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PREVIOUS OUTCOMES AND REFERENCE DEPENDENCE: A META STUDY OF REPEATED INVESTMENT TASKS WITH AND WITHOUT RESTRICTED FEEDBACK

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Abstract:

When investment is repeated, previous outcomes (winning/losing) as well as the current budget level (gain/loss domain) influence decisions. The first is related to the so-called "gamblers fallacy". The second to value function relative to some reference point. Both effects have been extensively studied, however not their interaction.

We present a meta-study of five experiments initially conducted to investigate myopic-loss-aversion. We observe that investment is related to the number of previous winning rounds as well as to the current budget position relative to a reference point. These effects persist when the analysis is extended to settings with restricted flexibility concerning investment.

JEL: C91, D81, G11

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1. INTRODUCTION

Most outcomes are not evaluated in absolute terms, but with respect to our expectations. While an unexpected gain of a small price might increase our happiness enormously (Schwarz and Strack, 1999), receiving the same small price might lead to anger and frustration when expectations were high. This holds for outcomes from gambles and investment, but equally for salaries (Kirchsteiger, 1994) and negotiation results (Gimpel, 2007). What creates and defines expectations is so far little understood by economists. Experience, knowledge, personality and emotions might all influence expectations concerning outcomes and thus reactions to them. The fact that the same outcome will sometimes be evaluated positively while in other situations negatively has been modeled by economists with the use of value functions including a reference points (Kahneman and Tversky, 1979). What defines the reference point is however not always clear. It can be seen as a representation of the status quo (Samuelson and Zeckhauser, 1988) or be modeled by taking into account expectations (Kőszegi and Rabin, 2007). A reference point implies that dependent on whether an outcome is seen as a relative gain or loss, reactions to the outcome can be crucially different. Since expectations can differ, the same outcome might therefore result in very different evaluations. Specifically it is generally assumed that losses weight heavier than gains (loss aversion) and that risk taking behavior differs between the gain and loss domain.

In addition to our relative situation also how we got to it will influence its evaluation. An unequal bargaining outcome will be accepted if seen as the outcome of a series of unlucky events while the same outcome might be refused when considered as being due to the unfair behavior of another agent (Kirchsteiger, 1994). In an uncertain environment probabilities will be updated based on outcomes and therefore outcomes will influence expectations concerning the future. And even if probabilities are fixed and known, biases have been documented concerning expectations, for example the "hot hand effect" and the "gamblers fallacy" (Tversky and Kahneman, 1971; Croson and Sundali, 2005).

A large literature has focused on loss aversion and at the same time biases concerning previous outcomes have been extensively studied. However, so far, the two effects have been rarely discussed in combination. Obviously real live decision situations will be characterized by the current budget level as well as by the events that lead to this situation. It is therefore highly desirable to compare the impact of previous experiences and the current situation on choices to determine their relative importance and their interaction.

This paper presents a meta-analysis of five different experimental studies that were initially design to investigate the effect of aggregate feedback and reduced flexibility on risk taking[1] (cf. myopic loss aversion; Bernartzi and Thaler, 1995; Gneezy and Potters, 1997; Thaler et al., 1997). We use this data to investigate how previous outcomes (i.e. the number of winning or losing rounds encountered) and the current budget (i.e. absolute losses or gains relative to a natural reference point) influence investment decisions in future periods. We show that small gains decrease investment and that larger gains increase investment. For losses we observe the opposite pattern. Namely small losses increase investment while larger losses decrease investment. This effect is opposite to the "peanuts effect" discussed in the literature and in line with the "magnitude effect" (Weber and Chapman, 2005).[2] We extend this model to account also for the number of previously encountered winning and losing rounds. We observe evidence for the gamblers fallacy, namely for the tendency to reduce investment when recent gains were frequent. Both effects co-exist and predict behavior very well.

We then extend our analysis to the data on investment when feedback and flexibility are restricted. We observe that even if feedback is restricted the "gamblers fallacy" effect is present. Focus shifts from the immediately preceding periods to the total history of gains and losses but still a higher number of previous winning rounds predict a decrease in investment. Thus reduced feedback does not change probability judgments concerning the future. Also reduced feedback does not increase investment when in the loss domain. We rather observe the opposite effect, namely a decrease in investment when small losses are encountered. The main difference under reduced feedback and flexibility is time. Over rounds investment is significantly increasing, independent of experience and current earnings. We will hypothesize that this effect must be related to a general increase of optimism and confidence under reduced feedback.

The rest of the paper is structured as follows. In section 2 we give an overview of experimental studies of the value function relative to some reference point and studies investigating the impact of previous outcomes on future risk taking. Section 3 presents the data used for this study and compares the five different experiments used. Section 4 presents a

[1] The implementation of aggregate feedback and reduced flexibility implies that investment decisions have to be fixed for a number of periods in advance (reduced flexibility). Thus subjects fix their investment level for the next three periods and receive after the periods have passed information about the outcome (aggregate feedback).

[2] It should be noted however that assuming probability weighting we cannot conclude from the shape of the utility function the actual risk behavior. Thus only assuming expected utility theory, we can say that convexity of the utility function implies risk seeking behavior (Abdellaoui et al., 2007). In our case however the probability of winning is p=1/3 which should according to experiments on probability weighting be one of the least distorted values (e.g. Bleichrodt and Pinto, 2000).

random effects Tobit regression of repeated investment for the frequent feedback case. This model is extended to the reduced feedback case in section 5. Section 6 concludes.

2. EXPECTATIONS AND EXPERIENCE

Ever since value functions allowing for a reference point were introduced by Markowitz (1952) and Kahnemann and Tversky (1979) attempts have been made to define their precise shape. This concerns as well the question whether losses are overweighed compared to gains, but also the curvature of the function for gains and losses, respectively. The value function by Kahnemann and Tversky (1979) predicts risk aversion for gains and risk seeking for looses. The function by Markowitz is further characterized by the "peanuts effect" (Prelec and Loewenstein, 1991) implying decreasing risk aversion for decreasing monetary amounts in the gain domain.

Experiments investigating the shape of the value function proceed usually by eliciting the certainty equivalent for gambles, or the probabilities that make participants indifferent between a certain amount and a gamble (Abdellaoui, 2000, 2007). For this approach preferences for gambles in either the gain or loss domain relative to the current status-quo are considered. This implies that the current state of the world is taken as the reference point and the outcome from the gamble, as well as the certain outcome are in either the gain or loss domain. A problem with this approach is that it is not clear which value is taken as a reference point by participants. It might be the status-quo or it might be the expected earnings from participation in the experiment. Hypothetical questions circumvent this problem to a certain degree by framing the question such that it is clear what should be taken as the reference point. However hypothetical questions might fail to incentivize respondents to state their true preferences (Beattie and Loomes, 1997).

