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Abstract

This paper attempts to identify behavioral patterns and compare their average success considering several criteria of bounded rationality. Experimentally observed choice behavior in various decision tasks is used to assess heterogeneity in how individual participants respond to 15 randomly ordered portfolio choices, each of which is experienced twice. Treatments differ in (not) granting probability information and in (not) eliciting aspirations. Since in our setting neither other regarding concerns nor risk attitude matter and probability of the binary chance move is (optimal) choice-irrelevant, categorizing decision types relies on parameter dependence and choice adaptations. We find that most participants reduce systematically sub-optimality when following the identified criteria.

Keywords

(Un)Bounded Rationality, Satisficing, Experiments, Heterogeneity

JEL Codes

D03, D81, C91

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Behavioral Patterns and Reduction of Sub-Optimality: An Experimental Choice Analysis

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Abstract

This paper attempts to identify behavioral patterns and compare their average success considering several criteria of bounded rationality. Experimentally observed choice behavior in various decision tasks is used to assess heterogeneity in how individual participants respond to 15 randomly ordered portfolio choices, each of which is experienced twice. Treatments differ in (not) granting probability information and in (not) eliciting aspirations. Since in our setting neither other regarding concerns nor risk attitude matter and probability of the binary chance move is (optimal) choice-irrelevant, categorizing decision types relies on parameter dependence and choice adaptations. We find that most participants reduce systematically sub-optimality when following the identified criteria.

JEL: D03; D81; C91.

Keywords: (Un)Bounded Rationality, Satisficing, Experiments, Heterogeneity

1 Introduction

Accepting that sub-optimality is nearly universal (see Conlisk, 1996; Selten, 2001; and Gigerenzer, 2006 for a review of the literature), we attempt to identify behavioral patterns to improve decision success, by reducing the distance between individuals' actual choices and the optimal ones. In this

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paper, the individual data previously used by — (2017) via aggregating across individuals are analyzed to assess individual heterogeneity in decision making using several criteria of behavioral improvement and of reasonable parameter dependence (Erev and Haruvy, 2013; Conte et al., 2015).

The experimental choice tasks are designed to unambiguously distinguish optimal and sub-optimal choices and to avoid various idiosyncratic characteristics by which one can rationalize such individual heterogeneity in decision making. Specifically, the decision tasks experimentally induce risk neutrality, have only individual consequences and focus on numerical parameter constellations letting optimal choices not depend on probability (information). We additionally distinguish optimality with and without intra-personal payoff aggregation and partly elicit and incentivize aspiration data.¹ Moreover, since participants confront successively twice fifteen different and randomly ordered choice tasks, we also can assess experience effect.

The experimental setup is designed to explore fundamental aspects of decision theory. The decision tasks are framed as portfolio choices² and employ binary lottery incentives.³ Given an initial endowment, each subject allocates it between a risky asset and a risk-free asset; both investment returns determine the probability (in points) of winning the higher payoff (€14), rather than the lower payoff (€4), in both the good and the bad state. The investment is set-optimal when one cannot obtain more in one state without having to reduce what one obtains in the other state. Since deriving the optimal investment, i.e. the investment maximizing the expected utility across both states, may be cumbersome, participants could repeatedly use a slider before committing to one slider position.

Satisficing is testable in the experimental treatments eliciting aspiration levels and incentivizing optimal aspiration formation. Rather than only one aspiration in expected utility terms, participants form payoff aspirations for each realization of the binary random event (the good and the bad state), which allows to test set-optimal satisficing. Satisficing, however, must not be (set)-optimal: an investment choice is satisficing when its success in each random state guarantees the respective aspiration, i.e. when the investment return in each random state is sufficient for what one aspires.

¹For an analysis of the concepts of aspiration and satisficing, see the seminal contributions of Simon (1955), Siegel (1957) and Manski (2017), Sauermann and Selten (1962) and Selten (1998) for the adaptation theory (AAT). For experimental analyses, see Selten et al. (2012) and Hey et al. (2017).

²To avoid other relevant concerns, see Harrison and Johnson (2006).

³This induces risk neutrality in decision making (see Roth and Malouf, 1979, for an early use in bargaining).

Our previous aggregate data analysis concluded that, in spite of the weak rationality requirements, optimality and optimal satisficing are rare, and there is striking heterogeneity in the individual behavior of participants within and across treatments.

The aim of this study is to investigate whether and how individual participants are able to improve their investment decisions via reducing the distance between their actual choices and the optimal ones. Since the familiar tools for rationalizing individual heterogeneity in behavior are experimentally controlled or excluded, we essentially categorize boundedly rational behavior via criteria of behavioral improvement to confirm that participants learn and thereby enhance their success. Although we are not born optimizers, we may still improve our success by learning. To achieve this aim, we assess three basic criteria of behavioral improvement (improving slider use, reducing antimonotonicity, improving when experiencing the same task again). Improving according to these criteria should enhance individual success. In the treatments eliciting aspiration levels we additionally investigate improvement in aspiration formation. Altogether we find that our criteria of behavioral improvement are correlated and enhance average success in terms of investment choices and the consequent payoffs.

The rest of the paper is organized as follows. Section 2 formally describes the choice tasks. Section 3 presents the experimental protocols. Section 4 specifies the improvement criteria, and Section 5 reports the evidence for the selected criteria, their correlations and their use in identifying different behavioral types. Section 6 assesses how improvement affects average success. Section 7 concludes.

2 Choice tasks and treatments

In each choice task (or case), the decision maker is endowed with an integer amount $e (> 0)$ and decides which amount i , with $0 \leq i \leq e$, to invest in a risky asset, whose variable repayment rate is $r(i) = e - i$ in case of the good state (boom) and 0 in case of the bad state (doom). The remaining amount $e - i$ has a constant repayment rate $c > 0$, irrespective of good or bad state. The probabilities of boom and doom are p and $1 - p$ with $0 < p < 1$. Participants are subjected to binary lottery

incentives;⁴ specifically, the choice of i determines the probability of earning €14 rather than only €4.

The return from investing i in the risky asset and $e - i$ in the safe one is $(e - i)c$ in case of doom and $(e - i)(c + i)$ in case of boom. Since, due to the binary lottery incentives, expected utility is the probability $P(i)$ of earning more (€14) rather than less (€4) and $P(i)$ is restricted to $0 \leq P(i) \leq 1$, the expected utility is given by

$$P(i) = (1 - p) \cdot \min \{1, (e - i)c\} + p \cdot \min \{1, (e - i)(c + i)\} \quad (1)$$

Across all cases, one has $(e - i)c < 1$ via $ec < 1$. Thus, constrained optimization requires to determine the level i for which

$$P(i) = (1 - p)(e - i)c + p \cdot \min \{1, (e - i)(c + i)\} \quad (2)$$

is maximal.

So expected utility depends on the choice of i via $[1 - P(i)]u(\text{€}4) + P(i)u(\text{€}14)$, with $u(\cdot)$ denoting the utility of money for all $0 \leq i \leq e$. Setting $u(\text{€}4) = 0$ and $u(\text{€}14) = 1$ only assumes that more money, €14, is preferred to less, €4, and shows that $P(i)$ represents the expected utility of choice i .

Participants confronted the cases illustrated in Table 1, whose rows specify the integer endowment e , constant repayment rate c , probability p , optimal investment $i^* = \frac{e-c}{2} - \frac{\sqrt{(e+c)^2 - 4}}{2}$, expected utility $P(i^*)$, as well as €14 - probabilities $\bar{P}(i^*)$ and $\underline{P}(i^*)$ in boom and doom implied by i^* . Due to i^* being a corner maximum of the utility curve, see the $P(i)$ curve in Figure 1, the positive probability p is not (optimal) choice-relevant but only payoff-relevant. Thus, probability information and transformation (see Kahneman and Tversky, 1979, and Prelec, 1998) do not matter for optimality.

The between-subjects treatments design differs in information regarding probabilities of the good

⁴For a critical assessment, see Selten et al. (1999) which, however, questions expected utility theory, not binary lottery incentives. Rejecting binary lottery incentives but maintaining expected utility theory is impossible.

