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

Abstract

This paper investigates whether limited liability and moral hazard affect risk-taking through motivated beliefs. On the one hand, limited liability pushes investors towards taking excessive risks. On the other, such excesses make it hard for investors to maintain a positive self-image when moral hazard is present. Using a novel experimental design, we show that subjects form motivated beliefs to self-justify their excessive risk-taking. For the same investment opportunity, subjects invest more and are significantly more optimistic about the success of the investment if their failure can harm others. We show that more than one third of the investment increase under limited liability can be explained through motivated beliefs. Moreover, using a treatment with limited liability but no moral hazard, we show that motivated beliefs are formed subconsciously and can lead to the paradoxical result of investors taking larger risks when their investment can harm a third party than when it cannot. These results underscore the importance of motivated beliefs in regulatory policy as they show that one should target not only bad incentives but also "bad beliefs."

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1 Introduction

There is a vast literature in psychology showing that people distort their beliefs to reach the conclusions they want to arrive at (e.g., Hastorf and Cantril, 1954; Messick and Sentis, 1979; Kunda, 1990). Some of the reasons behind such self-serving beliefs are maintaining a positive self-image in the face of a morally questionable action or rationalizing actions that conflict with one's beliefs (Festinger, 1957). In most cases, the outcomes of belief distortions are confined to the private sphere (e.g., Schwardmann et al., forthcoming; Caplin and Leahy, 2001). However, collective distortions within a firm, institution, or industry can have a strong social impact if the regulatory agencies turn a blind eye to such unpleasant realities (Bénabou and Tirole, 2016).

An example of such collective distortions might have occurred during the recent financial crisis. Most of the literature considers excessive risk-taking as one of the main causes behind the crisis (Brunnermeier, 2009; Taylor et al., 2010), yet it is not clear why such excessive risk-taking took place. While some authors argue that excessive risk-taking could originate from the implicit and explicit guarantees inherent in the financial sector (Acharya et al., 2010; Hakenes and Schnabel, 2014), others argue that investors modified their beliefs to take larger unjustifiable risks while still maintaining a positive self-image (Barberis, 2013; Bénabou, 2015).[1] The reason for such modified beliefs is the tension that limited liability creates in the investors' minds. On the one hand, limited liability pushes investors towards taking excessive risks. On the other, such excesses make it hard for investors to maintain a positive self-image, creating a mental discomfort (Bénabou and Tirole, 2016; Festinger, 1957). To attenuate this mental discomfort, investors may manipulate how they process information and form *motivated beliefs* to justify their actions (Gino et al., 2016).

In this paper, we try to identify the presence of motivated beliefs in investors under limited liability and quantify the effects of such motivated beliefs on the risk taken by investors. To do so, we design an experiment where all subjects take part in three different treatments. In each treatment, subjects decide on the fraction of a given fixed endowment to invest in a risky asset. However, before investing, subjects receive a noisy signal indicating whether the investment will succeed or fail. They then (a) state their beliefs about the likelihood that the investment will succeed and (b) decide how much of their endowment to invest in it. If the investment is successful, the investor always collects all the gains. If the investment fails, the allocation of losses will depend on the treatment: in the *Baseline* (*BL*) treatment, the investor internalizes all losses from her risky investment. In two limited liability treatments, the losses are shared with other subjects. In the first of these treatments (*Matched* (*MA*)), each investor is matched to a single loss-taking subject with whom she shares the losses. In the second (*Diffusion* (*DF*)), all losses are pooled and paid equally by all loss-taking subjects in the session.

Both limited-liability treatments (*MA* and *DF*) incentivize selfish subjects to take larger risks than in *BL*, creating a negative externality on loss-taking subjects (i.e., moral hazard). However, because the signal is ambiguous enough for subjects to form motivated beliefs, subjects can self-justify their morally questionable investments in *MA* and *DF* by being excessively optimistic about the success probabilities of their investments. Furthermore, in *DF* investments should be higher and beliefs less optimistic than in *MA* due to the diffusion of responsibility (Falk and Szech, 2013; Alós-Ferrer et al.,

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

2021). To confirm that self-image is driving our results we also run a *No Matches* (*NM*) treatment. In it, investors have limited liability, but failed investments do not result in losses for other subjects. Because in this treatment there is no moral hazard, there is no reason to form motivated beliefs, so investors should invest more than in the *BL* treatment but hold the same beliefs about the investment's likelihood of success.

Our results show that investors form motivated beliefs: For the same signal, the same investor invests a larger proportion of her endowment in the risky asset and states a higher likelihood of success under limited liability with moral hazard than under full liability. Moreover, using mediation analysis (Imai et al., 2011, 2013), we *isolate* and *quantify* the causal effect of limited liability on investment decisions that works through the formation of motivated beliefs. The results show that about one-third of the increase in investment under limited liability is due to the formation of motivated beliefs.

Additionally, we use the *NM* treatment to pin down the psychological channel through which motivated beliefs are formed in our setup. As hypothesized, motivated beliefs are formed due to self-image concerns. Alternative channels such as anticipatory utility or wishful thinking (Brunnermeier and Parker, 2005; Bridet and Schwardmann, 2020) play no discernible role. The *NM* treatment also uncovers what appears to be a paradoxical result: under limited liability, investors take larger risks when their actions can harm loss-takers than when they cannot. We attribute this behavior to investors forming more optimistic beliefs in the *MA* treatment when loss takers are involved, indicating that motivated beliefs are formed subconsciously and outweigh the eventual other-regarding preferences that would lead to lower investments in under limited liability with moral hazard.

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 of this literature 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 recently, Ahrens and Bosch-Rosa (2019) detect the presence of motivated beliefs when subjects share investment profits but are not responsible for their losses, and Gneezy et al. (2020) study how conflicts of interests can trigger motivated beliefs in laboratory subjects. In this paper, we confirm the presence of motivated beliefs in a more revealing within-subject comparison and, most importantly, we are the first to quantify the relative contribution of incentives and motivated beliefs on risk-taking, as suggested by Barberis (2013), Bénabou (2013), or Bénabou (2015).

The second strand of the literature to which we contribute refers to 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 (Bartling et al., 2015; Sutter et al., 2016; Behnk et al., 2017; Alós-Ferrer et al., 2021). Based on these results, we expected the diffusion of responsibility in the *DF* treatment to reduce the demand for motivated beliefs and to further enhance decision-makers' risk-taking compared to the *MA* treatment. However, we cannot detect any significant effects of the diffusion of responsibility on subjects' stated beliefs nor on the amounts invested.

This paper is structured as follows. Section 2 explains the experimental design, Section 3 presents the experiment's results, and Section 4 concludes.

2 Experimental Design

The experiment follows a within-subject design with two types of sessions. In the first type (run between January and February 2019), all subjects participate in the *BL*, *MA*, and *DF* treatments. In the second type of session (run in September 2021), subjects go through the *BL*, *MA*, and *NM* treatments.[2] 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 to invest in a risky asset. The asset yields a gain of $0.75X$ if the investment is successful (where $X \in [€0; €8]$ is the amount invested in the risky asset) and yields a loss of X (in treatments *BL*, *MA*, and *DF*) or $.25X$ (in treatment *NM*) if the investment fails.

Treatments *BL*, *MA*, and *DF* differ in how the loss is distributed among subjects if the investment fails (see Section 2.2). To avoid hedging, we pay only one decision per treatment that is randomly determined at the end of the experiment. Similarly, to prevent learning and income effects, subjects receive no feedback on the outcomes of their decisions until the end of the experiment. To prevent potential order effects, we run different treatment orders.[3]

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

2.1 Signal

In each round, the ex-ante probability of success of an investment is of $p = 1/2$. However, before each investment decision, subjects receive a signal that indicates whether the investment will fail or succeed. This signal consists of a 20x20 matrix containing red and blue dots, and it is flashed to subjects for eight seconds (we refer to these matrices as 'Dot Spots," see Figure 1 for two examples). The number of red and blue dots in the matrix signals the outcome of the investment for that round: if the matrix contains more red than blue dots, the investment succeeds, and if it contains more blue than red dots, the investment fails. Because the number of red dots ranges between 120 and 280, subjects do not have sufficient time to count the dots. To them, the signal appears to be noisy and is assumed to induce subjective beliefs about the success of the investment.[4]

Immediately after seeing each matrix, subjects are asked to estimate the investment's success proba-

[2] Importantly, while subjects knew that there would be multiple "blocks" during the experiment, they did not know the details for each block (i.e., treatment) until immediately before each treatment.

[3] The orders for sessions with the *BL*, *MA*, and *DF* treatments are: 1) *BL*, *MA*, *DF*; 2) *MA*, *DF*, *BL*; and 3) *DF*, *MA*, *BL*. The orders for sessions with *BL*, *MA*, and *NM* treatments are: 1) *BL*, *MA*, *NM*, and 2) *MA*, *NM*, *BL*. The number of sessions with each order is balanced within each type of sessions.

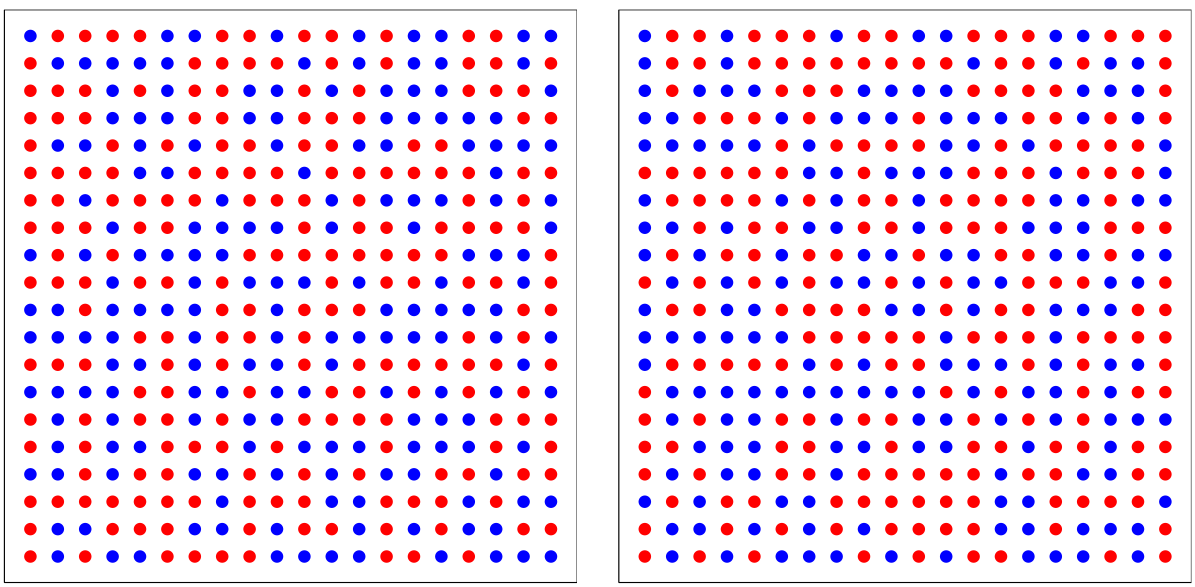
[4] Using data from pilot experiments, we chose Dot Spots that convey some information about the success probability of the investment, but are generally noisy enough for subjects not to be certain about the success or failure of the investment.

bility and to make their investment decision for the round.[5] Hence, we have two observations for every round and subject; the estimated success probability of the investment and the investment decision, conditional on the signal shown.

