Euro**. At the end of the experiment, your achieved earnings will be paid to you in cash.

Structure of the Experiment

The experiment can be divided into three stages. All stages are equally relevant for your payoff. The three stages comprise decision problems, where risky events play a role. In a risky event it is unsure, which outcome occurs.

You decide, which of two risky events you prefer. The form of the risky events will be described when explaining the stages in-depth.

Overall you will make 120 individual decisions in the three sections of the experiment.

Payoff in the experiment

To determine your payoff of the experiment, one of your 120 decisions from the three sections will be selected randomly. This takes place after you have made all your decisions. For this the experimenter will draw one out of 120 cards, labeled with numbers from 1 to 120, from a ballot-box. Every number occurs only once in the ballot-box whereby the draw of a particular number is equally likely. The outcome of the risky event, that you have chosen will actually be determined afterwards. These random draws will be explained in-depth when describing the sections of the experiments.

Note that only one of your 120 decisions determines your earnings of the experiment and that each of your 120 decisions can determine your entire earnings of the experiment.

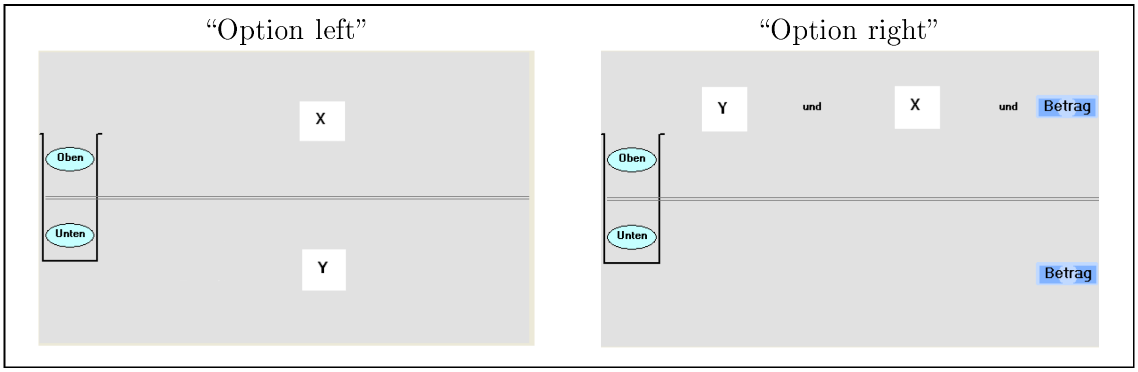
Also note that the risky events can comprise negative outcomes. You receive an endowment in form of a coupon. The coupons are allocated to the outcome of the risky event. Hence your payoff is made up of the two components

Endowment and **Outcome of the chosen risky event**.

After the experiment, the decision relevant for payoff and the outcome of the risky event will be randomly will be determined for each participant in the seminar room. For this participants will be called on successively.

Decision situation

The risky events displayed in following figure describe the decision situation, you face in the three stages of the experiment, in an abstract way. In decision situation you decide which of the two risky events (here: "Option left" and "Option right") you prefer.



Both the risky event "Option left" and "Option right" comprise one random draw (Random draw 1), that is depicted by the balls "Up" and "Down". Random draw 1 is: With 50% chance you are in state "Up" or with 50% chance in state "Down".

We now look at the risky event "**Option left**": If the ball "Up" will be drawn, the outcome is X. X can either be a fixed amount or another random draw (Random draw X). If ball "Down" is drawn, the outcome is Y. Also Y can either be a fixed amount or another random draw (Random draw Y).

In risky event "**Option right**" X and Y follow, if Ball "Up" is drawn. In addition a Amount (blue bank note) is added to both state "Up" and state "Down". If ball "Down" is drawn, you receive the amount indicated on the bank note. If ball "Up" is drawn, X and Y follow and the Amount (blue bank note) is added.