Table 1: Cases and optimal choices

Case	e	c	p	i^*	$P(i^*)$	$\bar{P}(i^*)$	$\underline{P}(i^*)$
1	2	0.22	0.66	0.41	0.78	1	0.35
2	2	0.34	0.51	0.22	0.81	1	0.60
3	2	0.40	0.40	0.14	0.85	1	0.75
4	2	0.43	0.32	0.09	0.88	1	0.82
5	2	0.45	0.27	0.07	0.90	1	0.87
6	3	0.15	0.29	0.21	0.59	1	0.42
7	3	0.23	0.23	0.12	0.74	1	0.66
8	3	0.27	0.18	0.07	0.83	1	0.79
9	3	0.29	0.14	0.05	0.88	1	0.86
10	3	0.30	0.12	0.04	0.90	1	0.89
11	4	0.11	0.17	0.15	0.52	1	0.42
12	4	0.17	0.13	0.09	0.71	1	0.67
13	4	0.20	0.10	0.05	0.81	1	0.79
14	4	0.22	0.08	0.03	0.88	1	0.87
15	4	0.22	0.07	0.03	0.88	1	0.87

and the bad state and aspiration elicitation: in treatments 1 and 3 (T1 and T3 hereafter), participants are aware of probability p , whereas in treatments 2 and 4 (T2 and T4 hereafter), no information about probability p is provided. The known (in treatments 1 and 3) or unknown (in treatments 2 and 4) probabilities of boom and doom are p and $1 - p$, respectively, with $0 < p < 1$. In treatments T3 and T4, participants choose not only i but also their aspiration levels for the probability of earning €14 in case of boom and doom, respectively, denoted by $\bar{A}$ and $\underline{A}$, with $\bar{A} \geq \underline{A}$. In the following, we refer to $\bar{A}$ and $\underline{A}$ as aspirations. Since in boom and doom the probabilities of earning €14 are $\bar{P}(i) = \min \{1, (e - i)(c + i)\}$ and $\underline{P}(i) = (e - i)c$, respectively, the choice of i satisfies the aspiration profile $(\bar{A}, \underline{A})$ if $\bar{P}(i) \geq \bar{A}$ and $\underline{P}(i) \geq \underline{A}$. With the help of the choices i , $\bar{A}$ and $\underline{A}$ one can therefore test the satisficing hypothesis. Satisficing is set-optimal if $\bar{P}(i) = \bar{A}$, $\underline{P}(i) = \underline{A}$ and i satisfies $0 \leq i \leq i^*$. Otherwise, one could increase $\underline{P}(i)$ without decreasing $\bar{P}(i) = 1$, or vice versa. To test (set-optimal) satisficing, aspiration formation is incentivized. A participant earns €14 with probability $\bar{A}$ or $\underline{A}$ when satisficing in boom or doom, respectively, and otherwise nothing at all (meaning they earn €4 with probability 1). In particular, he experiences "burning money" when sets an aspiration level lower than the probability implied by its own investment choice (i.e., when $\bar{P}(i) > \bar{A}$ or $\underline{P}(i) > \underline{A}$ in boom and doom, respectively) or experiences "committing suicide" when, on the contrary, he sets an aspiration level greater than the probability implied by its own investment choice (i.e., when $\bar{A} > \bar{P}(i)$ or $\underline{A} > \underline{P}(i)$ in boom and doom, respectively). In treatment T2, which

does not provide probability information and does not elicit aspirations, participants are asked for their (not incentivized) subjective probability $\hat{p}$ of boom. This subjectively-stated probability $\hat{p}$ in T2 and the aspirations $\bar{A}$ and $\underline{A}$ in T3 and T4 can be once revised before confirming one's choice of i without affecting the maximum number of slider use (six) per choice task.

Figure 1 illustrates the i allocations and the related probabilities $P(i)$, $\bar{P}(i)$, $\underline{P}(i)$.

Figure 1: Illustration of payoff incentives

3 Experimental protocols

The experiment consists of two phases with 15 rounds each, corresponding to the 15 cases in Table 1 which participants confront in idiosyncratic random orders.⁵ At the beginning of each round participants are endowed with an amount of token which can be allocated in a risk-free bond with a state-independent repayment factor (c in Table 1, and a risky asset whose repayment factor changes with the market condition and the amount invested in it. The four treatments differ in terms of probability information and aspiration elicitation. In T1 and T3, participants are informed of the probabilities of boom and doom (p and $1 - p$), about which they are unaware in T2 and T4. Only in T2 they report their beliefs $\hat{p}$ and $1 - \hat{p}$ and only in T3 and T4 participants state their aspirations $\bar{A}$ and $\underline{A}$ for both states, (not) knowing the probability p in T3 (T4). The four treatments are depicted in Table 2.

⁵ — (2017) also analyze three control cases with $c = 0$.

Table 2: The 2×2 -factorial between subjects treatments

Choice Format	Probability Information	
	p given	p unknown
<i>I</i> -treatment (direct i -choice)	T1 1. $i_1, i_2, i_3, i_4, i_5, i_6$ $\rightarrow$ final choice of i	T2 1. $\hat{p}$ 2. $i_1, i_2, i_3, i_4, i_5, i_6$ $\rightarrow$ final choice of i
	T3 1. $\bar{A}, \underline{A}$ 2. $i_1, i_2, i_3, i_4, i_5, i_6$ $\rightarrow$ final choice of i	T4 1. $\bar{A}, \underline{A}$ 2. $i_1, i_2, i_3, i_4, i_5, i_6$ $\rightarrow$ final choice of i

Before choosing i , participants can test up to six choices of i by moving a cursor on the scroll bar, as depicted in Figure 2 for T1 and T2⁶ (and in Figure 4, in Appendix B, for T3 and T4).⁷ The cursor allows participants to change the endowment share (i/e) invested in the risky asset and thus the probabilities $\bar{P}(i)$ and $\underline{P}(i)$ of gaining €14, which are represented by the left (right) column height in boom (left) or doom (right). After confirming their final choice, participants proceed to the next round.

Let us illustrate the example in Figure 2 with the endowment of $e = 3$, the repayment factor for the risk-free bond $c=0.29$, and probability of 14% (p) and 86% ($1 - p$), respectively, for boom and doom. In the example, the participant invests in the risky asset $i = 1$ which leaves for the risk-free bond $(e - i)=2$. This determines the probability of earning €14 and the complementary probability of earning €4, which both depend on good or bad state.

In the good state, the probability of earning €14 is given by the sum of repayment of the risk-free bond, $c(e - i)$, and the repayment of the risky asset, $(e - i)i$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the good market condition. In this example, the probability of earning €14 is approximately 80%.

In the bad state, the probability of earning €14 is given only by the repayment of the risk-free bond, $c(e - i)$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the bad market condition. In the example,

⁶The probability information is the only difference between T1 and T2

⁷In the experimental setting of T3 and T4 the aspiration level is set on the €14 bar probabilities and we avoid confusion with the second (complementary) bar.

the probability of earning €14 is approximately 50%. The translated instructions (see Appendix B) provide more details regarding how treatments are described.

Figure 2: Investment choice in T1

The altogether 30 choices i are the only choice data in T1. In T2 we additionally elicit in each round the stated probability $\hat{p}$ by asking participants to write down their expectations regarding the probabilities of market in good or bad state, before the investment choice (see Instructions for treatment T2 in Appendix B). Similarly, in T3 and T4 we elicit in each round the aspirations $\bar{A}$ and $\underline{A}$, by asking participants to assess them before the investment choice (see Instructions for treatments T3 and T4).

The experiment was performed in the Cesare Lab of Luiss University in Rome with 298 student participants. The number of participants per treatment varies from 71 to 78. For each treatment, we conducted three sessions with student participants, recruited using Orsee (Greiner, 2004) from different fields of study (mainly Economics, Law and Political Sciences). No one participated in more than one session. The experiment was computerized using z-tree (Fischbacher, 2007). The sessions lasted approximately 90 minutes. After each session, the participants answered a brief questionnaire, mainly to collect demographic information, before being privately paid in cash for a randomly selected round.⁸

⁸Paying participants only for a random round is required by binary-lottery incentives and avoids past-earnings effects.

4 Improvement criteria

Our data show that participants quite systematically behave sub-optimally. But do participants learn to improve their success? In our setting, participants may learn in three main ways:

1. Improving slider attempts.

For each participant, denote by i_{t^*} the last confirmed slider position. For participants with repeated slider attempts in the same task, one can investigate the last slider adjustment $i_{t^*} - i_{t^*-1}$, and, if available, the second-last ones, $i_{t^*-1} - i_{t^*-2}$, etc.

Based on this notation, slider use is improving for $i_{t^*} \geq i^*$ when

$$(1.1) \quad i_{t^*} < i_{t^*-1} \text{ or}$$

$$(1.2) \quad i_{t^*} \leq i_{t^*-1} \leq i_{t^*-2}$$

with at least one weak inequality being strict.⁹

2. Reducing antimonicity

We define two types of antimonicity, timewise and casewise. More specifically, denote by $k = 2, \dots, 15$ the round in a given phase in which a given participant encounters a specific case.

Timewise monotonicity requests for two successive choices i_k and i_{k-1} that $(i_k - i_{k-1})$ has the same sign as $(i_k^* - i_{k-1}^*)$, for the optimal choices i_k^* and i_{k-1}^* , i.e., if

$$(2.i) \quad \text{sign}(i_k - i_{k-1}) \times \text{sign}(i_k^* - i_{k-1}^*) > 0.$$

Casewise monotonicity (within a given phase) similarly postulates

$$(2.ii) \quad \text{sign}(i_k - i_{k'}) \times \text{sign}(i_k^* - i_{k'}^*) > 0 \text{ with } k \neq k'.$$

The latter requirement is more demanding by allowing to compare every case k with all 14 other cases k' , often separated by several intermediate cases between k and k' . We thus mea-

⁹In a similar manner, one could check slider positions for $i_{t^*-\tau} \leq i^*$ with $\tau = 1, 2$ to determine whether they return to the range $[0, i^*]$ via $i_{t^*} \leq i^*$; however, such an analysis is omitted because only too few data are available.

sure as an improvement the reduction of the individual frequencies of cases in which 2.i and 2.ii are not met.