An important characteristic of our signals is that by maintaining the same number of red dots, but varying the pattern in which they are shown, we can present subjects with "informationally identical" matrices without enabling them to learn or anchor their expectations to particular patterns. This allows us to compare the behavior of the *same subject* for *identical* investment opportunities across treatments. See Figure 1 for an example of two *informationally identical* signals and Appendix B for more details on the exact number of red dots and the ordering of the signals.

In the sessions run in September 2021 (those including the *NM* treatment), we incentivized beliefs using a binarized scoring rule (Hossain and Okui, 2013) that pays either €2 or €0.[6] This payment is based upon a randomly selected round within each treatment, which totals to a potential payoff of €6 for accurate beliefs across all treatments. To avoid hedging, in each treatment we tell subjects that the round chosen for the belief payoffs will not be that chosen for the investment payoffs.

Figure 1: Two "Informationally Identical" Dot Spot Matrices



Two matrices with 215 red dots but a different pattern.

2.2 Treatments

Baseline: In the *BL* treatment, each subject absorbs any profits or losses from her investment. Therefore, subject i wins $0.75X_i$ if her investment is successful and loses X_i if it fails. Hence, in *BL*,

[5] The success probability and investment decision for a given signal are all stated in the same screen.

[6] The Binarized Scoring Rule is an incentive compatible rule that is robust to the preferences of subjects, making it ideal for our setup.

subject i's payoff P_i^{BL} is given by

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

The *BL* treatment provides us with the benchmark behavior of each subject. Most comparisons will be made relative to this treatment as it provides subjects with the most "natural" investment environment, abstracting from any limited liability or moral hazard concerns.

Matched: In the *MA* treatment, half of the subjects are randomly assigned the role of "investors" and the other half are "loss-takers."[7] Subjects are anonymously and randomly matched such that every investor b $\in \{1, 2, ..., B\}$ is associated with exactly one loss-taker t $\in \{1, 2, ..., T\}$.[8] Subjects know their type and that both the matches and the player types will be kept for the whole treatment.[9]

In this setup, the investment X_b of investor b affects the payoff of her matched loss-taker if and only if the investment fails. So if the investment is successful, the investor gains $0.75X_b$ on top of her initial endowment and the loss-taker gets to keep her initial endowment intact. If the investment fails, the investor 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 investor b for investment X_b is

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

while the payoffs for loss-taker t are

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

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

Since in the *MA* treatment, the investor bears only a part of the eventual losses, she is tempted to make larger investments than in the *BL* treatment. Therefore, for an informationally identical signal, we expect investors to invest more in MA than in BL (Hypothesis 1, H1). If investors process information rationally, they should state the same beliefs in treatments MA and BL for informationally identical signals (Hypothesis 2, H2). However, because any failed investment exerts a negative externality on an

[7] In the instructions, we used the term "Type A" and "Type B" for investors and loss-takers, respectively.

[8] For the first type of session (i.e., those including *DF*), we ran nine sessions in total. Eight sessions had 20 subjects and thus 10 loss-takers and 10 investors. The ninth session only had 18 subjects (9 investors and 9 loss-takers) due to no-show subjects. For the second type of sessions (i.e., those including *NM*) we ran ten sessions. However, due to the coronavirus pandemic, we had a lower number of subjects. A total of six sessions had 12 subjects, two had 10 subjects, and two had 8 subjects.

[9] Subjects also 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 treatment.

anonymous loss-taker, investors might bias upwards their beliefs about the success of the investment to self-justify their selfish actions while maintaining a positive self-image (Gino et al., 2016; Bénabou, 2015). Hence, our counter-hypothesis is that for an informationally identical signal, investors are more optimistic about the success probabilities in *MA* than in *BL*.

Diffusion: In the *DF* treatment, the losses of a failed investment are distributed across *all* loss-takers. As in treatment *MA*, if the investor'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 investor loses $0.25X_b$, and *all loss-takers* evenly share the loss of $0.75X_b$. Hence, the payoffs of investor 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 investors in the experimental session, and $\mathbb{1}_{\mathbb{b}}^{\mathbb{DF}}$ is an indicator variable that takes on the value of one if investor b's investment fails and zero otherwise.

The *DF* treatment diffuses the responsibility of investors as the loss of any failed investment is shared across many subjects, each paying a small portion of the losses. For the same signal, a subject who processes information rationally should invest the same as in the *MA* treatment (hypothesis 3, H3) and state the same probabilities as in the *MA* treatment (hypothesis 4, H4). However, previous literature has shown that subjects can simultaneously behave altruistically towards individual subjects, but selfishly regarding large groups (Alós-Ferrer et al., 2021; Kirchler et al., 2016). Therefore, for an *informationally identical* signal, investors might invest more in the *DF* treatment than in the *MA* treatment. At the same time, due to the lower need to form motivated beliefs, investors might be less optimistic about the success of the same investment in *DF* than in *MA*.

No Matches: In the *NM* treatment, the payoffs of investors are determined in the same way as in *MA* and *DF*, but a failed investment has no external effect on other subjects. In *NM*, all subjects are investors and their payoff functions are equivalent to Equation 2.

The *NM* treatment allows us to pinpoint the source of subjects' biased beliefs. Because there is no moral hazard, investors do not need to self-justify their actions through motivated beliefs. Therefore, if the source of motivated beliefs is a concern for self-image, for an *informationally identical* signal, the stated beliefs in *NM* should be the same as in *BL* (Hypothesis 5, H5). A rejection of Hypothesis 5 would indicate that motivated beliefs do not originate from self-image concerns but from another psychological source such as (e.g.,) anticipatory utility (Brunnermeier and Parker, 2005; Engelmann et al., 2019).

At the same time, because investors face the same payoffs in *NM* as in *MA*, a selfish investor *without motivated beliefs* should invest the same in *NM* as in *MA* (Hypothesis 6, H6). However, two opposing forces may pull investments away from this equality. On the one hand, the presence of other-regarding preferences *à la* Fehr and Schmidt (1999) may lead investors to invest less in *MA* than in *NM*. On the other hand, motivated beliefs might result in higher investments in *MA* than in *NM*. A rejection of H6 would indicate that one of these two effects dominates.

To clarify the experimental design, in Table 1 we summarize the differences between treatments and the hypotheses for each one of them.

Table 1: Summary of the Treatments and Hypotheses.

Treatment	**Share of Losses**	Limited Liability	Moral Hazard	Testable Hypotheses
BL	All subjects are responsible for 100% of their losses	No	No	Baseline
MA	Investor is matched with loss-taker. If losses, investor covers 25% and loss-taker covers 75%.	Yes	Yes	H1: investment higher than in *BL* H2: same beliefs as in *BL*
DF	Investor is matched with all loss-takers. Investors cover 25% of their losses, loss-takers cover evenly the 75% of all losses across all investors.	Yes	Yes	H3: same investment as in *MA* H4: same beliefs as in *MA*
NM	All subjects are responsible for 25% of their losses.	Yes	No	H5: same beliefs as in BL H6: same investment as in MA

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 the experiment, except that subjects are informed that the practice rounds have no monetary consequences, and subjects receive full feedback regarding their hypothetical payoffs after each round.

Additionally, before each treatment starts, all subjects participate in a risky investment task. In this task (as opposed to the uncertain investments just described), subjects make 11 independent investment decisions for 11 different assets, each 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 respective treatment (*BL*, *MA*, *DF*, *NM*), and the investor and loss-taker roles are maintained. Thus, the only difference between the risky investments and the uncertain investments is that investors *know* the success probabilities under risk, which leaves no room for motivated beliefs. 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.

Because in the risky rounds there is no space to form motivated beliefs, they allow us to pin down the channel through which motivated beliefs are formed (see Section 3.4). Additionally, starting each treatment with a simplified version of the task might help subjects think more about the payoff structure and the different outcomes in that treatment.

3 Results

A total of 286 subjects were recruited through ORSEE (Greiner, 2015).[10] Sessions lasted a little below 120 minutes and were conducted at the Experimental Economics Laboratory of the Technische Universität Berlin. Subjects earned, on average, €38, and the experiment was programmed and conducted using oTree (Chen et al., 2016). For the entire results section, we will only analyze the decisions made by investor subjects. We also pool the data of sessions with and without incentivized belief elicitation as we cannot detect any statistical differences between incentivized and non-incentivized beliefs (see Appendix E for details).[11]. Finally, because we are mainly interested in investments under uncertainty and the formation of motivated beliefs, we relegate any results of the risky investments to Appendix C.

3.1 Treatment Effects on Investment

In Figure 2, we present a cumulative distribution function of subjects' investments across all ten rounds of each of the three treatments (BL, MA, and DF). As can be seen, both the MA and DF distributions first-order stochastically dominate that for the investments under BL, implying that investor subjects made larger investments under limited liability than they did under full liability. This result is confirmed in Table 2, where we present the mean investments across all rounds in the *Total* column along with the investment for each Dot Spot matrix across all treatments. As can be seen, the investment is clearly increasing in the number of red dots of the signal (see Figure 6 of Appendix D.1 for a detailed graphical representation of investments for each type of matrix).

Table 2: Mean Investments for Dot Spot Matrices

	Total	**120**	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
BL	28.47	1.74	6.65	16.88	21.34	21.37	31.16	32.75	34.67	41.28	88.93
	(36.62)	(9.59)	(14.77)	(26.92)	(30.53)	(29.76)	(34.67)	(35.97)	(36.11)	(37.27)	(22.90)
MA	43.24	4.15	22.49	30.23	39.18	41.13	41.33	46.86	52.69	64.93	89.82
	(39.38)	(15.01)	(30.48)	(33.57)	(39.68)	(36.94)	(36.92)	(35.77)	(35.77)	(34.29)	(20.98)
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 matrix. Standard Deviations are shown in parentheses.