Studies using either hypothetical or real gambles have identified a value function that is concave for gains and convex for losses (Abdellaoui et al., 2007), even though results can differ dependent on the method used (Hershey and Schoemaker, 1985). Further there is some evidence of the peanuts effect, i.e. the fact that risk seeking is more common for low stakes gambles (Weber and Chapman, 2005). However in studies investigating inter-temporal choices an opposite effect has been observed. When eliciting preferences for payments either now or in the future, an earlier time preference has been observed for small scales than for larger scales. I.e. given the choice between \$10 now, and \$20 in one year the immediate option might be preferred, indicating that values need to be at least doubled to compensate for the delay. However for the choice between \$100 now and \$200 in one year a switch to the delayed option is often observed (Chapman and Winquist, 1998). When greater willingness to wait for an outcome is interpreted as a sign of lower risk aversion, the observed "magnitude effect" is therefore exactly opposed to the "peanuts effect". Whether larger stakes increase or decrease risk aversion might therefore depend on the method applied to elicit it (choices across gambles or time preferences). Another method to elicit risk aversion under different circumstances would be to consider risky choices when the participant is in either the gain or loss domain relative to his/her reference point. This implies that first gains or losses have to be realized to then observe changes in behavior. This seems to be a much more realistic environment, given that most decisions concerning risk are made under circumstances where gains or losses lead to the current position.

A repeated investment environment adds another possible bias to the situation. Not only whether the outcome is in the gain or loss domain relative to some reference point might influence risk taking, but also the events that lead to this situation. For example a point in the gain domain might be the result of a number of consecutive small gains or the result of a large gain and some small losses. Prior outcomes clearly influence probability judgments concerning the future. However a number of different biases have been documented, which makes it difficult to predict the impact on risk taking. For example a series of gains might either increase (hot hand effect) or decrease (gamblers fallacy) the willingness to take future risk. The two effects can be seen as stemming from different sources. The hot hand effect is related to the illusion of control (Langer, 1975). That is a player or "hand" is considered to be in a hot state, promising future gains. The gamblers fallacy is due to the "representativeness bias" or the "law of small numbers" (Tversky and Kahneman, 1971). This leads to the expectation that the probability of an event should be reflected in a proportional representation of the possible outcomes on all scales.

Many "mistakes" observed in trading environments are related to one or more of the effects discussed so far. Shefrin and Statman (1985) coined the term *disposition effect* "as shorthand for the predisposition toward get-evenitis". This effect describes the tendency to hold losing stocks too long and to sell winning stocks too early. An opposed observation concerns the house money effect, i.e. the tendency to take risk with the "house money" that was gained in previous periods. This tendency to become more risk seeking after gains has been observed for sequential gambles (Thaler and Johnson, 1990) as well as for market experiments (Gneezy et al., 2003). Whether outcomes are perceived as gains or losses will further depend on the bracketing of income streams. Narrow bracketing will lead to an appreciation of each gain or loss as such. Wide bracketing, that is the aggregation of multiple events, will make it easier to observe the expected value and will thus enhance expected value maximizing behavior. When the gamble has an expected value larger than its alternative, bracketing will therefore increase risk taking (myopic loss aversion). However when the gamble has an expected value that is smaller, bracketing will decrease risk taking (Haisley et al., 2008; Read et al., 1999). In general, previous gains and losses should have less of an impact on behavior when bracketing is wide. A number of experiments have been exploring this issue, known as myopic loss aversion (Gneezy and Potters, 1997; Thaler et al., 1997; Bellmare et al., 2005). These experiments observe higher investment in a risky option when feedback is given on an aggregate level after a certain number of rounds. However it is still largely unclear whether this effect is due to altered expectations caused by the different kinds of feedback, to reduced flexibility[3] or to a change in reactions to the same kind of outcomes since losses are now less directly experienced. Indeed it might be possible that bracketing will not influence the misjudgment of future probabilities ("hot hand effect" or "gamblers fallacy") but that due to the restriction of flexibility and the reduction of loss experiences, optimism and confidence are increased.

To explore these issues empirically we need observations of repeated risk taking choices where gains and losses relative to some reference level as well as the number of previous winning or losing rounds is known. Behavior in such an environment can then be analyzed as a dynamic environment. We collected data from five different experiments that have been conducted to investigate myopic loss aversion and the impact of flexibility and feedback on investment. This data pool offers us repeated investment choices from more than 400 participants in the two feedback treatments of the simple investment game proposed by Gneezy and Potters (1997). Even though this game has been repeatedly replicated, the dynamics of behavior have so far been largely ignored. An exception are Fellner and Sutter (2009) that study the dynamics in their data, however mainly focusing on treatment effects across feedback and flexibility conditions. The fact that the investment game has been repeatedly replicated applying identical parameters and instructions, enables us to combine results from these study to a meta-analysis investigating risk taking dynamics.[4] Even though each studies' focus was on another kind of treatment variation, in each study a treatment

[3] Flexibility has been experimentally explored by Bellemare et al. (2005), Langer and Weber (2008) and Fellner and Sutter (2009). While results are mixed it seems that a treatment allowing for feedback but reducing flexibility has similar consequences as a treatment reducing feedback and flexibility.

[4] It should be noted that parts of this data collection have been already used for other studies. Charness and Gneezy (2007) used observations from a number of investment games to investigate gender effects on risk taking behavior. Blavatskyy and Pogrebna (2006) used combined data from multiple investment studies to investigate whether myopic loss aversion or non-linear probability weighting is responsible for the observed effects.

allowing for frequent feedback and full flexibility and a treatment with reduced feedback and flexibility were present.

3. DATA

Data was collected from five different experiments that used the investment task proposed by Gneezy and Potters (1997) to investigate myopic loss aversion.[5] Each experiment compared different treatments concerning investment feedback and flexibility. However common to all experiments that were used for the analysis is that they included a high feedback treatment and a low feedback treatment. In the first part of our analysis we will solely concentrate on results from the high feedback treatment since it allows us to observe investment in a repeated investment task where investors had information about outcomes after every round. In section 4.3 we will then compare how predictions of investment behavior for the high feedback treatment compared to the low feedback treatment.

The investment task proposed to participants used the same probabilities and relative payoffs in all of the included studies. Participants had to decide how to distribute y points between a safe and a risky project. Points that were invested in the safe project were kept for sure. Points invested in the risky project had a 1/3 probability to be multiplied by 3.5 and a probability of 2/3 to be lost. Thus the expected value from the safe project was one point per invested point, while the expected value from the risky project was 1.17. Note that previous earnings could not be used for future investment. Thus in each round participant received a new endowment of y for investment.[6] The maximum amount y therefore stayed constant across all rounds of a study. Across the experiments we have slight variations in how many points (y) participants had in each round available and whether investment was done with points that were later exchanged into a monetary currency or directly with money. However accounting for the differences of when studies were conducted and exchange rates, we see that stakes for one round of investment were between 50 and 100 euro cents. Differences concerning the experiments are summarized in Table 1. Investment was repeated n times. Across studies we have a variation of minimal 9 and maximal 18 periods of repeated investment. In all studies treatment High (high frequency feedback) consisted of n repetitions of the same investment choice with immediate feedback about the outcome from investment

[5] To keep as many aspects of the investment situation constant we therefore do not include data from other experiments also investigating myopic loss aversion. Problematic variations include different probabilities and payoff and the possibility to use accumulated earnings for future investment (e.g. Thaler et al., 1997; Lange and Weber, 2008).

