Risk-Taking under Limited Liability: Quantifying the Role of Motivated Beliefs

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Abstract

This paper investigates whether limited liability affects risk-taking through motivated beliefs. To do so, we run a within-subject experiment in which subjects invest in a risky asset under full or limited liability. In both cases, before the investment is made, subjects observe a noisy signal that indicates whether the investment will succeed or fail. They then state the likelihood of the investment's success and decide how much to invest. Our results show a strong effect of limited liability on both the investment decision and the formation of motivated beliefs. Compared to subjects under full liability, subjects under limited liability not only invest larger amounts but are also significantly more optimistic about the success of their investments. Finally, we show that more than one-third of the increase in investment under limited liability can be explained through motivated beliefs.

Keywords: Limited Liability; Motivated Beliefs; Experiment
JEL classification: C91; D84; G11; G41

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1 Introduction

There is a vast psychological literature showing that people will distort their beliefs to reach conclusions they want to arrive at (e.g., Hastorf and Cantril, 1954; Messick and Sentis, 1979; Kunda, 1990). Some of the reasons behind these self-serving beliefs can be to maintain a positive self-image in the face of some morally questionable action or to rationalize actions that conflict with one's beliefs (Festinger, 1957). Such belief distortion not only affects many aspects of our daily life but can also have a social impact if an entire sector of the economy or certain regulatory agencies become blind to unpleasant realities or mounting risks (Bénabou and Tirole, 2016).

An example would be the recent financial crisis: it has been argued that one of the main causes was excessive risk-taking (Brunnermeier, 2009; Taylor et al., 2010). Yet while some authors argue that such behavior could come from the implicit and explicit guarantees inherent in the financial sector (Hakenes and Schnabel, 2014), others argue that investors modified their beliefs to take larger risks while still maintaining a positive self-image (Barberis, 2013; Bénabou, 2015).[1] If the connection between motivated beliefs and risk-taking has the effects suggested by this latter literature, then this connection would be a clear example of individual biases spilling over into a social phenomenon.

In this paper, we try to quantify the effects of such motivated beliefs on the risk-taking of financial investors. To do so, we design a within-subject experiment similar to Ahrens and Bosch-Rosa (2019) in which the authors find experimental evidence of motivated beliefs under limited liability. To be more precise, in our setup, subjects are given a fixed endowment to invest in a binary risky asset. Before this decision is made, a noisy signal indicates whether the investment will succeed or fail. Subjects first state their beliefs about the likelihood that the investment will succeed and then decide how much of their endowment to invest in it. If the investment is successful, then the investor always receives all the gains. If the investment fails, then the distribution of losses will depend on the treatment. In the *Baseline* (*BL*) treatment, the investor internalizes all losses arising from her risky investments, while in the limited liability treatments (*Matched* (*MA*) and *Diffusion* (*DF*)), such losses will be shared with other (passive) subjects.

There are several differences between the design of Ahrens and Bosch-Rosa (2019) and ours. First, while Ahrens and Bosch-Rosa (2019) run a between-subject design, we follow a within-subject design. This allows us to compare *almost identical investment opportunities* under full and limited liability for the same subject (see Section 2.1 for further details). Additionally, we introduce a new type of signal that allows us to study beliefs with a less noisy signal than in Ahrens and Bosch-Rosa (2019). Finally, while Ahrens and Bosch-Rosa (2019) stops at the detection of motivated beliefs under limited liability, we proceed to quantify the effects that such beliefs have on the risk-taking decisions of investors.

Additionally, we are interested in studying how the "diffusion" of responsibility affects the behavior of investors. To do so, all investors go through the two limited liability treatments mentioned above, *MA* and *DF*. In the first case, each investor is matched to a single passive subject with whom she shares the losses. In the second, the losses of all investors are pooled and are equally paid by all passive subjects in the session. Based on the results of Falk and Szech (2017), Sutter et al. (2016), and

[1] Notice that these are not mutually exclusive reasons but are instead most likely complementary.

Behnk et al. (2017), we hypothesize that the diffusion of responsibility across decision-makers allows for "more room" to form motivated beliefs and therefore allows for decision-makers to self-justify morally incorrect behavior.

Our results are straightforward. First, we replicate the observation of Ahrens and Bosch-Rosa (2019) that limited liability leads to investors forming motivated beliefs. For an almost identical investment opportunity, investors form more optimistic beliefs under limited liability than under full liability. Second, using mediator analysis (Imai et al., 2011, 2013), we are able to isolate and quantify the causal effect that limited liability has on the investment decisions through the changes in beliefs. In other words, we can measure how much of the change in investment, from full to limited liability, is due to motivated beliefs. Finally, we are not able to find any effect of diffusion of responsibility in the invested amounts under limited liability, nor on the formation of motivated beliefs.

Our study contributes to several strands of the literature. The first one is on the use of self-serving beliefs and motivated reasoning to justify selfish actions while still maintaining a positive self-image. Some examples are Exley (2016), who shows that individuals use risk as an *excuse* to give less to charity, or Gneezy et al. (2018), who demonstrate that subjects use motivated beliefs to (self-) justify corrupt behavior. More closely related to our study is Ahrens and Bosch-Rosa (2019), who detect the formation of motivated beliefs under limited liability in a similar between-subject design. In this paper, we confirm their results in a stronger *within-subject* design, but most importantly, we are able to isolate and quantify the causal effects of limited liability on investment taking, as suggested by Barberis (2013), Bénabou (2013), or Bénabou (2015).

We also contribute to the literature on the diffusion of responsibility and morals in markets (Falk and Szech, 2013; Sobel, 2007). Recent studies have shown that the diffusion of responsibilities among several agents increases anti-social behavior (Behnk et al., 2017; Bartling et al., 2015; Falk and Szech, 2017). Contrary to their results, we find no difference in the behavior of subjects when the effects of selfish decision are diffused across all decision-makers.

This paper is structured as follows. Section 2 explains the study's experimental design. Section 3 shows the experiment's results. Section 4 debates several limitations of our study, and Section 5 concludes.

2 Experimental Design

The experiment follows a within-subject design in which each subject participates in three different treatments: *BL*, *MA*, and *DF*. Each treatment has ten rounds, and for each round, subjects receive an endowment of €8. The subjects' task in each round is to decide what percentage of the endowment they want to invest in a risky asset. This asset asset yields a gain of $0.75X$ if the investment is successful and yields a loss of X if the investment fails (where $X \in [€0; €8]$ is the amount invested in the risky asset).

Before each round, subjects receive a noisy signal that gives them a hint on whether the investment will succeed or fail (see Section 2.1 for details on the signal). The three treatments differ in how the loss is distributed among the subjects (see Section 2.2). Importantly, to avoid any hedging, at the end of the experiment, we randomly determine which of the decisions become payoff relevant. To avoid learning and income effects, subjects receive no feedback on the outcomes of their decisions until the end of the experiment. Also, to avoid for potential order effects (e.g., learning effects or treatment spillovers), we run three orders of treatments.[2]

Finally, after the three treatments have occurred, subjects take part in a battery of personality elicitation tasks. These include measures of cognitive ability, overestimation, overplacement, overprecision, risk aversion, and loss aversion (see Appendix A for details on how exactly we elicit the additional variables). Additionally, subjects also answer some demographic questions on their field of study, gender, and age. After answering, subjects were finally shown a summary of the experimental outcomes and their individual payoffs.

2.1 Signal

As previously mentioned, before each investment decision, subjects receive a noisy signal that indicates whether the investment will succeed or fail. This signal consists of a 20x20 matrix containing red and blue dots, and it is flashed to subjects for eight seconds (see Figure 1 for an example).

The number of red dots in Figure 1 depends on the outcome of the investment for that round. Subjects are told that at the beginning of each round, the computer will determine with probability p = 1/2 whether the investment succeeds or not. If the investment succeeds, then the signal shown will contain more red dots than blue dots; if the investment fails, then the signal will contain more blue dots than red dots. Importantly, the number of red or blue dots was not the same for each period and would range from 120 red (blue) dots to 280 red (blue) dots.

Because subjects do not have sufficient time to count the dots, they can form subjective beliefs about the success of the investment. Immediately after seeing each matrix, subjects state their estimated success probability of the investment and make their investment decision for the round. Hence, for every round, we have the stated success probability of the investment and the investment decision of each subject, conditional on the signals they saw. For more details on the exact number of red dots shown and the ordering of the signals, see Appendix C.

2.2 Treatments

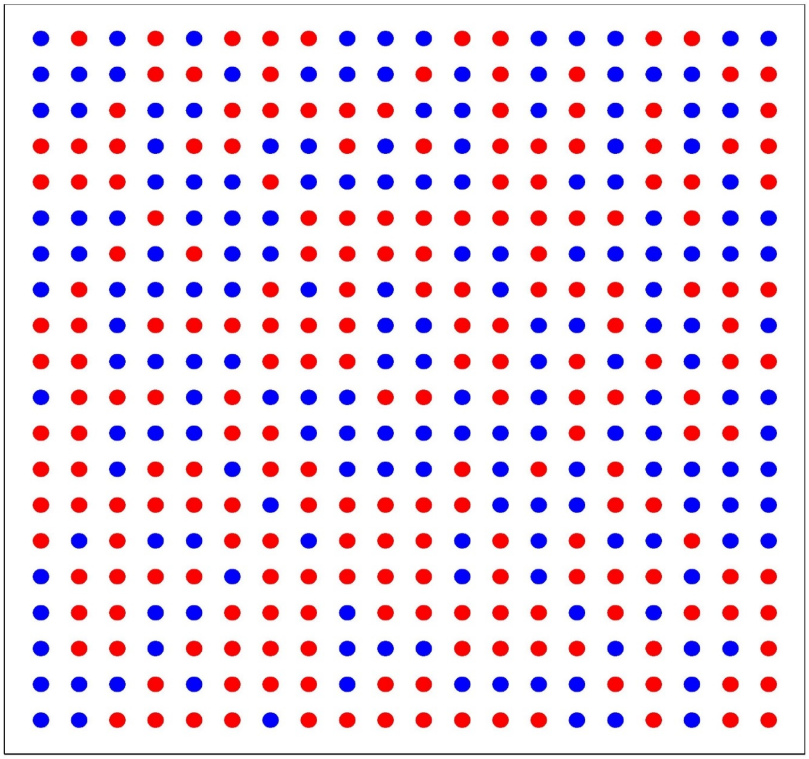
Baseline: In the *BL* treatment, there is no moral hazard, as each subject absorbs any profits or losses. Therefore, subject i wins $0.75X_i$ if his investment is successful and loses X_i if it fails. Hence, in *BL*, subject i's payoff P_i^{BL} is given by

$$P_i^{BL} = \begin{cases} €8 + 0.75 \times X_i^{BL} & \text{if the investment of } i \text{ is successful.} \\ €8 - 1.00 \times X_i^{BL} & \text{if the investment of } i \text{ fails.} \end{cases} \quad (1)$$

Matched: In the *MA* treatment, half of the subjects are randomly assigned the role of "bankers" and the other half are "loss-takers." Subjects are anonymously and randomly matched such that every

[2]These orders are 1) *BL*, *MA*, *DF*; 2) *MA*, *DF*, *BL*; and 3) *DF*, *MA*, *BL*.

Figure 1: Dot Spot



A Dot Spot with 215 red dots and 185 blue dots.

banker b $\in \{1, 2, ..., B\}$ is associated with exactly one loss-taker t $\in \{1, 2, ..., T\}$. Subjects know their type and that both the matches and the player types will be kept for the whole treatment.[3,4]

In this setup, the investment of the banker, X_b, affects the payoff of her matched loss-taker if and only if the investment fails. So, if the investment is successful, then the banker gains $0.75X_b$ on top of her initial endowment and the loss-taker gets to keep her initial endowment intact. On the other hand, if the investment fails, then the banker loses $0.25X_b$, while the loss-taker gets $0.75X_b$ subtracted from her endowment for the round.

Hence in MA, the payoff of banker b for investment X_b is

$$P_b^{MA} = \begin{cases} €8 + 0.75 \times X_b^{MA} & \text{if the investment of } b \text{ is successful.} \\ €8 - 0.25 \times X_b^{MA} & \text{if the investment of } b \text{ fails,} \end{cases} \tag{2}$$

[3]Subjects kept the same type across treatments, but because we kept subjects in the dark about future treatments, they did not know this until the beginning of the following (limited liability) treatment.