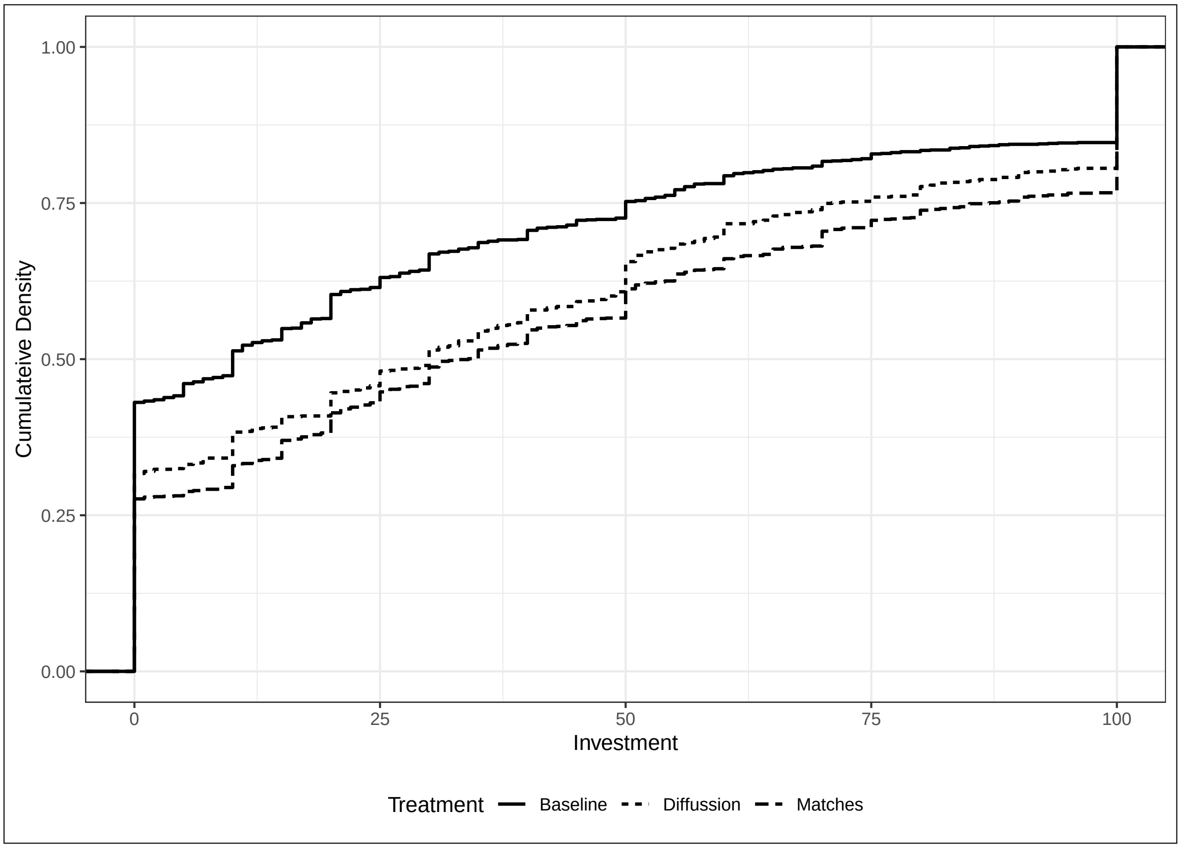
A within-subject Wilcoxon signed-rank tests comparing the *total* amount invested in each treatment shows clear statistical differences between *MA* and *BL* and between *DF* and *BL* (p-value < 0.001 in both cases). However, we do not detect any differences between the *MA* and *DF* treatments (p-value

[10]Of the 286 subjects, 178 participated in the first type of sessions (with *DF* treatment) and the remaining 108 participated in the second type of session (with the *NM* treatment).

[11]This result is consistent in the motivated beliefs literature, where incentives, even if high, are hardly able to de-bias subjects' beliefs (e.g., Engelmann et al. (2019) or Schwardmann et al. (forthcoming))

= 0.128). When comparing the investments for each type of matrix, we see large statistical differences between *MA* and *BL* and between *DF* and *BL*, but we detect no difference between *MA* and *DF* (see Table 14 of Appendix D.1 for a detailed breakdown of the p-values for each type of matrix).[12]

Figure 2: Cumulative Density Function across Treatments.



Cumulative density functions of subjects' investment (as percentage of the endowment) across the three treatments.

To have a better understanding of the data, Table 3 provides a regression of the percentage of the endowment invested by subjects ($Invest$) on dummy variables for the different treatments, dummies for the number of red dots in each Dot Spot, the different personality measures, and treatment order dummies. All errors are clustered at the subject level. As in Table14 and Figure 2, we see a strong and positive statistical difference between both limited liability treatments (*MA* and *DF*) and the baseline treatment (*BL*). On average, investors invest 13% of their endowment more in the *MA* treatment and 11% more in the *DF* treatment than in the *BL* treatment. We also confirm the informational value of the signals, as the amount invested is higher the more red dots are in the flashed matrix (e.g., investors invest on average 25% more in matrices with 195 red dots than in matrices with 120 red

[12] As explained in Appendix B, investors might see up to two informationally identical signals in each treatment. For example, an investor 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 investor's data would neither be used to compare *MA* and *BL* nor for the comparisons between *MA* and *DF*. If a subject receives two informationally identical signals in the same treatment, we take the average between both investments to compare with the other treatment(s).

dots).

Table 3: Effect of Signals and Treatments on Investment.

Dep. Variable: *Invest*	(1)	(2)	(3)	(4)
MA	12.76***	12.76***	13.23***	
	(1.402)	(1.405)	(1.470)	
DF	9.095***	10.57***	10.81***	-1.789
	(1.562)	(1.363)	(1.458)	(1.353)
185.dots	11.83***	11.85***	12.06***	15.77***
	(1.284)	(1.320)	(1.352)	(2.094)
190.dots	21.73***	21.47***	20.91***	24.44***
	(1.925)	(1.917)	(1.983)	(2.589)
195.dots	27.12***	26.90***	27.89***	31.41***
	(2.178)	(2.194)	(2.275)	(2.860)
199.dots	25.38***	25.27***	24.64***	29.99***
	(2.199)	(2.196)	(2.246)	(2.883)
201.dots	38.42***	38.45***	37.34***	40.98***
	(2.723)	(2.702)	(2.749)	(3.251)
205.dots	38.20***	38.34***	38.44***	41.25***
	(2.409)	(2.412)	(2.537)	(3.215)
210.dots	41.09***	41.27***	41.65***	49.09***
	(2.728)	(2.714)	(2.836)	(3.287)
215.dots	52.03***	51.93***	50.91***	59.17***
	(3.045)	(3.055)	(3.202)	(3.585)
280.dots	86.89***	86.80***	86.13***	85.37***
	(2.302)	(2.343)	(2.491)	(2.781)
Constant	-3.797***	-1.066	-9.140	0.673
	(1.206)	(18.21)	(18.64)	(21.43)
N	3750	3750	3480	2140
adj. R^2	0.359	0.373	0.368	0.353
Controls	No	Yes	Yes	Yes
Gender	No	No	Yes	Yes
BL included	Yes	Yes	Yes	No

Standard errors in parentheses

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

In the first three columns, we study the effects of the different signals and moral hazard treatments on the investment 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.

The difference between columns (1) and (2) is that the first one does not include any personality controls. 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 fewer observations than columns (1) and (2). Finally, in column (4), we only use the data for moral hazard treatments (*MA* and *DF*).

As in Tables 2 and 14, we cannot detect any statistical difference between the investments in the *DF* and *MA* treatments.

Overall, when studying the effects of our different treatments on the investments, we obtain two clear results. First, the limited liability treatments have a significant positive effect on investments. Second, we cannot reject the null hypothesis that 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. [H1]

ii) The investment levels in both limited liability treatments are similar, and we cannot detect any statistical differences in investment levels between the MA and DF treatments. [H3]

3.2 Treatment Effect on Beliefs

Figure 3 plots the cumulative density function for the stated probabilities that the investment will be successful across the *BL*, *MA*, and *DF* treatments. The CDF's show that subjects seem to be more optimistic in both the *MA* and *DF* treatments than in BL. This difference can also be seen in Table 4 where we report the average likelihood of success reported by investors across the ten rounds of each treatment (Column 1), and the subjective likelihood of success for each Dot Spot matrix (columns 2 to 10). A Wilcoxon signed-rank test comparing the average belief of subjects across the ten rounds shows strong statistical differences between MA and DF when compared to BL (p-value < 0.001 and p-value < 0.013, respectively), but no differences between MA and DF (p-value $= 0.068$).[13]

Table 4: Mean Stated Probabilities of Success for Dot Spot Matrices

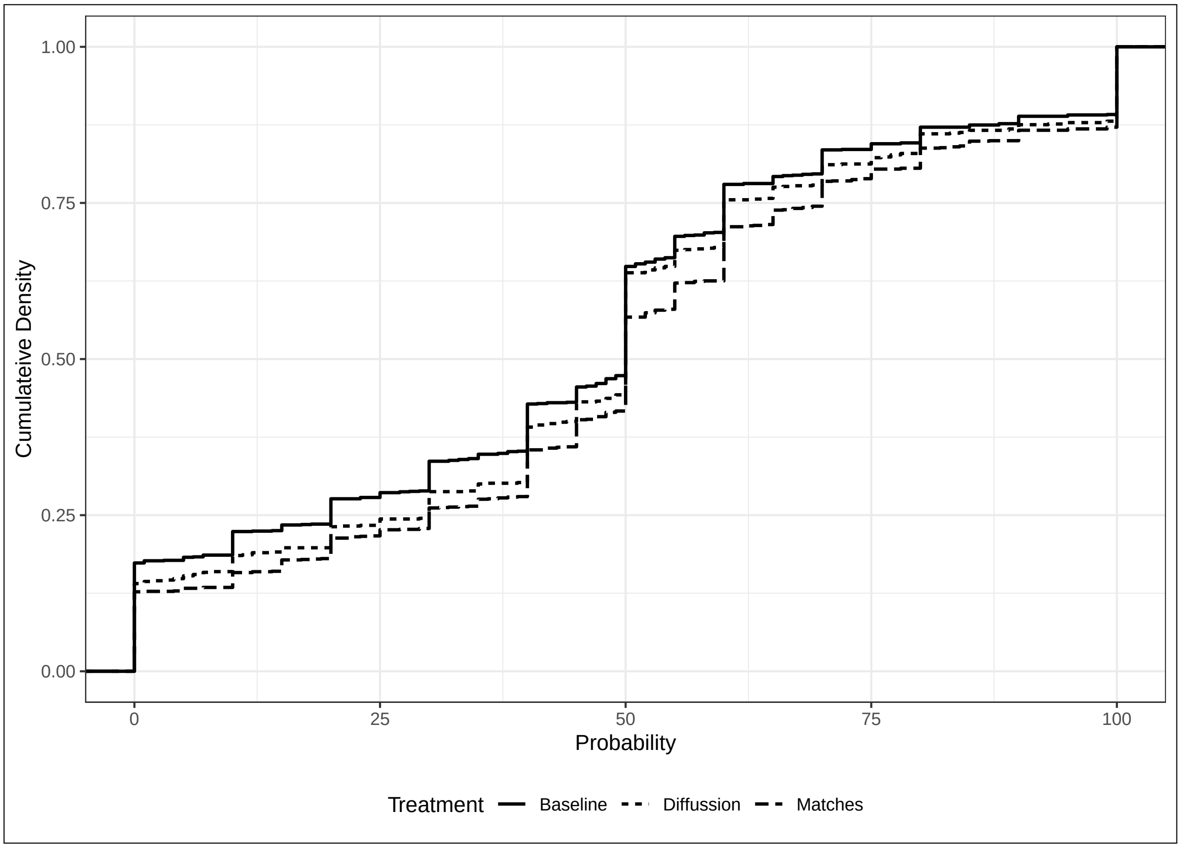
	Total	**120**	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
BL	44.48	9.35	25.91	39.90	40.49	41.30	52.56	49.65	48.00	59.58	90.26
	(36.68)	(17.21)	(23.69)	(24.98)	(27.72)	(23.29)	(26.99)	(25.95)	(25.11)	(21.76)	(14.83)
MA	49.92	9.99	33.50	37.69	46.03	48.90	52.64	53.35	59.10	67.73	90.60
	(30.21)	(14.70)	(23.34)	(22.96)	(29.35)	(24.38)	(25.59)	(23.56)	(22.78)	(21.27)	(11.89)
DF	47.20	9.18	26.73	42.07	39.38	40.75	55.28	49.78	56.64	64.70	90.52
	(30.14)	(17.37)	(21.17)	(19.31)	(23.82)	(22.63)	(22.78)	(24.52)	(24.39)	(24.58)	(15.95)

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 matrix. Standard Deviations are shown in parentheses.

