Risk-Taking under Limited Liability and Moral Hazard: Quantifying the Role of Motivated Beliefs *

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Abstract

This paper investigates whether limited liability and moral hazard affect risk-taking through motivated beliefs. On the one hand, limited liability encourages investors to take excessive risks. On the other, excessive risk-taking makes 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 its failure can harm others. We show that more than one third of the investment increase under limited liability and moral hazard can be explained through motivated beliefs. Moreover, through 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 compared to when it cannot. These results underscore the importance of motivated beliefs in regulatory policy, emphasizing that policymakers must not only address bad incentives but also address the role of "bad beliefs".

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A fundamental idea in social psychology is that people do not only want to make money – they also want to feel good about themselves, and it is hard to feel good about oneself if one is knowingly doing something that is potentially ruinous to others.

—Nicholas Barberis, *Psychology and the Financial Crisis of 2007-2008*

1 Introduction

Moral values are important determinants of economic decision-making as most people want to adhere to a set of ethical rules (e.g., Smith, 2010; Bénabou et al., 2018). However, as highlighted by Bénabou and Tirole (2011) and Gino et al. (2016), it takes very little for people to switch from "morally acceptable" behavior to more "immoral" actions.[1] These actions can range from being greedy, taking advantage of third parties, or failing to meet obligations with one's co-authors. In all such cases, the contradiction between one's positive self-image and one's actions creates a "demand" for internal justifications to realign self-image and behavior (Festinger, 1957; Bem, 1972; Bénabou and Tirole, 2011). A common way to satisfy such demand is to modify one's beliefs to form an internally coherent "narrative" in which actions fit "moral" values (Kunda, 1990; Bénabou and Tirole, 2016; Gino et al., 2016). In other words, a common way to maintain a positive self-image while performing "immoral" actions is to form "*motivated beliefs*" that can justify these actions.

Motivated beliefs might have contributed to the financial crisis in 2007/08. 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 unclear why such excessive risk-taking occurred. While some authors argue that excessive risk-taking came 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 maintain a positive self-image while taking larger unjustifiable risks (Barberis, 2013; Bénabou, 2015).[2] The reason for such biased beliefs is the tension created by limited liability in the minds of investors. On the one hand, there is a direct channel through which limited liability pushes investors towards taking excessive risks by capping potential losses (Cole et al., 2015). On the other, an indirect channel arises from investors' knowledge that if they are not carrying the loss, then someone else is. The presence of this negative externality creates a demand for "motivated beliefs" which pushes investors to bias their beliefs and justify their excessive risk-taking (Bénabou and Tirole, 2011; Barberis, 2013).

Before 2008, motivated beliefs might have pushed traders at mortgage desks to underestimate the riskiness of their investments or induced credit rating agencies to believe that subprime-linked products "truly" deserve an AAA rating (Barberis, 2013). Moreover, the formation of motivated beliefs could

[1] There is a long literature discussing what "moral actions" are and how they can be interpreted. This discussion ranges from the deontological treaties of moral philosophy (e.g., Kant, 2013) to more modern discussions in the psychology literature (Hardy and Carlo, 2011; Aquino and Reed II, 2002). However, such discussions are obviously beyond the scope of this paper. In the current paper, we follow the interpretation of moral identity towards others found in Hart et al. (1998), which defines it as "a commitment consistent with one's sense of self to lines of action that promote or protect the welfare of others."

[2] Notice that these are not mutually exclusive reasons, and one of our aims is to quantify the share of excessive risk-taking that can be attributed to motivated beliefs.

have "spilled over" across firms, institutions, or even industries (Bénabou, 2013; Bénabou and Tirole, 2016). For example, Cheng et al. (2014) report that securitization experts at financial firms increased their exposure to the housing market just before the crisis.[3]

In this paper, we try to identify and quantify the direct and indirect effects of limited liability on investors. To do so, we design an experiment where all subjects participate in three different treatments. In each treatment, subjects decide on the fraction of a given fixed endowment to invest in a risky asset. Before investing, subjects receive a noisy signal on 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 collects all the gains. If the investment fails, the allocation of losses will depend on the treatment: in *Baseline*, the investor bears all losses. In two limited liability treatments, the losses are shared with other subjects. In *Matched*, each investor is matched to a single loss-taking subject with whom she shares the losses. In *Diffusion*, the losses across all investors are pooled and evenly divided among all loss-taking subjects.[4]

