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PROSPECT-THEORY'S DIMINISHING SENSITIVITY VERSUS ECONOMICS' INTRINSIC UTILITY OF MONEY: HOW THE INTRODUCTION OF THE EURO CAN BE USED TO DISENTANGLE THE TWO EMPIRICALLY

ABSTRACT. The introduction of the euro gave a unique opportunity to empirically disentangle two components of utility: intrinsic value, a rational component central in economics, and the numerosity effect (going by numbers while ignoring units), a descriptive and irrational component central in prospect theory and underlying the money illusion. We measured relative risk aversion in Belgium before and after the introduction of the euro, and could consider changes in intrinsic value while keeping numbers constant, and changes in numbers while keeping intrinsic value constant. Intrinsic value significantly affected risk aversion, and the numerosity effect did not. Our study is the first to confirm the classical hypothesis of increasing relative risk aversion while avoiding irrational distortions due to the numerosity effect.

KEY WORDS: utility, currency change, prospect theory, psychology of money, money illusion, relative risk aversion

1. INTRODUCTION

The classical economic assumption of diminishing marginal utility is based on a natural intuition: the first dollar is spent on the most useful commodity, the second on the second-most useful commodity; and so on. Each new dollar brings less extra utility than the one before. Under expected utility, risk aversion results. Prospect theory (Kahneman and Tversky, 1979) makes different assumptions about marginal utility, based on the psychological principle of diminishing sensitivity. People are more sensitive to changes near their status quo than to changes remote from their status quo. For gains, this principle reinforces the implications of the classical economic assumption, with concave utility and a change from \$10 into \$20 having more impact than a change from \$110 into \$120. For losses, however, the principle implies a pattern opposite to the classical economic assumption, with convex utility and a change from −\$10 into −\$20 having more, rather than less, impact than a change from −\$110 to −\$120.

How can the classical economic predictions and those of prospect theory be so diametrically opposed to each other for losses? The explanation is that they concern different aspects of utility. The economic prediction concerns the intrinsic goodness of money, reflecting ways in which money improves the purchasing power and well-being of a consumer, and this is what "wealth" is commonly taken to designate. Prospect theory focuses on the general perception of quantity, as observed in many domains in psychology. The former aspect depends on final wealth and is rational, the latter depends on changes with respect to a perceived reference point and can lead to irrationalities. Kahneman's (2003) discussion of the value function of money in prospect theory, indeed, concerned general psychological perceptions, and not the intrinsic value that is typical of money and that distinguishes money from other quantities (pp. 703–705, and p. 710 2nd para of 2nd column). Thaler (1985) also explained prospect theory's value function through numerical perception: "… captures the basic psychophysics of quantity. The difference between \$10 and \$20 seems greater than the difference between \$110 and \$120, irrespective of the signs of the amounts in question" (p. 201). A special effect, contributing to diminishing sensitivity when quantitative stimuli are described numerically, is the *numerosity effect*: People focus on the numbers indicating a scale's value without concern for the unit or physical meaning of the scale.

If the perception of money were entirely driven by the numerosity effect, then it would be plausible that the utility of losses would mirror the utility of gains. More generally, decisions for losses would closely mirror decisions for gains, and, for instance, an equivalence between a sure gain $X and a lottery L over gains would lead to the mirrored equivalence between the sure loss −$X and the lottery −L over losses. This assumption, the reflection effect, was indeed put forward in original prospect theory (Kahneman and Tversky, 1979).

It is plausible, however, that both intrinsic value and the numerosity effect will affect decisions. These two components will jointly determine the utility of money as we observe it (Fennema and van Assen, 1999; Kahneman et al., 1997; Myagkov and Plott, 1997; Shafir et al., 1997). The numerosity effect is determined by the nominal value of money, irrespective of what the actual value of money is, and for the intrinsic-value component it is the other way around. Because for gains both components enhance concavity, concavity will be too pronounced there from a normative perspective (Rabin, 2000). For losses the two components have opposite effects, so that they are more clearly distinct. Instead of the strict reflection hypothesis of prospect theory of 1979, the following moderate version is plausible.

PARTIAL REFLECTION. For gains, utility is concave. For losses, utility is mildly convex and closer to linear than for gains.

Loewenstein and Prelec (1992, Condition V2) stated a similar hypothesis in terms of intertemporal elasticity of substitution. A literature search confirmed partial reflection.[1] For losses near ruin, the intrinsic value of money becomes so salient that it will dominate psychological perception, yielding concave utility again (Kahneman, 2003, p. 705). Partial reflection clearly demonstrates that both intrinsic value and the numerosity effect play a role. This joint role of both components will be investigated in this paper.

Whereas the two components are most clearly distinguished when comparing gains to losses, where they have diametrically opposite effects, losses are difficult to implement in an experiment. We will, therefore, disentangle the two components in another domain, with only gains, in our experiment. Further explanation is given later. The separation of intrinsic value and the numerosity effect is important (also for gains) because the former is normatively relevant, but the latter and, in general, reference-dependence, do not seem to be. We would not want a policy recommendation to depend on whether money is expressed as $\$x$ or as $100x$ cents. When prescribing decisions or making policy recommendations we would like to filter out the numerosity effect (Bleichrodt et al., 2005; Fennema and van Assen, 1998; Myagkov and Plott, 1997). When analyzing observations and communicating risks we should, however, reckon with the numerosity effect as an existing empirical phenomenon. The separation of intrinsic value and the numerosity effect is descriptively important for repeated decisions and learning, and for market situations, situations in which rationality will be enhanced (Myagkov and Plott, 1997, Result 4 and Conjectures 2 and 3; Plott 1986). To predict behavior in such situations, it is useful to know which aspects of utility, measured through the usual experiments such as reported in this paper, can be expected to be maintained and which will be reduced.

The numerosity effect has been studied in psychology (Galanter and Pliner, 1974; Atkinson et al., 1988, Part I of Vol. I; Pelham et al., 1994; Peters et al., 2006) and in medicine (Zorzi et al., 2002). It played a role in many economic studies, concerning payments in foreign or artificial currencies (Barron and Erev, 2003; Forsythe et al., 1982; Harris, 1991; Harrison, 1994; Jonas et al., 2002; Plott and Sunder, 1982; Soman et al., 2002, who have many more references), payments in probabilities instead of money (Allen, 1987; Anscombe and Aumann, 1963; Berg et al., 1986; Davis and Holt, 1993; Loomes, 1998; Roth and Malouf, 1979; Selten et al., 1999), the money illusion (Fehr and Tyran, 2001; Leontief, 1936; Shafir et al., 1997) and its role in inflation, and other topics (Benartzi and Thaler, 1995, p. 82; Huber et al., 2001). Edwards (1954, p. 399) suggested not using monetary outcomes, but qualitative outcomes, so as to avoid the numerosity effect.

