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SUBJECTIVE PROBABILITY WEIGHTING AND THE DISCOVERED PREFERENCE HYPOTHESIS*

ABSTRACT. Numerous studies have convincingly shown that prospect theory can better describe risky choice behavior than the classical expected utility model because it makes the plausible assumption that risk aversion is driven not only by the degree of sensitivity toward outcomes, but also by the degree of sensitivity toward probabilities. This article presents the results of an experiment aimed at testing whether agents become more sensitive toward probabilities over time when they repeatedly face similar decisions, receive feedback on the consequences of their decisions, and are given ample incentives to reflect on their decisions, as predicted by Plott's Discovered Preference Hypothesis (DPH). The results of a laboratory experiment with $N = 62$ participants support this hypothesis. The elicited subjective probability weighting function converges significantly toward linearity when respondents are asked to make repeated choices and are given direct feedback after each choice. Such convergence to linearity is absent in an experimental treatment where respondents are asked to make repeated choices but do not experience the resolution of risk directly after each choice, as predicted by the DPH.

KEY WORDS: learning, probability weighting, rational choice, nonexpected utility.

JEL CLASSIFICATION: D81, D83.

1. INTRODUCTION

A decade of extensive experimentation has convincingly shown that the reigning economic theory of rational decision making, expected utility theory (EUT), fails descriptively. Well-known examples of systematic violations of the EUT paradigm in

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the laboratory are the Allais paradox (Allais, 1953; Kahneman and Tversky, 1979), the willingness to pay/willingness to accept disparity (Knetsch and Sinden, 1984; Kahneman et al., 1990; Bateman et al., 1997), and the preference reversal phenomenon (Lichtenstein and Slovic, 1971; Lindman, 1971). These laboratory anomalies have been an important inspiration for the development of various alternative theories of preference (Starmer, 2000), and directly question the validity of informing public policy on the basis of classical preference theory.

Despite its descriptive inadequacy, the classical EUT framework remains the universal standard for many economists. A possible reason for the hesitation of many economist to abandon classical theories of preference is that several well-known experimental economists have questioned the (external) validity of the observed anomalous behavior by emphasizing the lack of adequate incentives, sufficient time to learn from experience, and direct feedback in these experiments (e.g., Smith, 1989; Plott, 1996; Binmore, 1999). As the argument goes, violations of rationality do not persist in real-life situations and market settings where opportunities to learn from experience with feedback and incentives via (market) interaction and arbitrage are present and, hence, anomalous behavior observed in one-shot hypothetical choice experiments without feedback has little relevance to behavior in markets or to real-life economic behavior in general. Binmore (1999, p. F23) took an extreme position by stating that "just as chemists know not to mix reagents in dirty test tubes, [...] there is no point in testing economic propositions in circumstances to which they should not reasonably be expected to apply"; according to Binmore, conventional economic theory only applies to situations where the problem is reasonably simple, where there are adequate incentives and there is sufficient time to learn from experience. In line with this argument, Charles Plott (1996) hypothesized that agents who participate in a laboratory experiment have a consistent set of preferences, but these underlying preferences only surface in choice environments where subjects are given sufficient opportunities and incentives for deliberation and learning (Plott, 1996; Myagkov and Plott, 1997). Plott's so-called *Discovered Preference Hypothesis* (DPH) thereby insulates EUT from a bulk of disconfirming experimental evidence obtained in single-shot, hypothetical choice environments without feedback, including the aforementioned disconfirming experimental evidence obtained by Allais (1953), Lichtenstein and Slovic (1971), Lindman (1971), Kahneman and Tversky (1979), Knetsch and Sinden (1984), Kahneman et al. (1990), Tversky and Kahneman (1992), and Bateman et al. (1997). Additionally, the DPH assumes that individual preferences will ultimately converge to the same underlying preferences regardless of the elicitation process, and hence these underlying preferences are in a sense discovered when agents repeatedly face similar decisions, receive feedback on the consequences of their decisions, and are given ample incentives to reflect on their decisions (Cubitt et al., 2001), contrary to the constructed view of preference as advocated by some psychologists (Slovic, 1995; Kahneman, 1996). In line with Braga and Starmer (2005), and Cubitt et al. (2001), we interpret the DPH in such a way that it predicts that the underlying preferences of agents are consistent with the normatively compelling axioms underpinning EUT, and, hence, the DPH predicts that utility for money is a stable concept.