In both limited-liability treatments, subjects are incentivized to take larger risks than in *Baseline* at the cost of a potential negative externality on the loss-taking subjects. In other words, in both limited-liability treatments, investors face *moral hazard*. However, the ambiguous nature of the signal allows individuals to form motivated beliefs to self-justify their morally questionable investments.[5] Moreover, the investments should be higher and beliefs less optimistic in *Diffusion* than *Matched* due to the diffusion of responsibility (Falk and Szech, 2013; Alós-Ferrer et al., 2021). To confirm that self-image is the channel through which subjects form motivated beliefs, we run a *No Matches* 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. Therefore, investors should invest more than in the *Baseline* treatment but hold the same beliefs about the investment's likelihood of success.

Our results are straightforward: while we find no effect of diffusion of responsibility across treatments, we find that investors form motivated beliefs under moral hazard. That is, for the same signal, investors invest more in the risky asset and state higher likelihoods 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 work through the formation of motivated beliefs. The results show that approximately one-third of the increase in

[3]Notice that the type of motivated beliefs described in Cheng et al. (2014) are not due to moral reasons, but most likely due to anticipatory utility or wishful thinking.

[4]This is akin to the implicit guarantees of governments to systemically relevant banks.

[5]As noted by Kunda (1990), people are constrained in how strong their motivated beliefs can be. There needs to be a certain degree of "credibility" in the story one wants to tell oneself. Barberis (2013) argues that this might be a reason why subprime securitization may have been fertile grounds for belief manipulation during the recent crisis. Because most subprime-linked products were exotic investments, it was very hard to disprove any claim about their quality. Additionally, given the complexity of the asset, investors could always form a narrative about why even for losing investments, the ex-ante assessment was the correct one (Barberis, 2013).

investment under limited liability with moral hazard is due to motivated beliefs.[6]

Finally, we use the *No Matches* 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, and alternative channels such as anticipatory utility or wishful thinking (Brunnermeier and Parker, 2005; Bridet and Schwardmann, 2020) play no discernible role. The *No Matches* treatment also reveals a seemingly paradoxical result - under limited liability, investors take larger risks when their actions can harm others than when they cannot. We attribute this behavior to investors responding to their own optimistically biased beliefs, which indicates that motivated beliefs are formed subconsciously and can backfire by pushing investors to take larger risks than without moral concerns.[7]

Our study contributes to several strands of the literature. The first one is the use of self-serving beliefs and motivated reasoning to justify selfish actions while preserving a positive self-image. Some examples of this literature are Rodriguez-Lara and Moreno-Garrido (2012), who show that individuals change their concept of redistributive justice depending on how it impacts their payoffs, Exley (2016), who shows that people use risk as a rationale for giving 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 motivated beliefs when subjects with social preferences share investment profits but are only partially responsible for their losses, while Gneezy et al. (2020) study how conflicts of interests can trigger motivated beliefs in laboratory subjects. Exley and Kessler (2019), introduce the term "motivated errors" and show that subjects will excuse selfish actions by appealing to honest mistakes and confusion. Finally, using a series of well-powered online experiments, Saccardo and Serra-Garcia (2023) show that people are sophisticated in their ability to form motivated beliefs and prefer to receive information in one form or another depending on their willingness to self-deceive. We go beyond these papers by confirming the existence of motivated beliefs using a within-subject design and quantifying the effects of motivated beliefs on risk-taking. We also pin down the channel through which such motivated beliefs are formed and show that motivated beliefs have such strong subconscious effects that they can backfire by inducing subjects to take more risk than in the absence of moral hazard. Moreover, our paper introduces a new experimental paradigm that yields seemingly robust results in a literature with mixed empirical outcomes (e.g., Krizan and Windschitl, 2007; Burton et al., 2022).