A clear empirical separation of the numerosity effect and intrinsic value is usually hard to obtain, because both

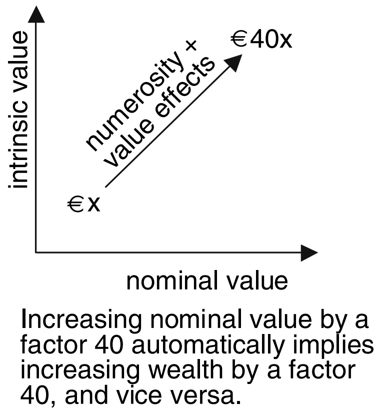


Figure 1. Usual Inseparability of value- and numerosity effects.

components covary with money (Figure 1). Some insights can be obtained if we compare different currencies of different countries. There are, however, difficulties with such comparisons. In between-subject designs they concern different people in different situations, and cultural and economic differences intervene. In within-subject designs, conversion problems will arise. Most subjects will then mentally convert foreign currencies into their own currency. Hence, if no numerosity effect is found, it may be due to such conversions. If a numerosity effect is found, it may be due to confusions regarding the unfamiliar currencies (Ragubir and Srivastava 2002). Hence, it is always difficult to draw clear conclusions.

Some authors used payments in artificial units. Then again problems can arise with subjects mentally converting to their own currency or with subjects being confused about the unfamiliar unit. Such problems are also likely to arise if we compare payments in cents to payments in dollars or euros. Comparisons across time, with the value of money changed by inflation, can also give insights, and this is the classical domain of the money illusion, but these comparisons are distorted by other changes over time.

Changes of currency in a country provide a good, though rare, opportunity to empirically separate the two components in controled experiments while minimizing the distortions just mentioned. Such an opportunity arose in Europe in 2002 through the introduction of the euro. We used this opportunity for an experimental study carried out in Belgium, with measurements in Belgium Francs in December 2001 and in euros in May 2002. Although mental conversions and confusions may still have occurred in our experiment, they are less likely in our design than in any other of the designs used before in the literature (see above). In the treatment in May 2002, the subjects had 4 months time to get used to the new unit of payment in their everyday life, something that will be impossible to implement in controled experiments otherwise.

From the 11 European countries that introduced the euro in 2002 we chose Belgium for the following reasons. First, Belgium's conversion rate, BF40 for €1, is round, so that round numbers before the conversion can correspond to round numbers after. Sonnemans (2006) found that differences in rounding affected investment behavior in the Netherlands. We wanted to avoid such distorting effects on behavior. Second and most important, the conversion rate in Belgium is considerable, unlike the reasonably round conversion rate of 1.96 in Germany for instance, so that there is room for considerable numerosity effects (Marques, 1999). Third, the other European countries with round and considerable conversion rates, Portugal and Italy, are farther remote from our own location than Belgium.

By relating amounts BFx to amounts €x, for various x, we could observe the effects of intrinsic value while keeping the numerosity effect constant. Similarly, by relating amounts BFx to amounts €$x/40$, we could observe the numerosity effect while keeping intrinsic value constant. We investigated the separation for gambles with positive prizes because for these gambles real incentives are easier to implement. In our design we can separate intrinsic utility and the numerosity effect also if they go in the same direction, so that there is no need to resort to losses. We therefore tested the separation of intrinsic value and the numerosity effect through increasing relative risk aversion (*RRA*) rather than through (partial) reflection. Further details of the plan of our study are discussed in Section 3.

The currency change generated many changes in the attitudes of people, and it may be conjectured that differences between our treatments are not due to numerosity effects or intrinsic value as we conjecture, but to such other changes. To investigate this possibility, we considered many studies into the psychology of money and of currency changes. Currency changes generate linguistic changes and, obviously, changes of coins and notes. The numerosity effect does not seem to be systematically affected by the former (Brysbaert et al., 1998) nor by the latter (Foltz et al., 1984; Noël and Serron, 1997). Other psychological effects may be generated by positive or negative attitudes towards, for example: (a) loss of the national identity; (b) a currency change and the corresponding arithmetic requirements; (c) a domestic versus a joint currency; (d) fear for nickle in the 1- and 2-euro coins.[2] Phenomena of these kinds clearly affect absolute levels of perceived utility, but have no clear effect on the curvature of utility as relevant to RRA. We, therefore, took RRA as the dependent variable in our experiment, and nominal value and intrinsic value as independent variables. The corresponding index $-U''(x)/xU'(x)$ of RRA is, indeed, the most commonly used index to describe curvature of utility ("risk aversion"). Because this index is distorted by empirical violations of expected utility, we will use a simpler and theory-free index in our experiment, explained latter.

The classical economic assumption is that RRA is increasing (Arrow, 1971 p. 97; Jevons, 1889 pp. 172–173), and many empirical studies have confirmed this.[3] In particular, Holt and Laury (2002) confirmed the assumption for high real incentives. The effect is commonly ascribed to intrinsic value, i.e. to increases in wealth. The numerosity effect, through the perception of higher numbers, also underlies it. The latter appears for instance from the ratio-difference principle, where people's processing of numbers consists of a mix of ratios and differences in situations where only one of these is appropriate (Baron, 1997; Darke and Freedman, 1993; Fantino and Goldshmidt, 2000; Fetherstonhaugh et al., 1997; Kirkpatrick and Epstein, 1992; Peters et al., 2006; Quattrone and Tversky, 1998, p. 727; Prelec and Loewenstein, 1991; Soman et al., 2002; Thaler, 1980).

We measured the RRA of 88 subjects in December 2001, shortly before the introduction of the euro, and did the same for 93 subjects in May 2002, when people had started to get accustomed to the euro. In this manner, we could distinguish between changes in risk attitude and concave utility that were generated by intrinsic value and changes generated by the numerosity effect. Our hypothesis was that increases in numerical perception and in intrinsic value both amplify RRA, and we wanted to investigate which of these effects was larger.

2. THE EXPERIMENT

2.1. *Procedure*

The treatments with BF payments were carried out on two different days in December 2001, just before the introduction of the euro. The treatments with € payments were carried out on two different days in May 2002, 4 months after the introduction of the euro. The design was between-subjects.

Two experimenters asked students in the meeting area of the University of Diepenbeek in Belgium whether they were willing to participate in a 10 minutes experiment. If students agreed to participate, they received a booklet with one page of instructions, seven pages with one choice task on each page, and a final page asking for demographics and giving information on how to contact us. Participants were asked to work quietly and individually. The stimuli and the procedure were tested in a pilot study of $n = 45$ subjects.