[4]An alternative to this design would have been to make all subjects invest under all treatments and only randomly decide at the end of the experiment which subject is a banker and who is a loss-taker. This would have provided us with more observations. However, we decided against this design, as it possibly would have distorted our treatment effects. For example, in this alternative design, subjects might have been more considerate of loss-takers when making their investment decisions because they are potentially a loss-taker themselves.

while the payoffs for loss-taker t are

$$P_t^{MA} = \begin{cases} €8 & \text{if the investment of } b \text{ is successful.} \\ €8 - 0.75 \times X_b^{MA} & \text{if the investment of } b \text{ fails.} \end{cases} \tag{3}$$

Both payoffs, P_b^{MA} and P_t^{MA}, are explained in detail to all subjects before the start of the *MA* treatment. Because the payoffs of a loss-taker t depend on the investment of her matched banker b (see Eq. 3), all bankers are informed that their investment decisions can only have negative effects on loss-takers.

Diffusion: In the *DF* treatment, the decision of each individual banker might influence the payoffs of *all* loss-takers. In this case, if the banker's investment is successful, then she gains $0.75X_b$ in addition to her initial endowment of €8. Yet, if the investment fails, then the banker loses $0.25X_b$ and *all loss-takers* evenly share the loss of $0.75X_b$. Hence, the payoffs of banker b in *DF* is equivalent to that in *MA* (see Eq. (2)), while the payoffs for loss-takers is

$$P_t^{DF} = €8 - \frac{0.75}{T} \times \sum_{b=1}^{B} (\mathbb{1}_{\mathbb{b}}^{\mathbb{DF}} X_b^{DF}), \tag{4}$$

where T is the number of loss-takers in the experimental session, B is the number of bankers in the experimental session, and $\mathbb{1}_{\mathbb{b}}^{\mathbb{DF}}$ is an indicator variable that takes on the value of one if banker b's investment fails and zero otherwise.

This treatment was introduced to study how the diffusion of responsibility affects the moral behavior of bankers. Based on the results of Falk and Szech (2017), Sutter et al. (2016), and Behnk et al. (2017), we hypothesize that the diffusion of responsibility across decision-makers allows for "more room" to form motivated beliefs and therefore for decision-makers to self-justify morally incorrect behavior. With this treatment, we therefore contribute to both the literature of morals and markets (Sobel, 2007; Falk and Szech, 2013) and the diffusion of responsibility (Falk and Szech, 2017).

2.3 Practice and Risk Rounds

To facilitate the understanding of the payoffs, and to get subjects acquainted with the interface before the experiment starts, subjects participate in five practice rounds. These practice rounds are identical to the first treatment of an experiment,[5] except (i) subjects are informed that the practice rounds have no monetary consequences and (ii) subjects receive full feedback regarding their choices.

Additionally, before each treatment starts, all subjects take part in a risky investment task. In this task, subjects make 11 independent investment decision for 11 different assets, each of which with a given probability of success (0%, 10%, 20%, ..., 100%). Each of these investments is independent, and for each of them, we provide subjects with up to €8 to invest. The payoff structure is exactly like that of the treatment (*BL*, *MA*, *DF*), and the banker and loss-taker roles are maintained. Thus,

[5] Recall that we run three orders of treatments: 1) *BL*, *MA*, *DF*; 2) *MA*, *DF*, *BL*; and 3) *DF*, *MA*, *BL*). Accordingly, order 1 had practice rounds for *BL*, order 2 had practice rounds for *MA*, and order 3 had practice rounds for *DF*.

the only difference between the risk and the treatments (BL, MA, and DF) is that with risk, bankers *know* their success probabilities. Again, to avoid hedging across investments, only 1 of the 11 different investments will count toward the final payoffs, and to avoid any wealth effects, this payoff will only be revealed once the experiment is over.

Introducing the risk investment task not only allows us to use it as a robustness test for our instrumental variable (IV) approach in Section 3.3, but it also allows us to control in case subjects make different decision under *uncertainty* than under *risk*, for example, due to ambiguity aversion. Additionally, starting each treatment with a simplified version of the task might help subjects think more about the payoff structure and the different outcomes of that treatment.

3 Results

A total of 178 subjects were recruited through ORSEE (Greiner, 2004). Of these, 58 participated in order 1 (*BL*, *MA*, *DF*), 60 in order 2 (*MA*, *DF*, *BL*), and 60 in order 3 (*DF*, *MA*, *BL*).[6] Sessions lasted roughly 130 minutes and were conducted at the Experimental Economics Laboratory of the Technische Universität Berlin. Subjects earned, on average, €32, and the experiment was programmed and conducted using oTree (Chen et al., 2016). For the entire results section, we only analyze the decisions made by bankers. In addition, because we are mainly interested in investments under uncertainty, we relegate any results of the risky investments to Appendix B, as they are qualitatively similar to the results of investment under ambiguity described in Section 3.1.

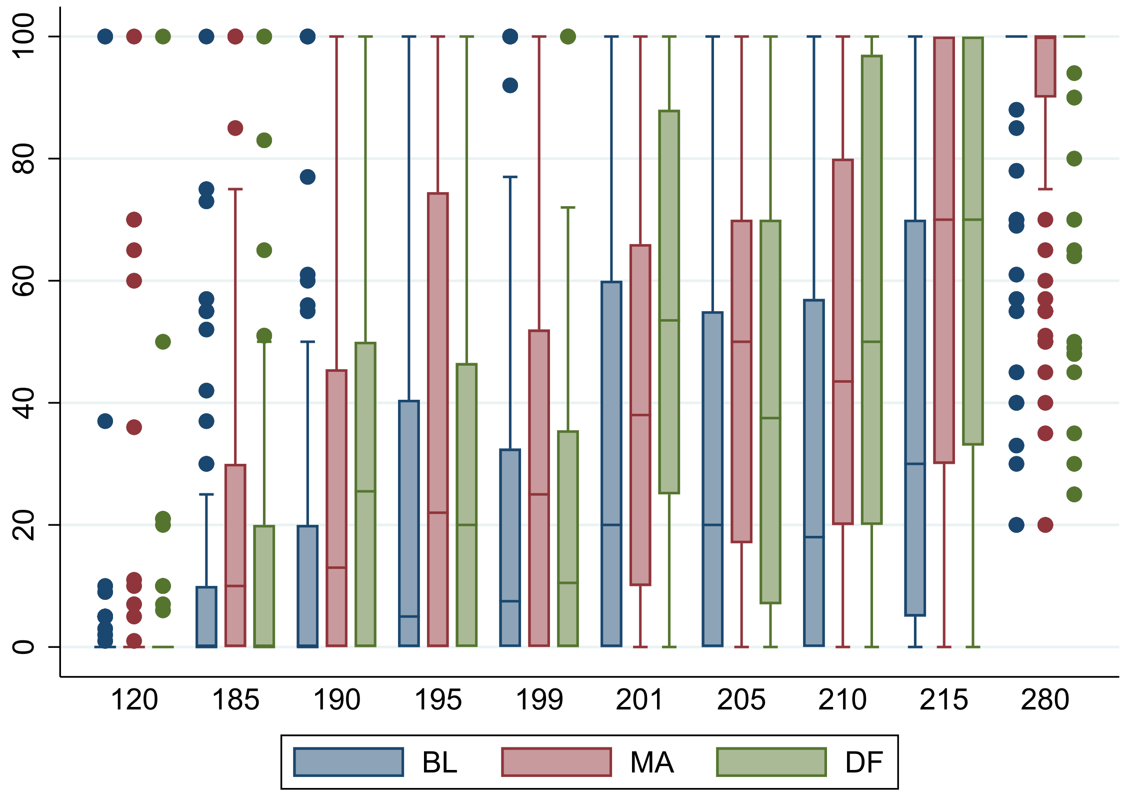
3.1 Treatment Effects on Investment

In this subsection, we investigate the effects of the treatments (*BL*, *MA*, *DF*) on the investment levels. Because we expect subjects to care more about their own monetary payoffs than about the payoffs of others, we hypothesize that the limited liability treatments, *MA* and *DF*, both lead to higher investment levels than the *BL* treatment. To compare the two limited liability treatments, we hypothesize that subjects invest more in the *DF* treatment, where the losses of an investment are distributed among many loss-takers. For a selfish banker (i.e., one that only cares about her own monetary payoffs), the two limited liability treatments provide exactly the same incentives. However, we hypothesize in Section 2.2 that bankers might invest more if the concerns for the agents covering the losses get diluted so that an individual loss-taker is not heavily affected by the individual banker's decision.

In Figure 2, we present the bankers' investments for each of the three treatments for each observed hint. The vertical axis illustrates the investment made by bankers as a percentage share of their endowment, while the horizontal axis represents the number of red dots shown in the matrix. The box plots show that the more red dots a matrix has, the more bankers invested in the asset, suggesting that the variations in the number of red dots carry informational content and influence the bankers' decisions.

[6] We ran nine sessions in total. Eight sessions had 20 subjects and thus had 10 loss-takers and 10 bankers. The ninth session only had 18 subjects (9 bankers and 9 loss-takers) due to subjects not showing up to the session.

Figure 2: Investments for Given Numbers of Red Dots



Investments made by bankers. The vertical axis represents the investment made as a percentage of the endowment. The horizontal axis shows the number of red dots in a Dot Spot. For each number of red dots, we show a box plot for every treatment (*BL*, *MA*, *DF*).

Figure 2 also points toward bankers investing more under limited liability (*MA* and *DF*) than in the *BL* treatment. This is confirmed in Table 1, where we present the mean investments across treatments; while bankers invest, on average, only 27.9% of their endowment in the *BL* treatment, in the limited liability cases, they invest 41.4% and 39.3% in *MA* and *DF*, respectively.

To better understand the differences across treatments, in Table 2 we present the results of within-subject Wilcoxon signed-rank tests, comparing investments across treatments and hints.[7] The p-values of the within-subject Wilcoxon signed-rank tests comparing the *total* amount invested in the treatments (first column on the left) clearly indicate that there are significant investment differences between *MA* and *BL* as well as between *DF* and *BL* (p-value < 0.001 in both cases). Also, while we observe substantial effects of limited liability compared to the *BL* treatment, there are no significant

[7] Recall from Section 2.1 that for each treatment (*BL*, *MA*, *DF*), a banker might see, up to two times, an image with the same number of dots. For example, a banker might see a Dot Spot with 195 red dots twice in *BL*, never in *MA*, and once in *DF*. In this case, for the Dot Spot with 195 red dots, this banker's data would neither be used for the comparisons between *MA* and *BL* nor for the comparisons between *MA* and *DF*. In the case a subject sees twice an image in the same treatment for a given number of red dots, we take the average between both investments for the comparison with the other treatment(s).

Table 1: Mean Investments for Dot Spots

	Total	120	185	190	195	199	201	205	210	215	280
BL	27.88	2.64	9.03	15.94	21.75	20.72	33.82	33.52	29.55	39.85	89.59
	(36.30)	(14.05)	(19.40)	(26.22)	(30.31)	(28.82)	(37.33)	(36.59)	(33.05)	(37.13)	(21.95)
MA	41.44	4.73	21.02	27.28	36.16	32.95	41.93	47.43	49.29	61.37	88.47
	(38.80)	(17.28)	(29.86)	(33.29)	(39.13)	(33.79)	(36.01)	(34.91)	(35.26)	(35.12)	(21.23)
DF	39.27	2.82	13.36	28.88	27.54	21.66	53.07	41.55	51.75	61.85	91.40
	(38.41)	(12.06)	(22.13)	(28.34)	(29.80)	(27.17)	(35.11)	(35.64)	(37.32)	(36.81)	(19.84)

Mean investments as a percentage share of the endowment. The column *Total* shows the aggregated average of all investments in a treatment. The other columns show the average investment for a given number of red dots in the Dot Spot. Standard Deviations are shown in parentheses.

Table 2: Wilcoxon Signed-Rank Tests for Dot Spots

	Total	120	180	190	195	199	201	205	210	215	280
p-**value BL = MA**	<0.001	0.406	0.001	0.032	0.052	0.009	0.027	0.002	<0.001	<0.001	0.305
p-**value BL = DF**	<0.001	0.019	0.019	0.015	0.166	0.043	<0.001	0.004	<0.001	<0.001	0.075
p-**value DF = MA**	0.286	0.993	0.543	0.713	0.455	0.632	0.343	0.520	0.392	0.288	0.220

The p-values comparing (paired) investments across treatments. We compare the aggregate investment for the same banker for the subset of similar Dot Spots (i.e., Dot Spots with the same number of red dots) that the banker sees in both treatments that are being compared. Note that, unlike in Table 1 and Figure 2, we thus only use a subset of banker data in Table 2.

differences between the *MA* and *DF* treatments. This is confirmed by comparing the total amounts invested in *MA* and *DF* (p-value = 0.286).