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 *Diffusion* treatment to reduce the demand for motivated beliefs and to further enhance decision-makers' risk-taking compared to the *Matched* treatment. However, we cannot detect any significant effects of the diffusion of responsibility on subjects' stated beliefs nor on the amounts

[6] Mediation analysis goes beyond causal analysis by trying to identify the "cause" of effects rather than just detecting the effect. In our case, it allows us to quantify how much of the effect of limited liability on investments is channeled through the formation of motivated beliefs and not just through a change in the incentive structure. See Celli (2022) for a survey on the current standing of mediation analysis in economic research.

[7] Note that for endogenously given success probabilities of investment, the same subject invests less if the failed investment harms others than if not. Hence, the observed behavior under uncertainty is not due to malicious behavior.

invested. We look forward to future work in this area to learn under which conditions a diffusion of responsibility affects behavior and beliefs.

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. The first type of session was conducted between January and February 2019, and all subjects participated in the *Baseline* (*BL*), *Matches* (*MA*), and *Diffusion* (*DF*) treatments. The second type of session was conducted in September 2021, and all subjects participated in the *BL*, *MA*, and *No Matches* (*NM*) treatments.[8] Each treatment consists of ten rounds. In each round, subjects receive an endowment of €8, and their task 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 the distribution of losses among subjects in the event of a failed investment (see Section 2.2). To avoid hedging, only one decision per treatment is paid, which is randomly selected 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.[9]

To facilitate subjects' understanding of the payoffs and familiarize them with the interface before the start of the experiment, they 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.

Finally, after the three treatments of each session, subjects participate in a battery of personality elicitation tasks. These tasks include cognitive ability measures, overestimation, overplacement, overprecision, risk aversion, and loss aversion (see Appendix A for a detailed explanation of the measures). Additionally, subjects answer 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. A translation of the instructions can be found in Appendix K.

[8] Importantly, while subjects were aware that there would be multiple "blocks" during the experiment, they were not informed of the details of each block (i.e., treatment) until immediately before each treatment.

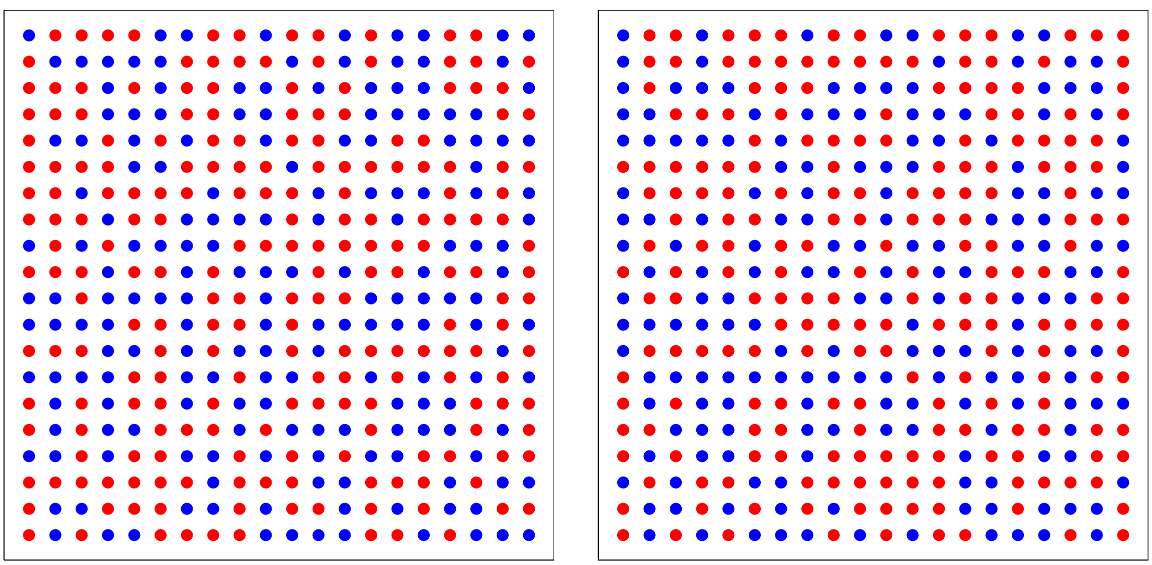
[9] The orders for sessions with the *BL*, *MA*, and *DF* treatments are: 1) *BL*, *MA*, *DF*; 2) *MA*, *DF*, *BL*; and 3) *DF*, *MA*, *BL*. The orders for sessions with *BL*, *MA*, and *NM* treatments are: 1) *BL*, *MA*, *NM*, and 2) *MA*, *NM*, *BL*. The number of sessions with each order is balanced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

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.[10]

Immediately after seeing each matrix, subjects are asked to estimate the investment's success probability and to make their investment decision for the round.[11] 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.