2.2. *Stimuli*

Each subject made seven choices between a lottery and a sure amount of money, such as between

- A lottery yielding BF600 with probability 15/20 and nothing otherwise,

or

- A sure amount of BF400.

Figure 2 depicts, in reduced form, examples of the choice tasks presented to the participants for each of the four treatments. The basic treatment was with low amounts of Belgium francs (*LBF*), as in Fig. 2a. The second treatment, in Fig. 2b, will be discussed later. Figure 2c depicts the third treatment (*L€*), with all amounts of Belgium francs in Fig. 2a replaced by euro-amounts of equal intrinsic value. It means that all numbers of Fig. 2a were divided by 40. Figure 2d depicts the fourth treatment (*H€*), with all amounts of Belgium francs in Fig. 2a replaced by the same numbers of euros, yielding 40 times higher intrinsic values. The second treatment (*HBF*), in Fig. 2b, replaced all €-amounts of the fourth treatment by BF-amounts of the same value, resulting in quantities of Belgium francs 40 times bigger than in the basic LBF treatment.

Table I in the results section gives a complete description of the probabilities and outcomes in the seven choice questions. The first two tasks served as learning exercises, to test for extreme risk attitudes and to discourage choices for certainty or for risk without inspecting the probabilities and outcomes. The order of the five experimental tasks was counterbalanced. The questionnaire was in Flamish.[4] An English translation is available in the Appendix.

2.3. *Implementation of real incentives*

Paying each participant according to one or more of their choices would have been too expensive, given the high stakes that could not be avoided in the high-payment treatment. We, therefore, developed a random-lottery incentive system depicted in Figure 3 (discussed in Section 5). The low-treatment subjects had a 1/2 chance, and the high-treatment subjects a 1/20 chance, to play one of their choices for real.

After the subjects had filled out the seven pages with choices, the LBF and L€ groups guessed odd or even, and the

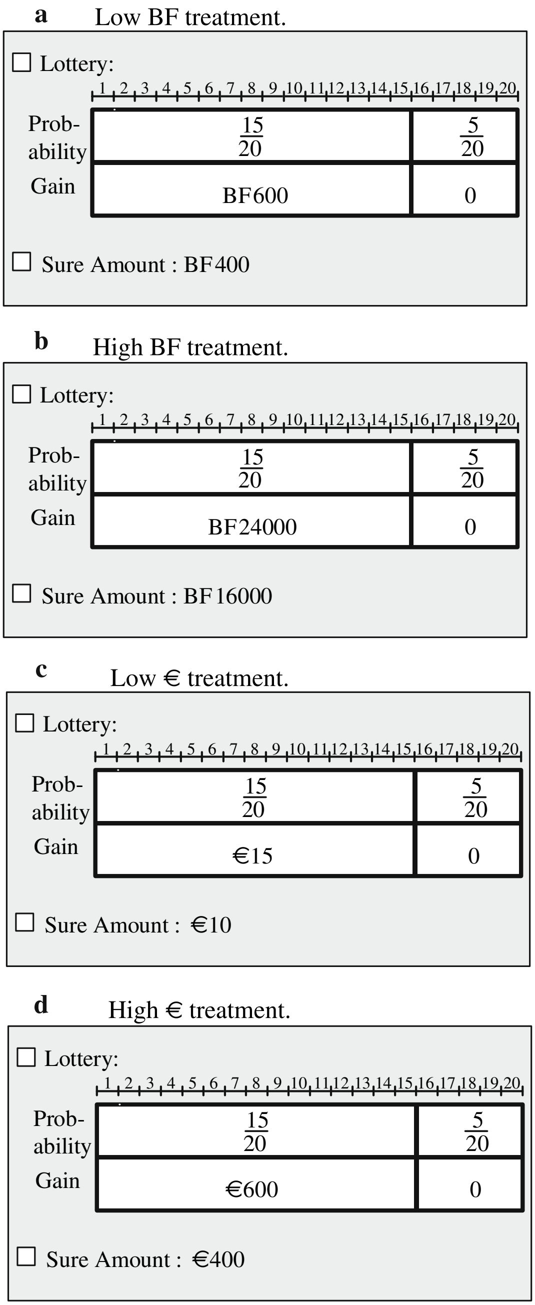


Figure 2. Examples of our stimuli.

TABLE I

Percentages of safe choices

	LBF			HBF			L€			H€		
#	Risky BF	Safe BF	% Safe	Risky BF	Safe BF	%S	Risky €	Safe €	%S	Risky €	Safe €	%S
1	.50:300	20	14%	.50:12000	800	09%	.50:7.5	0.5	13%	.50:300	20	16%
2	.05:220	200	100%	.05:8800	8000	100%	.05:5.5	5	100%	.05:220	200	98%
3	.05:2000	120	60%	.05:80000	4800	69%	.05:50	3	65%	.05:2000	120	62%
4	.25:800	200	70%	.25:32000	8000	82%	.25:20	5	73%	.25:800	200	87%
5	.50:200	100	42%	.50:8000	4000	80%	.50:05	2.5	46%	.50:200	100	58%
6	.75:600	400	30%	.75:24000	16000	51%	.75:15	10	40%	.75:600	400	53%
7	.95:200	160	09%	.95:8000	6400	20%	.95:05	4	23%	.95:200	160	27%
Total			46%			59%			51%			57%

In the LBF treatment, the first choice was between BF20 for sure (safe BF) and the lottery yielding BF300 with probability 0.50 and nothing otherwise (risky BF). 14% chose the safe option (% safe); etc.

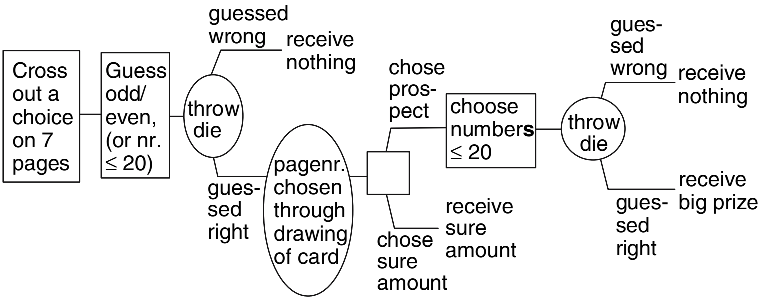


Figure 3. The random-lottery incentive system for motivating the participants.