The Amount on the blue bank note can take the following values

$$\boxed{\mathbf{-2.50, -2.25, -2.00, \ldots, -0.25, 0.00, 0.25, \ldots, 2.00, 2.25}.}$$

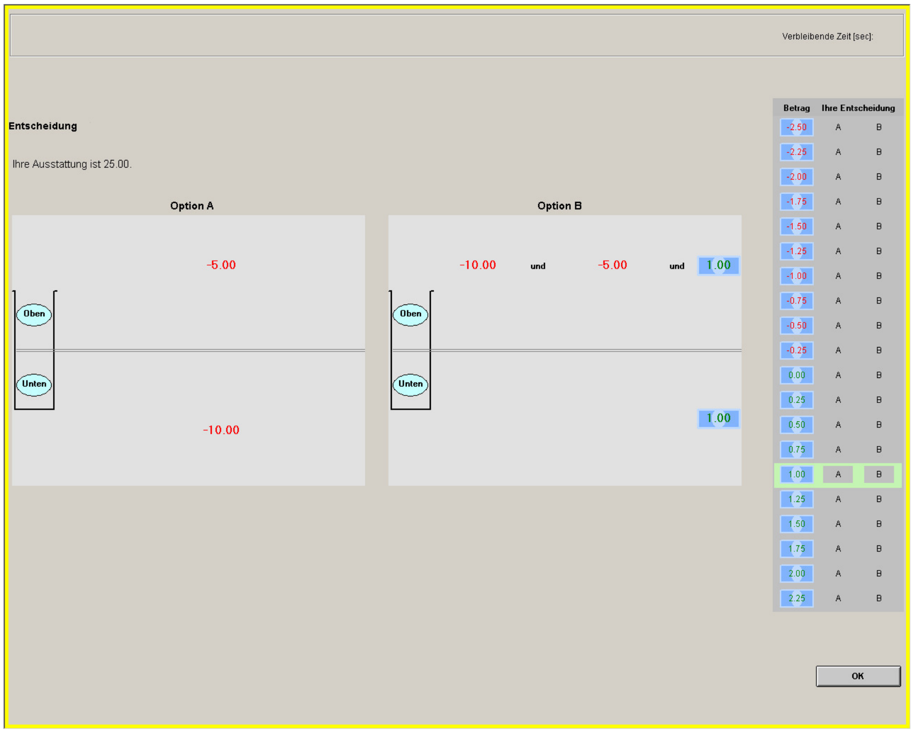
Hence, for each of these 20 Amounts follows one decision situation with two risky events. The Amount on the blue bank note is always added to the states "Up" and "Down" of that risky event, where both X and Y occur in state "Up" (here: "Option right").

Note that, on your decision screen on the computer the risky event, where the Amount (blue bank note) is added can either be the right or the left option.

First stage

In the first stage of the experiment you make 20 decisions. You choose on one decision screen at a time, which of the two different risky events—Option A or Option B—you prefer.

The risky events can comprise negative outcomes. For each decision in the first stage you receive an endowment of 25.00. An example of a decision situation in the first stage is provided in the following figure.



In the example above the Amount (blue bank note) is added to Option B. The size of the added Amount can be found in the column "Amount" on the right-hand side of the screen. For each Amount you decide whether you prefer Option A or Option B.

After activating an Amount in the column "Amount" you decide for this Amount by clicking on "A" or "B" whether you prefer Option A or Option B. A green frame marks the chosen option. You do not need to stick to a certain order of your decisions.

How is the outcome of the risky event (you have chosen) determined in the first stage? For Random draw 1 there are two balls in a ballot-box—one with the label "Up" another with the label "Down". Both balls can be drawn with the same chance.