Figure 1: Two "Informationally Identical" Dot Spot Matrices



Note: Both matrices contain 215 red dots but with a different pattern. Varying the pattern allows us to present across treatments different matrices that convey the same information but cannot be recognized as being identical.

An important characteristic of our within-subject design 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 across treatments. This allows us to compare the behavior of the *same subject*

[10]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.

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

for *identical* investment opportunities across treatments without enabling them to learn or anchor their expectations to particular patterns. 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, we incentivized beliefs using a binarized scoring rule (Hossain and Okui, 2013) that pays either €2 or €0.[12] 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.

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

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

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."[13] Subjects are matched anonymously and randomly such that each investor b $\in \{1, 2, ..., B\}$ is associated with exactly one loss-taker t $\in \{1, 2, ..., T\}$.[14] Subjects know their type and that both the matches and the player types will be kept for the whole treatment.[15]

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.

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

[13]In the instructions, "investors" were referred to as "Type A" and "loss-takers" as "Type B."

[14]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 session (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.

[15]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.

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

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

while the payoffs for loss-taker t are

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

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 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 investors 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 investors are responsible for 25% of their losses.	Yes	No	H5: same beliefs as in BL H6: same investment as in MA

2.3 Objective Risk Task

An important part of our experimental design relies on the "wiggle room" to form self-serving beliefs provided to subjects by our ambiguous signal. As suggested by (Kunda, 1990) and Bénabou et al. (2018), subjects cannot simply form any sort of motivated beliefs. Rather, beliefs are constrained by a certain degree of credibility. Except for the extreme cases, our signal is ambiguous enough to allow subjects to "credibly" form motivated beliefs. This allows us to study the formation of motivated beliefs.

However, under moral hazard treatments, two forces are pulling in opposite directions. On the one hand, social preferences such as those in Fehr and Schmidt (1999) might push investors in *MA* and *DF* treatments to invest less. On the other, motivated beliefs might push investors to take larger risks in MA and DF than in BL.

To disentangle both effects, we use a *risky investment task*. This task takes part before each treatment and in it, 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 subsequent treatment (*BL*, *MA*, *DF*, *NM*), and the investor and loss-taker roles are maintained. Thus, the only difference between risky and uncertain investments is that investors *know* the success probabilities under risk. Again, to avoid hedging across investments, only 1 of the 11 different investments will count toward the final payoffs. To avoid any wealth effects, this payoff will only be revealed once the experiment is over.

Because in the risky investment task, there is no space to form motivated beliefs, we can use it to disentangle the effects of social preferences from motivated beliefs and to pin down the channel through which motivated beliefs are formed (see Section 3.4). An additional advantage of the risky investment task is that starting each treatment with a simplified version of the task might help subjects think more about the payoff structure and the different outcomes of that treatment.

3 Results

A total of 286 subjects were recruited through ORSEE (Greiner, 2015).[16] Sessions lasted a little below 120 minutes and were conducted at the Experimental Economics Laboratory of the Technische Universität Berlin. On average, subjects earned €38, and the experiment was programmed using oTree (Chen et al., 2016). For the limited liability treatments, we will only analyze the decisions made by investor subjects. We pool the data of sessions with and without incentivized belief elicitation since we do not detect any statistical differences between incentivized and non-incentivized beliefs (see Appendix C for details).[17] Additionally, in appendix D we discuss any potential effects the order of treatments could have on subejcts' decisions. Finally, because the focus of the study is on investments under uncertainty and the formation of motivated beliefs, we relegate most results of the risky investments and its comparison to the ambiguity treatments to Appendix E.

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 and the investment for each Dot Spot matrix across all treatments. As can be seen, the

[16] 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).