HBF and H€ groups guessed one number between 1 and 20. They next threw a 20-sided die. If the resulting number did not agree with the prediction, the game was over and no money was paid. In the other case, the subjects drew one card at random from seven numbered cards. This number determined which of their seven choices made during the experiment was played out for real. If they had chosen the risky option in the choice selected, the probabilities were again generated by the subjects throwing a 20-sided die, where the numbers yielding the prize also had been chosen by the subjects before throwing the die.

2.4. *Subjects*

$N = 181$ subjects participated in the four treatments, $n = 43$ in LBF, $n = 45$ in HBF, $n = 48$ in L€, and $n = 45$ in H€. All participants were students from various departments of the University of Diepenbeek. As many were male as female, and they were of age between 17 and 24. Except 3, all were Flamish. Subjects were not permitted to participate more than once.

2.5. *Analysis*

As degree of RRA of each subject we took the number of safe choices excluding the two learning tasks. The four different treatments were compared through independent-samples t-tests and through 2 by 2 analysis of variance with number of safe choices as dependent variable and intrinsic value (high-low payment) and nominal value (euro-BF) as independent factors.

3. DISCUSSION OF THE PLAN OF OUR DESIGN

Figure 4 illustrates our design.

We compared the RRA in the four treatments. Diagonal comparisons constitute direct tests of RRA, and have been frequently conducted in the literature. *Constant RRA* means that risk attitude remains the same if all outcomes are multiplied by a common positive factor. It implies no changes along the diagonals in Figure 4. The common finding is increasing RRA, with more safe choices at the top of the diagonal arrows than at their bottom. Our hypothesis is that both horizontal and vertical moves in the direction of the arrows amplify RRA. In classical economic texts, where horizontal moves were considered irrelevant, it was common to explain the observed increases in RRA through vertical moves. Horizontal increases of RRA are supported by the ratio-difference principle, referenced above.

Horizontal comparisons between different nominal values while keeping the intrinsic values constant, and vertical comparisons between different intrinsic values while keeping the

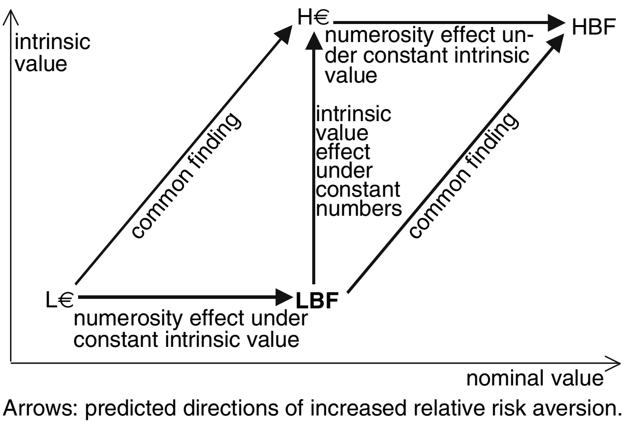


Figure 4. Plan of our design.

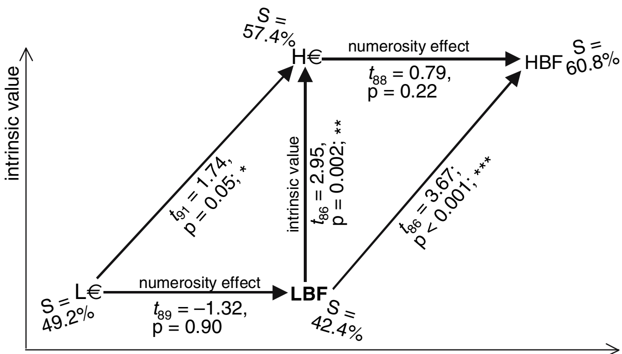
numbers constant, usually cannot be observed. Because of the introduction of the euro, we could make such observations.

4. RESULTS

Table I gives descriptive statistics. Questions 4 and 5 compare a lottery to its expected value and, hence, provide direct tests of risk aversion. Question 4 reveals significant risk aversion ($t_{180} = -9.02$, $p < 0.001$; also $p < 0.01$ for each of the four treatments). Question 5 does not yield significant deviation from risk neutrality (only for the HBF treatement there is significant risk aversion, $t_{43} = 4.98$, $p < 0.001$). We did not find gender effects in risk aversion ($t_{177} = 0.162$, $p = 0.872$).

Figure 5 depicts the results of t-tests, with the learning questions (choice # 1 and 2 in Table I) excluded. Including them would not change any of the conclusions. All reported significance probabilities are one-tailed. The intrinsic-value effect is in the predicted direction and is significant. The numerosity effects are not significant, with the strongest effect even marginally significant in the opposite direction.

Analysis of variance gave the same conclusions, with a highly significant effect of intrinsic value (F(1,180) =



S: % of safe choices; *: significant at 0.05; **: significant at 0.01; ***: significant at 0.001

Figure 5. Results of t-tests.

15.04, $p < .001$), a nonsignificant effect of nominal value ($F(1,180) = .23$, $p = .63$), and a nonsignificant interaction ($F(1,180) = 2.28$, $p = .13$). The absence of numerosity effects suggests that there was no difference in RRA between BF outcomes and € outcomes.

5. DISCUSSION

We discuss a number of limitations to our study. First, we would have preferred a within-subjects design, but this was not possible due to practical limitations.

Second, the procedure for implementing real incentives could not be entirely identical for the two treatments. The average gain over the seven choice tasks was about €5 (BF200) for the low-stimuli treatments and €200 euro (BF8000) for the high-stimuli treatments. Such large differences in payment between treatments could, obviously, not be avoided in view of the conversion factor of 40. Because of budgetary considerations, we could not pay all amounts for real in the high-payment treatments. We, therefore, introduced the 1/20 chance of playing one choice for real in the high-payment treatments. The resulting expected gain of €10 per participant for 10 min time (with no waiting or traveling time and no transaction costs because the selection and payment were on the spot) is still very favorable. For example, in Holt and Laury (2002) the majority of subjects (their "20*x* real treatment") earned an average of $68 while the experiment lasted an hour on average. Hence, the subjects in our high-payment treatment were among the best-paid per time unit in the literature.

In order to have the procedures for the low- and high-payment treatments as similar as possible, we introduced a 1/2 chance to play one choice for real in the low-payment treatments. It could not be 1/20 because then the payments would be too low and subjects would not be sufficiently motivated (Smith 1982, "payoff dominance"). For the low-payment treatment, the expected gain was €2.5.

The random-lottery incentive system, where not all choices are paid so as to avoid income effects and house money effects, but at most one choice is paid, has become the almost exclusively used incentive system for individual choice in experimental economics (Holt, 1986; Holt and Laury, 2002; Starmer and Sugden, 1991). We used a form where not for each participant one choice is played for real, but only for some randomly selected participants. This form was also used by Harrison, Lau, and Williams (2002). Two studies examined whether there was a difference between this form and the original form where each participant is paid, and did not find a difference (Armantier 2006, p. 406; Harrison et al., 2006, footnote 16).