Overall, when studying the effects of our different treatments, we find two clear results. First, the limited liability treatments have a significant positive effect on the level of risk-taking of bankers. Second, we cannot reject the null hypothesis that the investment levels in *MA* and *DF* are the same. We can thus summarize the results of Section 3.1 in Result 1:

Result 1 *Treatment Effects on Investment*

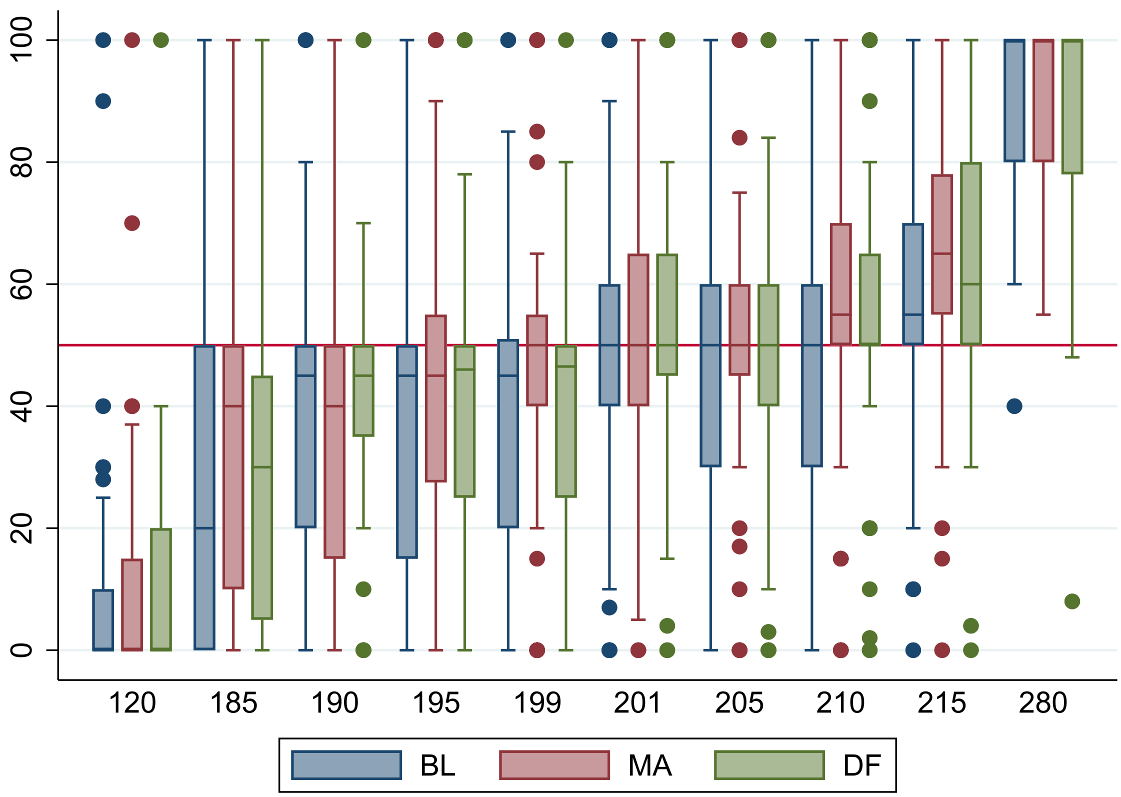
i) The investments in the limited liability treatments, MA and DF, are both significantly larger than in the BL treatment.

ii) The investment levels in both limited liability treatments are similar, and we cannot reject the null hypothesis that there are no differences in investment levels between MA and DF.

3.2 Treatment Effect on Beliefs

This subsection studies the effects of limited liability on the beliefs of bankers. Figure 3 plots the stated success probabilities of bankers for each Dot Spot type of matrix and for each treatment. The first thing to notice is that the signal is hard to interpret. As we can see, even if there is a slight upward trend, for most of the matrices, bankers report values close to the prior (50% probability of success) and only strongly deviate from the prior in the most extreme cases (120 and 280 red dots). Interestingly, it is only when the Dot Spots show more than 200 red dots that the median subject reports a success probability of 50% or more; before that, the median expected success is below 50%.

Figure 3: Stated success probabilities for Given Numbers of Red Dots



Stated success probabilities made by bankers. The vertical axis represents the subjective likelihood taht the investment will be successful as a probability between 0 and 100. The horizontal axis shows the number of red dots in a Dot Spot shown. For each number of red dots, we show a box plot for every treatment (BL, MA, DF). The red horizontal line marks the 50% probability of success.

Yet, when comparing the stated probabilities for each Dot Spot across treatments using a Wilcoxon signed-rank tests, we do not see any significant differences. As in Ahrens and Bosch-Rosa (2019), the differences in beliefs appear once we pool the data to run regressions. In columns (1) to (3) of Table 3, we use our balanced panel of 89 bankers and 30 rounds to regress the estimated success probability of bankers ($Prob$) on a dummy variable for the different treatments (MA and DF), a dummy for the number of dots in each matrix, and all of the personality and order controls.

The results show that the variation in the number of red dots has a large impact on the beliefs: for example, the perceived success probabilities in specification (3) are, on average, 32.9 percentage points larger for a matrix with 195 red dots (*195.dots*) than for a matrix with 120 red dots. But most importantly, in all specifications the treatment variables MA and DF are statistically significant and positive. This indicates that in both limited liability treatments, bankers are more optimistic about the success of their investments.

The difference between columns (1) and (2) is that in the second, we include the personality controls described in Appendix A. Interestingly, none of the controls has any explanatory power, so we omit them from the table. The difference between columns (2) and (3) is the inclusion of a dummy for gender. Because in one session we did not record the gender of subjects, column (3) has less observations than columns (1) and (2).

In column (4), we only use the data for moral hazard treatments (*MA* and *DF*) to test for any differences in the formation of motivated beliefs. As in Tables 1 and 2, there is no difference between both treatments, as *DF* is not significantly different from zero.

Result 2 *Treatment Effects on Beliefs*

i) The subjective success probability of investments in the limited liability treatments, MA and DF, are both significantly larger than in the BL treatment.

ii) The subjective success probability of investments in both limited liability treatments are similar, and we cannot reject the null hypothesis that there are no differences in investment levels between MA and DF.

Dep. Variable: *Prob*	(1)	(2)	(3)	(4)
MA	4.031***	4.034***	3.971***	
	(1.112)	(1.113)	(1.194)	
DF	2.703**	2.705**	3.070**	-0.917
	(1.096)	(1.097)	(1.191)	(1.230)
185.dots	19.05***	19.06***	19.30***	21.60***
	(1.918)	(1.935)	(2.029)	(2.396)
190.dots	29.16***	29.08***	27.94***	27.61***
	(2.159)	(2.161)	(2.303)	(2.400)
195.dots	32.18***	32.12***	32.97***	34.86***
	(2.449)	(2.477)	(2.615)	(2.795)
199.dots	32.69***	32.66***	31.02***	32.88***
	(2.463)	(2.448)	(2.486)	(2.688)
201.dots	44.19***	44.12***	42.34***	43.30***
	(2.654)	(2.656)	(2.742)	(2.936)
205.dots	40.92***	40.87***	40.16***	41.48***
	(2.383)	(2.391)	(2.594)	(3.083)
210.dots	44.28***	44.25***	43.55***	47.11***
	(2.635)	(2.653)	(2.828)	(2.995)
215.dots	53.28***	53.16***	50.66***	53.56***
	(2.954)	(2.957)	(3.091)	(3.291)
280.dots	80.78***	80.66***	79.14***	79.11***
	(2.723)	(2.743)	(3.002)	(3.067)
Constant	7.150***	13.17	5.657	9.856
	(1.989)	(13.49)	(13.57)	(13.51)
N	2670	2670	2400	1600
adj. R^2	0.436	0.437	0.437	0.455
Number of Investors	89	89	80	80
Controls	No	Yes	Yes	Yes
Gender	No	No	Yes	Yes
Baseline Included	Yes	Yes	Yes	No

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: In the first three columns we study the effects of the different signals and moral hazard treatments on the estimated probability made by each investor. In the fourth column we use only the data for the moral hazard treatments. Robust standard errors clustered at the investor level in parentheses.

3.3 Quantifying the Effects of Motivated Beliefs

In this subsection, we investigate whether limited liability affects risk-taking through motivated beliefs. To do so, we use "causal mediation analysis," which tries to go beyond establishing *whether* there is a causal link between treatment and outcome and aims to identify the causal *mechanism* behind such a link. In Section 3.1, we show that bankers invest significantly more under limited liability, yet this does not necessarily imply that limited liability affects investments only through beliefs (e.g., the changes in incentives might also have a large impact on subjects). Therefore, to disentangle motivated beliefs from all other effects that limited liability might have on decision-makers, we follow Imai et al. (2011) and Imai et al. (2013). In these two papers, the authors show that an IV approach can be used to disentangle the effects of our mediator of interest (i.e., motivated beliefs) from all other effects of the treatment (i.e., the presence of limited liability). To see how this disentanglement works, first consider an incomplete benchmark IV regression:

$$Prob_{b,r} = \gamma_0 + \gamma_1 \times Treatment_{b,r} + \rho_{b,r}, \tag{5}$$

$$Investment_{b,r} = \delta_0 + \delta_1 \times \widehat{Prob_{b,r}} + \mu_{b,r}. \tag{6}$$

$Prob_{b,r}$ captures banker b's belief about the success probability of an investment in round r. $Treatment_{b,r}$ is a dummy variable that takes on the value of one in the limited liability treatments *MA* and *DF* and zero if the treatment is *BL*.[8] Finally, $Investment_{b,r}$ captures what percentage of the endowment banker b invests into the risky asset. Thus, while the first stage in Eq. (5) regresses the beliefs of bankers on the treatment, the second stage (Eq. (6)) regresses the investment on the estimated beliefs.

As can be seen from these two equations, this specification assumes that the treatment impacts investments only through beliefs. Yet, if the treatment also happens to have a direct impact on investments, as is likely in our setup (think of the change in incentives), then the exclusion restriction is violated and the model is misspecified.

Therefore, to isolate the effect of motivated beliefs on investment, we need to disentangle the effect of limited liability that works only through beliefs (henceforth the "indirect effect") from all other effects of our treatment (henceforth the "direct effects"). To do so, we introduce the variable $Dots_{b,r}$, which comprises dummies for the ten different numbers of red dots that we use for the Dot Spots (recall Table 9 in Section 2.1), into the first stage. This secondary source of exogenous variation in beliefs basically reconstructs the regression in Table 3 and allows us to then run the following IV regression:

$$Prob_{b,r} = \alpha_0 + \alpha_1 \times Treatment_{b,r} + \alpha_2 \times Dots_{b,r} + \epsilon_{b,r}, \tag{7}$$

$$Investment_{b,r} = \beta_0 + \beta_1 \times \widehat{Prob_{b,r}} + \beta_2 \times Treatment_{b,r} + u_{b,r}. \tag{8}$$

[8] Because the two limited liability treatments are statistically indistinguishable (recall Result 1 and Result 2), we pool them together for our mediator analysis. For a disaggregated analysis of the results for each treatment (MA and DF), see Appendix D.1.

The advantage of this model is that we can identify the effect of beliefs on investments by exploiting the variation in $Dots_{b,r}$ (instead of solely exploiting variation in beliefs due to $Treatment_{b,r}$). This feature allows us to include $Treatment_{b,r}$ as an explanatory variable in the second stage, which enables us to isolate the effect that limited liability has on beliefs from all other effects. Our main assumption to do so is that the number of red dots, $Dots_{b,r}$, affects the investment decision through a shift in subjects' beliefs.

We can now simply compute the complier average mediation effect (CACME) as the product of α_1 from Eq. (7) and β_1 from Eq. (8). This is the average effect of limited liability on investment that is mediated by beliefs among those bankers whose beliefs are affected by limited liability (see, e.g., Imai et al., 2011).[9] In contrast, the complier average direct treatment effect (CADE) captures all causal mechanisms of limited liability on investment that do not work through the beliefs and is simply given by β_2 in Eq. (8).

Table 4 shows the results from the first stage (Eq. (7)) for the three different specifications. The results show that the variation in the number of red dots has a large impact on the beliefs: for example, the perceived success probabilities in specification (3) are, on average, 31.7 percentage points larger for a matrix with 195 red dots (*Dots 195*) than for a matrix with 120 red dots. But most importantly, in all four specifications of Table 4, the variable $Treatment$ is statistically significant and positive. This finding indicates that, under limited liability, bankers increase their beliefs on the success of an investment by roughly 3.3 percentage points.

Table 5 presents the second-stage results for the same three specifications as in Table 4. On average, an increase in the perceived success probabilities by 1 percentage point increases the investment by approximately 1.1 percentage points in all three specifications. This effect is statistically significant at the 1% level. In specification (2), the CADE (i.e., β_2 in Eq. (8)) is approximately 6.97 percentage points. As a robustness check for these results, in Appendix D.2, we use different specifications to analyze the effects of beliefs on the investment decisions of bankers. The results corroborate the validity of our IV approach.