3. Reduction of non-improving across phases

When confronting each case once again in a new random order, the second investment choice i being closer to i^* in the sense of smaller $\max\{0, i - i^*\}$ is another form of learning.

For a given case, we compare the two i -choices i_1 in phase 1 and i_2 in phase 2 of a specific participant to asses individual improvement due to experience via reducing the frequency of improving choices across phases, specifically by identifying non-improving for each case via

$$(3) \max\{i_2 - i^*, 0\} > \max\{i_1 - i^*, 0\} \geq 0,$$

i.e., when for the given case, the 2nd-phase choice i_2 is further away than i_1 from the optimal choice i^* . We thus measure experience by reducing the individual frequency of cases with no improvement in the sense of (3).

Behavioral improvements altogether should increase the frequency of adjusting i nearer to i^* in the range i greater than i^* and consequently reducing the difference between $P(i^*)$ and $P(i)$, the expected loss due to sub-optimality. Additionally, behavioral improvement in T3 and T4 should reduce $\min\{\overline{P}(i) - \overline{A}, 0\}$ and $\min\{\underline{P}(i) - \underline{A}, 0\}$, "burning money", and decrease the frequency of non-satisficing via $\overline{A} > \overline{P}(i)$ or $\underline{A} > \underline{P}(i)$, "committing suicide".

5 Improvement evidence

Participants differ in terms of how often they comply with improvement criteria. Obviously, some criteria apply only to some between subjects treatments, e.g., improving slider use and antimonotonicity, are verified between phases while reduction of non-improving is analyzed across phases. In the following it will be shown that most participants improve their behavior and that this is payoff enhancing.

5.1 Slider attempts, antimonotonicity and reduction of non-improving

According to Figure 3, comparing earlier and later successive slider adjustments from left to right in phases 1 (top) and 2 (bottom), slider adjustments on average become smaller when approaching the final attempt i_{t^*} .

Figure 3: Adjustments in slider attempts for all treatments

In particular, the last slider adjustments significantly reduce the distance of the actual investment from the optimal one (see Table 13 for average $i_{t^*} - i^*$, $i_{t^*-1} - i^*$, $i_{t^*-2} - i^*$ in phases 1 and 2 in Appendix A). Moreover, in phase 2, the distances of the actual investments from the optimal investments are always smaller than in phase 1 (based on the Wilcoxon Signed Rank test – WSR hereafter – the difference between phase 1 and phase 2 is significant, p -value < 0.001). Participants adjust mainly towards the optimal investment in successive slider attempts and begin to adjust the slider more carefully and more deliberately, before confirming their choice of i . Table 3 reveals that

(later) slider trials (more) significantly (at the 1% level) reduce the differences between the actual and optimal i -choice across all cases.

Table 3: Correlations between slider adjustment trials and deviations from the optimal investment

	Phase 1			Phase 2		
	$i_{t^*} - i^*$	$i_{t^*-1} - i^*$	$i_{t^*-2} - i^*$	$i_{t^*} - i^*$	$i_{t^*-1} - i^*$	$i_{t^*-2} - i^*$
Try	-0.08*** (0.01)	-0.06*** (0.01)	-0.03*** (0.01)	-0.09*** (0.01)	-0.06*** (0.01)	-0.00 (0.01)
Constant	0.88*** (0.03)	0.87*** (0.03)	0.81*** (0.05)	0.72*** (0.02)	0.70*** (0.03)	0.50*** (0.05)
Observations	4530	4516	3484	4530	4523	3209

Result 1 *Aggregate tendencies suggest improvement on slider use.*

The analysis by treatment reveals large heterogeneity of improving slider use choices in phases 1 and 2. In more detail, Table 4 indicates that the share of improving slider use significantly increases from phase 2 to phase 1 only in treatments T1 and T2.

Table 4: Correct Slider Use: movement to the optimal i^* from the penultimate to the ultimate slider use

Treatment 1 (2340 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	72.22%	76.58%	0.016
# Subjects (rule > 50%)	69 (88.46%)	68 (87.18)%	0.343
# Subjects (rule > 60%)	64 (82.05%)	62 (79.49%)	0.116
# Subjects (rule >70%)	43 (55.13%)	54 (69.23%)	0.000
Treatment 2 (2340 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	70.68%	74.87%	0.023
# Subjects (rule > 50%)	70 (89.74%)	72 (92.31%)	0.030
# Subjects (rule > 60%)	63 (80.77%)	67 (85.90%)	0.001
# Subjects (rule >70%)	48 (61.54%)	49 (62.82%)	0.523
Treatment 3 (2250 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	52.98%	48.98%	0.058
# Subjects (rule > 50%)	44 (58.67%)	37 (49.33%)	0.000
# Subjects (rule > 60%)	29 (38.67%)	31 (41.33%)	0.197
# Subjects (rule >70%)	15 (20.00%)	19 (25.33%)	0.003
Treatment 4 (2130 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	57.18%	57.65%	0.827
# Subjects (rule > 50%)	46 (64.79%)	46 (64.79%)	1.000
# Subjects (rule > 60%)	37 (52.11%)	53.52 (38%)	0.515
# Subjects (rule >70%)	16 (22.54%)	22 (30.99%)	0.000

In our view, this is due to the fact that participants in treatments T3 and T4 have to additionally

focus on improving aspiration formation, i.e. the cognitive burden of aspiration formation weaken "improving slider use" across phases. At the individual level, one can categorize individual participants on the basis of improving slider use, by distinguishing three compliance levels of at least 50%, 60% and 70%. A significant improvement from phase 1 to phase 2 applies only to subjects at the 70% compliance level in all treatments except for treatment T2 (see Table 4). These subjects, who better utilize the slider, also should improve their average performance from phase 1 to phase 2.

Timewise antimonotonicity is greatly and significantly reduced from phase 1 to phase 2 in all treatments (see Table 5). Although the percentage of anti-monotonic choices is significantly greater in the cognitively more demanding satisficing treatments, T3 and T4, the average tendencies reveal overwhelming improvement. In all treatments, some participants defined as 'anti-monotonic' in phase 1 become 'monotonic' in phase 2, i.e., learn to behave more consistently, for all compliance levels, except the 70%.

Table 5: Timewise antimonotonicity

Treatment 1			
	Phase 1	Phase 2	P-value test mean difference
Choices	39.65%	28.19%	0.000
# Subjects (rule > 50%)	30 (38%)	11 (14%)	0.000
# Subjects (rule > 60%)	15 (19%)	7 (9%)	0.000
# Subjects (rule >70%)	7 (9%)	6 (8%)	0.262
Treatment 2			
	Phase 1	Phase 2	P-value test mean difference
Choices	44.51%	37.72%	0.001
# Subjects (rule > 50%)	39 (50%)	27 (35%)	0.000
# Subjects (rule > 60%)	20 (26%)	16 (21%)	0.000
# Subjects (rule >70%)	9 (12%)	6 (8%)	0.002
Treatment 3			
	Phase 1	Phase 2	P-value test mean difference
Choices	48.29%	43.64%	0.033
# Subjects (rule > 50%)	40 (53%)	33 (44%)	0.000
# Subjects (rule > 60%)	21 (28%)	18 (24%)	0.031
# Subjects (rule >70%)	13 (17%)	14 (19%)	0.411
Treatment 4			
	Phase 1	Phase 2	P-value test mean difference
Choices	59.05%	51.79%	0.001
# Subjects (rule > 50%)	53 (75%)	46 (65%)	0.000
# Subjects (rule > 60%)	36 (51%)	30 (42%)	0.000
# Subjects (rule >70%)	26 (37%)	15 (21%)	0.262

The frequencies of casewise antimonotonicity are greatly and significantly reduced from phase 1 to phase 2 in T1 and T2 (see Table 6) but to a lesser extent in T3 and T4 where on the individual

level we observe consistent improvement between phase 1 and phase 2 only at the 50% level of compliance.

As expected, also in the more cognitively demanding casewise antimonotonicity there is an overall improvement of individual investment behavior.