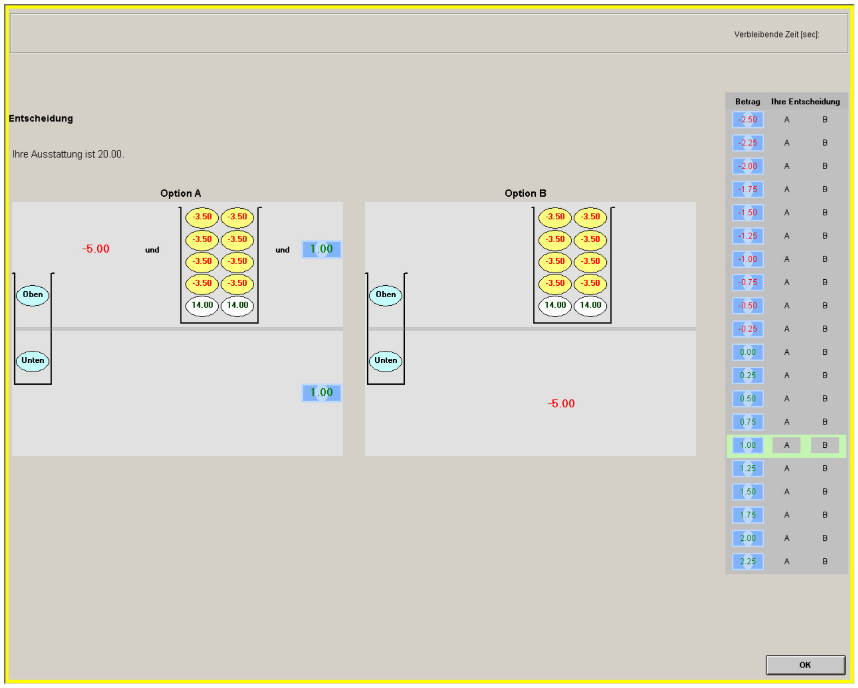
Please look at the example of this stage again!
Suppose, this decision has been randomly chosen to determine your payoff. In **Option A** *the outcome is* −5.00*, if in* Random draw 1 *the ball* "Up" *is drawn. If the ball* "Down" *is drawn the outcome is* −10.00*. Considering your* Endowment *of* 25.00 *in Option A results* "Up" 20.00 *and in stage* "Down" 15.00.

In **Option B** *the outcome is* −10.00 *and* −5.00 *and* 1.00 (Amount *on the blue bank note), if in* Random draw 1 "Up" *is drawn; overall* −14.00*. If ball* "Down" *is drawn, the outcome is* 1.00 (Amount on the blue bank note). *Considering your* Endowment *of* 25.00 *in Option B results in stage* "Up" 11.00 *and in stage* "Down" 26.00 *for your payoff.*

Second stage

In the second stage of the experiment you make 60 decisions. You choose on three decision screens each with 20 decision situtations, which of the two different risky events—Option A or Option B—you prefer.

The outcomes of the risky events can be negative. You receive an Endowment of <u>20.00</u>. An example of a decision situation in the second stage is provided in the following figure.



In the example above the Amount (blue bank note) is added to Option A. The size of the added Amount can be found in the column "Amount" on the right-hand side of the screen. For <u>each</u> Amount you decide whether you prefer Option A or Option B.

After activating an Amount in the column "Amount" you decide for this Amount by clicking on "A" or "B" whether you prefer Option A or Option B. A green frame marks the chosen option. You do not need to stick to a certain order of your decisions.

How is the outcome of the risky event (you have chosen) determined in the second stage? For Random draw 1 there are two balls in a ballot-box—one with the label "Up" another with the label "Down". Both balls can be drawn with the same chance (analogous to the first stage). As shown in the example above, in the second stage a second random draw (Random draw X) can be necessary to determine your payoff. In Random draw X a ball is drawn from a ballot-box containing 10 balls. This ball can either be white or yellow. Note that, the composition of white and yellow balls can change in the three decision screens in this stage. This ballot-box always contains 10 balls and within a decision screen (for 20 decisions) the composition of white and yellow balls are identical.

Please look at the example of this stage again!

Suppose, this decision situation has been randomly chosen to determine your payoff. If in **Option A** *in* Random draw 1 *the ball* "**Up**" *is drawn, the outcome is* -5.00*,* Random draw X *follows and* 1.00 (Amount *on the blue bank note).*

- *If in* Random draw X *a* <u>*yellow*</u> *ball is drawn, you lose* 3.50*. Considering your* Endowment *of* 20.00 *you receive* 12.50 *(*$= 20.00 - 5.00 - 3.50 + 1.00$*).*

- *If in* Random draw X *a* *<u>white</u> ball is drawn, you receive* 14.00. *Considering your* Endowment *you receive* 30.00 *(*= 20.00 − 5.00 + 14.00 + 1.00*).*