In Table 5, we use our balanced panel of 143 investors and 30 rounds to regress the estimated success probability of investors ($Prob$) 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

[13] We report the p-values for a Wilcoxon signed-rank test comparing the average belief of subjects for each Dot Spot matrix in Table 15 of Appendix D.2.

Figure 3: Stated Success Probabilities across Treatments.



Cumulative density functions of subjects' stated success probabilities across the three treatments.

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, once we use controls, the treatment variables MA and DF are positive and statistically significant. This indicates that in both limited liability treatments, investors are more optimistic about their investments' success.

The difference between columns (1) and (2) is that in the second, we include the personality controls described in Appendix A. Again, 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.[14] 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 Table 3, there is no difference between both treatments, as DF is not significantly different from zero.

[14]As mentioned in Section 3.1, in one session we failed to record the gender of subjects, so column (3) has fewer observations than columns (1) and (2).

Table 5: Effect of Signals and Treatments on Beliefs.

Dep. Variable: *Prob*	(1)	(2)	(3)	(4)
MA	4.174***	4.170***	4.114***	
	(0.855)	(0.855)	(0.892)	
DF	1.774*	2.792***	3.171***	-0.875
	(1.019)	(1.047)	(1.129)	(1.224)
185.dots	19.35***	19.32***	19.50***	21.70***
	(1.491)	(1.518)	(1.574)	(2.026)
190.dots	29.98***	29.78***	29.03***	28.10***
	(1.686)	(1.711)	(1.787)	(1.978)
195.dots	32.64***	32.56***	33.14***	34.37***
	(1.981)	(1.993)	(2.064)	(2.370)
199.dots	34.47***	34.28***	33.30***	35.38***
	(1.975)	(1.976)	(2.012)	(2.365)
201.dots	43.61***	43.69***	42.39***	42.68***
	(2.115)	(2.116)	(2.142)	(2.359)
205.dots	41.51***	41.46***	41.00***	41.40***
	(1.921)	(1.928)	(2.044)	(2.593)
210.dots	44.92***	45.01***	44.60***	47.81***
	(2.092)	(2.092)	(2.173)	(2.455)
215.dots	54.29***	54.21***	52.54***	55.10***
	(2.352)	(2.357)	(2.414)	(2.698)
280.dots	80.74***	80.61***	79.56***	79.51***
	(2.083)	(2.092)	(2.224)	(2.400)
Constant	7.608***	7.015	2.156	5.261
	(1.498)	(10.43)	(10.81)	(11.26)
N	3750	3750	3480	2140
adj. R^2	0.441	0.444	0.444	0.459
Controls	No	Yes	Yes	Yes
Gender	No	No	Yes	Yes
BL included	Yes	Yes	Yes	No

Standard errors in parentheses

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

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.

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. [H2 is rejected]

ii) The subjective success probabilities in both limited liability treatments are similar, and we cannot reject the null hypothesis that there are no differences in stated beliefs between MA and DF. [H4]

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 investors invest significantly more under limited liability, yet this result could be driven by investors' private incentives, their motivated beliefs, or both reasons combined.

To disentangle the effect of motivated beliefs from the direct effect that limited liability might have on decision-makers, we follow Imai et al. (2011) and Imai et al. (2013). These papers show how an instrumental variable (IV) approach can be used to disentangle the effects of a mediator of interest (in our case, motivated beliefs) from other potential effects of the treatment (e.g., the presence of limited liability). To do so, we run the following IV regression:

$$Prob_{b,r} = \alpha_0 + \alpha_1 \times MH_{b,r} + \alpha_2 \times Dots_{b,r} + \epsilon_{b,r}, \tag{5}$$

$$Investment_{b,r} = \beta_0 + \beta_1 \times \widehat{Prob_{b,r}} + \beta_2 \times MH_{b,r} + u_{b,r}. \tag{6}$$

In the first stage (Eq. 5), $Prob_{b,r}$ captures investor b's belief about the success probability of an investment in round r, $MH_{b,r}$ (which stands for Moral Hazard) is a dummy variable that takes on the value of one in the limited liability treatments with moral hazard (*MA* and *DF*) and zero if the treatment is *BL*, and $Dots_{b,r}$ comprises dummies for the ten different numbers of red dots that we use for the Dot Spots.[15] In the second stage (Eq. 6), $Investment_{b,r}$ captures the percentage of the endowment investor b invests into the risky asset. In other words, we use the stated probabilities as an instrument, relate the instrument to the incentives by Eq. 5 and combine the instrument with the respective treatment dummy as explanatory variables for investment in Eq. 6.

The advantage of this model is that we can identify the *indirect effect* of the treatment on investments mediated through beliefs by exploiting the variation in $Dots_{b,r}$ in the first stage. This feature allows us to include $MH_{b,r}$ as an explanatory variable in the second stage, isolating the *direct effect* that limited liability has on beliefs. To do so, our main assumption is that the number of red dots, Dotsb,r, affects the investment decision only by shifting subjects' beliefs.[16]

[15] We fold in both *MA* and *DF* treatments into the dummy MH because they are statistically indistinguishable (recall Result 1 and Result 2).

[16] Following the terminology of Imai et al. (2013), in our IV model we use an *encouragement* ($Dots_{b,r}$) to disentangle the causal effect of the treatment that works *through* the mediator ($Prob_{b,r}$) from all other causal effects of the treatment.

Table 6: First Stage Regressions for Prob

Dep. Variable: *Prob*	(1)	(2)	(3)
MH	3.255***	3.697***	3.802***
	(0.760)	(0.772)	(0.813)
185.dots	19.35***	19.31***	19.49***
	(1.491)	(1.519)	(1.574)
190.dots	30.03***	29.79***	29.03***
	(1.684)	(1.711)	(1.788)
195.dots	32.60***	32.53***	33.12***
	(1.983)	(1.994)	(2.063)
199.dots	34.51***	34.28***	33.31***
	(1.975)	(1.975)	(2.011)
201.dots	43.60***	43.68***	42.38***
	(2.115)	(2.116)	(2.143)
205.dots	41.56***	41.49***	41.02***
	(1.922)	(1.928)	(2.044)
210.dots	44.89***	45.00***	44.59***
	(2.095)	(2.093)	(2.174)
215.dots	54.32***	54.22***	52.54***
	(2.350)	(2.355)	(2.413)
280.dots	80.77***	80.61***	79.56***
	(2.082)	(2.092)	(2.225)
Constant	7.595***	6.873	2.053
	(1.495)	(10.42)	(10.79)
N	3750	3750	3480
adj. R^2	0.440	0.444	0.444
Gender	No	No	Yes
Controls	No	Yes	Yes

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

The treatment dummy *MH* identifies all treatments with limited liability and moral hazard (*MA* and *DF*). Robust standard errors clustered at the investor level in parentheses.

We can now simply compute the complier average mediation effect (CACME) as the product of α_1 from Eq. (5) and β_1 from Eq. (6). This is the average effect of limited liability on investment mediated by beliefs among those investors whose beliefs are affected by limited liability (see, e.g., Imai et al., 2011).[17] 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. (6).

Table 6 shows the results from the first stage (Eq. (5)) for the three different specifications. The results show that the variation in the number of red dots has a large impact on the beliefs and the variable

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

MH is statistically significant with a positive impact on beliefs. This finding indicates that, under limited liability and moral hazard, investors increase their stated probabilities of success by roughly 3 to 4 percentage points, depending on whether controls are included or not.

Table 7 presents the second-stage results for the same three specifications laid out in Table 6. 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. The direct treatment effects (i.e., β_2 in Eq. (6)) is approximately 8 percentage points.

Finally, using the first- and second-stage results from Tables 6 and 7, we obtain the indirect treatment effects, which is $3.697 \times 1.097 \approx 4.055$ in specification (2). Table 8 uses 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 the effect of motivated beliefs is statistically significant at the 1% level in all three specifications. As a robustness check for these results, we replicate the IV approach used in this section using the data for *MA* and *DF* separately (Appendix F.1) or only the incentivized beliefs data (Appendix F.2). The results corroborate the validity of our IV approach.

Overall, the results in Tables 6–8 indicate that limited liability has a large impact on the formation of motivated beliefs and that such beliefs are responsible for about 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 approximately one third of the increase in investment under limited liability.

Table 7: Second Stage with Instruments for Prob

Dep. Variable: *Investment*	(1)	(2)	(3)
MH	7.844***	7.985***	8.246***
	(1.250)	(1.241)	(1.315)
Prob (instrumented)	1.096***	1.097***	1.108***
	(0.0345)	(0.0350)	(0.0373)
Constant	-19.18***	-39.25*	-41.11*
	(2.176)	(20.95)	(22.87)
N	3750	3750	3480
adj. R^2	0.351	0.365	0.358
Gender	No	No	Yes
Controls	No	Yes	Yes

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

Robust standard errors clustered at the investor level in parentheses.

Table 8: Indirect (CACME) and Direct Treatment Effects (CADE)

Dep. Variable: *Investment*	(1)	(2)	(3)
Indirect Treatment Effect (CACME)	3.567***	4.055***	4.212***
	(0.834)	(0.846)	(0.902)
Direct Treatment Effects (CADE)	7.844***	7.984***	8.246***
	(1.298)	(1.254)	(1.317)
Observations	3750	3750	3480
Gender	No	No	Yes
Controls	No	Yes	Yes

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

Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

3.4 Identifying the Channel for Motivated Beliefs

The literature has identified two channels through which subjects might form biased beliefs in our setup. The first channel is anticipatory utility (e.g., Brunnermeier and Parker, 2005; Bénabou and Tirole, 2011; Engelmann et al., 2019). Anticipatory utility occurs when agents derive utility from future utility flows. In such cases, since agents derive utility from imagining good future outcomes, they form overoptimistic beliefs about the future.[18] Furthermore, as shown in Brunnermeier and Parker (2005), when agents are excessively optimistic due to anticipatory utility, they might strongly prefer positively skewed assets such as our limited liability investments.