A natural question to ask is whether the existing empirical evidence is consistent with the DPH. Indeed there is (some) evidence that anomalous behavior such as the willingness to pay/willingness to accept disparity (Coursey et al., 1987; Shogren et al., 1994), the endowment effect (Myagkov and Plott, 1996; List, 2004; Plott and Zeiler 2005), and the preference reversal phenomenon (Cox and Grether, 1996; Braga and Starmer, 2003), decays in repeated market settings with feedback and incentives, as predicted by the DPH. In addition, the results of a recent experiment performed by van de Kuilen and Wakker (2006) support the predictions of the DPH in case of the common ratio version of the Allais paradox, which is a tendency for preferences between a safe prospect that yields a prize of s euro with probability p and nothing otherwise, and a risky prospect that yields a prize of r euro with probability $0.8p$ and nothing otherwise (with $s < r$ and $0 \leq p \leq 1$), to be affected by the value of p, contradicting EUT.[1] More specifically, preferences are often found to switch from safe to risky if p changes from 1 to an intermediate value (see Camerer, 1995). Prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) can accommodate this choice pattern by allowing probabilities to be weighted in a nonlinear way. More specifically, in the prospect theory framework, the probability weighting function is assumed to have an inverse S-shape, which implies that agents are overly sensitive to extreme probabilities relative to intermediate probabilities, thus explaining the occurrence of the common ratio (and the common consequence-) version of the Allais paradox. Since subjective probability weighting can cause individual preferences to become inconsistent with the normatively compelling axioms of EUT, it is considered to be an irrational component of risk attitudes by most economists.

Van de Kuilen and Wakker (2006) found that individual choice behavior in the Allais paradox converged significantly to the predictions of EUT in an experimental treatment where respondents were given adequate incentives, sufficient opportunities for deliberation and learning, and direct feedback after each choice, whereas such greater conformity between the observed choice behavior and the predictions of EUT was absent in an experimental treatment where participants made repeated decisions but only received feedback at the end of the experiment when one of their choices was selected to be played out for real. The convergence of individual preferences toward rationality in the treatment with ongoing outcome feedback is in line with the DPH, because, as we interpret it, the DPH assumes that utility for money is a stable concept, whereas subjective probability weighting is not. Thus, the DPH predicts that participants in an experimental setting become more sensitive toward probabilities (i.e., individual choice behavior becomes more rational) by the direct resolution of uncertainty and the experience of the resulting outcome. Consider for example an agent who initially prefers a safe prospect that yields 30 euro for certain to a prospect that yields 40 euro with probability 0.8, and nothing otherwise. A psychological explanation for this choice is that the respondent anticipates a sense of regret when he chose the risky prospect and would fail to win a prize, which, in the prospect theory framework, amounts to the agent being overly sensitive toward certainty. Repeating the choice task may then cause the agent to become more sensitive toward probabilities because repetition itself represses psychological motives (Loewenstein, 1999) and/or because respondents initially fail to foresee the affective qualities corresponding to the consequence of their choice (Cubitt et al., 2001).[2] This explains the presence of convergence of individual choice behavior to rationality in the experimental treatment with ongoing outcome feedback and the absence of such convergence in the experimental treatment with terminal outcome feedback as reported by van de Kuilen et al. (2006).

Whether or not subjective probability weighting is a stable concept is an important question, because subjective probability weighting explains several often-observed systematic behavioral anomalies in stated preferences such as the coexistence of insurance and gambling, the reflection effect, and the aforementioned Allais paradox. This article addresses this question by experimentally testing the hypothesis that participants in an experiment become more sensitive toward probabilities when they are given the opportunity to learn from past decisions and directly experience the consequence of their decision by direct resolution of the risks involved after each choice, as predicted by the DPH. For this purpose, we repeatedly use a parameter-free measurement technique to obtain probability weighting functions introduced by van de Kuilen et al. (2007). The experimental results show that significant convergence of the probability weighting function toward linearity is indeed present in an experimental treatment where respondents make repeated choices and directly experience the resolution of risk after each choice. Such convergence to rationality is absent in an experimental treatment with terminal outcome feedback, suggesting that choice irrationalities caused by subjective probability transformation in decision environments with repetition and direct feedback are less persistent than often believed.