[6] This can be seen as a situation with a continuous income stream that is used for investment.

Table I: *Overview of included studies*

	Country (town) & method	observations High	observations Low	rounds	max amount
BK: Bellmare et al., (2005)	Netherlands (Tilburg); computer	44 students	44 students	9	70 euro cents
FS: Fellner and Sutter, (2009)	Germany (Jena); computer	30 students	30 students	18	100 points (= 50 euro cents)
GP: Gneezy and Potters (1997)	Netherlands (Tilburg); paper and pencil	41 students	42 students	9	200 dutch guilder cents (≈ 90 euro cents)
HL: Haigh and List (2005)	US (University of Maryland); paper and pencil	32 students; 27 traders = 59 total	32 students; 27 traders = 59 total	9	100 units (= 100 US cents for students ≈ 80 euro cents; traders: x4)
HW: Hopfensitz and Wranik (2008)	Switzerland (Geneva); computer	38 students	39 students	15	100 units (= 133 CHF cents ≈ 90 euro cents)
		total: 212	total: 214		

and the possibility to adjust investment. Treatment Low (low frequency feedback) restricted the flexibility and feedback frequency of outcomes. For this treatment investment was always to be fixed for three consecutive rounds. I.e. a choice only had to be made in rounds 1, 4, 7, ... Note that resolution of outcomes slightly varied across studies. Two studies (GP and HL) were conducted with paper and pencil and outcomes were resolved by picking a winning letter (respectively color) for each round. Outcomes across participants were therefore correlated during a session. For the other three studies the task was computerized and outcomes were announced to participants based on computerized random series. Outcomes during a session were therefore not necessarily correlated. Another difference concerns the study by HW that asked participants every three rounds to answer to a short psychological questionnaire.

Participants in the five included studies were mostly students from Universities in the Netherlands, Germany, Switzerland and the US. [7] Haigh and List (2005) combines observations from professional traders and students. Each study contains an almost equal number of observations for treatments High and Low. Overall we have 212 observations for treatment High and 214 observations for treatment Low. To make investment behavior

[7] Unfortunately not all studies report gender of the participants. We therefore do not include it in our analysis.

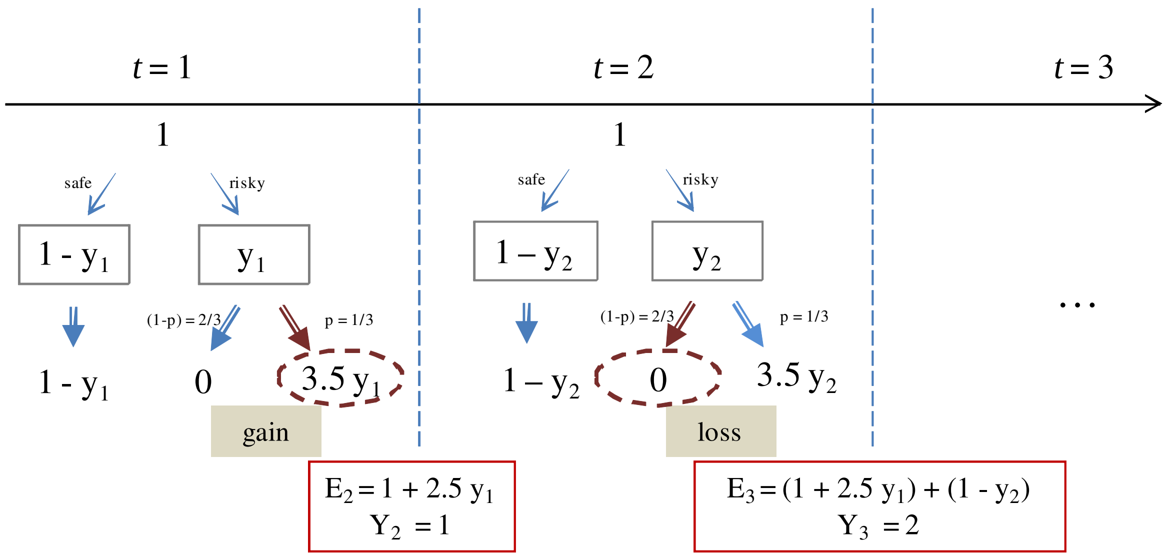

Figure 1: Timeline of events and calculation of current earnings (E_t) and the reference point (Y_t) after a period where the risky project resulted in gains; and where the risky project resulted in losses.

comparable across studies we normalize full investment to one. Thus a participant putting all his available points in a round in the risky project will have invested one unit of normalized investment. Normalized investment at time t (y_t) is thus a percentage of the maximal amount of points available for investment. Figure 1 illustrates the timeline of choices and the calculation of the current earnings at time t (E_t) and the amount that could have been earned with solely safe investment up to time t-1 (Y_t).

4. Analysis

We start our analysis with a quick recapitulation of aggregate investment results for the different studies. We then turn to an analysis of whether we observe differences in risk taking when earnings are in either the gain or loss domain. This model is then extended to also account for the events that lead to current relative income, namely the number of previous winning rounds. In a second step we compare this model for treatments High and Low.

4.1. Aggregate investment behavior across studies

Investment behavior across studies and rounds is summarized in Figure 2. Since the studies were mainly interested in comparing investment behavior across feedback treatments, mainly aggregate investment behavior over blocks of three rounds is presented in the original papers. The detailed investment pattern shows some variation; however we observe no clear time trend or pattern across studies. Across studies we observe quite some variability in investment

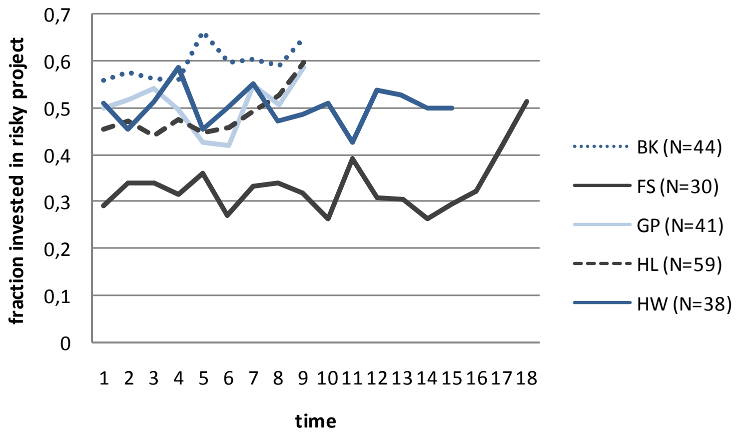

Figure 2: Investment behavior across rounds for treatment High

amount. BK report on average the highest amounts of investment (mean: 59%) and the lowest is reported by FS (mean: 33%).