A third problem concerns the timing of the experiment. It is, in general, desirable to observe different treatments as much as possible in similar situations. No significant historical changes should take place between the measurements, inflation should be as small as possible, and so on. For these reasons it was desirable to have our measurements before and after the introduction of the euro as close to each other as possible. It was also desirable, however, that subjects were maximally familiar with the unit of payment used, and considered it as "their" currency. We wanted to minimize subjects mentally converting euros into francs (or vice versa) during the experiment (Juliusson et al., 2006). For this reason, it was desirable to perform our measurement of the euro treatments long after the introduction in January 2002. The actual timing of our experiment was a compromise between the two, conflicting, desiderata.

Fortunately for our experiment, no major historical changes took place between December 2001 and May 2002. Only usual random factors due to differences such as winter versus spring, middle of the academic year versus end thereof, and a 5-months increase in age, remained. Four months is obviously not enough to get completely used to a new currency and to forget about the old one. Our population, young academic adults, can be expected to be among the fastest to get adapted though. Indeed, the percentage of support for the euro was higher among students (78% while grouped with self-employed people) than among other groups (European Commission, 2002, p. 76; Mussweiler and Englich, 2003). In April 2002, 80% of the Belgians indicated that they felt comfortable using the euro (European Commission, 2002, p. 79). We were lucky that in this, and several other, respects Belgium was among the most supportive countries for the euro. This was confirmed in EOS Gallup Europe (2002). To the extent that subjects converted euros back into francs before deciding, our study loses statistical power but not validity. Note that not only did we accept the null hypothesis of no numerosity effect, but even we came close to marginally rejecting this hypothesis in the direction *opposite* to the alternative hypothesis.

We used the number of safe choices as an index of RRA. The most commonly used index in the literature, through $-U''(x)/xU'(x)$ with U utility and x the outcome, assumes expected utility. There are, however, many empirical problems with expected utility (Starmer, 2000), which is why we preferred not to use the above index. Descriptively better theories such as prospect theory are more complex to implement. Because the index we used suffices to answer our research questions, is easy to understand, and does not require commitment to a theory, we decided to use it in our analysis. Relative to the parameters estimated by Tversky and Kahneman (1992), our participants usually stayed closer to expected value maximization.

6. CONCLUSION

The observed utility functions for money consist of a normatively relevant component based on intrinsic value, and the numerosity effect, a normatively irrelevant component reflecting the general perception of numbers. In general, measurements of utility cannot separate these two components. A change of currency in a country gives an opportunity to separate the two components after all, while avoiding a number of biases.

We carried out an empirical study in Belgium at the introduction of the euro in 2001, measuring the relative risk aversion of subjects. Because we were in the unique situation of having subjects get used to a different unit of payment for 4 months, and we considered the country in Europe, and the subpopulation of that country, that best accepted the euro, our design was optimal as regards avoiding mental conversions of currencies or confusions. It, accordingly, seems to be optimal for verifying the common economic hypothesis that relative risk aversion increases with wealth, and not just with perceived numbers.

Changes of nominal value did not have significant effects, but changes of intrinsic value did. This finding is positive for the economic, normatively oriented view on utility. We are the first to have demonstrated the classical economic hypothesis of increasing RRA while avoiding the distortions due to the numerosity effect.

APPENDIX: THE INSTRUCTIONS, TRANSLATED INTO ENGLISH

For each of the four treatments, the instruction were more or less the same, and only one sentence differed between the low- and the high-stimuli treatments. The instructions for the low-stimuli treatments are given hereafter, with the deviating sentence for the high-stimuli treatments given in square brackets.

INVESTIGATION OF OPINIONS ABOUT UNCERTAIN PAYMENTS

In this investigation, we are interested in opinions of people about uncertain payments. We will present seven choice situations to you. In each you can choose between the certain receipt of an amount of money or the playing of a lottery.

When playing the lottery you may win, with some probability, an amount of money, and you gain nothing otherwise. You can only gain money, and you will never lose money. There are no right or wrong answers for these questions, and they only concern your own preferences. Your preferences are what we are interested in!

- On each of the following seven pages there is an amount of money that you can gain with certainty and a lottery for money. You are asked each time what you would prefer most: receiving the sure amount of money or playing the lottery. Cross out your preference each time.

It is next determined whether one of your choices will be played for real. For this purpose, you will be asked to guess whether an odd or even number shows up when you throw a 20-sided die. [For this purpose, you will be asked to guess which number will come up when you throw a 20-sided die.]

- If you guessed wrong, the experiment is over and you, unfortunately, did not gain anything. If you guessed right, then one of the choices that you crossed out will be played for real.
- You then draw one of seven numbered cards to determine from which page the choice you made will be played out for real.
- From the selected page you receive the sure amount of money if that is what you crossed out, and we play the lottery if that is what you crossed out.

As said before, there are no right or wrong answers, and we are interested in your own preferences. It is also favorable for yourself to cross out your preferred option on each page. After all, if that page is selected, then we really carry out what you crossed out there.

NOTES

1. More concave utility for gains than convex utility for losses was found by Abdellaoui (2000, p. 1506), Abdellaoui et al. (2005a), Abdellaoui et al. (2005b), Abdellaoui et al. (2007a), Currim and Sarin (1989, p. 30), Fennema and van Assen (1999), Galanter and Pliner (1974, power 0.45 for gains, 0.39 for losses), Kahneman and Tversky (1979, p. 279), Laury and Holt (2007), List (2006), and Loomes (1998). Consistent with this, there was more pronounced risk aversion for gains than risk seeking for losses in Battalio et al. (1990, p. 32), Battalio et al. (1985), Budescu and Weiss (1987, p. 193), Camerer (1989, Table 5), Dickhaut et al. (2003), González-Vallejo et al. (2003, Fig. 1 and Table 2), Harless and Camerer (1994 p. 1281), Hershey and Schoemaker (1980, Table 3 and p. 409), Kühberger et al. (1999, pp. 216–217), Lopes and Oden (1999), Pennings and Smidts (2003), Schneider and Lopes (1986), Smith et al. (2002, Figure 2), Wakker et al. (2006), Weber and Bottom (1989, Exhibit 8). Unclear or balanced findings were obtained by Abdellaoui et al. (2007b), Booij and van de Kuilen (2006), Hogarth and Einhorn (1990, Tables 2 and 4), Kahneman and Tversky (1979), Schunk and Betsch (2006), and Tversky and Kahneman (1992). An opposite finding, with more convexity for losses than concavity for gains, was obtained by Fishburn and Kochenberger (1979, p. 511). In line with this, Cohen, Jaffray, and Said (1987, Table 3) and Levin and Hart (2003) found more risk seeking for losses than risk aversion for gains.
2. Bornemann (1976); Bruner and Goodman (1947); Furnham and Argyle (1998); Gamble et al. (2002); Jonas et al. (2002); Marques (1999); Meier-Pesti and Kirchler (2003); Müller-Peters (1998); Mussweiler and Englich (2003); Nestle et al. (2002); Pepermans et al. (1998); Stenkula (2004).
3. Baron (1997); Binswanger (1981); Harrison et al. (2005); Kachelmeier and Shehata (1992); Rapoport (1984). Mixed results are in Barsky et al. (1997). The opposite, decreasing RRA, has also been found, especially near ruin, by Cohn et al. (1975), Friend and Blume (1975), and Ogaki and Zhang (2001).
4. Thanks to Myriam Welkenhuysen for correcting the Flamish language.