The remainder of this article is organized as follows: Section 2 reviews prospect theory. Section 3 presents the details of the experimental design and explains the measurement technique we used to obtain individual probability weighting functions in a parameter-free way. The results of the experiment are reported in Section 4, followed by a discussion of these results and conclusions in Section 5. Finally, the experimental instructions can be found in the Appendix.

2. PROSPECT THEORY

In this article, prospect theory refers to the cumulative version of prospect theory, introduced by Tversky and Kahneman (1992). It corrects some theoretical problems of the original version of prospect theory, and can also deal with uncertainty, i.e., the case of unknown probabilities. In this article, we only consider positive monetary outcomes and, hence, loss aversion, another important aspect of prospect theory, plays no role. A *prospect* is a probability distribution over outcomes taking only finitely many outcomes; $(p_1 : x_1, \ldots, p_n : x_n)$ denotes a prospect yielding outcome x_i with probability p_i, where probabilities are nonnegative and sum to 1. For two outcomes, we suppress the second probability, and write $(p : x_1, x_2)$ for $(p: x_1, 1-p: x_2)$. Under prospect theory, each outcome x_i receives a subjective *decision weight*, denoted by π_i, which is obtained by subtracting the weighted probability of receiving only an outcome rank-ordered strictly better than x_i from the weighted probability of receiving x_i, or an outcome rank-ordered strictly better. That is, for a prospect $(p_1: x_1, \ldots, p_n: x_n)$ with $x_1 \geq \cdots \geq x_n$:

$$\pi_i = w(p_i + \cdots + p_1) - w(p_{i-1} + \cdots + p_1), \tag{2.1}$$

where $w : [0, 1] \to [0, 1]$ is a strictly increasing and continuous *probability weighting function*, with $w(0) = 0$ and $w(1) = 1$.

Under prospect theory, the value of the prospect (p_1: x_1,..., p_n:x_n) is:

$$\sum_{i=1}^{n} \pi_i U(x_i), \tag{2.2}$$

where U(x_i) is a continuous and strictly increasing *utility function*. EUT results as a special case, if $w(p) = p$ for all p, so that $\pi_i = (p_i + \cdots + p_1) - (p_{i-1} + \cdots + p_1) = p_i$ for all i.

3. THE EXPERIMENTAL METHOD

3.1. *Participants*

$N = 64$ undergraduate students participated in the experiment. Participants were undergraduate students from a wide range of disciplines randomly recruited at the University of Amsterdam through the e-mail list of CREED. 41% of the subjects were female, 59% were economics students, and the average age of the subjects was 21.7 years.

3.2. *Procedure*

The experiment was individual and computerized. Participants were seated in front of a personal computer and first received experimental instructions (see Appendix). Then they were asked to answer two practice choice questions to familiarize them with the experimental procedures. The choice questions were part of a larger experiment that all involved outright choices between two prospects named prospect L (left) and prospect R (right). The experiment itself was purely individual, and subjects made their choices under the direct supervision of the experimenter. Both prospects yielded prizes depending on the outcome of a roll of two 10-sided dice, generating probabilities $j/100$.[3] Prospects were framed as in Figure 1 below.

Participants were asked to indicate their choice by clicking on the button of their preferred prospect with the mouse.

PROSPECT L		
roll	probability	prize
1 till p	p %	x_{i-1} euro
p+1 till 100	$(100 - p)$%	Y euro

PROSPECT R		
roll	probability	prize
1 till p	p %	x_i euro
p+1 till 100	$(100 - p)$%	y euro

Figure 1. The framing of the prospect pairs

We used the neutral term prospect in the instructions to avoid potential confounding effects resulting from connotations with words such as lottery or gamble, and the position of each prospect was counterbalanced between participants to avoid a potential representation effect.