Since our main interest concerns the impact of relative gains or losses on future decisions we present relative earnings across rounds in Figure 3. Since points invested in the safe project could be kept with certainty, we take as the reference point of time *t*, the amount that would have been earned up to that point with solely safe investment.[8] Therefore at time *t*=2 one unit of normalized investment would have been earned by a participant that invested all his money in the safe option. A participant investing all his points in the risky option would either have received a gain or a loss. In the case of a loss he would have therefore earned 0 units at time *t*=2, which we will classify as a loss of one normalized unit. In case of a gain he would have earned 3.5 units at time t=2, which will be classified as a gain of 2.5. Therefore at time *t* a participant only investing in the safe project would have ensured a gain of (*t*-1) normalized units (Y_t). Any positive or negative deviation of current earnings (E_t) from this amount will be classified as either a gain or a loss. Figure 3:A presents mean relative earnings across rounds. As we see over time mean earnings increase. However we observe a large variance of individual earnings as is illustrated by a box and whisker plot in Figure 3:B[9]. We see that across rounds and treatments about half of the observations lie in a range from losses of approximately 1.5 to gains of 2. We therefore have quite some variability in whether decisions were taken in either the loss or gain domain.

[8] Certainly we cannot be sure that participants took indeed the possible earnings from the safe option as their reference point. As noted earlier, participants might have general expectations concerning their earnings from the study. However in the presented studies the instructions made explicit that an amount was given to participants which could be used to bet in a lottery. Bets could then result in either losses or gains. We therefore think that our assumption that the gains from the safe option are the reference point for most participants is substantive.

[9] Box indicating 25th percentile to 75th percentile. Whiskers from lower adjacent value to upper adjacent value.

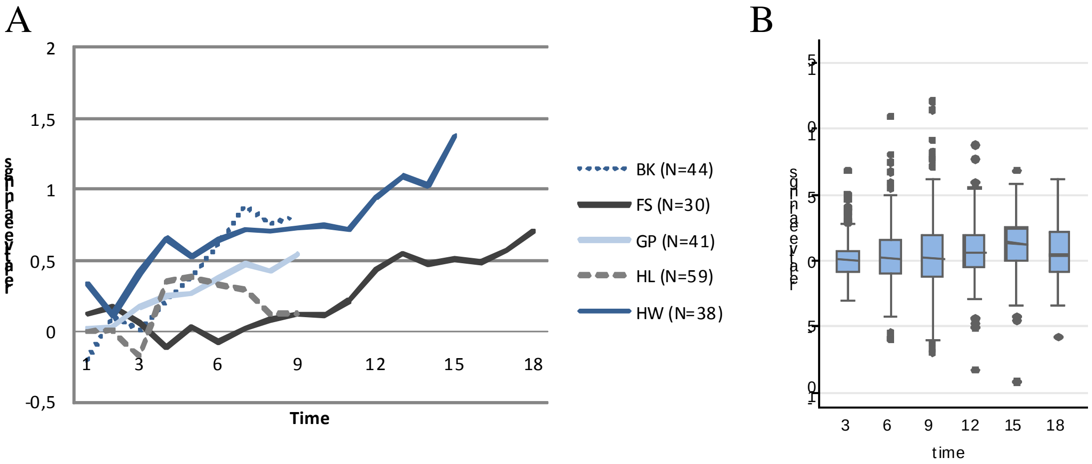

Figure 3: Relative earnings at time t for treatment High (i.e. difference between current earnings and earnings if up to point t-1 all points had been invested in the safe project) (A) mean split over study (B) box and whisker plot grouping all five studies.

4.2. INVESTMENT BEHAVIOR WITH FREQUENT FEEDBACK

We will now turn to a discussion of whether a decision being made while in either the gain or loss domain will influence the investment level. In Table 2, column 1 we present results from a random effects Tobit regression of investment at time t on relative earnings. We include gains and losses separately to account for possible differences.[10] A comparison across studies shows that with respect to our reference study by Gneezy and Potters (GP) only Fellner and Sutter (FS) report a significantly different investment level. We also observe a positive time trend of investment. Naturally investment in an investment environment will be strongly influenced by personality characteristics concerning risk-aversion, anxiety and the like. We will take first round investment as a proxy of general risk aversion. Investment in similar simple (non-repeated) investment situations has been previously used as a measure of risk aversion (e.g. Charness and Gneezy, 2003). We observe that indeed first round investment is highly predictive of later investment.

Deviations from the reference point are considered separately for gains and losses. Relative gains and losses and their square are all highly significant at a 1% level. When current earnings (E_t) are lower than the reference point Y_t, we first observe an increase in investment, however due to a negative sign of the square of losses investment eventually decreases. By contrast gains lead initially to a decrease in investment which due to a positive sign of its square will eventually increase again. For losses the switch from an increase to a

[10] To make comparisons with later results possible, observations are restricted to time points $t > 3$. This restriction has no noticeable effect on the presented regression results.

Table II: *Random effects Tobit regression of investment at time t (treatment High)*

	(1) invest(t)	marginal effect	(2) invest(t)	marginal effect
investmenet at t=1	1.004	1.004	0.971	0.971
	(11.27)***		(11.07)***	
Losses i.e. $\|E_t - Y_t\|$ if $E_t \leq Y_t$	0.121	0.121	0.089	0.089
	(5.04)***		(3.53)***	
Losses squared	-0.021	-0.021	-0.017	-0.017
	(5.31)***		(4.34)***	
Gains i.e. $\|E_t - Y_t\|$ if $E_t \geq Y_t$	-0.112	-0.112	-0.080	-0.080
	(5.91)***		(3.89)***	
Gains squared	0.012	0.012	0.009	0.009
	(4.40)***		(3.45)***	
Time	0.015	0.015	0.008	0.008
	(5.11)***		(1.31)	
dummy_BK	0.086	0.086	0.092	0.092
	(1.09)		(1.17)	
dummy_FS	-0.160	-0.160	-0.147	-0.147
	(1.81)*		(1.71)*	
dummy_HL	0.021	0.021	0.018	0.018
	(0.28)		(0.24)	
dummy_HW	-0.055	-0.055	-0.063	-0.063
	(0.70)		(0.78)	
win(t-1)			-0.133	-0.133
			(6.80)***	
win(t-2)			-0.077	-0.077
			(3.94)***	
win(t-3)			-0.022	-0.022
			(1.14)	
win(1 to t-1)			0.014	0.014
			(0.82)	
Constant	0.029		0.120	
	(0.40)		(1.63)	
Observations	1770		1770	
Number of participants	212		212	
Log likelihood	-981.879		-953.528	
Wald Chi^2	243.09 (df=10)		305.30 (df=14)	

Absolute value of z statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

decrease in investment, happens at an absolute deviation of approximately 5 units from the reference point (cf. also Figure 3, on relative earnings). For gains the switch from a decrease to an increase in investment happens approximately at an 8 unit deviation from the reference point.[11] We therefore conclude that aggregated gains or losses up to a certain point in time significantly influence investment choices. For small deviations, losses lead to an increase and gains to a decrease in investment. However both effects get reversed when deviations become larger.