Finally, using the first- and second-stage results from Tables 4 and 5, we obtain the CACME, which is $3.367 \times 1.092 \approx 3.675$ in specification (2). In Table 6, we use bootstrapped standard errors to test whether the effect of limited liability through the beliefs, $\alpha_1 \times \beta_1$, is statistically significant. We find that this effect of motivated beliefs is statistically significant at the 1% level in all three specifications.

Overall, our analysis in Tables 4–6 indicates that limited liability has a large impact on the formation of motivated beliefs and such beliefs are responsible for over one-third of the increase in investment under limited liability.

Result 3 *Quantitative Effects of Motivated Beliefs on Investment*

On average, motivated beliefs are responsible for over one-third of the increase in investment under limited liability.

[9] The concept of the CACME is thus similar to the local average treatment effect obtained from standard IV estimations.

Dep. Variable: *Prob*	(1)	(2)	(3)
Treatment	3.368***	3.367***	3.517***
	(0.942)	(0.942)	(1.019)
185.dots	19.02***	19.05***	19.38***
	(1.920)	(1.941)	(2.055)
190.dots	29.18***	29.07***	27.93***
	(2.157)	(2.171)	(2.323)
195.dots	32.14***	32.11***	32.98***
	(2.452)	(2.468)	(2.588)
199.dots	32.71***	32.63***	30.98***
	(2.460)	(2.449)	(2.483)
201.dots	44.19***	44.20***	42.46***
	(2.653)	(2.662)	(2.740)
205.dots	40.96***	40.93***	40.24***
	(2.383)	(2.376)	(2.584)
210.dots	44.27***	44.30***	43.65***
	(2.636)	(2.632)	(2.792)
215.dots	53.31***	53.22***	50.68***
	(2.950)	(2.945)	(3.053)
280.dots	80.79***	80.72***	79.25***
	(2.721)	(2.730)	(2.988)
Constant	7.145***	16.28	15.36
	(1.986)	(11.12)	(10.34)
Observations	2670	2670	2400
Number of Bankers	89	89	80
adj. R^2	0.436	0.437	0.438
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: First Stage Regressions for *Prob*. In all four columns the dummy for $Dots120$ is not included because of multicollinearity. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Investment*	(1)	(2)	(3)
Treatment	6.971***	6.970***	7.257***
	(1.344)	(1.341)	(1.460)
Prob (instrumented)	1.091***	1.092***	1.106***
	(0.044)	(0.045)	(0.050)
Constant	-19.18***	-39.25*	-41.11*
	(2.176)	(20.94)	(22.87)
N	2670	2670	2400
Number of Bankers	89	89	80
adj. R^2	0.351	0.365	0.358
Gender	No	No	Yes
Controls	No	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Second Stage with Instruments for *Prob*. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Investment*	(1)	(2)	(3)
Indirect Treatment Effect (CACME)	3.675***	3.675***	3.888***
	(1.038)	(1.059)	(1.110)
Direct Treatment Effects (CADE)	6.971***	6.970***	7.257***
	(1.403)	(1.325)	(1.508)
Observations	2670	2670	2400
Number of Bankers	89	89	80
Gender	No	No	Yes
Controls for Treatment Order	No	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Indirect (CACME) and Direct Treatment Effects (CADE). Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

4 Discussion

Experimental and quasi-experimental studies are often criticized for only focusing on the causal effect of a treatment on an outcome without explaining *how* and *why* it actually affects the outcome (e.g., Deaton, 2010; Heckman and Smith, 1995), yet the empirical identification of causal mediator effects is often challenging.[10] Randomization of the treatment alone is not sufficient to uncover the causal mediator effect, as it cannot disentangle the direct treatment effects from the treatment effects through the mediator. Using an additional source of variation (i.e., Dot Spots) in our mediator (i.e., beliefs), our design aims to avoid confounding the causal mediator effect.

However, our empirical identification and design also entails certain limitations. First, our regression specification, Eqs. (7) and (8), assumes a linear functional form. We will aim to address this concern in future versions of this project by non-parametrically estimating the average causal mediation effect, as in Imai et al. (2010). Second, while we incentivize the outcomes, we do not incentivize the beliefs of banker subjects.[11] While this might lead to experimenter demand effects, we opted to leave out incentives, as it would add yet another layer of complication to an already long experiment. Third, incentivizing beliefs could potentially counteract the intrinsic incentives that are responsible for motivated beliefs.[12]

Another potential limitation of our project is external validity. Our subject pool mainly consists of students who may or may not behave differently than financial employees. In a meta study, Fréchette (2011) finds that there are some instances in which student subjects and professionals show behavioral differences, but these differences are small, provided that the two populations are playing the same game. Additionally, Cornand and Heinemann (2019) argue that the qualitative results of laboratory experiments might carry more external validity than, for example, results based only on numerical simulations. Hence, while the external validity of an experiment with financial employees would be higher, we still expect our analysis to be informative. Another concern related to external validity is that we would ideally investigate decision-making in real financial markets. However, unlike observational data, the laboratory setting enables us to vary the limited liability incentives within-subject, to control the information that subjects receive regarding the success probabilities of investments, and to elicit individual beliefs.

The finding that motivated beliefs contribute to risk-taking under limited liability raises the question of how policy could affect them. In general, research has shown that debiasing motivated beliefs is difficult. Even experienced professionals (e.g., teachers, lawyers, and judges) are prone to self-serving biases (Babcock and Loewenstein, 1997; Eisenberg, 1994), and simply informing individuals about the existence of self-serving biases is an ineffectual debiasing tool (Babcock and Loewenstein, 1997). Nevertheless, there have been some successful attempts at debiasing motivated beliefs. It has been shown that self-serving assessments are mitigated when subjects make judgments *before* they receive infor-

[10]See Imai et al. (2011, 2013) for the difficulties associated with uncovering causal mechanisms.

[11]See Schlag et al. (2015) for a discussion of the trade-offs related to the usage of incentives for belief elicitation in experiments.

[12]Notice, however, that in a recent paper, Engelmann et al. (2019) study the effects of incentives on the formation of motivated beliefs and find no changes in beliefs across their different incentives.

mation regarding their incentives (Gneezy et al., 2016, 2018). Motivated beliefs and its consequences are also reduced by a more objective decision environment (Gneezy et al., 2018). Finally, Babcock et al. (1997) show that instructing subjects to question their own assessment by thinking about the weaknesses and counterarguments to their judgment mitigates self-serving biases substantially.

For policymakers who aim to reduce risk-taking under limited liability, it might thus be beneficial to force material risk-takers in the financial sector to more strongly rationalize their investment behavior based on objective and hard facts of the investment target or to make them justify in much detail why a potential investment could go wrong and who would suffer from it. However, all these treatments might lead to other distortions, and their effectiveness in a financial context has not yet been tested.

5 Conclusion

Gino et al. (2016) describe "motivated Bayesians" as those persons who bias, manipulate, or ignore information to self-justify immoral behavior. Some examples might be people who do not sort waste "because it is useless" (Piermattéo and Monaco, 2015) or parents who convince themselves that "it is not so cold outside" to avoid the struggle of putting a snowsuit on their young child. Indeed, self-serving beliefs are widely documented in the literature and have been shown to have effects on many different aspects of economic decision-making (e.g., Haisley and Weber, 2010; Ahrens and Bosch-Rosa, 2019; Schwardmann and Van der Weele, 2016), yet to our knowledge, we are the first to document and quantify the effects of motivated beliefs on risk-taking when limited liability is present.

We set up a within-subject experimental design where subjects make investments both under full and limited liability. These investments are preceded by a noisy signal that indicates whether the investment will succeed or fail. We exploit the variance in the noisy signal to use mediator analysis and disentangle the effect of limited liability that works through motivated beliefs from all other investment effects of limited liability. Our key result is that, for a given signal, subjects assign higher probabilities of success under limited liability than in the full liability treatment, resulting in a significant increase in risk-taking. This result confirms the theoretical predictions of Barberis (2013) and Bénabou (2015), who point toward motivated beliefs as important contributors to the recent financial crisis.

In Barberis (2013), the author points toward subprime securitization as an especially ripe area for motivated beliefs and excessive risk-taking. The reason is that subprime-linked products were so complex that they offered enough "belief wiggle room" for traders at banks' mortgage desks to easily manipulate their beliefs and justify their excessive risk-taking. Gino et al. (2016) argue that the formation of motivated beliefs depends critically on whether "the context provides sufficient flexibility to allow plausible justification that one can both act egoistically while remaining moral." In this experiment, we show that even a little bit of ambiguity is enough to trigger such self-serving beliefs. This has important implications for policymakers, as it shows that they must target not only bad incentives but also target "bad beliefs." How to do so effectively is an important question for future research.

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A Additional Variables

After the three treatments, subjects participate in a final block of 5 *parts*, which we use to elicit additional variables. In the first part, all subjects take a Raven test, which measures the participants' reasoning abilities. In this test, a subject is given eight graphical elements and must choose the missing ninth elements, which completes the pattern (see Figure 8 in Appendix E for an example). The test consists of three sets of twelve items each, and subjects are given 5 minutes per set. For each correctly answered item participants receive €0.10.

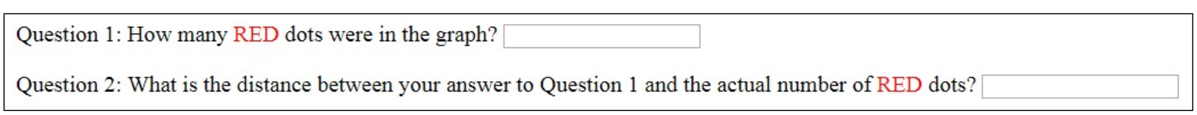
In part 2, subjects are asked two questions about their performance in the Raven test, which determine overestimation and overplacement, respectively. In the first question, we ask subjects how many of the 36 items in the Raven test they have answered correctly. The difference between this estimated number of correct answers, EOE_i, and the actual number of correct answers in the Raven test, AOE_i, gives us the level of *overestimation of subject i*, OE_i.

In the second question of part 2, each subject is asked how many participants in their own experimental session have answered less Raven questions correctly than they did, $EOPL_i$. The difference between $EOPL_i$ and the actual number of subjects that performed worse than subject i, $AOPL_i$, determines the *overplacement of subject i*, OPL_i.

The computer randomly chooses one of the two questions of part 2 to become payoff relevant. If the first question is chosen, the subject receives $P_i^{OE} = max\{€2 - €0.15 \times |EOE_i - AOE_i|; €0\}$. In case the second question is selected, the payoff for subject i is given by $P_i^{OPL} = max\{€2 - €0.15 \times |EOPL_i - AOPL_i|; €0\}$. Hence the more accurately the subject estimates her performance and relative performance in the Raven test, the higher is her expected payoff.

Part 3 elicits overprecision. It consists of 10 rounds and it is based on the method introduced in Ahrens et al. (2019). Before each round, subjects are shown a new Dot Spot containing a total of 400 red and blue dots. After seeing the graph, subjects answer the two questions shown in Figure 4. In

Figure 4: Overprecision Questions


Question 1: How many RED dots were in the graph?

Question 2: What is the distance between your answer to Question 1 and the actual number of RED dots?

the first question, subjects give an estimate $N_{i,r}$ of the number of red dots shown in round r. In the second question, subjects state their expected error, $EE_{i,r}$. This expected error is subject i's expected absolute distance between his estimate of the number of red dots $N_{i,r}$ and the actual number of red dots in the graphic, $A_{i,r}$.

For round r, we define overprecision as the difference between a subject's stated expected error $EE_{i,r}$ and his actual error, $AE_{i,r}$. Hence the overprecision of subject i in round r is given by $OP_{i,r} = AE_{i,r} - EE_{i,r}$ where $AE_{i,r} = |A_{i,r} - N_{i,r}|$. We define the *overprecision* of a subject i, OP_i, as the median value of the ten $OP_{i,r}$ values that we collect for each individual i. A subject is overprecise if $OP_i > 0$ (i.e., when her actual error is larger than her expected error) and underprecise if $OP_i < 0$.

The computer randomly chooses only one of the ten rounds and only one of the two questions for a subject's payoff in part 3. If the first question of round r is paid off, then the subject receives $P_{i,r}^{OP1} = max\{€5 - €0.05 \times AE_{i,r}; €0\}$. If the second question becomes payoff relevant, then the subject obtains $P_{i,r}^{OP2} = max\{€5 - €0.05 \times |AE_{i,r} - EE_{i,r}|; €0\}$. Hence the subject's payoff for both questions in part 3 is higher, the closer are the answers of the subject to the correct answers. Part 4 of the final block elicits risk and loss aversion using multiple price lists (see Tables 23 and 24 in Appendix E). In part 5, subjects state their field of study, age, and gender.