REFERENCES

Abdellaoui, M. (2000), Parameter-free elicitation of utilities and probability weighting functions, *Management Science* 46, 1497–1512.

Abdellaoui, M., Attema, A. E. and Bleichrodt, H. (2005a), *Intertemporal Tradeoffs for Gains and Losses: An Experimental Measurement of Discounted Utility*, iMTA/iBMG, Erasmus University, Rotterdam, the Netherlands.

Abdellaoui, M., Bleichrodt, H. and L'Haridon, O. (2007a), *A Tractable Method to Measure Utility and loss aversion under prospect theory, in preparation*, iMTA/iBMG, Erasmus University, Rotterdam, the Netherlands.

Abdellaoui, M., Bleichrodt, H. and Paraschiv, C. (2007b), Measuring loss aversion under prospect theory: A parameter-free approach, *Management Science* (forthcoming).

Abdellaoui, M., Vossmann, F., and Weber, M. (2005b), Choice-based elicitation and decomposition of decision weights for gains and losses under uncertainty, *Management Science* 51, 1384–1399.

Allen, F. (1987), Discovering personal probabilities when utility functions are unknown, *Management Science* 33, 542–544.

Anscombe, F.J. and Aumann, R.J. (1963), A definition of subjective probability, *Annals of Mathematical Statistics* 34, 199–205.

Armantier, O. (2006), Do wealth differences affect fairness considerations, *International Economic Review* 47, 391–429.

Arrow, K.J. (1971), *Essays in the Theory of Risk Bearing.* North-Holland, Amsterdam.

Atkinson, R.C., Herrnstein, R.J., Lindzey, G.E. and Luce, R.D. (1988, Eds.), S*tevens Handbook of Experimental Psychology (2nd ed)*, Wiley, New York.

Baron, J. (1997), Confusion of relative and absolute risk in valuation, *Journal of Risk and Uncertainty* 14, 301–309.

Barron, G. and Erev, I. (2003), Small feedback-based decisions and their limited correspondence to description-based decisions, *Journal of Behavioral Decision Making* 16, 215–233.

Barsky, R.B., Juster, F.T., Kimball, M.S. and Shapiro, M.D. (1997), Preference parameters and behavioral heterogeneity: An experimental approach in the health and retirement study, *Quarterly Journal of Economics* 112, 537–579.

Battalio, R.C., Kagel, J.H., and Jiranyakul, K. (1990), Testing between alternative models of choice under uncertainty: Some initial results, *Journal of Risk and Uncertainty* 3, 25–50.

Battalio, R.C., Kagel, J.H. and MacDonald, D.N. (1985), Animal's choices over uncertain outcomes: Some initial experimental evidence, *American Economic Review* 75, 597–613.

Benartzi, S. and Thaler, R.H. (1995), Myopic loss aversion and the equity premium puzzle, *Quarterly Journal of Economics* 110, 73–92.

Berg, J.E., Daley, L.A., Dickhaut, J.W. and O'Brien, J.R. (1986), Controlling preferences for lotteries on units of experimental exchange, *Quarterly Journal of Economics* 101, 281–306.

Binswanger, H.P. (1981), Attitudes towards risk: Theoretical implications of an experiment in rural India, *Economic Journal* 91, 867–890.

Bleichrodt, H., Doctor, J. and Stolk, E. (2005), A nonparametric elicitation of the equity-efficiency tradeoff in cost-utility, *Journal of Health Economics* 24, 655–678.

Booij, A.S. and van de Kuilen, G. (2006), *A Parameter-Free Analysis of the Utility of Money for the General Population under Prospect Theory*, CREED, University of Amsterdam, the Netherlands.

Bornemann, E. (1976), *The Psychoanalysis of Money.* Urizen Books, New York.

Bruner, J.S. and Goodman, C.C. (1947), Value and need as organizing factors in perception, *Journal of Abnormal and Social Psychology* 42, 33–44.

Brysbaert, M., Fias, W. and Noël, M.-P. (1998), The whorfian hypothesis and numerical cognition: Is "twenty-four" processed in the same way as "four-and-twenty"?, *Cognition* 66, 51–77.

Budescu, D.V. and Weiss, W. (1987), Reflection of transitive and intransitive preferences: A test of prospect theory, *Organizational Behavior and Human Decision Processes* 39, 184–202.

Camerer, C.F. (1989), An experimental test of several generalized utility theories, *Journal of Risk and Uncertainty* 2, 61–104.

Cohen, M., Jaffray, J.-Y. and Said, T. (1987), Experimental comparisons of individual behavior under risk and under uncertainty for gains and for losses, *Organizational Behavior and Human Decision Processes* 39, 1–22.

Cohn, R.A., Lewellen, W.G., Lease, R.C. and Schlarbaum, G.G. (1975), Individual investor risk aversion and investment portfolio composition, *Journal of Finance* 30, 605–620.

Currim, I.S. and Sarin, R.K. (1989), Prospect versus utility, *Management Science* 35, 22–41.

Darke, P.R. and Freedman, J.L. (1993), Deciding whether to seek a bargain: Effects of both amount and percentage off, *Journal of Applied Psychology* 78, 960–965.

Davis, D.D. and Holt, C.A. (1993), *Experimental Economics.* Princeton University Press, Princeton.

Dickhaut, J.W., McCabe, K., Nagode, J.C., Rustichini, A., Smith, K., and Pardo, J.V. (2003), The impact of the certainty context on the process of choice, *Proceedings of the National Academy of Sciences* 100, 3536–3541.

Edwards, W. (1954), The theory of decision making, *Psychological Bulletin* 51, 380–417.