The second channel through which subjects might form motivated beliefs in our experiment are self-image concerns (Bénabou and Tirole, 2011; Barberis, 2013; Grossman and Van Der Weele, 2017). The fundamental idea of this channel is that investors not only care about monetary gains, but also want to maintain a positive self-image. In the *MA* treatment, investors are presented with the opportunity to make large gains at low risk. However, investors also know that a loss-taking subject will have to cover most of the losses if the investment goes sour. This possibility creates mental discomfort in the investor, who wishes to maintain a positive self-image *while* taking large risks. As suggested in Barberis (2013) and Gino et al. (2016), in such situations investors might form motivated beliefs to convince themselves that the investment is less risky than it actually is.

We use the *NM* treatment to test which of the two channels is at work in our setup. Recall that in the *NM* treatment, we replicate the incentive structure of treatment *MA* (i.e., investors only lose 25% of the investment in case of a failed investment), but we exclude any moral hazard (i.e., investors are not matched to any loss-takers). If the channel through which motivated beliefs are formed is anticipatory utility, there should be no difference in the reported success likelihoods between the *MA* and *NM* treatments. However, if the channel at work are self-image concerns, we should observe investors reporting lower success likelihoods in *NM* than in *MA*. In fact, if motivated beliefs were solely due to self-image concerns, the subjective success likelihoods reported in the *BL* and *NM* treatments should be equal.

In Table 9 we regress the reported success likelihoods on treatment dummies for *MA* and *NM* using only the data from the sessions ran in 2021 (i.e., those that include the *NM* treatment). In the first two columns, the reference treatment is *BL*. The results show that subjects are significantly more optimistic about the investment in the *MA* treatment than in *BL*. However, we cannot detect any significant differences when comparing the *NM* to *BL*, which indicates that investors form motivated beliefs only when their self-image is at stake. In columns (3) and (4) we use only the data for *MA* and *NM* to compare the beliefs across both treatments and confirm this result: subjects report overly optimistic success probabilities to maintain a positive self-image and not due to anticipatory utility.

Additionally, in Table 10 we replicate Table 9 but with investment decisions as the dependent variable. In columns (1) and (2), we compare the two limited liability treatments (*MA* and *NM*) to the full liability treatment (*BL*). As expected, subjects invest more under limited liability. Surprisingly, investments appear to be higher when they can negatively impact a third party (*MA*) than when they cannot (*NM*). In columns (3) and (4) we directly compare the investments in *MA* and *NM* and

[18] As Brunnermeier and Parker (2005) put it, in such cases agents hold “incorrect but optimal beliefs.”

Table 9: Effect of the *NM* and *MA* Treatments on Beliefs.

Dep. Var.: *Prob*	(1)	(2)	(3)	(4)
MA	4.505***	4.508***		
	(1.349)	(1.355)		
NM	0.643	0.652	-3.942***	-3.934***
	(1.130)	(1.133)	(1.238)	(1.240)
185.dots	16.71***	16.85***	16.12***	15.96***
	(1.899)	(1.865)	(2.403)	(2.395)
190.dots	30.63***	30.81***	29.09***	29.01***
	(2.109)	(2.049)	(2.488)	(2.410)
195.dots	32.01***	31.94***	30.81***	30.50***
	(2.372)	(2.317)	(2.859)	(2.707)
199.dots	36.41***	36.45***	37.31***	37.22***
	(2.375)	(2.388)	(2.799)	(2.682)
201.dots	41.78***	41.77***	40.97***	40.62***
	(3.269)	(3.211)	(3.402)	(3.266)
205.dots	47.08***	47.18***	48.18***	48.05***
	(2.929)	(2.944)	(3.520)	(3.506)
210.dots	46.93***	46.76***	48.19***	47.83***
	(2.963)	(2.937)	(3.832)	(3.757)
215.dots	56.01***	55.91***	57.09***	56.81***
	(3.235)	(3.230)	(3.560)	(3.548)
280.dots	81.30***	81.33***	81.61***	81.19***
	(2.547)	(2.519)	(2.581)	(2.510)
Constant	8.410***	3.040	12.90***	-0.322
	(1.719)	(11.30)	(1.590)	(13.20)
N	1620	1620	1080	1080
Controls	No	Yes	No	Yes

Standard errors in parentheses

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

In columns (1) and (2), we use BL as the reference treatment. In columns (3) and (4), we use only the data for the *MA* and the *NM* treatments. The reference treatment is MA. Robust standard errors clustered at the investor level in parentheses.

note that subjects invest significantly *more* when there is moral hazard (*MA*) than when there is not. This is an unexpected outcome. Results 2 and 3 show that investors form motivated because *they care* about the impact of any potential losses on third parties. However, when comparing *MA* and *NM* we observe that, for the same incentive structure, investors take larger risks when third parties can be negatively affected.

We interpret the larger investments in *MA* than in *NM* as showing that motivated beliefs are formed subconsciously and therefore, pile on top of the already excessive risk-taking driven by limited liability. Because subjects are not aware that they are forming biased beliefs, they respond to their excessive optimism as they would to any other change of beliefs: by investing larger amounts whenever the

Table 10: Effect of Treatments on Investment.

Dep. Var.: *Investment*	(1)	(2)	(3)	(4)
MA	15.25***	15.25***		
	(2.665)	(2.671)		
NM	10.77***	10.79***	-3.942***	-4.598**
	(2.471)	(2.476)	(1.238)	(1.744)
185.dots	11.57***	11.97***	16.12***	13.87***
	(1.941)	(1.847)	(2.403)	(2.994)
190.dots	25.96***	26.34***	29.09***	29.73***
	(3.003)	(2.964)	(2.488)	(3.825)
195.dots	30.19***	29.58***	30.81***	31.08***
	(3.012)	(2.999)	(2.859)	(3.774)
199.dots	33.38***	33.23***	37.31***	41.11***
	(3.294)	(3.284)	(2.799)	(3.993)
201.dots	38.77***	38.86***	40.97***	40.61***
	(3.596)	(3.566)	(3.402)	(4.078)
205.dots	47.64***	48.17***	48.18***	52.74***
	(3.408)	(3.378)	(3.520)	(3.983)
210.dots	45.76***	45.24***	48.19***	51.88***
	(3.752)	(3.809)	(3.832)	(4.664)
215.dots	58.83***	58.35***	57.09***	66.23***
	(3.936)	(3.875)	(3.560)	(4.442)
280.dots	90.83***	90.75***	81.61***	90.39***
	(2.716)	(2.851)	(2.581)	(3.118)
Constant	-6.654***	-34.96	12.90***	-17.61
	(1.639)	(23.83)	(1.590)	(30.86)
N	1620	1620	1080	1080
Controls	No	Yes	No	Yes

Standard errors in parentheses

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

In columns (1) and (2), we use the data for all of the treatments, using BL as the reference treatment. In columns (3) and (4), we use only the data for the *MA* and the *NM* treatments. The reference treatment is *MA*. Robust standard errors clustered at the investor level in parentheses.

expected returns are higher. This interpretation is confirmed in Appendix G where we compare the investments of subjects in the risky rounds of the *MA* and *NM* treatments. In the risky rounds the success probabilities of investments are exogenously given, hence there is no space to form motivated beliefs.[19] Therefore, if subjects care about the negative impact of their decisions on third parties, they should invest less in the *MA* treatment than in the *NM* treatment. Table 31 of Appendix G shows that this is the case: when there is no space for motivated beliefs, subjects invest less when there is moral

[19]As described in Section 2.3, in the risky rounds subjects make investment decisions for 11 different assets, each with a given probability of success (0%, 10%, 20%, ..., 100%) with the same incentive structure than in the corresponding treatment (in this case, *NM* or *MA*).

hazard (MA) than when there is not (NM). This result is consistent with other-regarding preferences in the vein of Fehr and Schmidt (1999), and shows that the impact that motivated beliefs have on investment exceeds that of other-regarding preferences in treatment MA.

Furthermore, the relative sizes of the coefficients for the dummies NM and MA in Table 10 match our estimate of the direct and indirect treatment effects from Table 8. When comparing the investments in MA and BL, one third of the additional investment in MA is caused by motivated beliefs (indirect effect), while two thirds are caused by monetary incentives (direct effect). The qualitative matching of results in Table 8 and Table 10 validates the IV approach from Section 6, and shows the robustness of our results and experimental design.

Overall, the results from Tables 9 and 10 allow us to draw several important conclusions. First, in our setup, investors only form motivated beliefs to self-justify any risk-taking that might negatively impact a matched loss-taker. Second, this need to self-justify risky behavior results in *higher investments* than in situations with no matched loss-taker. This result, which seems counter-intuitive, shows how vulnerable subjects are to the formation of motivated beliefs and how these can have strong effects not only from a social perspective, but also from an individual one. We believe that the reported effects underscore the importance of motivated beliefs and their unexpected consequences in mechanism design and incentive structures (e.g., Schwardmann and Van der Weele, 2019; Bridet and Schwardmann, 2020).

Result 4 *Effect of self-image on beliefs and investments*

i) Under limited liability, motivated beliefs are only formed when investors need to self-justify their excessive risk-taking.

ii) The presence of motivated beliefs results in higher investments, which would not occur absent the need of investors to self-justify their actions.

4 Conclusion

Gino et al. (2016) describe as "motivated Bayesians" those agents who bias, manipulate, or ignore information to self-justify immoral behavior. Some examples are people who do not recycle "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. In a financial context, a recent strand of the literature has identified motivated beliefs as one of the main reasons behind the last financial crisis. Under limited liability, investors want to take excessive risks. However, such excesses make it hard to maintain a positive self-image. This tension creates a situation of mental discomfort that investors attenuate by being excessively optimistic about the outcome of their investments (Barberis, 2013; Bénabou, 2015).

To investigate the effects of limited liability on motivated beliefs we set up a within-subjects experimental design where participants make investments under full and under limited liability. Importantly, in the limited liability treatment, a third party absorbs most of the losses whenever the investment fails, creating a situation of moral hazard. Our results show that subjects assign a higher probability of success for the same investment opportunity and invest larger amounts under limited liability than under full liability. However, if one wants to identify the causal mediator effect through which the treatment affects the outcome, randomizing the treatment alone is not sufficient(Imai et al., 2011, 2013).[20] By using an additional source of variation (i.e., the noisy signals) in our mediator (i.e., the beliefs), we can *isolate* and *quantify* the causal effect of limited liability on investment decisions that work through the formation of motivated beliefs.