If in **Option A** *in* Random Draw 1 "Down" *is drawn, the outcome is* 1.00 *(*Amount *on the blue bank note). Considering your* Endowment 21.00 *result.*

If in **Option B** *in* Random draw 1 "Up" *is drawn,* Random draw X *follows.*

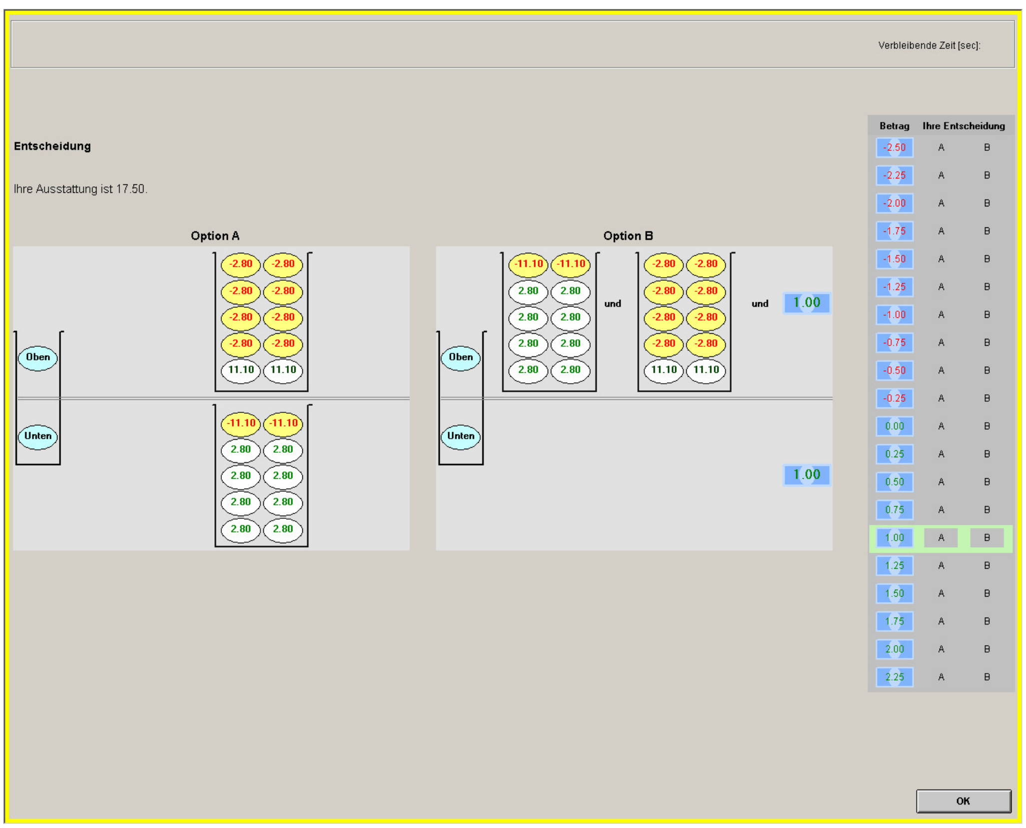
- *If in* Random draw X *a* *<u>yellow</u> ball is drawn, you lose* 3.50. *Considering your* Endowment *of* 20.00 *you receive* 16.50.
- *If in* Random draw X *a* *<u>white</u> ball is drawn, you receive* 14.00. *Considering your* Endowment *you receive* 34.00.

If in **Option B** *in* Random draw 1 "Down" *is drawn, the outcome is* −5.00. *Considering your* Endowment 15.00 *result.*

Third stage

In the second stage of the experiment you make <u>40</u> decisions. You choose on two decision screens each with 20 decision situations, which of the two different risky events—Option A or Option B—you prefer.

The outcomes of the risky events can be negative. You receive an Endowment of <u>17.50</u>. An example of a decision situation in the third stage is provided in the following figure.



In the example above the Amount (blue bank note) is added to Option B. The size of the added Amount can be found in the column "Amount" on the right-hand side of the screen. For <u>each</u> Amount you decide whether you prefer Option A or Option B.