3.3. *Stimuli of the first part*

In the first part of the experiment, we used the tradeoff method introduced by Wakker and Deneffe (1996) to elicit a sequence of three outcomes that are equally spaced in terms of utility. Therefore, indifferences $(1/4{:}x_1, 3) \sim (1/4{:}x_0, 4)$ and $(1/4{:}x_2, 3) \sim (1/4{:}x_1, 4)$, with $x_0 = 6$ were elicited. Applying the prospect theory formula to these indifferences, subtracting the resulting equations, dividing both sides by $w(1/4)$, and rearranging terms yields:

$$\mathrm{U}(x_2) - \mathrm{U}(x_1) = \mathrm{U}(x_1) - \mathrm{U}(x_0) \tag{3.1}$$

That is, under prospect theory, the obtained sequence of outcomes (x_0, x_1, x_2) is equally spaced in utility, irrespective of subjective probability transformation (Wakker and Deneffe, 1996). Contrary to other elicitation techniques often used to measure individual utility functions such as the certainty equivalent method, the probability equivalent method, and the lottery equivalent method (McCord and de Neufville, 1986), the tradeoff method retains validity under expected utility, the original version of prospect theory, rank-dependent utility, and cumulative prospect theory.

Since all further measurements in the experiment depended on the obtained indifference outcomes x_1 and x_2, these outcomes were elicited twice and the average of the two outcomes obtained was used as input in the rest of the experiment in order to reduce noise. To obtain indifference between prospects we used a bisection method similar to the method used by Abdellaoui (2000) and van de Kuilen et al. (2007). More specifically, on the basis of results of a pilot experiment, we hypothesized that indifference outcome x_1 would not exceed $x_0 + 10$ and took the interval $[x_0, x_0 + 10]$ as the first indifference interval, denoted by $[\ell^1, u^1]$. To construct the j+1th indifference interval from the jth indifference interval $[\ell^j, u^j]$, we determined whether the midpoint $(\ell^j + u^j)/2$ of $[\ell^j, u^j]$ was larger or smaller than x_1. To do so, we observed the choice between $(0.25{:}(\ell^j + u^j)/2, 3)$ and $(0.25{:}x_0, 4)$. A choice for the prospect $(0.25{:}(\ell^j + u^j)/2, 3)$ meant that the midpoint of the indifference interval was larger than the indifference outcome x_1, so that x_1 was contained in $[\ell^j, (\ell^j + u^j)/2]$, which was then defined as the j+1th indifference interval $[\ell^{j+1}, u^{j+1}]$. A choice for the prospect $(0.25{:}x_0, 4)$ meant that the midpoint of the indifference interval was smaller than the indifference outcome x_1, so that x_1 was contained in $[(\ell^j + u^j)/2, u^j]$, which was then defined as the j+1th indifference interval $[\ell^{j+1}, u^{j+1}]$. The computer performed five such iteration steps, ending up with the indifference interval $[\ell^6, u^6]$ (of length 10×2^{-5}), and took its midpoint as the elicited indifference outcome x_1. The same process was followed to elicit indifference outcome x_2 (substitute x_2 for x_1 and x_1 for x_0 above).

3.4. *Stimuli of the second part: subjective probability weighting*

In the second part of the experiment, we used the measurement technique introduced by van de Kuilen et al. (2007) to obtain probabilities $w^{-1}(1/2)$, $w^{-1}(3/4)$, and $w^{-1}(7/8)$ in a parameter-free way, where $w^{-1}(t)$ denotes the probability corresponding to a subjective probability weight of t. Hence, we only measured the upper part of the probability weighting function for each participant in order to make the experiment not too long. [4] We elicited individual inference between the prospects $L=(p{:}x_2,\ d{:}x_1,\ r{:}x_0)$ and $R=(p+g{:}x_2,\ r+b{:}x_0)$ with r the residual probability $1-p-d$. Applying the prospect theory formulas to this indifference, subtracting the common term $U(x_0)$ from both sides of the equation and dividing both sides by $U(x_1)-U(x_0)$, which according to equation (3.1) is equal to 1/2 $(U(x_2)-U(x_0))$, yields:

$$w(p+g)=(w(p)+w(p+d))/2. \tag{3.2}$$

That is, under prospect theory, indifference between prospects L and R implies that probability $p+g$ is the w midpoint between probability p and probability $p+d$ (van de Kuilen et al., 2007). Note that this measurement technique prescribes the use of different prospects L in the elicitation procedure.[5]