Specifically, our mediation analysis shows that about one third of the increase in investment under limited liability is due to the presence of motivated beliefs. Furthermore, using a treatment in which subjects invest under limited liability without moral hazard (i.e., with no third party absorbing any eventual losses), we identify self-image concerns as the psychological channel through which motivated beliefs are formed. This treatment also allows us to uncover an unexpected result: for the same investment, subjects invest larger amounts when there is moral hazard than when there is not. The reason is that investors tend to be more optimistic about the results of their investment whenever their investment may harm a third party. Ironically, these overly optimistic beliefs (needed to self-justify morally questionable actions) lead subjects to make even larger investments.[21]

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 own 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." Our experiment shows that even a little bit of ambiguity is sufficient to trigger such self-serving beliefs.

Perhaps the most surprising result is that subjects fool themselves into taking higher risks when their investments may lead to negative externalities. This excessive risk taking happens because subjects do not realize they are forming motivated beliefs. Therefore, motivated beliefs result in excessive risk-taking, not only from a social perspective, but also from an individual perspective. Our result has important implications for policymakers, as it shows that one should target not only bad incentives but also "bad beliefs."

[20] Indeed, 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).

[21] Notice that this result tackles a deeper question on how motivated beliefs are formed. It is not clear in the literature whether beliefs follow actions or actions follow beliefs (Kornblith, 1983). In our setup, if beliefs followed actions, then we should detect differences between *MA* and *NM* when compared to *BL*, but no differences between *MA* and *NM*. However, we believe that a deeper discussion of this topic is beyond the scope of this paper.

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A Additional Variables

After the three treatments, subjects participate in a final block of 5 *parts*, that were used 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 7 in Appendix H 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 expect to have answered correctly. The difference between this number, 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 about her expectation on how many participants in their own experimental session have answered fewer Raven questions correctly than she did herself, $EOPL_i$. 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 following the subjective error method described in Bosch-Rosa et al. (2021) and using the task introduced in Ahrens et al. (2019). It consists of 10 rounds and before each round r, subjects are shown a new matrix containing a total of 400 red and blue dots. After seeing the graph, subjects are asked to estimate the number of red dots ($N_{i,r}$) and the difference between their estimate and the true number of red dots, their subjective error $SE_{i,r}$. This subjective error is subject i's expected absolute distance between his estimate of the number of red dots Ni,r and the actual number of red dots in the graphic (Ai, r).

For round r, we define overprecision as the difference between a subject's stated subjective error $SE_{i,r}$ and her actual error, $AE_{i,r}$. Hence the overprecision of subject i in round r is given by $OP_{i,r} = AE_{i,r} – SE_{i,r}$ 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 $P_{i,r}^{OP2} = max\{€5 - €0.05 \times |AE_{i,r} – SE_{i,r}|; €0\}$. 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 35 and 36 in

Appendix H). In part 4, subjects state their field of study, age, and gender.

B Dot Spot details

As mentioned in Section 2.1, the computer determines whether the investment will succeed or fail before each round. 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 11.[22]

Two things are important to notice. First, the number of red dots shown is based on data from pilots. Except for the two extremes (120 and 280 red dots), the number of red dots shown is thought to convey some information about the investment's success probability 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 has 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 may be 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 differ in the pattern in which the dots are displayed. In other words, while different in aspect, they are *informationally identical* (see Figure 1 for an example with two different patterns of 215 red dots). Having such informationally identical matrices enables us to compare subjects' behavior across treatments for informationally identical investments.

Table 11: 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
NM	Success:	205	215	201	201	280	210	215	210	280	205
	Fail:	195	185	199	199	120	190	185	190	120	195

Number of red dots shown for each round and treatment depending on the investment outcome. Notice that the sequence for BL and NM is the same. Each matrix is *unique*, even if they have the same number of dots, the disposition is different.

[22] The sequences were picked by taking the first three number sequences generated using the web page www.random.org. The sequence of the dots shown in NM is the same as BL due to a programming oversight, the matrices are different.

C Risk

Figure 4: Investments for Given Probabilities in Risk Part

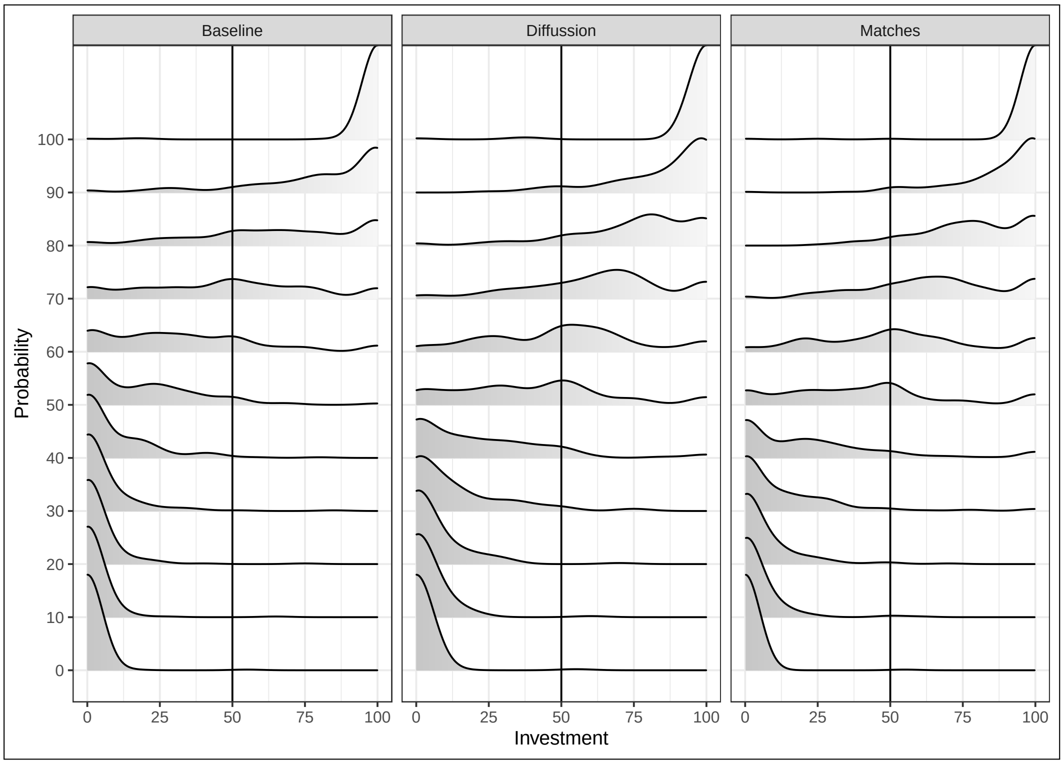

Figure showing the density estimates of investment made by all bankers for each type of matrix. The coloring of the distribution gets lighter as the investment gets higher. We present the results for all three treatments.

In each treatment (*MA*, *DF*, *BL*, and *NM*), subjects take part in a risky investment task in which the probabilities for success of the investment are explicitly given. Figure 4 plots the density estimates of the investment as a percentage share of the endowment for a given exogenous success probability (vertical axis). Overall, the densities in Figure 4 indicate that investors understood the incentives, as they tend to invest more for higher success probabilities.

Figure 4, and the means reported in Table 12 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 is also higher for most success probabilities. Exceptions only arise for the extreme probabilities (0% and 100%) where investors tend to invest either nothing or their whole endowment independent of the treatment. Finally, we present a within-subject Wilcoxon signed-rank test comparing the total investments made in the three treatments (Table 13) 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

Table 12: Mean Investments in Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
BL	32.89	1.19	2.14	3.49	5.26	9.34	18.91	32.48	46.94	65.58	79.92	96.51
	(38.60)	(8.12)	(9.56)	(11.05)	(12.13)	(15.40)	(20.85)	(27.46)	(29.53)	(29.32)	(26.23)	(16.56)
MA	41.73	0.42	3.41	5.61	12.37	23.03	40.41	52.48	65.65	78.80	89.00	98.36
	(40.23)	(4.61)	(8.83)	(11.12)	(20.11)	(27.56)	(29.36)	(27.82)	(24.86)	(18.70)	(16.34)	(11.19)
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 for all investors in the BL case, for the investors in the MA and DF treatments. Standard deviations are shown in parentheses.

Table 13: 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	0.500	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.500
p-value BL = DF	<0.001	0.500	0.059	0.010	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.187
p-value DF = MA	0.434	0.993	0.562	0.728	0.460	0.635	0.345	0.522	0.392	0.288	0.219	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.

success probability (Table 12). 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 rejected (p-value $= 0.431$).

D Extra Graphs and Tables

D.1 Effect of Treatments on Investment

Figure 5: Density of Investments for Each Type of Matrix

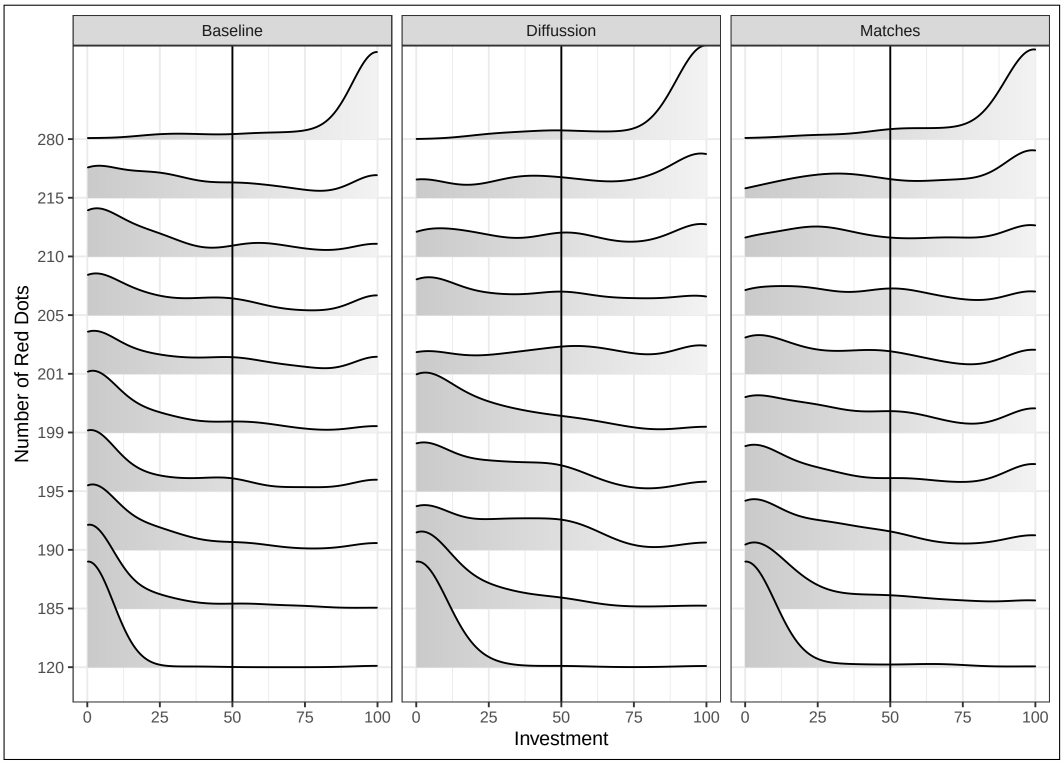

Figure showing the density estimates of the investment made by all bankers for each type of matrix. The coloring of the distribution gets lighter as the investment gets higher. We present the results for all three treatments.