Table 6: Casewise antimonotonicity

Treatment 1 (2340 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	40.5%	30.84%	0.002
# Subjects (rule > 50%)	31 (39.74%)	19 (24.36%)	0.040
# Subjects (rule > 60%)	22 (28.21%)	15 (19.23%)	0.190
# Subjects (rule >70%)	15 (19.23%)	13 (16.67%)	0.679
Treatment 2 (2340 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	44.99%	38.25%	0.028
# Subjects (rule > 50%)	41 (52.56%)	30 (38.46%)	0.078
# Subjects (rule > 60%)	29 (37.18%)	24 (30.77%)	0.401
# Subjects (rule >70%)	21 (26.92%)	15 (19.23%)	0.257
Treatment 3 (2250 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	48.50%	43.43%	0.106
# Subjects (rule > 50%)	47 (62.67%)	35 (46.67%)	0.050
# Subjects (rule > 60%)	36 (48.00%)	30 (40.00%)	0.327
# Subjects (rule >70%)	26 (34.67%)	24 (32.00%)	0.731
Treatment 4 (2130 investment choices)			
	Phase 1	Phase 2	P-value test mean difference
Choices	56.16%	51.29%	0.101
# Subjects (rule > 50%)	58 (81.69%)	47 (66.20%)	0.036
# Subjects (rule > 60%)	51 (71.83)	46 (64.79%)	0.371
# Subjects (rule >70%)	38 (53.52%)	32 (45.07%)	0.317

Result 2 *On average timewise and casewise antimonotonicity decrease from phase 1 to phase 2.*

In contrast with other behavioral improvements, we cannot compare the reduction of non-improving between phases 1 and 2.

Table 7: Non-improving frequency from phase 1 to phase 2

	T1	T2	T3	T4
# subjects	78	78	75	71
Average	3.440	4.115	6.107	6.775
s.d.	2.541	2.763	3.047	3.067

Notes: Average non-improving frequency. The non-improving individual frequency is a variable from 0 to 15.

Overall, Table 7 shows that the non-improving frequency is the smallest in treatment T1 and is

the highest in treatment T4 which requires to state the aspiration level without any information on the probability of the good or bad state.

5.2 Correlation among criteria

Pairwise correlating improvement in slider use and antimonotonicity reduction (see Table 8) reveals a significant positive correlation between slider use and casewise monotonicity in T1, T3 and T4 (in phase 2) but not T2. The correlation between slider use and timewise monotonicity is less clear in spite of the always significantly positive correlation between casewise and timewise monotonicity improvement.

Table 8: Pairwise correlation (using the threshold at 60%)

Correlation		Treatment 1		Treatment 2		Treatment 3		Treatment 4	
		Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
slider use/casewise monotonic	coeff.	0.1523	0.4772	-0.1061	-0.1105	0.2148	0.2985	0.1616	0.2731
	p-value	(0.183)	(0.000)	(0.355)	(0.336)	(0.064)	(0.009)	(0.178)	(0.021)
slider use/timewise monotonic	coeff.	0.0261	0.2848	0.0115	-0.1146	0.1293	0.2181	0.2685	0.1725
	p-value	(0.821)	(0.012)	(0.921)	(0.318)	(0.269)	(0.060)	(0.024)	(0.150)
casewise monotonic/timewise monotonic	coeff.	0.7785	0.6435	0.6418	0.762	0.5302	0.6882	0.6351	0.5346
	p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Correlations between individual dummies for a threshold of 60%.

Table 9 refines the correlation analysis between casewise and timewise monotonicity improvements by differentiating between participants with small ($<60\%$) and large ($\geq 60\%$) shares of correct slider adjustments. Correlation of monotonicity improvement is less relevant (although still significant) even for the smaller share of correct slider adjustments (lower panel in Table 8).

Table 9: Pairwise correlation (for a threshold of 60%) by slider use

share of "correct" slider choices $\geq 60\%$								
Definition of monotonic subject:	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Timewise and casewise monotonic correlation	0.832 (0.000)	0.689 (0.000)	0.645 (0.000)	0.768 (0.000)	0.704 (0.000)	0.713 (0.000)	0.574 (0.000)	0.531 (0.001)
share of "correct" slider choices $< 60\%$								
Definition of antimonotonic subject:	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Timewise and casewise antimonotonic correlation	0.603 (0.0224)	0.509 (0.044)	0.659 (0.008)	0.671 (0.024)	0.423 (0.003)	0.653 (0.000)	0.689 (0.000)	0.503 (0.003)

Notes: Correlations between individual dummies with a threshold of 60%.

Result 3 Across all four treatments, there are significant correlations between the improvement criteria regarding slider use and monotonically reacting to cases.

5.3 Experience

We consider the experience based on the improvement criteria for phases 1 and 2 by combining participants into 8 categories representing the average individual tendency of using correctly the slider use, time/casewise monotonicity with the non-improving frequency across phases.¹⁰ Table 10 reports the non-improving frequency separately for T1 and T2 and for phases 1 and 2, considering the other improving criteria.¹¹

Table 10: Non-improving frequency between phase 1 and phase 2

			Treatment 1						Treatment 2					
			Phase 1			Phase 2			Phase 1			Phase 2		
Correct slider use	Timewise monotonic	Casewise monotonic	#	Mean	S.d.	#	Mean	S.d.	#	Mean	S.d.	#	Mean	S.d.
yes	no	no	12	3.83	2.17	3	5.67	2.08	15	4.67	2.82	15	5.20	2.76
yes	no	yes	0	.	.	0	.	.	1	8.00	.	0	.	.
yes	yes	no	4	4.25	0.96	3	4.33	1.15	10	5.20	3.26	7	6.43	2.64
yes	yes	yes	48	3.21	2.65	56	2.82	2.30	37	3.46	2.65	45	2.80	1.91
no	no	no	3	3.33	2.52	4	4.25	2.63	3	5.67	3.79	1	10.00	.
no	yes	no	3	4.33	1.53	5	5.40	3.13	1	6.00	.	1	8.00	.
no	no	yes	0	.	.	0	.	.	1	7.00	.	0	.	.
no	yes	yes	8	3.50	3.51	7	5.14	3.02	10	3.30	1.70	9	6.00	2.83
			Treatment 3						Treatment 4					
			Phase 1			Phase 2			Phase 1			Phase 2		
Correct slider use	Timewise monotonic	Casewise monotonic	#	Mean	S.d.	#	Mean	S.d.	#	Mean	S.d.	#	Mean	S.d.
yes	no	no	6	6.83	4.26	4	6.00	3.16	14	6.21	3.47	11	6.82	3.16
yes	no	yes	.	.	.	.	.	.	.	.	.	1	8.00	.
yes	yes	no	4	5.75	4.35	3	6.67	5.13	10	6.00	3.27	9	6.78	3.87
yes	yes	yes	19	5.21	2.51	24	4.33	2.30	13	6.15	2.27	17	4.29	2.02
no	no	no	13	6.62	2.36	14	8.14	3.46	22	8.50	2.96	16	7.31	2.73
no	yes	no	13	6.77	3.27	9	7.11	2.57	5	5.80	3.03	10	9.70	2.41
no	no	yes	2	5.00	.	.	.	.	.	.	.	.	.	.
no	yes	yes	18	6.17	3.43	21	6.29	2.55	7	5.43	2.07	7	7.14	1.46

Notes: Dummies with 60% threshold. The non-improving individual frequency is a variable from 0 to 15.

The majority of participants are consistent (yes, yes, yes) with improving slider use and both measures of anti-monotonicity reduction, and this category invariantly has the lowest average non-improving frequency score in both T1 and T2 and both Phases 1 and 2; in particular, non-improving

¹⁰We adopt the 60% individual level of compliance per phase.

¹¹The reason for distinguishing phases 1 and 2 in Table 10 is that the categorization of the eight behavioral categories is independently performed for phase 1 and phase 2 data, i.e., an individual participant may belong in phase 2 to a different class than in phase 1.

frequency drops in average from 3.21 to 2.82 in T1 and from 3.46 to 2.80 in T2.¹² Categories with no such reduction of the average non-improving score usually contain rather few members.¹³

For treatments T3 and T4 we did not expect (see Table 10) the same low non-improving scores as for treatments T1 and T2 because participants in T3 and T4 face serious additional cognitive demands when forming aspirations $\bar{A}$ and $\underline{A}$ and trying to avoiding "burning too much money" and "committing suicide." Actually, the non-improving scores, reported in Table 10, confirm our expectations.

Nevertheless, the non-improving frequency, separately for T3 and T4 and for phase 1 and 2, show that all improvement criteria – "improving slider use", "reduced antimonotonicity" and "reduced non-improving" – are highly correlated, as in T1 and T2. Also, in this case, improving according to one criterion reliably predicts improvements in the other ones: those participants consistently in line with the improving criteria (yes, yes, yes) have the lowest non-improving score.¹⁴

Result 4 *Participants learn to react qualitatively to parameter changes, as suggested by optimality i^* .*

Altogether, we conclude that all improvement criteria – "improving slider use", "reduction of anti-monotonicity" and less "non-improving" – are highly correlated: improving according to one criterion reliably predicts improvements in the other ones, where, of course, the categorization is partly binary (only non-improving frequency is assessed numerically).

6 Success improvement

We distinguish different individual patterns based on individual compliance to improvement criteria in order to point out possible effects on reducing the sub-optimality $P(i^*) - P(i)$. We adopt the im-

¹²Table 14 (in the Appendix A) additionally controls for whether participants switch categories from phase 1 to 2. Again, the dominant categories are those with (yes, yes, yes)-participants in both phases (41 in T1 and 31 in T2), whose average non-improving score in phase 2 is 2.68 in T1 and 2.74 in T2, i.e. slightly lower than the respective phase 2-score in Table 10.