To find probability g that generated indifference between prospects L and R, the same bisection method as used by van de Kuilen et al. (2007) was used. Thus, the computer iteratively narrowed down so-called indifference intervals containing $p+g$, as follows. The first indifference interval $[\ell^1,\ u^1]$ was $[p,\ p+d]$, which contained probability $p+g$ by stochastic dominance. Thus, for probability $w^{-1}(1/2)$, the first indifference interval was [0,1], while the first indifference intervals for probabilities $w^{-1}(3/4)$ and $w^{-1}(7/8)$ were $[w^{-1}(1/2),\ 1]$ and $[w^{-1}(3/4),\ 1]$, respectively. To construct the $j+1$th indifference interval $[\ell^{j+1},\ u^{j+1}]$ from the jth indifference interval $[\ell^j,\ u^j]$, we determined whether the midpoint of $[\ell^j,\ u^j]$ was larger or smaller than $p+g$. To do so, we observed the choice between the prospects $(p{:}x_2,\ d{:}x_1,\ r{:}x_0)$ and $((\ell^j+u^j)/2{:}x_2,\ x_0)$. A choice for the prospect $((\ell^j+u^j)/2{:}x_2,\ x_0)$ meant that the midpoint was larger than $p+g$, so that $p+g$ was contained in $[\ell^j,\ (\ell^j+u^j)/2]$, which was then defined as the $j+1$th indifference interval $[\ell^{j+1},\ u^{j+1}]$. A choice for the prospect $(p{:}x_2,\ d{:}x_1,\ r{:}x_0)$ meant that the midpoint was smaller than $p+g$, so that $p+g$ was contained in $[(\ell^j+u^j)/2,\ u^j]$, which was then defined as the $j+1$th indifference interval $[\ell^{j+1},\ u^{j+1}]$. The computer performed five such iteration steps, ending up with $[\ell^6,\ u^6]$, and took its midpoint as the elicited indifference probability $p+g$.

Since prospects yielded prizes depending on the result of a roll with two 10-sided dice, we only allowed values $j/100$ for probabilities. When a particular midpoint probability was not a value $j/100$, the computer took the closest value $j/100$ on the left of this value if the value was lower than half, and on the right of this value if the value was higher than half.

3.5. *Stimuli of the third part & treatments*

In the third part of the experiment, participants were randomly subdivided over two treatments. In both treatments, probabilities $w^{-1}(1/2)$, $w^{-1}(3/4)$, and $w^{-1}(7/8)$, were elicited twice for each respondent, using the same measurement technique as in the second part of the experiment. The treatments solely differed in the amount of feedback that respondents received.

In the *terminal feedback* treatment, probabilities $w^{-1}(1/2)$, $w^{-1}(3/4)$, and $w^{-1}(7/8)$ were simply elicited twice again, similar as during the second part of the experiment. Hence, respondents did not directly experience the consequence of each decision by direct resolution of the risk involved after each choice.

In the *ongoing feedback* treatment, respondents were asked to roll the 10-sided dice directly after each choice, to directly determine the prize of the chosen prospect. Respondents then had to type in the result of their roll under the supervision of the experimenter and the computer would display the resulting prize of the chosen prospect on the computer screen. Respondents were told that if that particular choice question would then be randomly selected to be played out for real at the end of the experiment, the prize of the chosen prospect would thus already have been determined. Hence, after each choice, participants directly received feedback from their choices and, therefore, directly experienced the resolution of the risk involved and the consequence of their decision.

3.6. *Motivating participants*

We used performance-based real incentives to motivate participants based on the random lottery incentive system, the nowadays almost exclusively used incentive system for individual choice experiments (Myagkov and Plott, 1997; Harrison et al., 2002; Holt and Laury, 2002). At the end of the experiment, respondents were asked to roll two 10-sided dice in order to select one of their choices. The chosen prospect in that particular decision was played out for real, and the subject was paid out accordingly and in private. The main feature of this rewarding scheme is that it avoids income effects such as Thaler and Johnson's (1990) house money effect, while it has been shown empirically that it is indeed incentive compatible. In particular, respondents do not interpret choice tasks rewarded with the random lottery incentive system as one grand overall lottery (Cubitt et al., 1998; Starmer and Sugden, 1991).

Finally, note that answers from previous questions were reused in a later choice question during the experiment. As noted by Harrison (1986), this chained nature of the experiment could give subjects incentives for not truthfully answering questions so as to improve future stimuli. However, in order to exploit this chaining, subjects not only had to be aware of the presence of the chaining, but also had to understand the way in which future stimuli depended on current answers, which is highly unlikely. Indeed, results from a questionnaire at the end of a similar experiment showed that no subject was aware of the chained nature of the experiment (van de Kuilen et al., 2006). The prizes of the prospects faced by the respondents varied from €3 to approximately €25. The average payment was €8.65, while the experiment lasted approximately 25 minutes.