In column 2 we extend this model to also account for the number of previous winning rounds. We introduce dummies for winning in the last (t-1), second to last (t-2) and third to

[11] These values should however be taken as rough approximations given that only 5% of our observations lie below or above these limits.

last (t-3) period before the investment decision is taken. We also introduce a variable representing the total number of winning rounds encountered up to that point (win(1 to t-1)). We observe that the coefficients of the variables of model (1) concerning study dummies, first round investment and relative earnings, stay largely unchanged. However the previously highly significant time trend is no longer observed. Instead we see that having recently experienced a winning round significantly decreases investment in the risky project.

This is not only true for the last but also for the second to last round. However the coefficient is approximately halved from time (t-1) to (t-2). We therefore observe evidence of the gamblers fallacy and a decreasing importance of outcomes that happened further in the past. This effect coexists with the observed effects on risk taking dependent on whether the current balance is in either the gain or loss domain. We illustrate this interaction for small and positive total earnings in Figure 4. In general we observed a reduction in risk taking for small gains which is later inversed. Thus we can model this by a utility function which is concave for small gains. However having recently experienced winning rounds will further decrease the amount invested. Since recent winning rounds imply that total earnings at t-1 were lower than current total earnings we know that in this case $E_{t-1} \leq E_t$. Since we are considering a case where E_t is a relatively small gain it is likely that E_{t-1} was even in the loss domain. Thus the further decrease in risk taken is due to participants that just managed due to a lucky outcome to leave the loss domain and enter the gain domain. Not wanting to risk this recent gain (and fearing a return into the loss domain) thus leads to a reduction in investment. The opposite is true for participants that arrive at E_t following a loss. Logically for them E_{t-1} must have been larger or equal to E_t. Thus here we have participants that had significant earnings and lost some of them recently. Due to the previous positive experience they invest comparatively more than those coming from the loss domain.

We have thus in a way identified multiple reference points that influence decisions at the same time. Not only how current earnings are positioned relative to a reference point but also how previous earnings were positioned will influence behavior.

RESULT 1: *Investment in a repeated environment is influenced at the same time by previous wins and by earnings relative to a reference point. Previous wins reduce investment, we thus observe evidence of the "gamblers fallacy". Small absolute gains reduce investment and small losses increase investment. However this effect gets reversed for larger gains and losses due to an opposite coefficient of the square of gains and losses.*

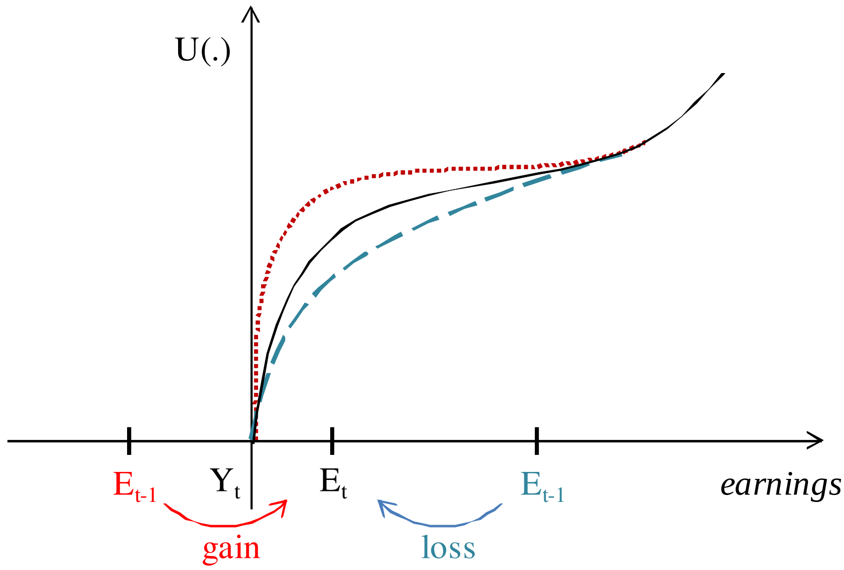

Figure 4: An illustration of the impact of previous outcome (gain versus loss) given the same level of current earnings (E_t). For small amounts in the gain domain we observe risk aversion. Even less risk is taken when a gain was previously experienced; which implies that E_{t-1} was lying to the left of E_t (doted line). Relatively more risk is taken when E_{t-1} was lying to the right of E_t (dashed line).

4.3. Investment dynamics with either frequent or infrequent feedback

After having identified the dynamics of risk taking in a *n* times repeated investment task, we will now extend our analysis to the observations from the treatments with reduced feedback and flexibility. In these treatments, investment decisions had to be fixed for three consecutive periods. That is dependent on the total number of rounds played, investment decisions were made in rounds $t = 1 + 3x$ (for $x \in [0, 5]$). The investment decision was fixed for the following three rounds and participants observed after this period their aggregate gains from the last three rounds. To extend our analysis to these treatments we therefore have to consider the reduced set of measures from these rounds $t = 1 + 3x$. Over all studies we therefore have between two and five repeated observations per participant. Figure 5 presents summary statistics concerning relative earnings and their distribution for treatment Low. We can see that mean earnings over all studies and rounds are positive, however there is significant variance concerning earnings throughout the data set. As for treatment High we observe that about half of the observations fall in a range from losses of approximately 1.5 normalized units to gains of 2 units.

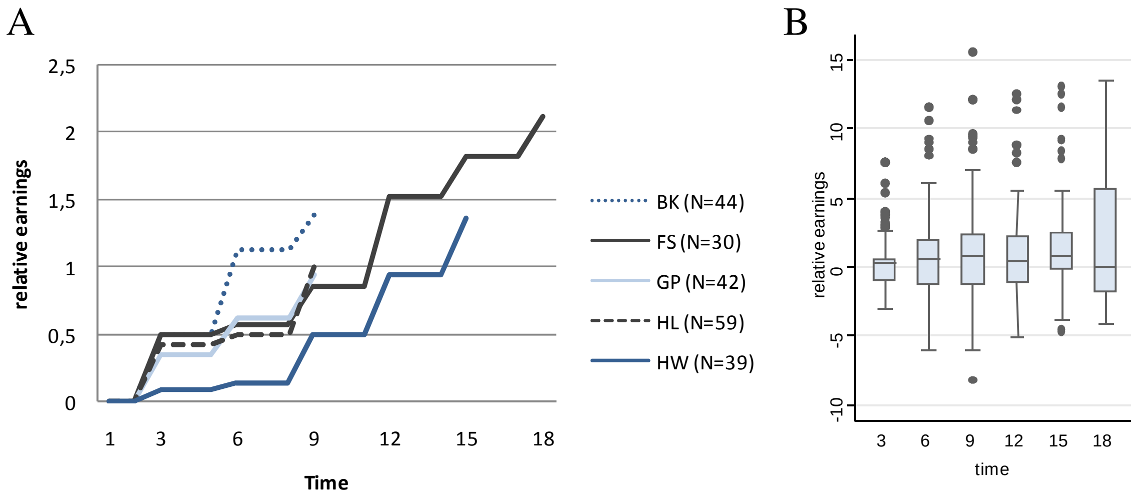

Figure 5: Relative earnings at time t for treatment Low (i.e. deviation from amount earned if up to point *t*-1 all points had been invested in the safe project) (A) mean split over study (B) box and whisker plot grouping all five studies

Table III presents results of a random effects Tobit regression for treatments High and Low for the reduced set of observations. We replicate the results presented in section 4.2 for the reduced data set in column 1. Note that the reduced set of time points also requires a grouping of previous winning rounds into one variable. We replace the dummy variable for a winning round at times *t*-1, *t*-2 and *t*-3, with the count of winning rounds in the last three rounds preceding the decision. The effect of investment in the first round and the treatment dummies is almost unchanged. Effect size and significance of relative earnings and the number of winning rounds previously encountered is reduced but still observable.