EOS Gallup Europe (2002), Euro attitudes—euro zone, flash Eurobarometer N^o 121/3, June 2002. URL: http://WWW.europa.eu.int/comm/public_opinion/archives/flash_arch.htm

European Commission (2002), Eurobarometer—public opinion in the European union. Report no. 57, Spring 2002. URL: [http://europa.eu.int/comm/dg10/epo/eb.html]

Fantino, E. and Goldshmidt, J.N. (2000), Differences, not ratios, control choice in an experimental analogue to foraging, *Psychological Science* 3, 229–233.

Fehr, E. and Tyran, J.-R. (2001), Does money illusion matter? *American Economic Review* 91, 1239–1262.

Fennema, H. and van Assen, M.A.L.M. (1998), Measuring the utility of losses by means of the tradeoff method, *Journal of Risk and Uncertainty* 17, 277–295.

Fetherstonhaugh, D., Slovic, P., Johnson, S.M. and Friedrich, J. (1997), Insensitivity to the value of human life: A study of psychophysical numbing, *Journal of Risk and Uncertainty* 14, 283–300.

Fishburn, P.C. and Kochenberger, G.A. (1979), Two-piece von Neumann-Morgenstern utility functions, *Decision Sciences* 10, 503–518.

Foltz, G.S., Poltrock, S.E. and Potts, G.R. (1984), Mental comparison of size and magnitude: size congruity effects, *Journal of Experimental Psychology: Learning, Memory and Cognition* 10, 442–453.

Forsythe, R., Palfrey, T.R. and Plott, C.R. (1982), Asset valuation in an experimental market, *Econometrica* 50, 537–568.

Friend, I. and Blume, M.E. (1975), The demand for risky assets, *American Economic Review* 65, 900–922.

Furnham, A. and Argyle, M. (1998), *The Psychology of Money*, Routledge, London.

Galanter, E. and Pliner, P. (1974), Cross-modality matching of money against other continua. In H. Moskowitz, B. Sharf, and J.C. Stevens (eds.), *Sensation and Measurement: Papers in Honor of S.S. Stevens*, Reidel, Dordrecht, the Netherlands, pp.65–76.

Gamble, A., Gärling, T., Charlton, J.P. and Ranyard, R. (2002), Euro illusion: Psychological insights into price evaluations with a unitary currency, *European Psychologist* 7, 302–311.

González-Vallejo, C.C., Reid, A.A. and Schiltz, J. (2003), Context effects: the proportional difference model and the reflection of preference, *Journal of Experimental Psychology: Learning, Memory, and Cognition* 29, 942–953.

Harless, D.W. and Camerer, C.F. (1994), The predictive utility of generalized expected utility theories, *Econometrica* 62, 1251–1289.

Harris, L. (1991), Stock price clustering and discreteness, *Review of Finance* 16, 1533–1597.

Harrison, G.W. (1994), Expected utility theory and the experimentalists, *Empirical Economics* 19, 223–253.

Harrison, G.W., Johnson, E., McInnes, M.M. and Rutström, E.E. (2005), Risk aversion and incentive effects: Comment, *American Economic Review* 95, 897–901.

Harrison, G.W., Lau, M.I., and Rutström, E.E. (2006), Estimating risk attitudes in Denmark: A field experiment, *Scandinavian Journal of Economics* (forthcoming).

Harrison, G.W., Lau, M.I. and Williams, M.B. (2002), Estimating individual discount rates in Denmark: A field experiment, *American Economic Review* 92, 1606–1617.

Hershey, J.C. and Schoemaker, P.J.H. (1980), Prospect theory's reflection hypothesis: A critical examination, *Organizational Behavior and Human Performance* 25, 395–418.

Hogarth, R.M. and Einhorn, H.J. (1990), Venture theory: A model of decision weights, *Management Science* 36, 780–803.

Holt, C.A. (1986), Preference reversals and the independence axiom, *American Economic Review* 76, 508–513.

Holt, C.A. and Laury, S.K. (2002), Risk aversion and incentive effects, *American Economic Review* 92, 1644–1655.

Huber, J., Ariely, D., and Fischer, G. (2001), Expressing preference in a principal-agent task: A comparison of choice, rating, and matching, *Organizational Behavior and Human Decision Processes* 87, 66–90.

Jevons, W.S. (1889), *The Theory of Political Economy* (5th edition 1957, Kelley and MacMillan, New York; other ed. Penguin, 1970.)

Jonas, E., Greitemeyer, T., Frey, D. and Schulz-Hardt, S. (2002), Psychological effects of the euro—experimental research on the perception of salaries and price estimations, *European Journal of Social Psychology* 32, 147–169.

Juliusson, A., Gamble, A., and Gärling, T. (2006), Learning the value of a new currency from prices, *Journal of Experimental Psychology: Applied* 11, 45–52.

Kachelmeier, S.J. and Shehata, M. (1992), Examining risk preferences under high monetary incentives: Experimental evidence from the people's republic of China, *American Economic Review* 82, 1120–1141; for comment see Kachelmeier, S.J. and Shehata, M. (1994), *American Economic Review* 84, 1104–1106.

Kahneman, D. (2003), A perspective on judgment and choice; mapping bounded rationality, *American Psychologist* 58, 697–720.

Kahneman, D. and Tversky, A. (1979), Prospect theory: An analysis of decision under risk, *Econometrica* 47, 263–291.

Kahneman, D., Wakker, P.P., and Sarin, R.K. (1997), Back to Bentham? Explorations of experienced utility, *Quarterly Journal of Economics* 112, 375–405.

Kirkpatrick, L.A. and Epstein, S. (1992), Cognitive-experiential self-theory and subjective probability: Further evidence for two conceptual systems, *Journal of Personality and Social Psychology* 63, 534–544.

Kühberger, A., Schulte-Mecklenbeck, M., and Perner, J. (1999), The effects of framing, reflection, probability, and payoff on risk preference in choice tasks, *Organizational Behavior and Human Decision Processes* 78, 204–231.

Laury, S.K. and Holt, C.A. (2007), Further reflections on prospect theory. In Cox, J.C. and Harrison. G. (eds.), *Risk Aversion in Experiments* (Experimental Economics, Volume 12), JAI Press, Greenwich, CT, forthcoming.

Leontief, W.W. (1936), The fundamental assumptions of Mr. Keynes' monetary theory of unemployment, *Quarterly Journal of Economics* 5, 192–197.

Levin, I.P. and Hart, S.S. (2003), Risk preferences in young children: Early evidence of individual differences in reaction to potential gains and losses, *Journal of Behavioral Decision Making* 16, 397–413.