[17] This result aligns with findings in the literature on motivated beliefs, where incentives, even if high, are hardly able to de-bias subjects' beliefs (see for example Engelmann et al. (2019) or Schwardmann et al. (2022))

investment is clearly increasing in the number of red dots of the signal (see Figure F.1 in Appendix F for a detailed graphical representation of investments for each type of matrix).

Table 2: Mean Investments for different Dot Spot Matrices.

	Total	**120**	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
BL	29.06	1.93	8.75	17.43	23.67	20.15	34.46	35.76	30.13	41.46	90.47
	(36.76)	(11.47)	(18.31)	(32.99)	(28.35)	(35.79)	(36.63)	(34.08)	(36.11)	(36.68)	(21.46)
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)

Note: 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 $= 0.128$). 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 F.1 in Appendix F for a detailed breakdown of the p-values for each type of matrix).

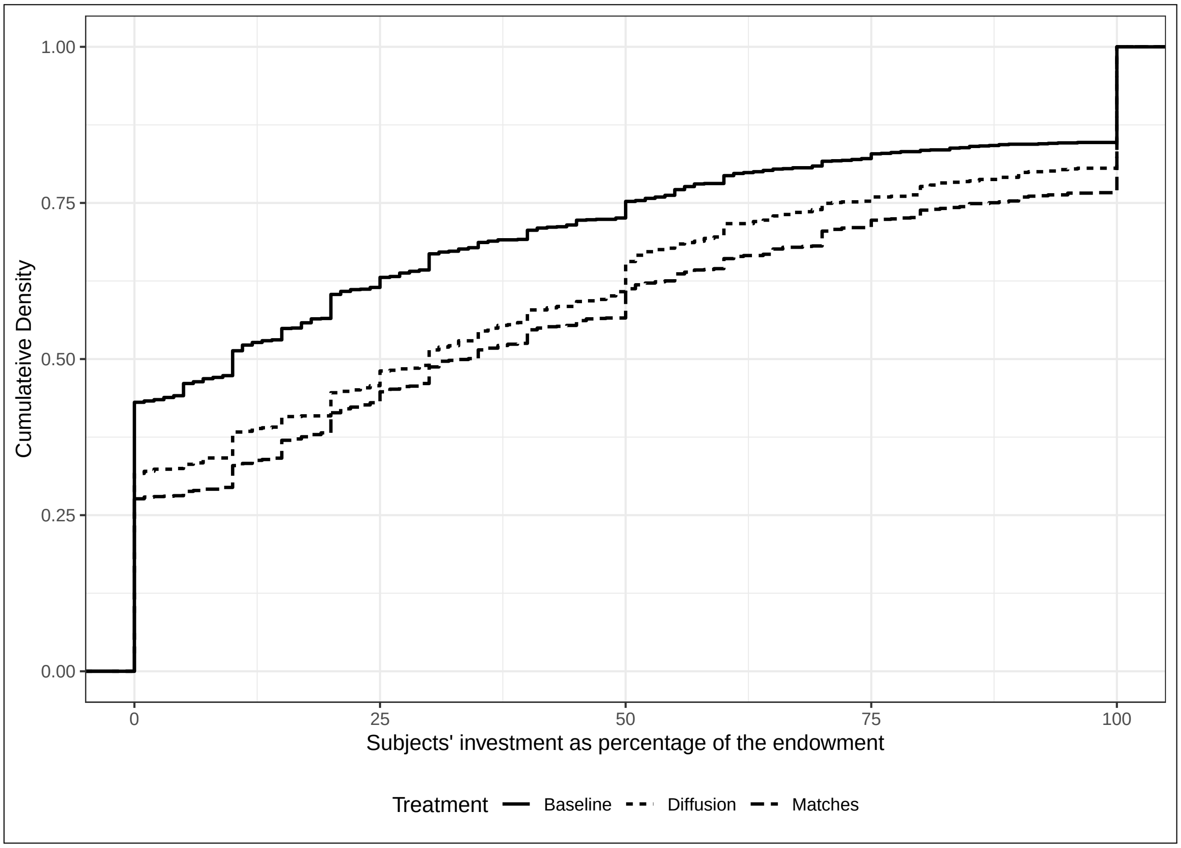
Table 3 provides a regression of the percentage of the endowment invested by subjects ($Invest$) on dummy variables for the different treatments (*MA* and *DF*), dummies for the number of red dots in each Dot Spot (*185.dots*,...,*280.dots*), and the different personality measures and treatment order dummies. The difference between columns (1) and (2) is that the first one does not include any personality controls. 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). In column (4), we only use the data for moral hazard treatments (*MA* and *DF*).