B Risk

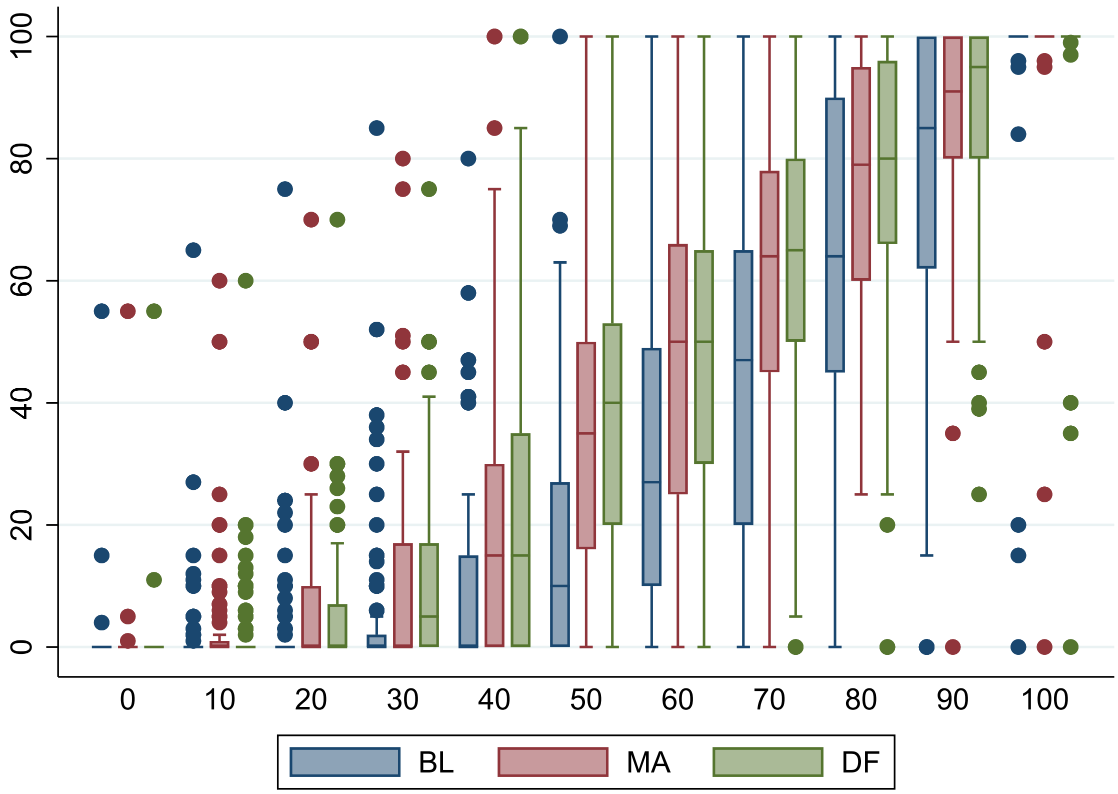
Figure 5: Investments for Given Probabilities in Risk Part

1	0% Erfolgswahrscheinlichkeit & 100% Verlustwahrscheinlichkeit	0
2	10% Erfolgswahrscheinlichkeit & 90% Verlustwahrscheinlichkeit	0
3	20% Erfolgswahrscheinlichkeit & 80% Verlustwahrscheinlichkeit	0
4	30% Erfolgswahrscheinlichkeit & 70% Verlustwahrscheinlichkeit	0
5	40% Erfolgswahrscheinlichkeit & 60% Verlustwahrscheinlichkeit	0
6	50% Erfolgswahrscheinlichkeit & 50% Verlustwahrscheinlichkeit	0
7	60% Erfolgswahrscheinlichkeit & 40% Verlustwahrscheinlichkeit	0
8	70% Erfolgswahrscheinlichkeit & 30% Verlustwahrscheinlichkeit	0
9	80% Erfolgswahrscheinlichkeit & 20% Verlustwahrscheinlichkeit	0
10	90% Erfolgswahrscheinlichkeit & 10% Verlustwahrscheinlichkeit	0
11	100% Erfolgswahrscheinlichkeit & 0% Verlustwahrscheinlichkeit	0

Screenshot of the Risky Investment round. Each row presents subjects with a certain probability of a successful investment. For each row subjects have an €8 endowment and can decide what percentage of it to invest in the asset using the scroll bar. The payoffs will be those of they are in (BL, MA, DF).

In the Risk part, the success probabilities of all investments are objectively given. Figure 6 shows the investments as a percentage share of the endowment (vertical axis) for a given exogenous success

Figure 6: Investments for Given Probabilities in Risk Part



Investments made by bankers in the Risk part. The vertical axis represents the investment made as a percentage of the endowment. The horizontal axis shows the given success probabilities. For each success probability, we show a box plot for every treatment (*BL*, *MA*, *DF*).

probability (horizontal axis). Overall, the box plots in Figure 6 indicate that bankers understood the incentives, as they tend to invest more for higher success probabilities.

Figure 6, as well as the means reported in Table 7, show that subjects invest significantly more in the limited liability treatments than in the *Baseline*. On average, subjects invest 31.7 (*BL*), 40.6 (*MA*), and 41.5 (*DF*) percent of their endowment. In line with this, the investment in the limited liability treatments are also higher for most success probabilities. Exceptions only arise for the extreme probabilities (0% and 100%) where – independent of the treatment – bankers tend to invest either nothing or their whole endowment. Finally, we present a within-subject Wilcoxon signed-rank test comparing the total investments made in the three treatments (Table 8) which confirms that the investments in both *MA* and *DF* are significantly higher than in *BL* (p-value < 0.001 in both cases).

While we observe substantial effects of the limited liability treatments compared to the *Baseline*, there are no significant differences between the two limited liability treatments, *MA* and *DF*. Not only are the total investment levels in these treatments similar, but also the investments for a given success probability (Table 7). A within-subject Wilcoxon signed-rank test comparing the *total* amount invested in both treatments confirms this picture, as the null hypothesis of no difference cannot be

Table 7: Mean Investments in Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
BL	31.69	0.83	1.94	3.29	5.08	8.56	17.30	30.13	45.46	62.83	76.43	96.74
	(37.98)	(6.03)	(7.83)	(10.18)	(12.99)	(14.86)	(20.48)	(25.61)	(29.27)	(29.40)	(27.64)	(16.16)
MA	40.56	0.69	3.94	5.69	9.94	19.43	36.21	49.26	61.73	75.49	86.42	97.37
	(38.95)	(5.85)	(10.54)	(11.92)	(16.00)	(24.30)	(26.88)	(26.33)	(25.13)	(19.54)	(18.24)	(14.12)
DF	41.50	0.74	2.92	5.39	12.08	21.13	39.70	51.21	63.36	75.74	86.82	97.43
	(39.15)	(5.93)	(7.79)	(10.80)	(16.96)	(23.98)	(27.79)	(26.46)	(25.25)	(23.06)	(17.64)	(14.00)

Mean investments as a percentage share of the endowment for the Risk part. The column *Total* shows the aggregated average of all investments in a treatment. The other columns show the average investment for a given success probability of the investment. Standard deviations are shown in parentheses.

Table 8: Wilcoxon Signed-Rank Tests for Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
p-value BL = MA	<0.001	0.554	0.034	0.020	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.320
p-value BL = DF	<0.001	0.1573	0.071	0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.105
p-value DF = MA	0.431	0.993	0.543	0.7133	0.455	0.632	0.343	0.520	0.392	0.288	0.220	0.186

The p-values of the within-subject Wilcoxon signed-rank test comparing (paired) investments in the Risk part across treatments. The *Total* column compares the *total* amount invested in the treatments. The other columns compare the investments for given exogenous probabilities in the treatments.

rejected (p-value = 0.431).

C Dot Spot details

As mentioned in Section 2.1, before each round the computer determines whether the investment will succeed or fail. If it succeeds, then the matrix shown to subjects will have more red than blue dots, if the investment fails, then the matrix shown to subjects will have more blue than red dots. The number of dots shown for each round in all three treatments can be found in Table 9. [13]

Two things are important to notice. First, the number of red dots shown are based on data from pilots. Except for the two extremes (120 and 280 red dots), the number of red dots shown are thought to convey some information about the success probability of the investment, while still being noisy enough to create uncertainty over the outcome. Second, in each pair the matrices are mirror images of each other. We do this to hold constant the level of difficulty in reading a signal within each pair. This is important as we use the effects that the variation in the number of red dots have on the beliefs of subjects to identify the effects of motivated beliefs on risk-taking under limited liability (see Section 3.3).

Finally, notice that the number of dots shown is repeated within and across treatments. This means that a subject might see more than once a matrix with the same number of red dots (e.g., a matrix with 120 red dots can potentially be seen in rounds 5 and 9 of BL, rounds 6 and 8 of MA, and rounds 2 and 8 of DF). Yet, while these matrices have the *same number* of dots, they each differ in the *pattern* of the dots. See for an example Figure 7, in it we show two "similar" matrices each containing 215 red dots. Having these "similar" matrices with the same number of red dots but with different patterns enables us to compare identically informative signals across treatments, while preventing subjects from learning from (or anchoring to) previously shown signals.

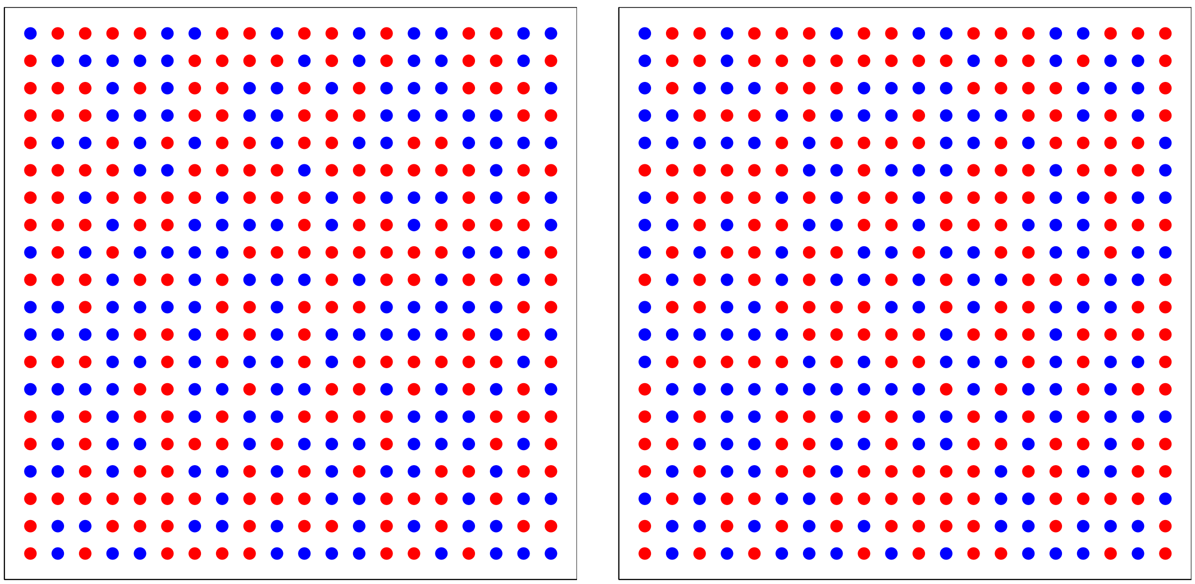
Table 9: Red Dots Shown in Each Round

Round		1	2	3	4	5	6	7	8	9	10
BL	Success:	205	215	201	201	280	210	215	210	280	205
	Fail:	195	185	199	199	120	190	185	190	120	195
MA	Success:	210	205	215	210	201	280	201	280	215	205
	Fail	190	195	185	190	199	120	199	120	185	195
DF	Success:	210	280	201	210	205	215	215	280	205	201
	Fail:	190	120	199	190	195	199	155	120	195	199

Number of red dots shown for each round and treatment depending on the outcome of the investment.

[13] The sequences were picked by taking the first three number sequences generated using the web page www.random.org.

Figure 7: Two "Similar" Matrices



Two "similar" matrices with 215 red dots each, but a different dot pattern.

D Robustness checks of the IV

D.1 Disaggregating the treatments in the IV approach

In this section we report the results of the instrumental variable approach of Section 3.3 for each of the two limited liability treatments (MA and DF). In Tables 10 and 11 we run the first stage regression (eq. 7) for treatments MA and DF respectively. The results are practically identical, with the coefficient for the MA treatment being slightly higher than for the DF treatment.[14] Overall, we observe no differences in the first stage across treatments and the results are in the order of magnitude of those in Table 4.

Tables 12 and 12 show the second stage (eq. 8). Again we see that the results are similar to those in Table 5, as the differences between treatments are minimal. Because of the similar results in both first and second stage, the CACME and CADE for the MA and DF treatments (Tables 14 and 15, respectively) are very similar to those of the pooled data (Table 6).

[14]The significance of the treatment effect for DF, when not controlling for gender, is above the 1% threshold. Yet, as can be seen from the SE, it is very close to it (p-value=0.013).