List, J.A. (2006), Using Hicksian surplus measures to examine consistency of individual preferences: Evidence from a field experiment, *The Scandinavian Journal of Economics* 108, 115–134.

Loehman, E. (1998), Testing risk aversion and nonexpected utility theories, *Journal of Economic Behavior and Organization* 33, 285–302.

Loewenstein, G.F. and Prelec, D. (1992), Anomalies in intertemporal choice: Evidence and an interpretation, *Quarterly Journal of Economics* 107, 573–597.

Loomes, G. (1998), Probabilities vs money: A test of some fundamental assumptions about rational decision making, *Economic Journal* 108, 477–489.

Lopes, L.L. and Oden, G.C. (1999), The role of aspiration level in risky choice: A comparison of cumulative prospect theory and SP/A theory, *Journal of Mathematical Psychology* 43, 286–313.

Marques, J.F. (1999), Changing 'Europe'—the euro as a new subject for psychological research in numerical cognition, *European Psychologist* 4, 152–156.

Meier-Pesti, K. and Kirchler, E. (2003), Attitudes towards the euro by national identity and relative national status, *Journal of Economic Psychology* 24, 293–299.

Müller-Peters, A. (1998), The significance of national pride and national identity to the attitude toward the single European currency: A Europe-wide comparison, *Journal of Economic Psychology* 19, 701–719.

Mussweiler, T. and Englich, B. (2003), Adapting to the euro: Evidence from bias reduction, *Journal of Economic Psychology* 24, 285–292.

Myagkov, M.G. and Plott, C.R. (1997), Exchange economies and loss exposure: Experiments exploring prospect theory and competitive equilibria in market environments, *American Economic Review* 87, 801–828.

Nestle, F.O., Speidel, H. and Speidel, M.O. (2002), High nickel release from 1- and 2-euro coins, *Nature* 419, 132.

Noël, M.-P. and Serron, X. (1997), On the existence of intermediate representations in numerical processing, *Journal of Experimental Psychology: Learning, Memory, and Cognition* 23, 697–720.

Ogaki, M. and Zhang, Q. (2001), Decreasing relative risk aversion and tests of risk sharing, *Econometrica* 69, 515–526.

Pelham, B.W., Sumarta, T.T, and Myaskovsky, L. (1994), The easy path from many to much: The numerosity heuristic, *Cognitive Psychology* 26, 103–133.

Pennings, J.M.E. and Smidts, A. (2003), The shape of utility functions and organizational behavior, *Management Science* 49, 1251–1263.

Pepermans, R., Burgoyne, C.B., and Müller-Peters, A. (1998), European integration, psychology and the euro, *Journal of Economic Psychology* 19, 657–661.

Peters, E., Västfjäll, D., Slovic, P., Mertz, C.K., Mazzocco, K. and Dickert, S. (2006), Numeracy and decision making, *Psychological Science* 17, 407–413.

Plott, C.R. (1986), Rational choice in experimental markets, *Journal of Business* 59, S301–S327.

Plott, C.R. and Sunder, S. (1982), Efficiency of experimental security markets with insider information: An application of rational-expectations models, *Journal of Political Economy* 90, 663–698.

Prelec, D. and Loewenstein, G.F. (1991), Decision making over time and under uncertainty: A common approach, *Management Science* 37, 770–786.

Quattrone, G.A. and Tversky, A. (1988), Contrasting rational and psychological analyses of political choice, *American Political Science Review* 82, 719–736.

Rabin, M. (2000), Risk aversion and expected-utility theory: A calibration theorem, *Econometrica* 68, 1281–1292.

Raghubir, P. and Srivastava, J. (2002), Effect of face value on product valuation in foreign currencies, *Journal of Consumer Research* 29, 335–347.

Rapoport, A. (1984), Effects of wealth on portfolios under various investment conditions, *Acta Psychologica* 55, 31–51.

Roth, A.E. and Malouf, M.W. (1979), Game-theoretic models and the role of information in bargaining, *Psychological Review* 86, 574–594.

Schneider, S.L. and Lopes, L.L. (1986), Reflection in preferences under risk: who and when may suggest why, *Journal of Experimental Psychology: Human Perception and Performance* 12, 535–548.

Schunk, D. and Betsch, C. (2006), Explaining heterogeneity in utility functions by individual differences in decision modes, *Journal of Economic Psychology* 27, 386–401.

Selten, R., Sadrieh, A. and Abbink, K. (1999), Money does not induce risk neutral behavior, but binary lotteries do even worse, *Theory and Decision* 46, 211–249.

Shafir, E., Diamond, P.A. and Tversky, A. (1997), Money illusion, *Quarterly Journal of Economics* 112, 341–374.

Smith, K., Dickhaut, J.W., McCabe, K. and Pardo, J.V. (2002), Neuronal substrates for choice under ambiguity, risk certainty, gains and losses, *Management Science* 48, 711–718.

Smith, V.L. (1982), Microeconomic systems as an experimental science, *American Economic Review* 72, 923–955.

Soman, D., Wertenbroch, K., and Chattopadhyay, A. (2002), Currency numerosity effects on the perceived value of transactions, INSEAD, working paper 124/MKT, Fontainebleau, France.

Sonnemans, J. (2006), Price clustering and natural resistance points in the Dutch stock market: A natural experiment, *European Economic Review* 50, 1937–1950.

Starmer, C. (2000), Developments in non-expected utility theory: The hunt for a descriptive theory of choice under risk, *Journal of Economic Literature* 38, 332–382.

Starmer, C. and Sugden, R. (1991), Does the random-lottery incentive system elicit true preferences? An experimental investigation, *American Economic Review* 81, 971–978.

Stenkula, M. (2004), The euro cash changeover process, *Kyklos* 57, 265–286.

Thaler, R.H. (1980), Towards a positive theory of consumer choice, *Journal of Economic Behavior and Organization* 1, 39–60.

Thaler, R.H. (1985), Mental accounting and consumer choice, *Marketing Science* 4, 199–214.

Tversky, A. and Kahneman, D. (1992), Advances in prospect theory: Cumulative representation of uncertainty, *Journal of Risk and Uncertainty* 5, 297–323.

Wakker, P.P., Timmermans, D.R.M., and Machielse, I.A. (2006), The effects of information about probabilities on insurance decisions, *Management Science*, (forthcoming).

Weber, E.U. and Bottom, W.P. (1989), Axiomatic measures of perceived risk: Some tests and extensions, *Journal of Behavioral Decision Making* 2, 113–131.

Zorzi, M., Priftis, K. and Umiltà, C. (2002), Neglect disrupts the mental number line, *Nature*, May, 417, 138–139.

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