The results show that both dummies for the limited liability treatments are positive and statistically significant. On average, investors raise their investment by 13% of their endowment in the *MA* treatment and by 11% in the *DF* treatment compared to the *BL* treatment. The full range of Dot Spot dummies can be found in Table F.2 in Appendix F. It shows that there is informational value in the signal. The more red dots a matrix contains, the more do subjects invest (e.g., investors invest on average 12% more in matrices with 185 red dots than in matrices with 120 red dots).[18] Because none of the controls has any explanatory power, we omit them from the table.[19] Finally, as in the non-parametric tests, in Column (4) we cannot detect any statistical difference between the investments in the *DF* and *MA* treatments.

[18]In Table F.3 of Appendix F, we replicate the regression from Table 3 using a continuous variable for the number of dots and get qualitatively identical results for treatment effects.

[19]Similarly, when we compare investments across treatments for matrices with the same number of dots, personality has very limited explanatory power, see Table F.4 of Appendix F

Figure 2: Cumulative Density Function across Treatments.



Overall, we obtain two clear results when studying the effects of our different treatments on the investments in parametric and non-parametric ways. First, the limited liability treatments have a significant positive effect on investments (Hypothesis H1 in Table 1). Second, we cannot reject the null hypothesis that investment levels in *MA* and *DF* are the same (Hypothesis H3 in Table 1).[20] We can thus summarize the results of Section 3.1 as:

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]

[20]If we test the differences in investment using the Risk treatment, where the probabilities are given exogenously, we replicate Results *1.i* and *1.ii*, showing the robustness of these results.

Table 3: Effect of Signals and Treatments on Investment.

	(1) *Invest*	(2) *Invest*	(3) *Invest*	(4) *Invest*
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)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
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

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

Note: 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. In all cases, we show the extreme values for the range of the dummy variables for the Dot Spot matrices, Table F.2 in Appendix F reports all dummy coefficients. Robust standard errors clustered at the investor level are shown in parentheses.

3.2 Treatment Effect on Beliefs

To get an overview of the differences in beliefs across *BL*, *MA*, and *DF*, Figure 3 plots the cumulative density function for the stated probabilities that the investment will be successful across all three treatments. The figure shows that, on aggregate, subjects seem more optimistic in *MA* and *DF* treatments than in *BL*. This difference can also be seen in Table 4 where we break down 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 (see Table G.1 in Appendix G for a detailed breakdown of the p-values for each matrix).