Dep. Variable: *Prob*	(1)	(2)	(3)
Treatment (MA)	4.065***	4.061***	3.990***
	(1.112)	(1.113)	(1.198)
185.dots	19.87***	19.87***	19.92***
	(2.175)	(2.175)	(2.191)
190.dots	27.49***	27.49***	26.78***
	(2.383)	(2.380)	(2.539)
195.dots	33.45***	33.50***	33.93***
	(2.679)	(2.718)	(2.847)
199.dots	33.22***	33.13***	30.93***
	(2.704)	(2.701)	(2.632)
201.dots	43.21***	43.36***	41.46***
	(2.992)	(3.003)	(3.032)
205.dots	41.02***	41.04***	40.44***
	(2.405)	(2.399)	(2.584)
210.dots	42.55***	42.63***	42.03***
	(2.953)	(2.943)	(3.054)
215.dots	52.21***	52.28***	49.45***
	(3.110)	(3.118)	(3.115)
280.dots	80.52***	80.60***	79.29***
	(2.723)	(2.748)	(2.984)
Constant	7.452***	11.37	11.00
	(1.922)	(12.22)	(11.05)
Observations	1780	1780	1600
Number of Bankers	89	89	80
adj. R^2	0.419	0.420	0.423
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: First Stage Regressions for *Prob* using *BL* and *MA* data. In all three columns the dummy for *Dots*120 is not included because of multicollinearity. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Prob*	(1)	(2)	(3)
Treatment (DF)	2.762**	2.752**	3.139***
	(1.086)	(1.087)	(1.180)
185.dots	16.59***	16.69***	16.68***
	(2.393)	(2.429)	(2.605)
190.dots	30.77***	30.68***	29.38***
	(2.575)	(2.590)	(2.797)
195.dots	29.45***	29.57***	30.38***
	(2.914)	(2.922)	(3.163)
199.dots	30.78***	30.67***	29.02***
	(2.681)	(2.710)	(2.828)
201.dots	44.44***	44.58***	42.76***
	(2.956)	(2.971)	(3.095)
205.dots	39.13***	39.05***	38.70***
	(2.724)	(2.712)	(2.925)
210.dots	41.98***	42.10***	41.59***
	(2.872)	(2.858)	(3.066)
215.dots	51.62***	51.56***	49.08***
	(3.270)	(3.234)	(3.403)
280.dots	81.09***	81.13***	79.45***
	(2.923)	(2.977)	(3.270)
Constant	8.196***	15.63	13.26
	(2.175)	(11.80)	(11.96)
Observations	1780	1780	1600
Number of Bankers	89	89	80
adj. R^2	0.436	0.438	0.437
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: First Stage Regressions for *Prob* using *BL* and *DF* data. In all three columns the dummy for *Dots*120 is not included because of multicollinearity. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Invest*	(1)	(2)	(3)
Treatment (MA)	7.212***	7.200***	7.899***
	(1.593)	(1.593)	(1.705)
Prob (instrumented)	1.058***	1.060***	1.071***
	(0.0478)	(0.0485)	(0.0532)
Constant	-17.75***	-25.88	-29.12
	(2.219)	(20.87)	(21.94)
N	1780	1780	1600
adj. R^2	0.332	0.343	0.337

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Second Stage with Instruments for *Prob* using BL and MA data. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Invest*	(1)	(2)	(3)
Treatment (DF)	6.878***	6.876***	6.755***
	(1.397)	(1.397)	(1.514)
Prob (instrumented)	1.104***	1.104***	1.120***
	(0.0456)	(0.0467)	(0.0517)
Constant	-19.72***	-39.51*	-38.91*
	(2.271)	(20.70)	(22.98)
N	1780	1780	1600
adj. R^2	0.369	0.381	0.373

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Second Stage with Instruments for *Prob* using BL and DF data. Robust standard errors clustered at the investor level in parentheses.

Dep. Variable: *Invest*	(1)	(2)	(3)
Indirect Effect (CACME)	4.301***	4.305***	4.274***
	(1.200)	(1.190)	(1.256)
Direct Effects (CADE)	7.212***	7.199***	7.898***
	(1.602)	(1.524)	(1.698)
Observations	1780	1780	1600
Number of Bankers	89	89	80
Gender	No	No	Yes
Controls for Treatment Order	No	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Indirect (CACME) and Direct Treatment Effects (CADE). Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

Dep. Variable: *Invest*	(1)	(2)	(3)
Indirect Effect (CACME)	3.049***	3.039***	3.515***
	(1.179)	(1.187)	(1.301)
Direct Effects (CADE)	6.877***	6.875***	6.754***
	(1.471)	(1.392)	(1.571)
Observations	1780	1780	1600
Number of Bankers	89	89	80
Gender	No	No	Yes
Controls for Treatment Order	No	Yes	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: Indirect (CACME) and Direct Treatment Effects (CADE). Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

D.2 Alternative Specifications

In this section we check how robust the results of Table 5 are to alternative specifications. In of Table 16 we run a linear regression of $Investment_{b,r}$ on $Prob_{b,r}$ and the two different treatments (MA and DF) along with all of the control variables we use in Table 4. As can be seen, the results of the regressions in Table 16 are close to those of 5. That is, the effect of instrumented and non-instrumented beliefs on investments are very similar. Moreover, if we regress the investment ($InvestmentR_{b,gr}$) of each Banker b for a given risk gr of the Risk part of each treatment, the results are again very similar to those of Table 5 (see Table 17).

The similarity in the results of all three specifications makes us confident that our IV approach is the adequate strategy to decompose the indirect effects of motivated beliefs on the investment decision of Bankers under limited liability. In this direction, when comparing Tables 16 and 17, it seems like the treatment effects are larger when the probabilities are exogenously given (i.e., in the Risk part). We believe that an explanation for such difference is that in the Dot Spot part, a fraction of the treatment effect is channeled through the motivated beliefsand ends up reflected in the stated probabilities $Prob_{b,r}$ instead of directly on the treatment dummy. Of course, even if part of the treatment effect is absorbed by the beliefs of the bankers, the effect of $Prob_{b,r}$ is smaller than that $GivenRisk$, since in the first case there is ambiguity on the outcome of the investment, while in the latter the odds are known with certainty.

Finally, in Tables 18 and 19 we reproduce Tables 16 and 17, but using a logistic models instead of linear regressions. Once again, the effect of given probabilities on the investment of bankers is very close to that of subjective probabilities. Also, the effect of the treatments are larger when the risk of the investment is given than when the investment has ambiguous odds, supporting again the idea that part of the treatment effect is absorbed by the formation of motivated beliefs.

Dep. Var.: *Investment*	(1)	(2)	(3)
Prob	0.955***	0.954***	0.956***
	(0.0313)	(0.0314)	(0.0362)
Treatment(MA)	7.827***	7.834***	8.591***
	(1.574)	(1.576)	(1.692)
Treatment(DF)	7.484***	7.488***	7.538***
	(1.459)	(1.461)	(1.587)
Raven		0.243	0.190
		(0.585)	(0.670)
Overestimation		0.315	0.378
		(0.351)	(0.450)
Overplacement		-0.0471	-0.215
		(0.363)	(0.424)
Overprecision		-0.250	-0.175
		(0.163)	(0.182)
Risk aversion		-0.215	-0.0509
		(0.544)	(0.612)
Loss aversion		-0.965*	-0.995
		(0.580)	(0.637)
Order 2		0.154	1.297
		(3.797)	(4.884)
Order 3		-0.731	-0.280
		(3.687)	(4.673)
Female			-2.616
			(3.320)
Constant	-13.32***	-5.681	-5.568
	(2.006)	(18.49)	(20.19)
N	2670	2670	2400
adj. R^2	0.602	0.615	0.588
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: Regression for Investment on Stated Probability. Robust standard errors clustered at the investor level.

Dep. Var.: *InvestmentR*	(1)	(2)	(3)
Given Risk	1.023***	1.023***	1.019***
	(0.0256)	(0.0257)	(0.0281)
Treatment(MA)	8.869***	8.869***	9.278***
	(1.126)	(1.127)	(1.213)
Treatment(DF)	9.811***	9.811***	9.736***
	(1.149)	(1.151)	(1.238)
Raven		-0.0144	0.256
		(0.495)	(0.547)
Overestimation		0.156	-0.128
		(0.365)	(0.280)
Overplacement		0.209	0.396
		(0.271)	(0.324)
Overprecision		-0.138	-0.161
		(0.108)	(0.123)
Risk aversion		-0.219	-0.301
		(0.474)	(0.520)
Loss aversion		-0.849*	-0.862*
		(0.438)	(0.470)
Order 2		-4.767*	-7.002**
		(2.778)	(3.426)
Order 3		-2.257	-3.664
		(2.489)	(3.052)
Female			2.224
			(2.687)
Constant	-19.48***	-4.479	-10.69
	(1.459)	(15.68)	(16.96)
N	2937	2937	2640
adj. R^2	0.704	0.713	0.707
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: Regression for Investment on Given Risk. Robust standard errors clustered at the investor level.

Dep. Var.: *Investment*	(1)	(2)	(3)
Prob	0.0682***	0.0693***	0.0687***
	(0.00697)	(0.00744)	(0.00795)
Treatment(MA)	0.694***	0.712***	0.770***
	(0.150)	(0.151)	(0.156)
Treatment(DF)	0.549***	0.590***	0.625***
	(0.142)	(0.143)	(0.151)
Raven		-0.113	-0.151**
		(0.0729)	(0.0734)
Overestimation		0.0138	0.0176
		(0.0671)	(0.0750)
Overplacement		-0.0371	-0.0513
		(0.0365)	(0.0439)
Overprecision		-0.0211	-0.0207
		(0.0175)	(0.0173)
Risk aversion		0.0731	0.0933
		(0.0641)	(0.0645)
loss aversion		-0.0153	-0.0320
		(0.0683)	(0.0727)
Order 2		-0.313	0.105
		(0.513)	(0.569)
Order 3		0.146	0.517
		(0.426)	(0.481)
Female			0.334
			(0.460)
Constant	-2.466***	0.515	1.118
	(0.366)	(2.224)	(2.263)
N	2670	2670	2400
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: Logit regression for Investment on Stated Probability. Robust standard errors clustered at the investor level in parentheses.

Dep. Var.: *InvestmentR*	(1)	(2)	(3)
Given Risk	0.0788***	0.0818***	0.0829***
	(0.00627)	(0.00708)	(0.00730)
Treatment(MA)	0.962***	0.997***	1.079***
	(0.155)	(0.161)	(0.175)
Treatment(DF)	1.094***	1.134***	1.223***
	(0.169)	(0.178)	(0.193)
Raven		-0.0689	-0.0453
		(0.0778)	(0.0809)
Overestimation		0.0481	0.00521
		(0.0786)	(0.0678)
Overplacement		0.0319	0.0574
		(0.0427)	(0.0453)
Overprecision		-0.00607	-0.0158
		(0.0158)	(0.0166)
Risk Aversion		0.0272	0.0155
		(0.0629)	(0.0679)
Loss Aversion		0.0154	0.0303
		(0.0664)	(0.0655)
Order 2		-0.105	-0.222
		(0.470)	(0.518)
Order 3		0.0774	0.110
		(0.412)	(0.444)
Female			0.473
			(0.400)
Constant	-3.325***	-1.853	-2.835
	(0.354)	(2.294)	(2.442)
N	2937	2937	2640
Controls	No	Yes	Yes
Gender	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19: Logit regression for Investment on Given Probability. Robust standard errors clustered at the investor level in parentheses.

E Instructions

These are the instructions for the treatment order *Baseline*, *Matched*, *Diffusion*. The instructions are translated from German.

Welcome to our Experiment!

During the experiment it is neither allowed to use any electronic devices nor to communicate with other participants. Please do only use the programs and functions designed for the experiment. Please do not talk to other participants. Please do not write on the instructions. You will find pen and paper in front of your computer for additional notes. If you have any questions, please raise your hand. We will then come to you and answer your question. In any case, please do not ask the question out loud. If the question is relevant for all participants, we will repeat and answer it aloud. If you do not comply with these rules, we have to exclude you from the experiment and the payoff.

This experiment consists of **four blocks**. Each **block** consists of several **parts**. We will read the instructions before working on the respective blocks and parts together. At the end of the experiment, the payoff for the four blocks is disclosed to you.

General Instructions for Block 1

Block 1 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these 11 rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 1 is disclosed at the end of the experiment.

In each round of block 1 you have an **initial endowment of 8 euro** and decide on the percentage share of your 8 euro you want to invest. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we provide a **scroll bar** with which you can state the share of your endowment you want to invest.

Payoff:
Your **amount to be invested** is your chosen **percentage times 8 euro**. The investment can either succeed or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will additionally gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0. **Hence, you will lose the entire amount to be invested (100%).**

You will receive the share of the initial endowment which you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. The amount to be invested equals I = 0.6 × 8 euro = 4.80 euro. The remainder of the initial endowment (3.20 euro) is not invested.