4. EXPERIMENTAL RESULTS

We excluded seven participants form the analysis because they clearly gave systematic heuristic answers, such as always choosing the left prospect or always choosing the right prospect. The following analysis is based on the remaining 57 subjects.

4.1. *The utility function*

Two 2-sided Wilcoxon signed-rank tests show that the first and second measurement of indifference values x_1 and x_2 did not differ significantly from each other (for x_1: $z = 1.54$, p-value $= 0.1249$, for x_2: $z = 1.62$, p-value $= 0.1046$). The obtained median indifference values of x_1 and x_2 were 8.98 and 11.49, respectively, which might suggest the existence of a convex utility function. However, a two-sided Sign test indicates that this deviation from linearity is not statistically significant (p-value $= 0.1263$). This finding supports the conjecture that utility is approximately linear for small to moderate monetary amounts (Wakker and Deneffe, 1996).

4.2. *The probability weighting function*

The obtained median values of $w^{-1}(1/2)$, $w^{-1}(3/4)$, and w^{-1} (7/8) over all respondents and treatments were 0.74, 0.88, and 0.92, respectively. This suggests that subjects generally underweighted probabilities, which is consistent with the results from common findings in the field for probabilities exceeding 0.5, and can explain the existence of several choice anomalies such as the common-ratio and the common-consequence effect (Kahneman and Tversky, 1992; Gonzalez and Wu, 1999; Abdellaoui, 2000; Bleichrodt and Pinto, 2000).

Figure 2 below displays the obtained probability weighting functions based on median data. For clarification, the probability weighting function labeled 1st is the probability weighting function obtained in the second part of the experiment. Hence, respondents in both treatments did not receive any feedback during the elicitation procedure of this probability weighting function. The probability weighting function labeled 2nd and 3rd are the two probability weighting functions elicited in the third part of the experiment. Thus,

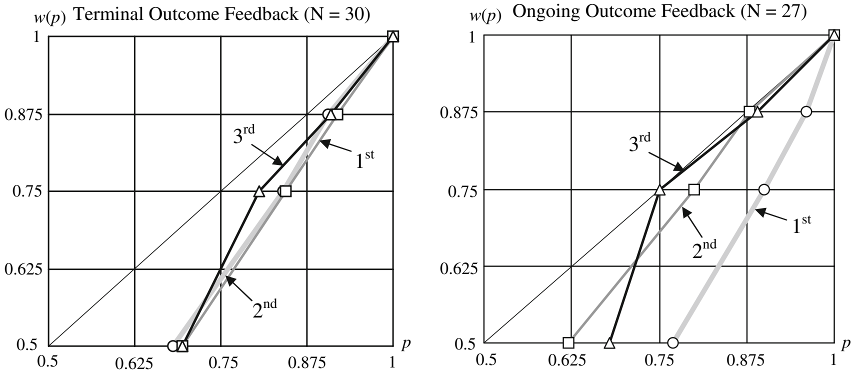

Figure 2. The obtained probability weighting functions

during the elicitation procedure of these probability weighting functions, respondents did not receive any feedback after each choice in the terminal feedback treatment, while they did receive direct feedback in the treatment with ongoing outcome feedback, as explained in Section 3.2. As can be seen in Figure 2, the probability weighting function converges to linearity under the ongoing feedback treatment, but such convergence is absent in the treatment with terminal outcome feedback. Also, convergence to linearity is most pronounced for probabilities $w^{-1}(3/4)$ and $w^{-1}(7/8)$. Table I below presents the results from several one-sided Wilcoxon signed-rank tests performed to test the hypotheses that the obtained probabilities $w^{-1}(s)$ are significantly larger than probabilities s under the different treatments, for each of the three obtained probability weighting functions.

First, the results of the non-parametric tests show that deviations from linearity are indeed present and persistent in the treatment with terminal outcome feedback. The only obtained probability that does not differ significantly from linearity is probability $w^{-1}(7/8)$ measured in the first part of the experiment. All other probabilities deviate significantly from linearity, showing that deviations from linearity are present and persistent over time under the terminal feedback treatment.