Table 14: Wilcoxon Signed-Rank Tests for Investments

	Total	**120**	**180**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
p*-value *BL = MA	<**0.001**	0.152	<0.001	0.006	0.032	0.009	0.018	<0.001	<0.001	<0.001	0.320
p*-value *BL = DF	<**0.001**	0.023	0.019	0.015	0.168	0.043	<0.001	0.004	<0.001	<0.001	0.062
p*-value *DF = MA	**0.128**	0.993	0.543	0.713	0.455	0.632	0.343	0.520	0.392	0.288	0.220

In column *Total* we present a Wilcoxon Signed-Rank Tests comparing investors' aggregate invested amount across treatments. All other columns present a Wilcoxon Signed-Rank Tests comparing the investments made by investors for each type of matrix across treatments.

D.2 Effect of Treatments on Beliefs

Figure 6: Density of the Stated Likelihood of Success for Each Type of Matrix

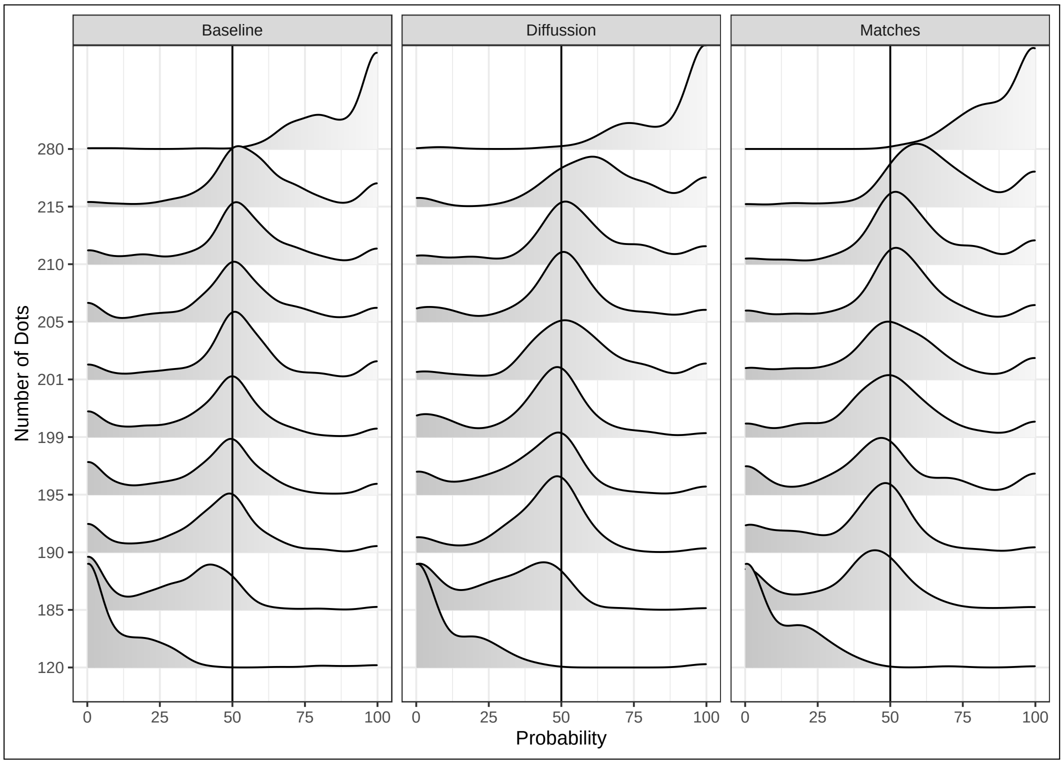

Figure showing the density estimates of the likelihood of success made by all bankers for each type of matrix. The coloring of the distribution gets lighter as the likelihood gets higher. We present the results for all three treatments.

Table 15: Wilcoxon Signed-Rank Tests for Stated Likelihoods

	Total	**120**	**180**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
p*-value *BL = MA	**<0.001**	0.267	0.049	0.550	0.022	< 0.001	0.719	0.518	0.011	< 0.001	0.129
p*-value *BL = DF	**<0.013**	0.230	0.761	0.989	0.596	0.127	0.023	0.451	0.001	< 0.001	0.858
p*-value *DF = MA	**0.068**	0.679	0.083	0.020	0.018	0.419	0.868	0.635	0.459	0.146	0.367

In column $Total$ we present a Wilcoxon Signed-Rank Tests comparing investors' aggregate invested amount across treatments. All other columns present a Wilcoxon Signed-Rank Tests comparing across treatments the investments made by investors for each type of matrix.

E Incentivized Beliefs

One concern from the original series of experiments was that beliefs were not incentivized. This lack of incentives might have pushed subjects to state high probabilities for each investment to justify their excessive risk-taking in view of the experimenter (and not to themselves). To test whether incentivization affects stated beliefs, in Table 16 we present the p-values of a Mann Whitney U test comparing the subjective probabilities for each Dot Spot of the unincentivized (BL and MA) and incentivized (BL* and MA*) baseline and matches treatments. As it is clear from the results, incentivizing beliefs does not seem to change the subjective probabilities reported by subjects.

Table 16: Effects of Incentives on Beliefs

	120	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
BL = BL*	0.043	0.895	0.660	0.925	0.469	0.906	0.503	0.197	0.122	0.794
MA = MA*	0.012	0.587	0.129	0.692	0.018	0.835	0.994	0.873	0.225	0.370

Mann Whitney U test comparing beliefs in incentivized (BL, MA) and incentivized (BL*, MA*) treatments. The columns report the p-value of the Mann Whitney U test comparing the reported probabilities for each number of red dots in the Dot Spot.

The results from Table 16 are supported by those of Table 17. In Table 17, we present the results of running a regression of the subjective beliefs of subjects on a dummy for each of the different dot spots and a dummy which takes value 1 if the beliefs are non-incentivized ($Noincentives$). In the first two columns we use only the data for the BL treatment and in the third and fourth columns we use only the data for the investors in the MA treatment. The results show that the incentives do not affect the stated beliefs in either of the two treatments (BL and MA). If we run the same regression using the data from both treatments and interact the incentive dummy with treatments, we find no significant interaction effects.[23] Finally, as a robustness test, we exploit the within-subject aspect of our experiment to calculate for each subject i and each matrix type ($m \in 120, 185, ..., 280$) the effect of the treatment on beliefs. That is, we calculate $effect = prob_{i,m}^{MA} - prob_{i,m}^{BL}$ for those subjects in sessions with unincentivized beliefs and $effect^{*} = prob_{i,m}^{MA^{*}} - prob_{i,m}^{BL^{*}}$ for those sessions with incentivized beliefs. A Mann-Whitney U test detects no statistical differences across $effect$ and $effect^{*}$ (p-value = 0.438).

Therefore, given the results of Table 16 and Table 17, we conclude that subjects reported their objective beliefs both when they were incentivized and when they were not. Our results are in line with the findings of the recent literature. An example is Enke et al. (2021) who study whether large stakes can eliminate a series of well documented biases such as anchoring or base rate neglect. Their results show that large stakes increase subjects' effort (measured as time invested in the question), but cannot eliminate the bias in the answers.

[23] Similarly, interacting the incentive dummy with the different Dot Spot dummies does not yield any statistically significant effects.

Table 17: Effect of incentives on beliefs.

	Baseline		Matches	
Dep. Variable: *Prob*	(1)	(2)	(3)	(4)
No Incentive	-0.904	-0.654	-3.917	-5.205*
	(2.000)	(2.414)	(2.697)	(2.851)
185.dots	16.63***	16.16***	23.19***	23.68***
	(1.596)	(1.629)	(2.231)	(2.261)
190.dots	29.26***	28.64***	27.36***	26.89***
	(1.651)	(1.735)	(2.036)	(2.058)
195.dots	29.63***	29.36***	35.63***	36.01***
	(1.861)	(1.961)	(2.800)	(2.813)
199.dots	31.09***	30.08***	38.65***	37.79***
	(1.831)	(1.895)	(2.518)	(2.555)
201.dots	41.06***	40.31***	42.55***	41.44***
	(1.951)	(1.995)	(2.371)	(2.426)
205.dots	39.79***	39.75***	43.39***	42.56***
	(1.841)	(1.926)	(2.467)	(2.541)
210.dots	41.36***	41.43***	49.09***	48.55***
	(2.115)	(2.202)	(2.506)	(2.587)
215.dots	49.06***	48.59***	57.69***	56.22***
	(1.933)	(2.001)	(2.743)	(2.814)
280.dots	79.15***	78.77***	80.25***	79.68***
	(1.699)	(1.769)	(2.001)	(2.114)
Constant	15.23**	15.27**	12.45	12.06
	(6.670)	(6.837)	(11.58)	(10.55)
N	2860	2680	1430	1340
Controls	Yes	Yes	Yes	Yes
Gender	No	Yes	No	Yes

Standard errors in parentheses

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

In all columns the dummy variable ($Noincentive$) takes a value of 1 if the beliefs were not incentivized. In the first two columns we use only the data for the BL treatment, in columns (3) and (4) we use the data for the MA treatment. Robust standard errors clustered at the investor level in parentheses.

F Robustness: Alternative IV Specifications

F.1 Disaggregating the treatments in the IV approach

This section reports the instrumental variable approach of Section 3.3 for each of the two limited liability treatments (MA and DF). In Tables 18 and 19 we run the first stage regression (eq. 5) for treatments MA and DF respectively. The results are practically identical, with the MA treatment coefficient being slightly higher than for the DF treatment.[24] Overall, we observe no differences in the first stage across treatments and the results are in the order of magnitude of those in Table 6.

Tables 20 and 20 show the second stage (eq. 6). Again, we see that the results are similar to those in Table 7, as the differences between treatments are minimal. Because of the similar results in both the first and second stage, the CACME and CADE for the MA and DF treatments (Tables 22 and 23, respectively) are very similar to those of the pooled data (Table 8).