- If the investment succeeds, I = 4.80 is multiplied with 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, remains in your possession. Altogether you receive 3.20 euro + 1.75 × 4.80 euro = 11.60 euro.
- If the investment fails, you will lose the amount to be invested I = 4.80. The amount not invested, 3.20 euro, remains in your possession. Altogether you receive 3.20 euro.

These payoffs for successful or failed investments respectively **apply for the entire block** (part 1 and part 2). **The conditions under which the investment is successful, however, differ among part 1 and part 2.**

Specific Instructions for Block 1 Part 1

Part 1 consists of **one round with 11 decision situations**, summarized in a table (see Table 20). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table 20

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table 20, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

Example:

Suppose you would have stated, among other things, in Table 20 (using the scroll bar) that you want to invest 40% of your endowment in *decision situation 6* and 70% of your endowment in *decision situation 9*.

- If the computer randomly chooses *decision situation 6* for the payoff, the investment will be successful with a probability of 50% (see Table 20) and your amount to be invested equals 40% $\times$ 8 euro = 3.20 euro.
- If the computer randomly chooses *decision situation 9* for the payoff, the investment will be successful with a probability of 80% (see Table 20) and your amount to be invested equals 70% $\times$ 8 euro = 5.60 euro.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific Instructions for Block 1 Part 2

Part 2 consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Your amount to be invested I equals percentage $\times$ 8 euro. Remember: In the end exactly one of the eleven rounds from both parts of block 1 is randomly chosen for your payoff.

Before each round of part 2, the computer randomly chooses whether or not the investment will be successful . Before your investment decision you will receive a **hint** in each round whether the investment will be successful or fail in this round. This hint consists of a graph containing a total of **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If the graph contains more RED than BLUE dots, the investment succeeds with certainty.

If the graph contains more blue than RED dots, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on “confirm entry”. As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on “confirm entry”.

Summary of Block 1

In block 1 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose the entire (100%) amount to be invested.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round whether the investment will be successful in this round.

To begin with, you will do three practice rounds for part 1 and five practice rounds for part 2. **In these practice rounds you cannot earn money**, they are only there in order to clarify both parts. After the practice rounds you will do block 1 consisting of one round of part 1 with eleven decision situations and ten rounds of part 2. Out of these eleven rounds the computer randomly chooses exactly one round for **your actual payoff**.

This is the end of the instructions for block 1. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the “Continue” button in order to start with block 1.

General Instructions for Block 2

Block 2 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these eleven rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 2 is disclosed at the end of the experiment.

In block 2 the computer will randomly choose whether you are **type A or type B.** This role will persist throughout all eleven rounds of block 2. On your screens you can see whether you are type A or type B. **Each type A will be assigned to exactly one type B (and each type B will assigned to exactly one type A).** You will neither learn throughout nor after the experiment which type B is assigned to which type A.

Each type A will make an investment decision in **block 2** which can influence his own payoff and also the payoff of his assigned type B. If you receive the role of type B, your decision will not have any effects on the payoff.

For all type A the following holds:

In each round of block 2 you have an **initial endowment of 8 euro** and you decide which percentage share you want to **invest**. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we will provide a **scroll bar** with which you can indicate the percentage share of your endowment you want to invest.

The **amount to be invested** is the chosen **percentage times 8 euro**. The investment can either be successful or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0.75. **Hence, you will lose one quarter (25%) of the amount to be invested. An amount of three quarters (75%) of your amount to be invested is subtracted from the endowment of 8 euro of the type B assigned to you.**

You will keep the share of the endowment you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. Then the amount to be invested equals I $= 0.6 \times 8$ euro = 4.80 euro. The rest of the endowment (3.20 euro) is not invested.

- If the investment is successful, I = 4.80 euro is multiplied by 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, will remain in your possession. In total you will receive 3.20 euro + 1.75×4.80 euro = 11.60 euro. Type B is not influenced by your decision and receives 8 euro.

- If the investment fails, you will lose one quarter of the amount to be invested I = 4.80 (i.e., 1.20 euro). The amount not invested will entirely remain in your possession. In total you will receive 8 euro – 1.20 euro = 6.80 euro. The type B assigned to you loses three quarters of your amount to be invested, hence, 3.60 euro. Type B, hence, receives 8 euro – 3.60 euro = 4.40 euro.

For all type B the following holds:

In block 2 you have an initial endowment of 8 euro. Your payoff depends on the investment of the type A assigned to you.

You will make the same decisions as participant of type A. **However, all your decisions in block 2 will not affect your payoff.** Your payoff of block 2 only depends on the decisions of the type A assigned to you.

For all type A and B the following holds:

These payoffs for successful or failed investments respectively **hold for the entire block 2** (part 1 and part 2). **The conditions under which the investment is successful differ between part 1 and part 2.**

Specific instructions for Block 2 Part 1

As in block 1, part 1 consists of **one round with 11 decision situations**, summarized in a table (see Table 21). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table 21

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table 21, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific instructions for Block 2 Part 2

As in the previous block, part 2 consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Your amount to be invested I equals percentage $\times$ 8 euro. Remember: In the end exactly one of the eleven rounds from both parts of block 2 is randomly chosen for your payoff.

As in part 2 of block 1, **before each round** the computer randomly chooses whether or not the investment will be successful. Before your investment decision you will receive a **hint** in each round which indicates whether the investment will be successful or fail in this round. This hint consists of a graph containing a total **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If there are more RED than BLUE dots in the graph, the investment succeeds with certainty.

If there are more BLUE than RED dots in the graph, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on "confirm entry".

Summary of Block 2

In block 2 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

For type A it holds for both parts: If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose one quarter (25%) of your amount to be invested. The type B assigned to you will lose three quarters (75%) of your amount to be invested.

For type B it holds for both parts: You make the same decisions as participants of type A. However, your decisions in block 2 do not have any effects on the payoff.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round which indicates whether the investment will be successful in this round.

This is the end of the instructions for block 2. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to start with block 2.

General Instructions for Block 3

Block 3 consists of **two parts. Part 1 has one round, part 2 has ten rounds.** The computer will randomly choose **exactly one** of these eleven rounds for your payoff whereby each round is chosen with the same probability. The payoff for block 3 is disclosed at the end of the experiment.

In block 3 you will be the same type (type A or type B) as in block 2. Each type A will make an investment decision in **block 3** which can influence his own payoff and also the payoff of all type B individuals. If you received the role of type B, your decision will not have any effects on the payoff.

For all type A the following holds:

In each round of block 3 you have an **initial endowment of 8 euro** and you decide which percentage share of your 8 euro you want to **invest**. Thereby, you can choose an arbitrary **percentage** between 0% and 100%. In order to do so, we will provide a **scroll bar** with which you can indicate the percentage share of your endowment you want to invest.

The **amount to be invested** is the chosen **percentage times 8 euro**. Thereby, the investment can either be successful or fail.

- If the investment is **successful**, the amount to be invested is multiplied by 1.75. **Hence, you will gain three quarters (75%) of your amount to be invested.**
- If the investment **fails**, the amount to be invested is multiplied by 0.75. **Hence, you will lose one quarter (25%) of your amount to be invested. The type B individuals on aggregate will lose three quarters (75%) of your amount to be invested. Thereby, each type B will bear the same share of the loss in this experiment.**

You will keep the share of the endowment you do not invest, 8 euro minus the amount to be invested I, irrespective of whether the investment succeeds or fails.

Example:

Suppose you decide to invest 60% of your 8 euro. Then the amount to be invested equals I = 0.6 × 8 euro = 4.80 euro. The rest of the endowment (to the amount of 3.20 euro) is not invested.

- If the investment is successful, I = 4.80 euro is multiplied by 1.75. Hence, you will gain three quarters (75%) of the amount to be invested. The amount not invested, 3.20 euro, will remain in your possession. In total you will receive 3.20 euro + 1.75 × 4.80 euro = 11.60 euro. No type B individual is influenced by your decision.
- If the investment fails, you will lose one quarter of the amount to be invested I = 4.80 (i.e., 1.20 euro). The amount not invested will entirely remain in your possession. In total you will receive 8 euro – 1.20 euro = 6.80 euro. The type B individuals on aggregate lose three quarters (75%) of your amount to be invested (i.e., 3.60 euro). This loss is shared equally among all type B individuals. If, for example, 10 type B individuals participate in your experiment, each type B individual loses 0.36 euro.

For all type B the following holds:

In block 3 you have an initial endowment of 8 euro. Your payoff depends on the investment of the type A individuals. You will make the same decisions as participants of type A. However, all your decisions in block 3 will not affect your payoff. Your payoff of block 3 only depends on the decisions of the type A individuals.

For all type A and B the following holds:

These payoffs for successful or failed investments respectively **hold for the entire block 2** (part 1 and part 2). **The conditions under which the investment is successful differ between part 1 and part 2.**

Specific instructions for Block 3 Part 1

As in both previous blocks, part 1 again consists of **one round with 11 decision situations**, summarized in a table (see Table 22). If **part 1 is paid off**, the computer randomly chooses **one** of the 11 situations to be executed. Thereby, each of the 11 situations is chosen with the same probability.

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table 22, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

Please indicate for each of these 11 situations how much of your initial endowment of 8 euro you want to invest if the respective situation is drawn.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the position of the eleven

Situation	Success probability of the investment	Amount to be invested (Percentage of 8 euro)
1	0%	Scroll bar
2	10%	Scroll bar
3	20%	Scroll bar
4	30%	Scroll bar
5	40%	Scroll bar
6	50%	Scroll bar
7	60%	Scroll bar
8	70%	Scroll bar
9	80%	Scroll bar
10	90%	Scroll bar
11	100%	Scroll bar

Table 22

scroll bars. In order to complete part 1 and to start the next round, you have to click on "confirm entry".

Specific instructions for Block 3 Part 2

As in the previous blocks, part 2 again consists of **ten rounds**. In each round you decide which percentage share of your 8 euro you want to invest. Thereby, you can choose any arbitrary percentage between 0% and 100%. Remember: In the end exactly one of the eleven rounds from both parts of block 3 is randomly chosen for your payoff.

Before each round in part 2, the computer randomly chooses whether or not the investment will be successful. Before your investment decision you will receive a **hint** in each round which indicates whether the investment will be successful or fail in this round. This hint consists of a graph containing a total **of 400 RED and BLUE dots** that will be shown to you for 8 seconds. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more RED than BLUE dots. In this case the investment will be successful. With a probability of 1/2 (hence 50%) the computer chooses a graph which contains more BLUE than RED dots. In this case the investment fails.

If there are more RED than BLUE dots in the graph, the investment succeeds with certainty.

If there are more BLUE than RED dots in the graph, the investment fails with certainty.

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked for your estimation of the probability that there were more RED than BLUE dots in the preceding graph (hence, you state your estimation of the success probability of the investment). This statement does not affect your payoff.

As soon as you made both decisions, please click on “confirm entry”. As long as you did not confirm your entries, you can change the position of the scroll bar and change your opinion on the success probability. In order to complete a round in part 2 and to continue, you have to click on “confirm entry”.

Summary of Block 3

In block 3 you make investment decisions. The **payoffs** of a successful or failed investment respectively are **identical** for part 1 and part 2:

For type A it holds for both parts:

If the investment is **successful**, you will gain three quarters (75%) of the amount to be invested. If the investment **fails**, you will lose one quarter (25%) of your amount to be invested. The type B individuals on aggregate will lose three quarters (75%) of your amount to be invested. Thereby, each type B will bear the same share of the loss in this experiment.

For type B it holds for both parts:

You make the same decisions as participants of type A. However, your decisions in block 3 do not have any effects on the payoff.

Part 1 and part 2 differ with respect to the conditions under which the investment is successful. In part 1 the success probability is given in each situation. In part 2 you receive a hint in each round which indicates whether the investment will be successful in this round.

This is the end of the instructions for block 3. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to start with block 3.

General Instructions for Block 4

Block 4 consists of **four parts**. We will read the specific instructions for each part together directly before the respective part.

Specific Instructions for Block 4 Part 1

In this part you will solve 36 **exercises**. These **36 exercises** will be split on **three pages** such that there will be twelve exercises on each page.

All exercises follow the same structure as shown in Figure 8. There are three rows and three columns with geometric patterns and the **element** on the bottom right is missing. Your task is to choose the **element** among eight given elements which fits best to the other patterns. Only one of the eight elements given is correct.