After activating an AMOUNT in the column "Amount" you decide for this AMOUNT by clicking on "A" or "B" whether you prefer Option A or Option B. A green frame marks the chosen option. You do not need to stick to a certain order of your decisions.

How is the outcome of the risky event (you have chosen) determined in the third stage? For RANDOM DRAW 1 there are two balls in a ballot-box—one with the label "Up" another with the label "Down". Both balls can be drawn with the same chance (analogous to the first and second stage).

As shown in the example above, in the second stage a second random draw (RANDOM DRAW X) and/or a third random draw (RANDOM DRAW Y) can be necessary to determine your payoff.

In RANDOM DRAW X a ball is drawn from a ballot-box containing 10 balls. This ball can either be white or yellow. Note that, the composition of white and yellow balls can change in the three decision screens in this stage. This ballot-box always contains 10 balls and within a decision screen (for 20 decisions) the composition of white and yellow balls are identical. Analogously, this is true for RANDOM DRAW Y. Notice that the composition of yellow and white balls across RANDOM DRAW X and RANDOM DRAW Y can differ (see the example above).

Please look at the example of this stage again!
Suppose, this decision situation has been randomly chosen to determine your payoff.

If in **Option A** *in* RANDOM DRAW 1 *the ball* "Up" *is drawn,* RANDOM DRAW X *follows.*

- *If in* RANDOM DRAW X *a yellow ball is drawn, you lose* 2.80*. Considering your* ENDOWMENT *of* 17.50 *you receive* 14.70*.*
- *If in* RANDOM DRAW X *a white ball is drawn, you receive* 11.10*. Considering your* ENDOWMENT *you receive* 28.60*.*

If in RANDOM DRAW 1 *the ball* "Down" *is drawn,* RANDOM DRAW Y *follows.*

- *If in* RANDOM DRAW Y *a yellow ball is drawn, you lose* 11.10*. Considering your* ENDOWMENT *of* 17.50 *you receive* 6.40*.*
- *If in* RANDOM DRAW Y *a white ball is drawn, you receive* 2.80*. Considering your* ENDOWMENT *you receive* 20.30*.*

If in **Option B** *in* RANDOM DRAW 1 "Up" *is drawn* RANDOM DRAW Y *and* RANDOM DRAW X *follow and the* AMOUNT *of* 1.00 *(blue bank note) is added.*

- *If in* RANDOM DRAW X *and in* RANDOM DRAW Y *a yellow ball is drawn, you lose* 2.80 *(from* RANDOM DRAW X *) and* 11.10 *(from* RANDOM DRAW Y*). Considering your* ENDOWMENT *of* 17.50 *you receive* 4.60 *(*$= 17.50 - 11.10 - 2.80 + 1.00$*).*
- *If in* RANDOM DRAW X and in RANDOM DRAW Y a white ball is drawn, you receive 11.10 (from RANDOM DRAW X) and 2.80 (from RANDOM DRAW Y). *Considering your* ENDOWMENT *of* 17.50 *you receive* 32.40 *(*$= 17.50 + 11.10 + 2.80 + 1.00$*).*

- *If in* Random draw X *a* *white* *ball and in* Random draw Y *a* *yellow* *ball is drawn, you receive* 11.10 *(from* Random draw X) *and you lose* 11.10 *(from* Random draw Y*). Considering your* Endowment *you receive* 18.50 *(*$= 17.50 + 11.10 - 11.10 + 1.00$*).*
- *If in* Random draw X *a* *yellow* *ball and in* Random draw Y *a* *white* *ball is drawn, you lose* 2.80 *(from* Random draw X*) and you receive* 2.80 *(from* Random draw Y*). Considering your* Endowment *you receive* 18.50 *(*$= 17.50 - 2.80 + 2.80 + 1.00$*).*

If in **Option B** *in* Random draw 1 "Down" *is drawn, the outcome is* 1.00 (Amount *on the blue bank note). Considering your* Endowment 18.50 *result.*

Before the experiment will start now, please note: You are asked comprehension questions before each stage starts. These questions should familiarize you with the decision task in each stage.

After the experiment, you are asked to answer a questionnaire. For answering the questionnaire you receive independently from your earnings during the experiment € 4.