¹³An exception is phase 1 of T2 and the case (no, yes, yes), whose non-improving frequency score is 3.30 and thus smaller than the score of 3.46 for (yes, yes, yes).

¹⁴Exceptions exist is phase 1 of T4, e.g. case (no, yes, yes) with only 7 participants whose non-improving score is 5.43, less than 6.00 for (yes, yes, yes).

provement criteria, i.e. improving slider attempts, reducing timewise antimonotonicity and reducing casewise antimonotonicity which generate the 8 categories in Table 9, without explicitly referring to non-improving frequency¹⁵ but considering the relevant correlation with the other dimensions.¹⁶ Table 11, based on this 2x2x2-factorial improvement classification, i.e. the 8 rows in the upper and lower subtable, reports the average expected success $P(i)$ and the success loss $P(i^*) - P(i)$, separately for phase 1 and phase 2 (since individual participants may belong to different categories in phases 1 and 2) and treatments T1 and T2. Participants with "yes" for all three criteria represent the majority (48 or 56 in T1, and 37 or 45 in T2) with their number increasing from phase 1 to phase 2. Furthermore, the success $P(i)$ of earning €14 of this fully compliant group is generally the highest and increases from phase 1 to phase 2. For T1 and T2, this result confirms that experience enhances success.

Table 11: Success in T1 and T2

Correct slider use	Timewise monotonic	Casewise monotonic	Treatment 1											
			Phase 1								Phase 2			
			# subjects	% of the total	$P(i)$	std. dev.	$P^* - P$	std. dev.	# subjects	% of the total	$P(i)$	std. dev.	$P^* - P$	std. dev.
yes	no	no	12	15.38%	0.652	0.058	0.145	0.058	3	3.85%	0.661	0.084	0.136	0.084
yes	no	yes	0	0.00%	.	.	.	.	0	0.00%	.	.	.	.
yes	yes	no	4	5.13%	0.613	0.070	0.184	0.070	3	3.85%	0.687	0.013	0.110	0.013
yes	yes	yes	48	61.54%	0.745	0.042	0.052	0.042	56	71.79%	0.767	0.024	0.030	0.024
no	no	no	3	3.85%	0.576	0.035	0.221	0.035	4	5.13%	0.625	0.063	0.172	0.063
no	yes	no	3	3.85%	0.487	0.076	0.310	0.076	5	6.41%	0.602	0.111	0.195	0.111
no	no	yes	0	0.00%	.	.	.	.	0	0.00%	.	.	.	.
no	yes	yes	8	10.26%	0.696	0.061	0.101	0.061	7	8.97%	0.748	0.097	0.049	0.097
tot. subjects			78						78					
Correct slider use	Timewise monotonic	Casewise monotonic	Treatment 2											
			Phase 1								Phase 2			
			# subjects	% of the total	$P(i)$	std. dev.	$P^* - P$	std. dev.	# subjects	% of the total	$P(i)$	std. dev.	$P^* - P$	std. dev.
yes	no	no	15	19.23%	0.680	0.037	0.117	0.037	15	19.23%	0.703	0.052	0.094	0.052
yes	no	yes	1	1.28%	0.763		0.034		0.00%	.	.	.	.	.
yes	yes	no	10	12.82%	0.66	0.062	0.134	0.062	7	8.97%	0.687	0.043	0.110	0.043
yes	yes	yes	37	47.44%	0.737	0.037	0.060	0.037	45	57.69%	0.772	0.016	0.024	0.016
no	no	no	3	3.85%	0.590	0.051	0.207	0.051	1	1.28%	0.576		0.221	
no	yes	no	1	1.28%	0.514		0.283		1	1.28%	0.590		0.292	
no	no	yes	1	1.28%	0.725		0.072		0	0.00%	.	.	.	.
no	yes	yes	10	12.82%	0.748	0.034	0.049	0.034	9	11.54%	0.752	0.073	0.045	0.073
tot. subjects			78						78					

Notes: Dummies with a threshold of 60%.

Result 5 *In treatment T1 and T2, participants compliant with the three improvement criteria succeed in increasing the probability of earning €14, reducing the distance $P(i^*) - P(i)$. This success improvement increases from phase 1 to phase 2.*

¹⁵Thus, we obviously cannot refer separately to phases 1 and 2 and note the greater success in phase 2 than in phase 1

¹⁶In the following analysis, as in the previous, compliance with a selected criterion is calculated based on 60% average compliance.

Table 12: Success in T3 and T4

			Treatment 3 (Boom)									
			Phase 1					Phase 2				
Correct slider use	Timewise monotonic	Casewise monotonic	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$
yes	no	no	6	8%	0.287	0.092	98%	4	5%	0.092	0.161	97%
yes	no	yes	0	0%	.	.	0%	0	0%	.	.	0%
yes	yes	no	4	5%	0.290	0.149	98%	3	4%	0.205	0.210	98%
yes	yes	yes	18	25%	0.272	0.147	94%	24	33%	0.287	0.192	96%
no	no	no	13	18%	0.322	0.067	99%	14	19%	0.305	0.084	100%
no	yes	no	13	18%	0.320	0.096	98%	9	12%	0.335	0.114	98%
no	no	yes	2	3%	0.270	0.069	100%	0	0%	.	.	0%
no	yes	yes	17	23%	0.334	0.093	98%	19	26%	0.33	0.108	98%
total subjects			73					73				
			Treatment 3 (Doom)									
			Phase 1					Phase 2				
Correct slider use	Timewise monotonic	Casewise monotonic	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$
yes	no	no	5	8%	0.157	0.101	81%	4	6%	0.184	0.159	83%
yes	no	yes	0	0%	.	.	0%	0	0%	.	.	0%
yes	yes	no	4	6%	0.151	0.105	85%	3	4%	0.140	0.074	93%
yes	yes	yes	19	30%	0.276	0.111	87%	23	33%	0.285	0.182	90%
no	no	no	10	16%	0.119	0.095	68%	13	19%	0.118	0.056	73%
no	yes	no	9	14%	0.162	0.114	73%	7	10%	0.161	0.138	58%
no	no	yes	1	2%	0.246	.	100%	0	0%	.	.	100%
no	yes	yes	16	25%	0.244	0.093	88%	20	29%	0.269	0.118	80%
total subjects			64					70				
			Treatment 4 (Boom)									
			Phase 1					Phase 2				
Correct slider use	Timewise monotonic	Casewise monotonic	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$
yes	no	no	14	19.72%	0.309	0.095	98%	11	15.49%	0.302	0.125	100%
yes	no	yes	0	0.00%	.	.	0%	1	0.322%	.	.	0%
yes	yes	no	10	14.08%	0.266	0.130	99%	9	12.68%	0.226	0.134	98%
yes	yes	yes	13	18.31%	0.213	0.150	99%	17	23.94%	0.087	0.102	99%
no	no	no	22	30.99%	0.339	0.076	98%	16	22.54%	0.336	0.139	98%
no	yes	no	5	7.04%	0.309	0.053	84%	10	14.08%	0.362	0.131	97%
no	no	yes	0	0.00%	.	.	0%	0	0.00%	.	.	0%
no	yes	yes	7	9.86%	0.304	0.109	99%	7	9.86%	0.180	0.183	99%
total subjects			71					71				
			Treatment 4 (Doom)									
			Phase 1					Phase 2				
Correct slider use	Timewise monotonic	Casewise monotonic	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$	# subjects	% of the total	$P - A$ if $P > A$	std. Dev.	frequencies $P > A$
yes	no	no	12	18.46%	0.165	0.084	89%	11	16.67%	0.137	0.092	92%
yes	no	yes	0	0.00%	.	.	0%	1	1.52%	0.290	.	100%
yes	yes	no	10	15.38%	0.164	0.091	81%	8	12.12%	0.165	0.110	90%
yes	yes	yes	13	20.00%	0.146	0.081	86%	17	25.76%	0.101	0.079	91%
no	no	no	19	29.23%	0.135	0.061	77%	15	22.73%	0.155	0.079	77%
no	yes	no	4	6.15%	0.188	0.109	55%	7	10.61%	0.221	0.153	69%
no	no	yes	0	0.00%	.	.	0%	0	0.00%	.	.	0%
no	yes	yes	7	10.77%	0.238	0.092	80%	7	10.61%	0.165	0.128	85%
total subjects			65					66				

Notes: Dummies with a threshold of 60%.

Because success in T3 and T4 depends not only on the investment choice i but also on the aspirations $\underline{A}$ and $\bar{A}$, Table 12 distinguishes for the same improvement classification (the 8 rows) the average amounts of "burned money" $P - A$ when positive, separately for boom, $\bar{P}(i) - \bar{A}$, and doom, $\underline{P}(i) - \underline{A}$. In T4, the (yes, yes, yes)-group of participants with "yes" for all three binary improvement criteria "burn", on average, the least amount in boom and doom and phase 2. For T3, the effect is less pronounced.