TABLE I

Counts of $w^{-1}(p)-p>0$ over time & treatments

	Terminal feedback ($N=30$)			Ongoing feedback ($N=27$)		
$w(p)^{-1}-p$	1st	2nd	3rd	1st	2nd	3rd
$p=1/2$	22*	19*	22*	20*	19*	20*
$p=3/4$	21*	23*	21*	19*	15	13
$p=7/8$	18	22*	21^{ms}	21^{ms}	14	17

Note: *($^{\mathrm{ms}}$) denotes significance at the 5%(10%) level using a one-sided Wilcoxon signed-rank test

For the first obtained probability weighting function under the ongoing feedback treatment, all obtained probabilities differ (marginally) significantly from linearity. However, as Table I shows, the obtained probabilities $w^{-1}(3/4)$ and $w^{-1}(7/8)$ do not differ significantly from linearity when they are measured the second and third time under the treatment with ongoing outcome feedback. In addition, a series of two-sided Wilcoxon signed-rank tests show that there is a significant difference between the first and the third obtained probability weighting function in the ongoing feedback treatment (for $w^{-1}(1/2)$: $z = 3.232$, p-value $= 0.001$, for $w^{-1}(3/4)$: $z = 2.993$, p-value $= 0.003$, and for $w^{-1}(7/8)$: $z = 2.418$, p-value $= 0.016$), whereas this significant difference is absent in the terminal feedback treatment (for $w^{-1}(1/2)$: $z = -0.238$, p-value $= 0.812$, for $w^{-1}(3/4)$: $z = 0.185$, p-value $= 0.853$, and for $w^{-1}(7/8)$: $z =$ 0.185, p-value $= 0.853$). Hence, these results show that convergence of probability weighting to linearity occurs only in the treatment with ongoing outcome feedback, that is, individual choice behavior only converges to rationality if participants experience the resolution of any risk directly after each choice.

5. DISCUSSION & CONCLUSION

As a reaction to the existence of several systematic behavioral anomalies in stated preferences, which directly question the validity of using classical techniques to elicit preferences, several leading experimental economists have stressed the importance of proper learning and incentives, such as occurrings in many real-life situations and markets, when testing economic theories in the laboratory (Smith, 1989; Plott, 1996; Binmore, 1999).

According to this argument, in many (market) situations, agents receive feedback, have sufficient time to learn from experience, and are motivated by proper incentives, and, therefore, irrational behavior cannot persist. This argument has been summarized by Plott's Discovered Preference Hypothesis, which assert that "individuals have a consistent set of preferences over states, but such preferences only become known to the individual with thought and experience" (Myagkov and Plott, 1997, p. 821). Hence, this hypothesis directly challenges the validity of all disconfirming evidence obtained in one-off hypothetical choice environments. The results of the experiment presented in this article confirm the predictions of the DPH *in casu* prospect theory's subjective probability weighting: individual preferences became more consistent with the normative predictions of EUT in an experimental treatment where subjects had the opportunity to learn from past decisions and immediately experienced the possible outcome of each decision; the subjective probability weighting function converged significantly to linearity in this treatment. Such significant convergence to linearity was absent in the experimental treatment without any feedback directly after each choice, supporting the DPH.

Thus, on the one hand, our results suggest that choice irrationalities in decision environments with repetition and feedback are less persistent than often believed. On the other hand, our results suggest that the classical EUT applies only to choice situations where agents make repeated decisions, and "what is repeated must include not only the act of decision, but also the resolution of any uncertainty and the experience of the resulting outcome" (Cubitt et al., 2001, p. 393). Of course, defenders of the classical EUT model could argue that in many economically relevant choices, agents can apply what they learn in one situation to their behavior in another. However, the existing empirical evidence suggests that there is limited transfer of knowledge across tasks (Loewenstein, 1999). Hence, exploring anomalous behavior and developing new models of preference that can explain these anomalies is a relevant and important topic for future research.

APPENDIX: EXPERIMENTAL INSTRUCTIONS

[Instructions have been translated from Dutch to English]
Welcome at this experiment. If you have any question while reading these instructions, please raise your hand. The experimenter will then come to your table to answer your question. This experiment takes about half an hour. We ask you to make a number of decisions during this experiment. Each time, you choose between two so-called "prospects." Both prospects yield certain prizes depending on the roll of the two 10-sided dice similar to the ones that are lying on your table right now.