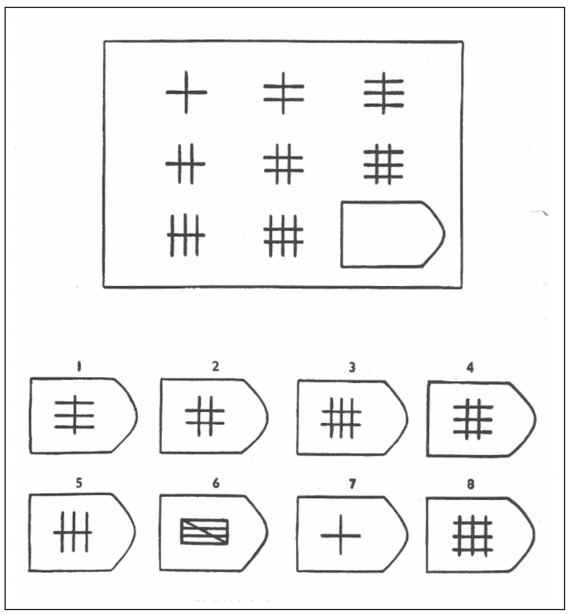


Figure 8

You **choose the element** using a **drop-down list** (see Figure 9). You will find this drop-down list on the left below each task. In order to complete the 12 tasks of each page, you can arbitrarily scroll up or down. You do not have to answer the tasks in the specified order. **For all three pages you have 5 minutes each.** If the time is up for one page, the computer registers all your answers and you will receive 0.10 euro for each correct answer. At the end of the experiment you will learn how many tasks you solved correctly. You can of course click on "continue" before the expiration of the 5 minutes. However, in this case you cannot return to this page anymore.

This is the end of the instructions for part 1. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue"

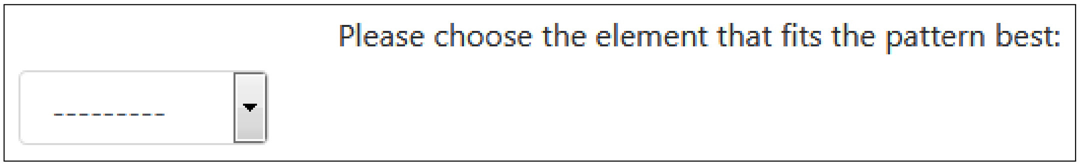


Figure 9

button in order to answer the questions.

Specific Instructions for Block 4 Part 2

In **part 2** you will be asked two questions regarding **part 1.**

Question 1: What do you think, how many exercises did you solve correctly in the previous part?

Here you indicate, in how many of the exercises of the previous part (block 4, part 1) you have chosen the correct element in your opinion. Remember: in part 1 there were three pages with 12 exercises each, hence, in total 36 exercises. You can type in every number from 0 to 36.

Question 2: What do you think, how many participants have solved less exercises correctly than you in the previous part?

Here you indicate, how many of the present 20 participants in your opinion have chosen less often the correct element than you in part 1. You can type in every number from 0 to 19.

Payoff:

For both questions your payoff depends on the precision of your answer. The lower the distance between your answer and the correct answer to a question, the larger your payoff. The payoff for one question equals **€2 - €0.15** $\times$ **distance**. If the payoff should be smaller than zero euro, you will receive zero euro instead. Hence, you cannot incur any losses in part 2.

Example Question 1:

Suppose the answer to Question 1 regarding your number of correctly solved exercises is 10 and in fact you have solved 12 exercises correctly. Then the distance equals 2. Your payoff for Question 1 is thus **€2 - €0.15** $\times$ **2 = €1.70**.

Example Question 2:

Suppose the answer to Question 2 is 11 and in fact 12 participants have solved less exercises correctly than you. Then the distance equals 1. Your payoff for question 2 is thus **€2 - €0.15** $\times$ **1 = €1.85**.

The computer will randomly choose **exactly one** of both questions of **part 2** for your payoff. You will learn about your payoff for part 2 at the end of the experiment.

Question 1 will appear first. As soon as you have answered Question 1, please click on "confirm entry". Afterwards, question 2 appears. As soon as you have answered Question 2, please again click on "confirm entry" in order to complete part 2 and to start with the next part.

This is the end of the instructions for part 2. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to answer the questions.

Specific instructions for Block 4 Part 3

Part 3 consists of **10 rounds.** In **each round** a new graphic consisting of a total of 400 dots will be shown to you. In each graphic there are between 0 an 400 RED dots and all the other dots are BLUE. Each graphic is shown to you for 8 seconds and completely disappears from your screen afterwards. Afterwards, you will make **two estimations.**

Estimation 1: How many RED dots were in the graphic?

Estimation 2: How large is the difference between your Estimation 1 and the actual number of RED dots?

In **Estimation 1** you indicate your estimate about how many RED dots were in the graphic shown to you. In **Estimation 2** you indicate your estimate about how far your **Estimation 1** is off the **actual number** of RED dots in the graphic.

Example:

Suppose you estimate that there were 211 RED dots in the graphic. Hence, your estimate 1 is 211. Suppose you think that your Estimation 1 deviates by 24 in expected values from the actual number of RED dots. Hence, your Estimation 2 is 24.

Payoff:

For both questions your payoff depends on the precision of your answer. The smaller the **absolute distance** of your answer to the correct answer of an estimation, the higher your payoff. The payoff for an estimation equals **€5 - €0.05** $\times$ **absolute distance.** If this payoff should be smaller than zero, you will receive zero euro instead. Hence, you cannot make any losses in part 3.

Example for Estimation 1:

Suppose your estimation about the number of RED dots is 211 and the actual number of RED dots is 180. Then, the absolute distance equals 211 - 180 = 31. Hence, the payoff for Estimation 1 is €5 - €0.05 $\times$ 31 = €3.45.

Example for Estimation 2:

Suppose you estimated that the distance of your Estimation 1 to the actual number of RED dots equals 24 in expected values and therefore indicated 24 as Estimation 2. In fact, your estimation error in Estimation 1 was 31. Therefore, the distance between your Estimation 2 and the correct answer equals: 31 - 24 = 7. Hence, the payoff for Estimation 2 is €5 - €0.05 $\times$ 7 = €4.65.

Your payoff for part 3 is determined by the computer randomly choosing **exactly one of both estimations** from **one of the ten rounds** of part 3. You will learn about your payoff at the end of the experiment.

Please click on "confirm entry" in each round as soon as you have entered Estimation 1 as well as Estimation 2.

This is the end of the instructions for part 3. If you have any questions, please raise your hand. We will then come to you and answer quietly. If you do not have any questions, please click on the "Continue" button in order to start with the 10 rounds of part 3.

Specific instructions for Block 4 Part 4

In this part we will subsequently present you **two tables** with **15 rows each**. In both tables, **Table 23** and **Table 24**, you have to choose between **lotteries** and a **safe amount**. At the end of the experiment the computer randomly chooses **one row** from **one of both tables** for your payoff with an equal probability. Both tables are chosen with a probability of 50 percent and each row within a table has the same probability to be chosen.

Table 23:

In the **lotteries** of Table 23 you will win a positive amount in addition to your previously achieved credit with a probability of 50% and with a probability of 50% your credit will remain unchanged.

As you can infer from Table 23, **the lottery becomes more unattractive the lower the row**. In row 1 there is a 50 percent chance that you gain **€8.00**. In row 2, in contrast, there is a 50 percent chance, that you gain **€7.50**. **Your task is to decide until which row you prefer the lottery over a safe payment of €2.50.**

Example (see Table 23): Suppose that you prefer the lottery over the safe amount of €2.50 as soon as the lottery increases your credit by at least €4.50 in the case of success. In this case you choose row 8 in Table 23. This means that you receive the safe payment of €2.50 if the computer randomly chooses one of the rows 9 to 15. If the computer randomly chooses one of the rows 1 to 8, your payoff is decided upon by the lottery given in the chosen row. Hence, if the computer chooses, for example, row 5, you will gain €6 in addition to your previous credit with a probability of 50% and with a probability of 50% your credit remains unchanged.

Table 24:

In the **lotteries** of Table 24 you will win 5 euro in addition to your previously achieved credit with a probability of 50% and with a probability of 50% a given amount will be deducted from your previous credit.

As you can infer from Table 24, **the lottery becomes more unattractive the lower the row**. In row 1 there is a 50 percent chance that you lose **€0.50** of your previous credit. In row 2, in contrast, there is a 50 percent chance, that you lose **€1.00** of your previous credit. **Your task is to decide until which row you prefer the lottery over a safe payment to the amount of €0.**

Example (see Table 24): Suppose that you prefer the lottery over the safe amount of 0€ as long as the lottery decreases your credit by at most €3.50 in the case of a loss. In this case you choose row 7 in Table 24. This means that you receive the safe payment to the amount of €0 if the computer randomly chooses one of the rows 8 to 15. If the computer randomly chooses one of the rows 1 to 7, your payoff is decided upon by the lottery given in the chosen row. Hence, if the computer chooses, for example, row 3, you will gain €5 in addition to your previous credit with a probability of 50% and with a probability of 50% you will lose €1.50 of your previous credit.

Please choose up to which row you prefer the lottery over a safe amount of €2.50.

		Choose the safe amount for ALL rows
1	**€8.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for row 1 and the safe amount for rows 2 to 15
2	**€7.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 2 and the safe amount for rows 3 to 15
3	**€7.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 3 and the safe amount for rows 4 to 15
4	**€6.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 4 and the safe amount for rows 5 to 15
5	**€6.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 5 and the safe amount for rows 6 to 15
6	**€5.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 6 and the safe amount for rows 7 to 15
7	**€5.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 7 and the safe amount for rows 8 to 15
8	**€4.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 8 and the safe amount for rows 9 to 15
9	**€4.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 9 and the safe amount for rows 10 to 15
10	**€3.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 10 and the safe amount for rows 11 to 15
11	**€3.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 11 and the safe amount for rows 12 to 15
12	**€2.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 12 and the safe amount for rows 13 to 15
13	**€2.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 13 and the safe amount for rows 14 to 15
14	**€1.50 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for rows 1 to 14 and the safe amount for row 15
15	**€1.00 with 50% prob. & €0.00 with 50% prob.**	Choose the lottery for ALL rows

Table 23

Note that the computer randomly chooses exactly **one row** from **one of both tables** with an equal probability for your payoff. At the end of the experiment you will learn which table and row has been chosen randomly by the computer. If you have chosen the lottery in the row chosen by the computer, you will additionally learn the outcome of the lottery.

If you have any questions, please raise your hand. We will then come to you and answer quietly. If prompted, please click on the "continue" button in order to continue.

Please choose up to which row you prefer the lottery over a safe amount of €0.00.

		Choose the safe amount for ALL rows
1	**€5.00 with 50% prob. & -€0.50 with 50% prob.**	Choose the lottery for row 1 and the safe amount for rows 2 to 15
2	**€5.00 with 50% prob. & -€1.00 with 50% prob.**	Choose the lottery for rows 1 to 2 and the safe amount for rows 3 to 15
3	**€5.00 with 50% prob. & -€1.50 with 50% prob.**	Choose the lottery for rows 1 to 3 and the safe amount for rows 4 to 15
4	**€5.00 with 50% prob. & -€2.00 with 50% prob.**	Choose the lottery for rows 1 to 4 and the safe amount for rows 5 to 15
5	**€5.00 with 50% prob. & -€2.50 with 50% prob.**	Choose the lottery for rows 1 to 5 and the safe amount for rows 6 to 15
6	**€5.00 with 50% prob. & -€3.00 with 50% prob.**	Choose the lottery for rows 1 to 6 and the safe amount for rows 7 to 15
7	**€5.00 with 50% prob. & -€3.50 with 50% prob.**	Choose the lottery for rows 1 to 7 and the safe amount for rows 8 to 15
8	**€5.00 with 50% prob. & -€4.00 with 50% prob.**	Choose the lottery for rows 1 to 8 and the safe amount for rows 9 to 15
9	**€5.00 with 50% prob. & -€4.50 with 50% prob.**	Choose the lottery for rows 1 to 9 and the safe amount for rows 10 to 15
10	**€5.00 with 50% prob. & -€5.00 with 50% prob.**	Choose the lottery for rows 1 to 10 and the safe amount for rows 11 to 15
11	**€5.00 with 50% prob. & -€5.50 with 50% prob.**	Choose the lottery for rows 1 to 11 and the safe amount for rows 12 to 15
12	**€5.00 with 50% prob. & -€6.00 with 50% prob.**	Choose the lottery for rows 1 to 12 and the safe amount for rows 13 to 15
13	**€5.00 with 50% prob. & -€6.50 with 50% prob.**	Choose the lottery for rows 1 to 13 and the safe amount for rows 14 to 15
14	**€5.00 with 50% prob. & -€7.00 with 50% prob.**	Choose the lottery for rows 1 to 14 and the safe amount for row 15
15	**€5.00 with 50% prob. & -€7.50 with 50% prob.**	Choose the lottery for ALL rows

Table 24

This is the last part of the experiment. After the experiments ends, there will be a short questionnaire. Thank you for your participation!