[24]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)
MA	4.193***	4.186***	4.124***
	(0.854)	(0.856)	(0.894)
185.dots	19.93***	19.88***	19.84***
	(1.556)	(1.578)	(1.579)
190.dots	29.22***	29.05***	28.66***
	(1.737)	(1.751)	(1.818)
195.dots	33.51***	33.44***	33.62***
	(2.072)	(2.095)	(2.160)
199.dots	35.28***	35.03***	33.87***
	(2.042)	(2.046)	(2.042)
201.dots	42.76***	42.97***	41.72***
	(2.231)	(2.235)	(2.236)
205.dots	41.75***	41.78***	41.43***
	(1.889)	(1.898)	(1.994)
210.dots	44.00***	44.14***	43.88***
	(2.198)	(2.189)	(2.233)
215.dots	53.92***	53.93***	52.33***
	(2.374)	(2.390)	(2.395)
280.dots	80.55***	80.52***	79.66***
	(1.965)	(1.980)	(2.078)
Constant	7.660***	6.981	3.662
	(1.387)	(10.19)	(10.49)
N	2860	2860	2680
adj. R^2	0.432	0.435	0.437
Controls	No	Yes	Yes
Gender	No	No	Yes

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

Table 18: 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)
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
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 19: 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)
MA	8.321***	8.312***	8.803***
	(1.400)	(1.403)	(1.467)
Prob (instrumented)	1.079***	1.081***	1.090***
	(0.0352)	(0.0353)	(0.0374)
Constant	-18.93***	-14.37	-16.93
	(1.635)	(17.13)	(17.09)
N	2860	2860	2680
adj. R^2	0.341	0.353	0.350

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

Table 20: 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)
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 21: 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)	4.523***	4.523***	4.493***
	(0.938)	(0.920)	(0.991)
Direct Effects (CADE)	8.321***	8.312***	8.802***
	(1.419)	(1.378)	(1.459)
Observations	2860	2860	2680
Gender	No	No	Yes
Controls for Treatment Order	No	Yes	Yes

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

Table 22: 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
Gender	No	No	Yes
Controls for Treatment Order	No	Yes	Yes

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

Table 23: 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.

F.2 Incentivized Beliefs

In this sections we report the instrumental variable approach of Section 3.3 using only the data from sessions where beliefs were incentivized. In Table 24 we run the first stage regression (eq. 5)

Table 24: First Stage Regressions for Prob

Dep. Variable: *Prob*	(1)	(2)
MA	4.493***	4.492***
	(1.330)	(1.337)
185.dots	19.95***	20.23***
	(2.014)	(1.995)
190.dots	31.61***	31.80***
	(2.370)	(2.351)
195.dots	33.52***	33.46***
	(3.241)	(3.275)
199.dots	38.20***	38.37***
	(2.948)	(3.009)
201.dots	41.93***	42.07***
	(3.198)	(3.229)
205.dots	43.12***	43.49***
	(3.100)	(3.144)
210.dots	46.82***	46.92***
	(3.061)	(3.061)
215.dots	56.92***	56.94***
	(3.596)	(3.620)
280.dots	80.53***	80.84***
	(2.651)	(2.692)
Constant	7.994***	-1.660
	(1.780)	(9.998)
N	1080	1080
adj. R^2	0.454	0.459
Number of Bankers	36	36
Controls	No	Yes

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

In all four columns, the dummy for $Dots120$ is not included because of multicollinearity. Robust standard errors clustered at the investor level in parentheses.

Table 25: Second Stage with Instruments for Prob

Dep. Variable: *Investment*	(1)	(2)
MA	10.20***	10.19***
	(2.630)	(2.649)
Prob (instrumented)	1.114***	1.114***
	(0.0495)	(0.0495)
Constant	-21.06***	-47.69**
	(2.307)	(21.40)
N	1080	1080
adj. R^2	0.361	0.376
Controls	No	Yes

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

Robust standard errors clustered at the investor level in parentheses.

Table 26: Indirect (CACME) and Direct Treatment Effects (CADE)

Dep. Variable: *Investment*	(1)	(2)
Indirect Treatment Effect (CACME)	5.005***	4.999***
	(1.462)	(1.482)
Direct Treatment Effects (CADE)	10.195***	10.200***
	(2.297)	(2.554)
Observations	1080	1080
Controls	No	Yes

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

Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

F.3 Alternative Specifications

In this section we check how robust the results of Table 7 are to alternative specifications. In Table 27 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 6. The results of the regressions in Table 27 are close to those of 7. That is, the effect of instrumented and non-instrumented beliefs on investments are very similar. Moreover, in Table 28 we use the data from the risk part of each treatment and regress the investment of each investor b for a given risk gr ($InvestmentR_{b,gr}$). The results are again very similar to those of Table 7.

The similarity in the results of all three specifications makes us confident that our IV approach is adequate to decompose the indirect effects of motivated beliefs on investors' investment decisions under limited liability. Additionally, in Tables 29 and 30 we reproduce Tables 27 and 28, but using a logistic models instead of linear regressions. Once again, the effect of given probabilities on investors' investment is very close to that of subjective probabilities.

Dep. Var.: *Investment*	(1)	(2)	(3)
Prob	0.976***	0.973***	0.977***
	(0.0239)	(0.0242)	(0.0266)
MA	8.881***	8.898***	9.414***
	(1.333)	(1.334)	(1.394)
DF	7.555***	8.000***	7.913***
	(1.545)	(1.352)	(1.443)
Constant	-14.36***	-10.47	-13.74
	(1.562)	(15.25)	(15.72)
N	3750	3750	3480
adj. R^2	0.614	0.621	0.605
Controls	No	Yes	Yes
Gender	No	No	Yes

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

Table 27: Regression for Investment on Stated Probability. Robust standard errors clustered at the investor level.

Dep. Var.: *InvestmentR*	(1)	(2)	(3)
Given Risk	1.046***	1.046***	1.045***
	(0.0193)	(0.0193)	(0.0205)
MA	9.833***	9.833***	10.14***
	(0.887)	(0.888)	(0.926)
DF	8.645***	10.29***	10.17***
	(1.196)	(1.032)	(1.091)
Constant	-19.46***	-5.639	-10.76
	(1.047)	(12.98)	(13.35)
N	4125	4125	3828
adj. R^2	0.713	0.724	0.720
Controls	No	Yes	Yes
Gender	No	No	Yes

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

Table 28: Regression for Investment on Given Risk. Robust standard errors clustered at the investor level.

Dep. Var.: *Investment*	(1)	(2)	(3)
Prob	0.0727***	0.0736***	0.0731***
	(0.00596)	(0.00619)	(0.00647)
MA	0.790***	0.792***	0.829***
	(0.131)	(0.133)	(0.136)
DF	0.647***	0.610***	0.629***
	(0.167)	(0.138)	(0.146)
Constant	-2.727***	-1.497	-0.857
	(0.313)	(2.019)	(2.083)
N	3750	3750	3480
Controls	No	Yes	Yes
Gender	No	No	Yes

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

Table 29: 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	0.0814***	0.0832***	0.0840***
	(0.00506)	(0.00529)	(0.00545)
MA	1.049***	1.072***	1.127***
	(0.129)	(0.132)	(0.140)
DF	1.101***	1.180***	1.252***
	(0.168)	(0.156)	(0.168)
Constant	-3.415***	-3.237*	-3.876**
	(0.279)	(1.839)	(1.956)
N	4125	4125	3828
Controls	No	Yes	Yes
Gender	No	No	Yes

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

Table 30: Logit regression for Investment on Given Probability. Robust standard errors clustered at the investor level in parentheses.

G Robustness: Psychological Channel

In Table 31 we regress the investment in the risky rounds of the *NM* and *MH* treatments (i.e., when the probability of success of the investment was exogenously given) using *MA* as the baseline. The regression includes dummies for each of the possible given success probability (*success_x%*) as well as the controls used in all previous tables. As one would expect, the investment in *NM* is higher than in *MA* as subjects are more reluctant to invest when any losses might harm a third-party, confirming that subjects hold social preferences (Fehr and Schmidt, 1999) and take into account the moral hazard present in the *MH* treatments.

Table 31: Effect of Treatments and Exogenously Given Risk on Investment.

Dep. Var.: *InvestmentR*	(1)	(2)
NM	2.180**	2.180**
	(0.970)	(0.974)
success_10%	2.278***	2.278***
	(0.592)	(0.594)
success_20%	6.037***	6.037***
	(1.344)	(1.349)
success_30%	19.34***	19.34***
	(3.519)	(3.531)
success_40%	31.44***	31.44***
	(4.214)	(4.228)
success_50%	49.01***	49.01***
	(4.210)	(4.225)
success_60%	59.87***	59.87***
	(3.861)	(3.875)
success_70%	73.27***	73.27***
	(3.211)	(3.222)
success_80%	84.72***	84.72***
	(2.230)	(2.238)
success_90%	93.49***	93.49***
	(1.592)	(1.597)
success_100%	99.93***	99.93***
	(0.0744)	(0.0747)
Constant	-1.016**	-4.679
	(0.481)	(23.59)
N	1188	1188
adj. R^2	0.745	0.782
Controls	No	Yes

Standard errors in parentheses

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

Regression of Investment on Given Risk. Robust standard errors clustered at the investor level in parentheses.

H 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%. 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 32). 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 32

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table 32, 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 32 (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 32) and your amount to be invested equals 40% × 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 32) and your amount to be invested equals 70% × 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 eleven scroll bars' position. 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 × 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 to estimate 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 scroll bar’s position and change your opinion on the success probability. 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 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 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 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 = 0.6×8 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 33). 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 33

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table 33, 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 × 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 34). 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 34, 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 34

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 7. 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.

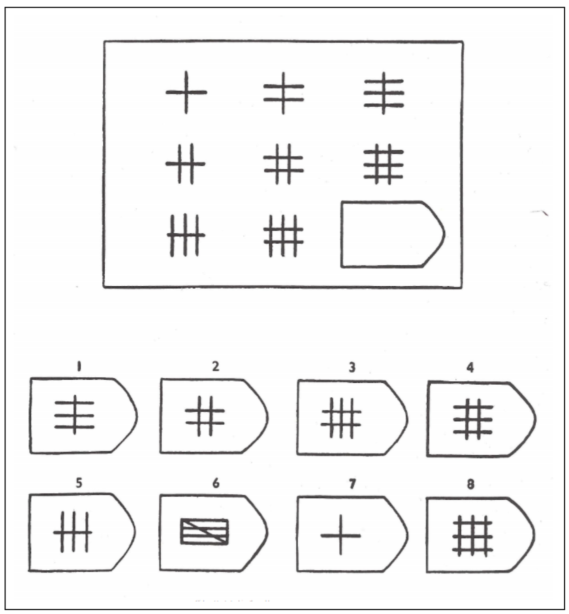

Figure 7

You **choose the element** using a **drop-down list** (see Figure 8). 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 <u>each</u>.** 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"

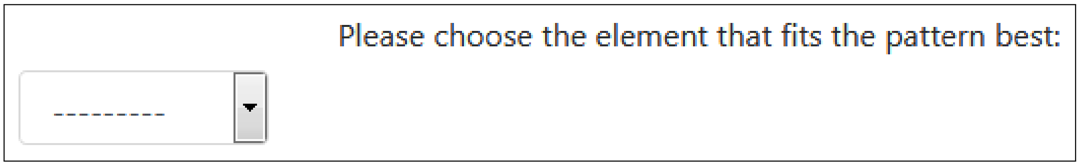

Figure 8

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** × **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** × **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** × **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 × 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 × 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 35** and **Table 36**, 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 35:

In the **lotteries** of Table 35 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 35, **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 35): 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 35. 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 36:

In the **lotteries** of Table 36 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 36, **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 36): 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 36. 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 35

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 36

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