Considering the high frequencies of "burning money" cases (see column frequencies $P > A$ in Table 12 which are almost 100% in both boom and doom) improvement in satisficing occurs

when burning less money in boom and doom. The same applies to "committing suicide", based on $\overline{P}(i) < \overline{A}$ or $\underline{P}(i) < \underline{A}$, i.e. non satisficing. Nearly all participants learn to avoid non-satisficing when transforming the visually displayed column height (see Figure 4 in Appendix A) into numerical aspirations, $\overline{A}$ and $\underline{A}$.

Result 6 *Participants compliant with the three improvement criteria succeed in reducing "burning money" ($P - A$), especially in treatment T4.*

7 Conclusions

Our previous analysis reported in — (2017) shows nearly exclusive sub-optimality, irrespective of whether optimality is interpreted as expected utility maximization or in the set-optimal sense of not being able to do better in boom without harming success in doom, or vice versa. Suboptimality is revealed by positive differences $i - i^*$ (as all $i \leq i^*$ are at least set-optimal). Further, sub-optimality is revealed by treatments eliciting aspirations via "burning money", which is still consistent with satisficing, and "committing suicide", which violates satisficing.

From this starting point, we have identified different criteria for how well participants manage to reduce sub-optimality and improve their success, for example, by letting $\max\{0, i - i^*\}$, $\overline{P}(i) - \overline{A}$ and $\underline{P}(i) - \underline{A}$, when positive, shrink. One criterion applies to successive slider attempts before confirmation. Another improvement aspect is to react qualitatively to parameter changes in the optimal investment level i^* in the sense of timewise and casewise monotonicity. Finally, individual improving can be assessed since all 15 tasks are confronted twice, once in the first phase and once in the second phase.

We have used all criteria to demonstrate that most participants systematically reduce sub-optimality and thereby considerably enhance their success. Participants still do not behave optimally, but, being only boundedly rational, they learn how to improve decision making. Actually nearly all of them become satisficers.¹⁷ Even for those participants who still score poorly in terms of the improvement

¹⁷We admit that our method of incentivizing aspiration formation by letting participants lose all chances of earning more €14, rather than only €4 is partly responsible for the striking confirmation of satisficing, at least in phase 2 of treatments T3 and T4.

criteria, it seems possible that improving how to use the slider and listen to advice, for example, that $\max\{0, i - i^*\}$ is sub-optimal, will also help them improve their decision making.

We hope to explore in future research if some sort of advice could speed up behavioral improvements and possibly avoids sub-optimality altogether.

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Appendix A

Figure 4: Investment choice in T3 and T4

Table 13: Summary results regarding slider adjustments

Variable	Phase 1			Phase 2		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
$i_{t^*} - i^*$	4530	0.551	0.745	4530	0.413	0.688
$i_{t^*-1} - i^*$	4516	0.640	0.841	4523	0.486	0.782
$i_{t^*-2} - i^*$	3484	0.659	0.824	3209	0.477	0.760
$i_{t^*-3} - i^*$	2888	0.732	0.828	2527	0.533	0.787

Table 14: Non-improving frequency by improvement criteria in phases 1 and 2

Correct slider use	Timewise monotonic Phase 1	Casewise monotonic	Treatment 1					Treatment 1				
			(no,no,no)	(no,yes,no)	(no,yes,yes)	(yes,no,no)	(yes,yes,no)	(yes,yes,yes)	(no,yes,yes)	(yes,no,no)	(yes,yes,no)	(yes,yes,yes)
no	no	no	1	1	1	1	1	1	1	10.00	2	2
		Mean	3.00	6.00				1.00			3.50	3.50
no	no	S.d.	.	.	.	.	.	.	.	.	0.71	0.71
		Obs									1	1
no	yes	no	1		1	1	1		1		7.00	
		Mean	6.00		4.00	3.00	3.00		6.00			
no	yes	S.d.	.	.	.	.	.	.	.	.	.	.
		Obs										
yes	no	yes	2	2	1	2	1	7	3	2	5	5
		Mean	3.00	3.50	3.00	4.50	5.00	2.71	4.00	3.50	2.80	2.80
yes	no	S.d.	1.41	4.95	.	0.71	.	2.93	2.65	2.12	1.10	1.10
		Obs						4		5	4	6
yes	yes	no						4.00	5.60	5.60	7.25	2.17
		Mean						2.58	1.52	1.52	2.22	1.94
yes	yes	S.d.						.	.	.	.	.
		Obs							1	1		
yes	yes	yes							8.00	8.00		
		Mean							.	.		
yes	yes	S.d.							.	.		
		Obs										
yes	yes	no						3	1	5	1	3
		Mean						4.00	8	4.20	9.00	4.67
yes	yes	S.d.						1.00	.	4.09		0.58
		Obs						41		1		31
yes	yes	yes	1	1	4	1	8.00	2.68	5	7.00		2.74
		Mean	8.00	8.00	5.00			2.25	7.20			2.03
yes	yes	S.d.	.	.	3.37	.	.	.	2.77	.	.	.
		Obs										

Notes: Dummies with 60% threshold.

INSTRUCTIONS FOR THE EXPERIMENT

(Not part of Instructions: Treatment 1)

Welcome to our experiment!

Please, read the instructions carefully.

During this experiment you will be asked to make several decisions. These decisions as well as random events will determine your earning. We will now explain the experiment and the payment mechanism.

The experiment consists of two identical phases of 18 rounds each. At the beginning of each round you are endowed with an amount of money that can be allocated in two kinds of investment: investment A and investment B. Investment A is a risk-free bond with **constant** repayment factor, **independent of the market condition**; Investment B is a risky asset whose repayment factor **changes with the market condition and the amount invested in it**.

The market can be in good or bad conditions whose probabilities are communicated in each round.

At the end of the experiment, the computer will randomly select a round and you will be paid for that round.

Once the experiment has been completed, you will be asked to answer a questionnaire whose information will be strictly reserved and will be used only anonymously and for research purposes.

Please, work in silence and do not disturb other participants. If you have some doubts, please, raise your hand and wait: one experimenter will come and help you as soon as she can.

ENJOY!

INVESTMENT CHOICE

In each round you will be endowed with an amount of money (e), which varies from round to round, that can be allocated between investment A and investment B, by moving the cursor in the bar (see screenshot). Investment A has a **constant** repayment factor (c), **independent of the market condition**; Investment B is risky and its repayment factor **changes with market condition (good or bad) and the amount invested**: specifically, the investment in B is lost in bad market condition and repays only in good market condition.

Market is in good or bad condition with known probabilities, p respectively $(1-p)$, which will be communicated in each round.

We will illustrate the choice task in the following example. This will help to familiarize with the screenshots for the investment decisions (see the figure below).

Assume that in a given round you are endowed with $e = 3$. You must choose how much to invest in the risky asset B (i) and how much to invest in the risk-free bond A ($e-i$).

The repayment factor for the risk-free bond A is 0.29 (c).

The repayment factor for the risky asset B depends on the amount you invest (i) and on the market condition, good or bad, whose probabilities, in the example, are 14% (p) and 86% ($1-p$) respectively. In particular, the repayment factor of the risky investment i is $(e-i)$ in good market condition and 0 in bad market condition.

Given the endowment (in the example, $e=3$) and the repayment factor of the risk-free bond (in the example, $c=0.29$), your investment in the risky asset (in the example, $i=1$) and your investment in the risk-free bond (in the example, $(e-i)=2$) will determine your probability of earning €14 and the complementary probability of earning €4, which both depend on good or bad market condition, as will be shortly explained.

Please, note that your choice will affect only the probability of earning €14 or €4.

In the good market condition, the probability of earning €14 is given by the sum of repayment of the risk-free investment, $c*(e-i)$, and the repayment of the risky investment, $(e-i)*i$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the good market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 80%.

In the bad market condition, the probability of earning €14 is given only by the repayment of the risk-free investment, $c \cdot (e-i)$. In the example, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the bad market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 50%.

Before making your final decision on how much to invest in the risky asset (i) you can try and visualize the effects of your choice on the probability of earning €14 in the two different market conditions by scrolling the cursor on the bar. You have several attempts before your final one. **You can move the cursor at most 6 times.** You can, of course, confirm also an earlier try. The count of your attempts is shown in the centre of the screen by the number between the two columns (in the example, 1 try). The number in the upper right corner up, instead, shows the time elapsed in the current round: for each round, you have **at most 60 seconds** to make your final choice (in the example, you still have 53 seconds left).

Warning: if you do not confirm your investment choice in time, your last choice before the time expiration will be considered.

YOUR EARNING IN THE EXPERIMENT

As already explained, in this experiment you can **earn either €14 or €4**. Your actual earning will depend on the randomly chosen payment round, on your investment decision and on the market condition in that round.