We apply now the same model to observations from the treatments with Low feedback and flexibility (Table III: column 2). Again we observe that our proxy for risk aversion (investment at *t*=1) is highly significant and strongly predictive of later behavior. We observe no significant differences across the different included studies. The effect of relative earnings is however affected by the reduction of feedback and flexibility. We observe the same tendency for relative gains (even though the coefficients for gains fail to reach significance). However when the current balance is in the loss domain we now observe a significant reduction in investment for small values. This negative coefficient is cancelled out due to a significant positive impact of squared losses. Thus small absolute losses under reduced feedback reduce investment, while large deviations might increase investment.

It is interesting to note that the earlier observed "gamblers fallacy" is still apparent. Even though only aggregate information about gains from the last three rounds was given in the Low feedback treatment, the number of winning rounds from the last block of rounds was

Table III: *Random effects Tobit regression of investment at time t (t = 4, 7, 10, 13, 16) for treatment High and Low*

	(1) treatment **High**	marginal effect	(2) treatment **Low**	marginal effect
	invest(t)		invest(t)	
investment at t=1	0.911	0.911	1.078	1.078
	(9.05)***		(13.59)***	
Losses i.e. $\lvert E_t - Y_t \rvert$ if $E_t \leq Y_t$	0.075	0.075	-0.096	-0.096
	(1.89)*		(2.58)**	
Losses squared	-0.010	-0.010	0.017	0.017
	(1.69)*		(1.67)*	
Gains i.e. $\lvert E_t - Y_t \rvert$ if $E \geq Y_t$	-0.058	-0.058	-0.014	-0.014
	(1.59)		(0.64)	
Gains squared	0.013	0.013	0.003	0.003
	(2.42)**		(1.41)	
Time	-0.002	-0.002	0.026	0.026
	(0.17)		(2.94)***	
dummy_BK	-0.003	-0.003	0.071	0.071
	(0.03)		(1.13)	
dummy_FS	-0.183	-0.183	-0.024	-0.024
	(2.02)**		(0.36)	
dummy_HL	-0.022	-0.022	0.071	0.071
	(0.28)		(1.19)	
dummy_HW	0.022	0.022	-0.089	-0.089
	(0.26)		(1.43)	
win(t-3 to t-1)	-0.080	-0.080	-0.032	-0.032
	(3.40)***		(1.90)*	
win(1 to t-1)	0.006	0.006	-0.051	-0.051
	(0.25)		(1.85)*	
Constant	0.207		0.112	
	(2.52)**		(1.65)*	
Observations	590		596	
Number of participants	212		214	
Log likelihood	-336.918		-147.526	
Wald Chi^2	164.20 (df=12)		250.50 (df=12)	

Absolute value of z statistics in parentheses
** significant at 10%; ** significant at 5%; *** significant at 1%*

easily deducible for participants.[12] Only the order of events was not revealed. The impact of the number of previous winning rounds is now not exclusively restricted to the last three rounds preceding the decision but to all previous rounds. That is more wins in the last three rounds and more overall wins in the game so far reduce investment. Indeed we observe that the magnitude of the joint coefficient of these two variables is very close to the coefficient of wins in the last three rounds in treatment High.

Our final observation concerns the highly significant and positive time trend for reduced feedback and flexibility. This time trend implies increased investment independent of the number of previous winning rounds and of the current earnings. This effect seems surprising but might be related to a general increase in confidence and optimism observed for situations of reduced flexibility (Hopfensitz and Wranik, 2008). While winning and losing

[12] In some of the studies outcomes were even explicitly shown, however without indicating their order.

still influences risk taking and even though absolute losses now lead to more risk averse decisions, the overall experience from reduced flexibility and feedback seems to increase confidence in the risky option over time.

RESULT 2: *When feedback and flexibility are reduced we still observe an impact of previous wins (gamblers fallacy). Also deviations from the reference point are still influential; however the effects are less pronounced and inversed for losses. That is small losses now reduce investment. The main difference between treatments High and Low is a significantly positive time trend under low feedback and flexibility.*

5. DISCUSSION AND CONCLUSION

In this paper we presented a meta-study of five repeated investment experiments to investigate the relative importance of either previous events (winning or losing) or relative earnings (loss aversion) on decisions taken. A large literature has previously investigated whether risk taking behavior differs in the gain versus the loss domain and whether previous wins increase or decrease future risk taking. The two effects can however be independent. Gains relative to an initial reference point can be due to a large gain followed by some small losses or by a number of small gains. Thus it is possible that both effects coexist and influence behavior jointly. Indeed we can show for our sample of 200 participants from five different studies, that the relative position to the reference point is highly predictive of behavior. When participants are in the gain domain they reduce investment. When they are in the loss domain they increase investment. However due to a significantly positive effect of the squared of gains as well as losses this effect is cancelled out when gain or losses get larger. In addition we observe that participants display signs of the "gamblers fallacy". Having won in the last or second to last round significantly decreases the amount invested. We can therefore show that the two effects co-exist and are two independent behavioral biases.

When we extend the same analysis to observations from treatments where feedback and flexibility were restricted we observe that previous events and relative earnings both keep playing a significant role. However the effect of gains is weaker and the effect of losses is even inversed. This implies that small losses now lead to a decrease in investment while for larger losses investment will increase again. What is interesting is the fact that the gamblers fallacy is still strongly present. Thus even though detailed information about individual gains and losses was not available, the number of previous winning round and the total number of winning rounds encountered significantly influence risk taking. The higher the number of previous winning rounds the more investment gets reduced. The largest difference between the model of frequent and reduced feedback concerns a highly significant time trend in treatment Low. This effect might be related to differences in experienced emotions and evaluations due to reduced feedback. Previous experimental research has shown that in dynamic investment settings anticipated and experienced emotions (Hopfensitz and van Winden, 2008) and evaluations concerning the future (Hopfensitz and Wranik, 2008) influence choices. Given that loss aversion is based on the assumption that "losses loom larger than gains" it is to be expected that reduced feedback will reduce the experience of negative emotions and increase optimistic evaluations concerning the future. Thus the significantly positive time trend might can be seen as a representation of increased confidence in the future and decreased fear of negative experiences. What is interesting is that this effect is independent from the actual number of gains and the relative income position. The effect of myopic loss aversion seems therefore to develop over time and not be anticipated ex-ante. This might have important implications for when and where myopic loss aversion is going to be observed.