As you can see, one 10-sided die has the values 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 and the other 10-sided die has the values 00, 10, 20, 30, 40, 50, 60, 70, 80, and 90. If we code the sum of the roll "a 0 and a 00" as 100, the sum of a roll with both 10-sided dice thus, yields a random number from 1 up until 100.

The prospects from which you have to choose named Prospect L (left) and Prospect R (right) will be presented in the following way:

PROSPECT L		
roll	probability	prize
1 till 40	40 %	10 euro
41 till 100	60 %	5 euro

PROSPECT R		
roll	probability	prize
1 till 20	20 %	15 euro
21 till 100	80 %	2 euro

In this case, Prospect L yields a prize of 10 Euro if the sum of the roll with both 10-sided dice is 1 up until 40, and if the sum of a roll is 41 up until 100, Prospect L yields a prize of

5 Euro, as you can see. Similarly, Prospect R yields a prize of 15 Euro if the sum of a roll with both 10-sided dice is 1 up until 20, and otherwise Prospect R yields a prize of 2 Euro, in this case.

Both the prizes and the probabilities of yielding certain prizes can vary across decisions. We ask you to choose between Prospect L and Prospect R each time, by clicking the corresponding button with the mouse.

At the end of this experiment, we will ask you to randomly select one of you decisions by rolling the two 10-sided dice. Then, the prize of the prospect you have chosen in that particular decision will be determined by rolling the two 10-sided dice again. Only the resulting prize of the chosen prospect will be paid out for real.

There are no right or wrong answers during this experiment. It exclusively concerns your own preferences. In them, we are interested. At every decision, it is best for you to choose the prospect that you want most. Surely, if you select the envelope containing the blue card at the end of the experiment, that decision can be selected at the end of the experiment. Then, the chosen prospect will be played out. Of course, you would like that prospect to be the prospect you want most. If you have no further questions, you can now start with the experiment by clicking on the "Continue" button below.

NOTES

1. According to EUT, a decision maker weakly prefers the safe (risky) prospect to the risky (safe) prospect, if and only if $U(s) = 0.8U(r)$ $(U(s) = 0.8U(r))$, where U(.) is a strictly increasing and continuous *utility function* scaled such that $U(0) = 0$. Hence, preferences between the safe and the risky prospect are independent of the value of p under EUT.
2. In the example, after the resolution of the risk involved, the agent will learn that the non-chosen prospect would have yielded a higher prize 80% of the time, and experience a sense of regret that he did not choose the risky prospect instead. This might cause the respondent to adjust his probability weight attached to probability 0.8 upward, changing the preference of the person from the safe

prospect to the risky prospect. Thus, in the example, the agent initially chose the safe prospect because he underestimated the pain of regret he would feel when the risky prospect would yield a higher prize and/or overestimated the pain of regret he would feel when the risky prospect would yield nothing.

3. One 10-sided die was numbered from 0 till 9, while the other 10-sided die was numbered from 00 till 90. Since we informed subjects that the roll 0–00 would be coded as 100, the sum of a roll with both 10-sided dice resulted in a random number ranging from 1 till 100.
4. We chose to measure the upper part of the probability weighting function, in order to be able to relate our results with van de Kuilen et al. (2006) findings, because the upper part explains the occurrence of the common ratio version of the Allais paradox. More specifically, according to prospect theory, the common ratio version of the Allais paradox occurs because agents relatively overweight certainty compared to probability 0.8, a phenomenon often called the *certainty effect* (Kahneman and Tversky, 1979; Tversky and Kahneman 1992).
5. More specifically, we elicited the probabilities $w^{-1}(1/2)$, $w^{-1}(3/4)$, and $w^{-1}(7/8)$, such that individuals were indifferent between the prospects (x_1) and $(w^{-1}(1/2){:}x_2, x_0)$, the prospects $(w^{-1}(1/2){:}x_2, x_1)$ and $(w^{-1}(3/4){:}x_2, x_0)$, and the prospects $(w^{-1}(3/4){:}x_2, x_1)$ and $(w^{-1}(7/8){:}x_2, x_0)$.

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