In particular, at the end of the experiment the earning of **€14 or €4** will be selected by the computer with a probability that depends on:

1. the round randomly chosen for the final payment;
2. your investment choice in that round;
3. the market condition in that round (either good or bad).

In addition, you will receive a show up fee of €4.

The total earning will be paid individually, privately and immediately after the experiment to each participant.

INSTRUCTIONS FOR THE EXPERIMENT

(Not part of Instructions: Treatment 2)

Welcome to our experiment!

Please, read the instructions carefully.

During this experiment you will be asked to make several decisions. These decisions as well as random events will determine your earning. We will now explain the experiment and the payment mechanism.

The experiment consists of two identical phases of 18 rounds each. At the beginning of each round you are endowed with an amount of money that can be allocated in two kinds of investment: investment A and investment B. Investment A is a risk-free bond with **constant** repayment factor, **independent of the market condition**; Investment B is a risky asset whose repayment factor **changes with the market condition and the amount invested in it**.

The market can be in good or bad conditions whose probabilities are unknown. Before the investment choice, you will be asked to state your expectations regarding the probabilities of market in good or bad conditions.

At the end of the experiment, the computer will randomly select a round and you will be paid for that round.

Once the experiment has been completed, you will be asked to answer a questionnaire whose information will be strictly reserved and will be used only anonymously and for research purposes.

Please, work in silence and do not disturb other participants. If you have some doubts, please, raise your hand and wait: one experimenter will come and help you as soon as she can.

ENJOY!

INVESTMENT CHOICE

In each round you will be endowed with an amount of money (e), which varies from round to round, that can be allocated between investment A and investment B, by moving the cursor in the bar (see screenshot). Investment A has a **constant** repayment factor (c), **independent of the market condition**; Investment B is risky and its repayment factor **changes with market condition (good or bad) and the amount invested**: specifically, the investment in B is lost in bad market condition and repays only in good market condition.

Market is in good or bad condition with unknown probabilities.

We will illustrate the choice task by the following example. This will help to familiarize with the screenshots for the investment decisions (see the figure below).

Assume that in a given round you are endowed with $e = 3$. You must choose how much to invest in the risky asset B (i) and how much to invest in the risk-free bond A ($e-i$).

The repayment factor for the risk-free bond A is 0.29 (c).

The repayment factor for the risky asset B depends on the amount you invest (i) and on the market condition, good or bad. In particular, the repayment factor of the risky investment i is $e-i$ in good market condition and 0 in bad market condition.

Given the endowment (in the example, $e=3$) and the repayment factor of the risk-free bond (in the example, $c=0.29$), your investment in the risky asset (in the example, $i=1$) and your investment in the risk-free bond (in the example, $(e-i)=2$) will determine your probability of earning €14 and the complementary probability of earning €4, which both depend on good or bad market condition, as will be shortly explained.

Please, note that your choice will affect only the probability of earning €14 or €4.

In the good market condition, the probability of earning €14 is given by the sum of repayment of the risk-free investment, $c*(e-i)$, and the repayment of the risky investment, $(e-i)*i$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the good market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 80%.

In the bad market condition, the probability of earning €14 is given only by the repayment of the risk-free investment, $c \cdot (e-i)$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the bad market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 50%.

Before making your final decision on how much to invest in the risky asset (i) you can try and visualize the effects of your choice on the probability of earning €14 in the two different market conditions by scrolling the cursor on the bar. You have several attempts before your final one. **You can move the cursor at most 6 times.** You can, of course, confirm also an earlier try. The count of your attempts is shown in the centre of the screen by the number between the two columns (in the example, 1 try). The number in the upper right corner up, instead, shows the time elapsed in the current round: for each round, you have **at most 60 seconds** to make your final choice (in the example, you still have 53 seconds left).

Warning: if you do not confirm your investment choice in time, your last choice before the time expiration will be considered.

Before the investment choice, in each round you will be asked to state your expectations about the market conditions. In particular, you will be asked to state your expectation regarding the market in good condition and the computer will automatically generate the complementary probability for the market in bad condition.

STATEMENT OF THE EXPECTATIONS ABOUT MARKET CONDITIONS

In each round, before your investment choice, you have to state your expectations regarding the probabilities of market in good or bad condition, as shown in the screenshot.

PROBABILITIES MARKET CONDITIONS PHASE 1 - Round 1

State your probability for good market condition.

IMPOSTA 60

The probability that the market is in bad conditions is (%) 40

CONFIRM

When inserting the probability for good market condition, clicking on "IMPOSTA" the computer automatically generates the complementary probability for bad market condition. By clicking on "Confirm", in the lower right corner of the screen, you can then proceed with your investment choice.

YOUR EARNING IN THE EXPERIMENT

As already explained, in this experiment you can **earn either €14 or €4**. Your actual earning will depend on the randomly chosen payment round, on your investment decision and on the market condition in that round.

In particular, at the end of the experiment the earning of **€14 or €4** will be selected by the computer with a probability that depends on:

1. the round randomly chosen for the final payment;
2. your investment choice in that round;
3. the market condition in that round (either good or bad).

In addition, you will receive a show up fee of €4.

The total earning will be paid individually, privately and immediately after the experiment to each participant.

INSTRUCTIONS FOR THE EXPERIMENT

(Not part of Instructions: Treatment 3)

Welcome to our experiment!

Please, read the instructions carefully.

During this experiment you will be asked to make several decisions. These decisions as well as random events will determine your earning. We will now explain the experiment and the payment mechanism.

The experiment consists of two identical phases of 18 rounds each. At the beginning of each round you are endowed with an amount of money that can be allocated in two kinds of investment: investment A and investment B. Investment A is a risk-free bond with **constant** repayment factor, **independent of the market condition**; Investment B is a risky asset whose repayment factor **changes with the market condition and the amount invested in it**.

The market can be in good or bad conditions whose probabilities are communicated in each round.

At the end of the experiment, the computer will randomly select a round and you will be paid for that round.

Once the experiment has been completed, you will be asked to answer a questionnaire whose information will be strictly reserved and will be used only anonymously and for research purposes.

Please, work in silence and do not disturb other participants. If you have some doubts, please, raise your hand and wait: one experimenter will come and help you as soon as she can.

ENJOY!

INVESTMENT CHOICE

In each round you will be endowed with an amount of money (e), which varies from round to round, that can be allocated between investment A and investment B, by moving the cursor in the bar (see screenshot). Investment A has a **constant** repayment factor (c), **independent of the market condition**; Investment B is risky and its repayment factor **changes with market condition (good or bad) and the amount invested**: specifically, the investment in B is lost in bad market condition and repays only in good market condition.

Market is in good or bad condition with known probabilities, p respectively $(1-p)$, which will be communicated in each round.

We will illustrate the choice task by the following example. This will help to familiarize with the screenshots for the investment decisions (see the figure below).

Assume that in a given round you are endowed with $e = 3$. You must choose how much to invest in the risky asset B (i) and how much to invest in the risk-free bond A ($e-i$).

The repayment factor for the risk-free bond A is 0.29 (c).

The repayment factor for the risky asset B depends on the amount you invest (i) and on the market condition, good or bad, whose probabilities, in the example, are 14% (p) and 86% ($1-p$) respectively. In particular, the repayment factor of the risky investment i is $(e-i)$ in good market condition and 0 in bad market condition.

Given the endowment (in the example, $e=3$) and the repayment factor of the risk-free bond (in the example, $c=0.29$), your investment in the risky asset (in the example, $i=1$) and your investment in the risk-free bond (in the example, $(e-i)=2$) will determine your probability of earning €14 and the complementary probability of earning €4, which both depend on good or bad market condition, as will be shortly explained.

Please, note that your choice will affect only the probability of earning €14 or €4.

In the good market condition, the probability of earning €14 is given by the sum of repayment of the risk-free investment, $c*(e-i)$, and the repayment of the risky investment, $(e-i)*i$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the good market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 80%.

In the bad market condition, the probability of earning €14 is given only by the repayment of the risk-free investment, $c \cdot (e-i)$. In the example, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the bad market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 50%.

Before making your final decision on how much to invest in the risky asset (i) you can try and visualize the effects of your choice on the probability of earning €14 in the two different market conditions by scrolling the cursor on the bar. You have several attempts before your final one. **You can move the cursor at most 6 times.** You can, of course, confirm also an earlier try. The count of your attempts is shown in the centre of the screen by the number between the two columns (in the example, 1 try). The number in the upper right corner up, instead, shows the time elapsed in the current round: for each round, you have **at most 60 seconds** to make your final choice (in the example, you still have 53 seconds left).

Warning: if you do not confirm your investment choice in time, your last choice before the time expiration will be considered.

Before the investment choice, in each round you will be asked to state the probability of earning €14 instead of €4 that would make you satisfied, both for market in good and bad condition separately. You will earn €14 with the probability that makes you satisfied if the probability implied by your investment choice i (the height of €14-column in the screenshot) is not smaller than the probability that makes you satisfied (in the screenshot your stated satisficing probability is shown by the horizontal line). On the contrary, if the probability implied by your investment choice i (the height of the €14-column in the screenshot) is smaller than the probability that makes you satisfied, you will earn €14 with 0% probability.