APPENDIX A: METHODS OVERVIEW

In the following we cite from the method sections of the five included studies.

Gneezy and Potters (1997):

In the experiment, subjects were confronted with a sequence of twelve identical but independent rounds of a lottery (betting game). In each of the first nine rounds [...], subjects were endowed with 200 cents. They had to decide which part (X_t) of this endowment they wanted to bet in the lottery. In the lottery there was a probability of 2/3 of losing the amount bet and a probability of 1/3 of winning two and a half times the amount bet. Subjects were fully informed about the objective probabilities of winning and losing, and about the corresponding size of gains and losses. It is important to stress that subjects could not bet any money accumulated in previous rounds. Hence, the maximum bet in each round is 200 cents, independently of the outcome of the bet in any of the previous rounds.

[...] The crucial feature of the design is that there were two different treatments: Treatment H (high frequency) and Treatment L (low frequency). In Treatment H the subjects played the rounds one by one. At the beginning of round 1 they had to choose how much of their endowment of 200 cents to bet in the lottery. Then they were informed about the realization of the lottery in round 1. Only then could they decide how much of their new endowment of 200 cents to bet for round 2, and so on. Hence, in this treatment subjects made nine betting decisions [...]. In Treatment L, however, subjects played the rounds in blocks of three. At the beginning of round 1, subjects had to decide how much of their endowment of 200 cents to bet in the lotteries of rounds 1, 2, and 3. In addition, these bets were restricted to be equal. If a subject bet X in round 1, (s)he also bet X in rounds 2 and 3.

Bellemare et al (2005):

Participants were confronted with a sequence of nine independent draws of the same gamble. For each draw an individual received an endowment of 70 Eurocents, which could be totally or partially invested. In the gamble, there was a probability of 1/3 of winning two and a half times the amount bet. With probability 2/3 the amount would be lost entirely. Subjects were fully informed about the objective probabilities of winning and losing, and about the corresponding size of gains and losses. It is important to stress that subjects could not bet any money accumulated in previous rounds. Hence, the maximum bet in each round was 70 Eurocents, independently of the outcome of the bet in any of the previous rounds. First, we replicated the GP treatments H (high frequency information/high flexibility) and L (low frequency information/low flexibility) in order to provide a basis for comparison. In treatment H the subjects played the gambles one by one. At the beginning of round one they had to choose how much of their endowment of 70 Eurocents to bet in the lottery. Then they were informed about the realization of the lottery in round one. Only then they could decide how much of their new endowment of 70 Eurocents to bet in round two, and so on. Hence, in this treatment subjects made nine subsequent betting decisions.

In treatment L, on the other hand, subjects played the nine rounds in blocks of three. At the beginning of round one, subjects had to decide how much of their endowment of 70 Eurocents to bet in the lotteries of rounds one, two, and three. In addition, these bets were restricted to be equal. If a subject bet X in round one, she also bet X in rounds two and three. After subjects decided on their bets, they were informed about the realizations for rounds one, two, and three at the same time. Subsequently, subjects decided how much to bet in rounds four, five, and six, and so on. [...]

We ran a computerized experiment with a total of twelve sessions in September 2003. Participants were recruited via email from the subject pool of the CentER lab at Tilburg University comprising 500 people at the time of recruitment. The invitation announced a decision-making experiment that would last no longer than 40 min, with a reward that would depend on their decisions. The experiment was held in the CentER lab, where students were seated in separated compartments.

Haigh and List (2005):

We used a straightforward 2 × 2 experimental design. [...] Using a between-person experimental design, we included both undergraduate students and professional traders in two distinct treatments: Treatment F (denoting frequent feedback) and Treatment I (denoting infrequent feedback). And to ensure comparability with the extant literature, we followed Gneezy and Potters (1997) when crafting our experimental protocol and parameters. [...] In Treatment F, subjects were confronted with a sequence of nine rounds in which they were endowed with 100 units per round [...]. In each of the nine rounds, the subject decided what portion of this endowment (0, 100) she desired to bet in a lottery that returned two-and-a-half times the bet with one-third probability and nothing with two-thirds probability. [...] Subjects were made aware of the probabilities, payoffs, and the fact that the lottery would be played directly after all subjects had made their choices for that round. Thus, subjects played rounds one by one. Subjects were therefore aware of the fact that they could earn anywhere between 0 and 350 units in each round. Finally, subjects were informed that monies earned were to be summed and paid in private at the end of the experiment. Contrasting with this “frequent feedback” environment is Treatment I, which is identical to Treatment F, except that in Treatment I agents placed their bets in blocks of three. Rather than placing their round bet and realizing the round outcome before proceeding to the next round, in Treatment I agents decided in round t how much of their 100-unit endowment they wished to bet in the lotteries for each of three rounds, t, $t + 1$, and $t + 2$. Following Gneezy and Potters (1997), we restricted the bets to be homogeneous across the three rounds. Most importantly, after subjects placed their bets, they were informed about the *combined* realization of the three rounds.

[...] We recruited 64 subjects for our student treatments from the undergraduate student body at the University of Maryland. Each treatment was run in a large classroom on the College Park campus of the University of Maryland. To ensure that decisions remained anonymous, the subjects were seated far apart from each other. The trader subject pool included 54 professional traders from the CBOT. Each of the trader treatments was run in a large room on-site at the CBOT. As in the case of the students, communication between the subjects was prohibited and the traders were seated such that no subject could observe another individual’s decision (and payoffs).

Fellner and Sutter (2009):

All experimental treatments are variations of the basic investment task of Gneezy and Potters (1997). Subjects are endowed with 100 ECU (experimental currency units, with 100 ECU = 50 Euro-Cents) in each of a total of 18 rounds. They can decide to keep the endowment with zero interest or invest any amount $X \in [0, 100]$ in a risky lottery. If the lottery wins (with probability ⅓), subjects win 2.5 times the amount invested (in addition to keeping their initial endowment). If the lottery loses (with probability ⅔), the amount invested is lost.

[...] Subjects were invited for participation by using the recruitment system ORSEE (Greiner, 2004), and the sessions were run computerized using the software z-Tree (Fischbacher, 2007). Each of the treatments was conducted in a separate session, and no subject could participate in more than one session.

Hopfensitz and Wranik (2009):

To allow comparison with earlier results, our experiment is based on the research designs by Gneezy and Potters (1997) and Bellemare et al. (2005). In the baseline treatment, participants faced 15 consecutive investment rounds. Participants received 100 points for each round, which could be fully or partially invested into one of two choices. Earnings from previous rounds could not be used for future investment. One of the two investment choices was safe (i.e., every point invested would be added to the final earnings), and the other choice was risky. The risky choice returned the invested points multiplied by 3.5 with p=1/3, and returned nothing in 2/3 of the cases. Thus, participants could either earn 2.5 times their investment (relative to the points they had received at the beginning of the round) or lose their investment. To make losses salient, the instructions and computer interface clearly stated that participants had an initial amount of capital which they could either keep or invest. The expected value of the risky choice was therefore larger than the expected value of the safe choice.