STATEMENT OF THE PROBABILITY OF EARNING €14 THAT MAKES YOU SATISFIED

In each round, before your investment choice, you will have to state the probability of earning €14 instead of €4 that would make you satisfied for both markets in good condition (P_{sb}) and in bad condition (P_{sc}), separately.

Warning: the probability that makes you satisfied for the market in good condition cannot be smaller than the probability for the market in bad condition.

In the example below P_{sb} is set at 60% and P_{sc} is set at 50%.

Satisficing probabilities

State the probability of earning €14 instead of €4 that would make you satisfied (be aware that the probability for market in good condition cannot be smaller than the probability for market in bad condition)

in good market condition I would be satisfied by the probability of $P_{sb}(\%)$: 60

in bad market condition I would be satisfied by the probability of $P_{sc}(\%)$: 50

CONFIRM

By clicking on "Confirm", in the lower right corner of the screen, you can then proceed with your investment choice.

Warning: you can modify the probability that makes you satisfied only once, by clicking on the button "I want to modify P_{sb} and P_{sc} ".

YOUR EARNING IN THE EXPERIMENT

As already explained, in this experiment you can **earn either €14 or €4**. Your actual earning will depend on the randomly chosen payment round, on your investment decision and on the market condition in that round and on your stated aspiration levels.

In particular, at the end of the experiment the earning of **€14 or €4** will be selected by the computer with a probability that depends on:

1. the round randomly chosen for the final payment;
2. your investment choice in that round;
3. the market condition in that round (either good or bad);
4. whether the probability of earning €14 that makes you satisfied is achieved in the following way:
 - a) If the probability of earning €14 that makes you satisfied is achieved, the probability of earning €14 is equal to your satisficing probability for the market condition of the round randomly chosen.

In the example, the market in good condition and the investment choice $i=1$ determine a probability of 80% of earning €14. Since the stated satisficing probability for the market in good condition is 60%, the result is the following:

 - You achieved the stated satisficing probability of 60%;
 - You earn €14 with probability 60% and €4 with probability 40%.
 - b) If the probability of earning €14 that makes you satisfied is not achieved, the probability of earning €14 is 0%.

In the example, in case of market in bad condition and the investment choice $i=1$, the result is the following:

 - You earn €14 with probability 0%, which means that you earn €4 with probability 100%.

In addition, you will receive a show up fee of €4.

The total earning will be paid individually, privately and immediately after the experiment to each participant.

INSTRUCTIONS FOR THE EXPERIMENT

(Not part of Instructions: Treatment 4)

Welcome to our experiment!

Please, read the instructions carefully.

During this experiment you will be asked to make several decisions. These decisions as well as random events will determine your earning. We will now explain the experiment and the payment mechanism.

The experiment consists of two identical phases of 18 rounds each. At the beginning of each round you are endowed with an amount of money that can be allocated in two kinds of investment: investment A and investment B. Investment A is a risk-free bond with **constant** repayment factor, **independent of the market condition**; Investment B is a risky asset whose repayment factor **changes with the market condition and the amount invested in it**.

The market can be in good or bad conditions whose probabilities are unknown.

At the end of the experiment, the computer will randomly select a round and you will be paid for that round.

Once the experiment has been completed, you will be asked to answer a questionnaire whose information will be strictly reserved and will be used only anonymously and for research purposes.

Please, work in silence and do not disturb other participants. If you have some doubts, please, raise your hand and wait: one experimenter will come and help you as soon as she can.

ENJOY!

INVESTMENT CHOICE

In each round you will be endowed with an amount of money (e), which varies from round to round, that must be allocated between investment A and investment B, by moving the cursor in the bar (see screenshot). Investment A has a **constant** repayment factor (c), **independent of the market condition**; Investment B is risky and its repayment factor **changes with market condition (good or bad) and the amount invested**: specifically, the investment in B is lost in bad market condition and repays only in good market condition.

Market is in good or bad condition with unknown probabilities.

We will illustrate the choice task by an example. This will help to familiarize with the screenshots for the investment decisions (see the figure below).

Assume that in a given round you are endowed with $e=3$. You must choose how much to invest in the risky asset B (i) and how much to invest in the risk-free bond A ($e-i$).

The repayment factor for the risk-free bond A is 0.29 (c).

The repayment for the risky asset B depends on the amount you invest (i) and on the market condition, good or bad. In particular, the repayment factor of the risky investment i is $e-i$ in good market condition and 0 in bad market condition.

Given the endowment (in the example, 3) and the repayment factor of the risk-free bond (in the example, 0.29), your investment in the risky asset (i) and your investment in the risk-free bond ($e-i$) will determine your probability of earning €14 and the complementary probability of earning €4, which both depend on good or bad market condition.

Please, note that your choice will affect only the probability of earning €14 or €4.

In the good market condition, the probability of earning €14 is given by the sum of repayment of the risk-free investment, $c*(e-i)$, and the repayment of the risky investment, $(e-i)*i$. In the screenshot, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the good market condition. In the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 80%.

In the bad market condition, the probability of earning €14 is given only by the repayment of the risk-free investment, $c*(e-i)$. In the example, the probability of earning €14, calculated by the computer, is represented by the height of the column corresponding to the bad market condition. In

the example, given the investment choice of $i=1$ in the risky asset and $(e-i)=2$ in the risk-free bond, the probability of earning €14 is approximately 50%.

Before making your final decision on how much to invest in the risky asset (i) you can try and visualize the effects of your choice on the probability of earning €14 in the two different market conditions by scrolling the cursor on the bar. You have several attempts before your final one. **You can move the cursor at most 6 times.** You can, of course, confirm also an earlier try. The count of your attempts is shown in the centre of the screen by the number between the two columns (in the example, 1 try). The number in the upper right corner up, instead, shows the time elapsed in the current round: for each round, you have **at most 60 seconds** to make your final choice (in the example, you still have 53 seconds left).

Warning: if you do not confirm your investment choice in time, your last choice before the time expiration will be considered.

Before the investment choice, in each round you will be asked to state the probability of earning €14 instead of €4 that would make you satisfied, both for market in good and bad condition

separately. You will earn €14 with the probability that makes you satisfied if the probability implied by your investment choice i (the height of €14-column in the screenshot) is not smaller than the probability that makes you satisfied (in the screenshot your stated satisficing probability is shown by the horizontal line). On the contrary, if the probability implied by your investment choice i (the height of the €14-column in the screenshot) is smaller than the probability that makes you satisfied, you will earn €14 with 0% probability.

STATEMENT OF THE PROBABILITY OF EARNING €14 THAT MAKES YOU SATISFIED

In each round, before your investment choice, you will have to state the probability of earning €14 instead of €4 that would make you satisfied for both markets in good condition (P_{sb}) and in bad condition (P_{sc}), separately.

Warning: the probability that makes you satisfied for the market in good condition cannot be smaller than the probability for the market in bad condition.

In the example below P_{sb} is set at 60% and P_{sc} is set at 50%.

Satisficing probabilities

State the probability of earning €14 instead of €4 that would make you satisfied (be aware that the probability for market in good condition cannot be smaller than the probability for market in bad condition)

in good market condition I would be satisfied by the probability of $P_{sb}(\%)$: 60

in bad market condition I would be satisfied by the probability of $P_{sc}(\%)$: 50

CONFIRM

By clicking on "Confirm", in the lower right corner of the screen, you can then proceed with your investment choice.

Warning: you can modify the probability that makes you satisfied only once, by clicking on the button "I want to modify P_{sb} and P_{sc} ".

YOUR EARNING IN THE EXPERIMENT

As already explained, in this experiment you can **earn either €14 or €4**. Your actual earning will depend on the randomly chosen payment round, on your investment decision and on the market condition in that round.

In particular, at the end of the experiment the earning of **€14 or €4** will be selected by the computer with a probability that depends on:

1. the round randomly chosen for the final payment;
2. your investment choice in that round;
3. the market condition in that round (either good or bad);
4. whether the probability of earning €14 that makes you satisfied is achieved in the following way:
 - a) If the probability of earning €14 that makes you satisfied is achieved, the probability of earning €14 is equal to your satisficing probability for the market condition of the round randomly chosen.

In the example, the market in good condition and the investment choice $i=1$ determine a probability of 80% of earning €14. Since the stated satisficing probability for the market in good condition is 60%, the result is the following:

 - You achieved the stated satisficing probability of 60%;
 - You earn €14 with probability 60% and €4 with probability 40%.
 - b) If the probability of earning €14 that makes you satisfied is not achieved, the probability of earning €14 is 0%.

In the example, in case of market in bad condition and the investment choice $i=1$, the result is the following:

 - You earn €14 with probability 0%, which means that you earn €4 with probability 100%.

In addition, you will receive a show up fee of €4.

The total earning will be paid individually, privately and immediately after the experiment to each participant.