[...] In the baseline treatment, participants had to make a new investment decision in each round and received investment performance feedback after each round. We therefore call this treatment High (short for "high feedback"). In contrast, participants in the Low treatment ("low feedback") were required to fix their investment choice for three consecutive rounds and received aggregate feedback about their returns from these three rounds. [...]

Since the aim of our study is to identify individual differences, evaluations, and emotions underlying myopic loss aversion, we asked participants to respond to questionnaires before and during the task. [...] During the experimental session, we measured baseline evaluations and emotions before the first investment round. Then, every three rounds, after receiving feedback concerning their investment, subjects were asked to: (1) indicate and rate the most prominent emotion they experienced; (2) answer a number of questions concerning evaluations of past and future rounds.

REFERENCES:

Abdellaoui, M. (2000). Parameter-free Elicitation of Utility and Probability Weighting Functions, *Management Science*, 46(11), 1497–1512.

Abdellaoui, M., H. Bleichrodt and C. Parschiv (2007). Loss Aversion Under Prospect Theory: A Parameter-Free Measurement, *Management Science*, 53(10), 1659-1674.

Beattie, J., and G. Loomes (1997). The impact of incentives upon risky choice experiments. *Journal of Risk and Uncertainty*, 14:155–168.

Bellemare, C., M. Krause, S. Kroeger and C. Zhang (2005). Myopic loss aversion: information feedback vs. investment flexibility. *Economics Letters*. 87(3):319-324.

Benartzi, S. and R. Thaler (1995). Myopic loss aversion and the equity premium puzzle. *The Quarterly Journal of Economics*. 110(1):73-92.

Blavatskyy, P. and G. Pogrebna (2006). Myopic Loss Aversion Revisited: the Effect of Probability Distortions in Choice Under Risk. *IEW Working Paper* No. 249

Bleichrodt, H. and J.L. Pinto (2000). A parameter-free elicitation of the probability weighting function in medical decision analysis. *Management Science*. 46: 1485-1496.

Chapman, G. and J. Winquist (1998). The magnitude effect: Temporal discount rates and restaurant tips. *Psychonomic Bulletin and Review*. 5(1):119-123.

Charness, G. and U. Gneezy (2007). Strong Evidence for Gender Differences in Investment. *working paper.*

Croson, R. and J. Sundali (2005). The Gambler's Fallacy and the Hot Hand: Empirical Data from Casinos. *The Journal of Risk and Uncertainty*. 30:195-209.

Fehr-Duda, H, A. Bruhin, T.F. Epper and R. Schubert (2008). Rationality on the Rise: Why Relative Risk Aversion Increases with Stake Size, *working paper, University of Zurich, no. 0708.*

Fellner, G. and M. Sutter (2009). Causes, consequences and cures of myopic loss aversion - An experimental examination. *The Economic Journal*. 119(537): 900-916.

Fellner, G. and B. Maciejovsky (2007). Risk attitude and market behavior: Evidence from experimental asset markets. *Journal of Economic Psychology.* 28(3): 338-350.

Gimpel, H. (2007) Loss Aversion and Reference-Dependent Preferences in Multi-Attribute Negotiations. *Group Decision and Negotiation,* 16:303–319.

Gneezy, U. and J. Potters (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics*. 112(2):631-645.

Gneezy, U., A. Kapteyn and J. Potters (2003). Evaluation Periods and Asset Prices in a Market Experiment. *Journal of Finance*. 58: 821-838.

Green, L. and J. Myerson (2004). A Discounting Framework for Choice with Delayed and Probabilistic Rewards, *Psychological Bulletin*. 130(5): 769-792.

Haigh, M. and J. List (2005). Do professional traders exhibit myopic loss aversion? An experimental analysis. *The Journal of Finance*. 60(1):523-534.

Haisley, E., R. Mostafa and G. Loewenstein (2008). Myopic risk-seeking: The impact of narrow decision bracketing on lottery play. *Journal of Risk and Uncertainty*. 37: 57-75.

Hershey, J. and P. Schoemaker (1985). Probability versus Certainty Equivalence Methods in Utility Measurement: Are They Equivalent? *Management Science*, 31(10): 1213-1231.

Hopfensitz, A. and F. van Winden (2008). Dynamic Choice, Independence, and Emotions. *Theory and Decision,* 64: 249-300.

Hopfensitz, A. and T. Wranik (2008). Psychological and Environmental Determinants of Myopic Loss Aversion. *NETSPAR discussion paper.* nr. 2008-013.

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

Kirchsteiger, G. (1994) The role of envy in ultimatum games. Journal of Economic Behavior and Organization, 25:373-389.

Kőszegi, B. and M. Rabin (2007). Reference-Dependent Risk Attitudes. *American Economic Review*. 97(4): 1047-1073.

Kumar, A. and L. Sonya Seongyeon (2008). How Do Decision Frames Influence the Stock Investment Choices of Individual Investors? *Management Science*. 54(6): 1052-1064.

Langer, E. (1975). The Illusion of Control, *Journal of Personality and Social Psychology,* 32: 311–328.

Langer, T. and M. Weber (2008). Does commitment or feedback influence myopic loss aversion? An experimental analysis. *Journal of Economic Behavior and Organization*. 67:810-819.

Markowitz, H. (1952). The utility of wealth. *Journal of Political Economy*. 60(2): 151–158.

Pinon, A. and M. Weber (2006). The influence of present and prior alternatives on risk aversion. *Working paper.*

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

Read, D., G. Loewenstein and M. Rabin (1999). Choice Bracketing. *Journal of Risk and Uncertainty*. 19:171-197.

Samuelson, W. and R. Zeckhauser (1988). Status quo bias in decision making. *Journal of Risk and Uncertainty,*1(1):7-59.

Schwarz, N. and N. Strack (1999). Reports of subjective well-being: Judgmental processes and their methodological impli-cations. In Kahneman, Diener and Schwarz, 61–84.

Shefrin, H. and M. Statman (1985). The Disposition to Sell Winners Too Early and Ride Losers Too Long: Theory and Evidence. *Journal of Finance.* 40(3):777-790.

Thaler, R., A. Tversky, D. Kahneman and A. Schwartz (1997). The effect of myopia and loss aversion on risk taking: An experimental test. *The Quarterly Journal of Economics*. 112(2):647-661.

Thaler, R. and E. Johnson (1990). Gambling with the House Money and Trying to Break Even: The Effects of Prior Outcomes on Risky Choice. *Management Science*, 36(6): 643-660.

Tversky, A. and D. Kahneman (1971). Belief in the law of small numbers. *Psychological Bulletin, 76*, 105-110.

Weber, B.J. and G.B. Chapman (2005). Playing for peanuts: Why is risk seeking more common for low-stakes gambles? *Organizational Behavior and Human Decision Processes*. 97: 31-46.

Weber, M. and H. Zuchel (2003). How do Prior Outcomes Affect Risk Attitude ? *University of Mannheim, Working Paper*.