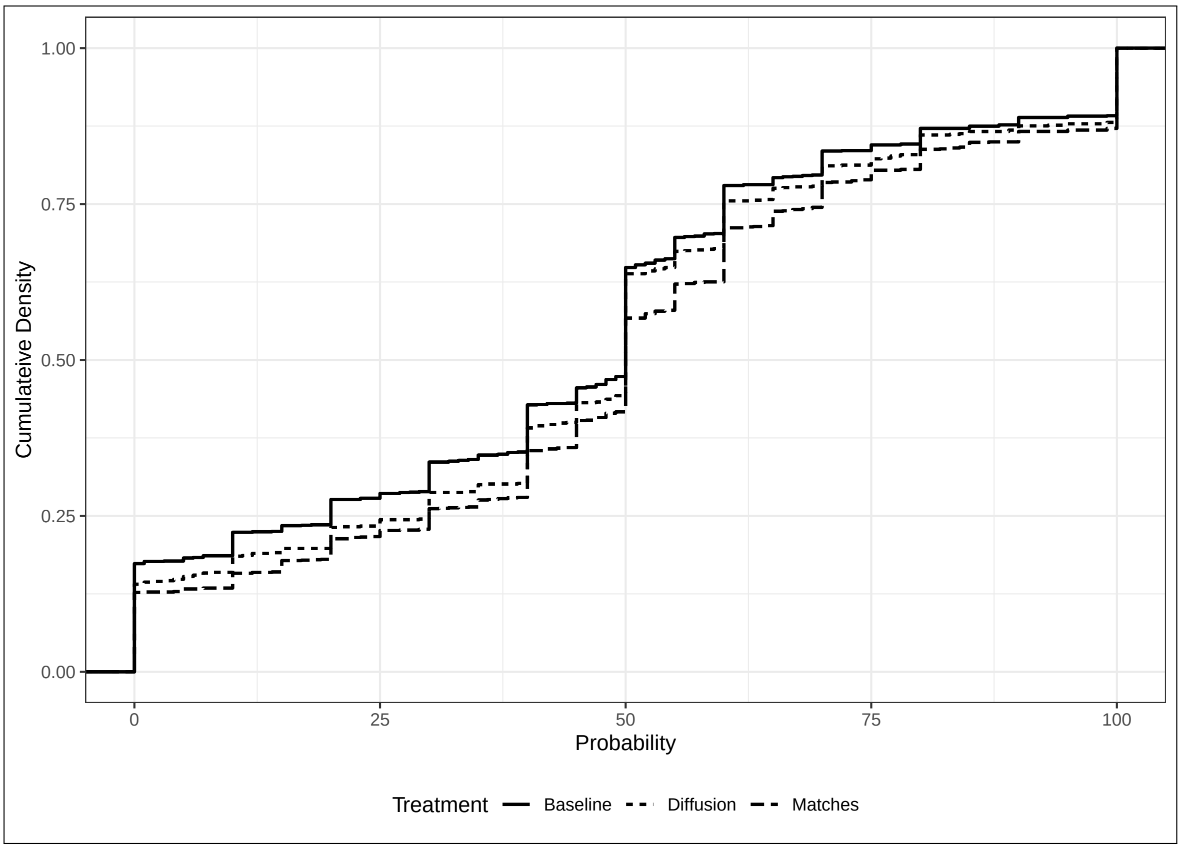
In Table 5, we reproduce Table 3 but with the estimated success probability of investors ($Prob$) as the dependent variable. The results show that the variation in the number of red dots has a large impact

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

	Total	120	185	190	195	199	201	205	210	215	280
BL	44.78	10.11	26.86	39.39	39.86	41.44	51.00	49.88	51.57	59.16	89.37
	(30.21)	(17.69)	(22.46)	(23.80)	(26.60)	(24.70)	(25.27)	(25.58)	(25.22)	(22.12)	(14.71)
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)

Note: 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.

Figure 3: Cumulative density functions of stated success probabilities across treatments.



on the beliefs: for example, the perceived success probabilities in specification (3) are, on average, 19.5 percentage points larger for a matrix with 185 red dots than for a matrix with 120 red dots. Table G.2 in Appendix G shows the dummies for all the possible matrices, confirming that the matrices are informationally relevant to investors.[21] More importantly, once we use controls, the coefficients for treatment dummies MA and DF are positive and statistically significant, indicating that in both limited liability treatments, investors are more optimistic about their investments' success. As in Table

[21]Table G.3 in Appendix G replicates Table 5 using a continuous variable for the number of dots and shows qualitatively identical results for the treatment effects.

h!]

Table 5: Effect of Signals and Treatments on Beliefs.

	(1)	(2)	(3)	(4)
	Prob	*Prob*	*Prob*	*Prob*
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)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
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

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

Note: 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. Table G.2 in Appendix G shows the dummies for all the possible matrices. Robust standard errors clustered at the investor level in parentheses.

3, in column (4) we see no difference between *MA* and *DF*.[22]

Similar to the results on investment, limited liability and moral hazard have an impact on the formation of beliefs. Our parametric and non-parametric analysis show that: (i) in *MA* and *DF* investors are significantly more optimistic about their investments' success (rejecting Hypothesis H2 in Table 1) and (ii) we see no difference between the beliefs reported in *MA* and those in *DF* (Hypothesis H4 in

[22]When we compare the reported beliefs across treatments for matrices with the same number of dots, personality has very limited explanatory power. See Table G.4 in Appendix G.

Table 1).[23] We can thus summarize the results of Section 3.2 as:

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 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 and moral hazard affect risk-taking *through* motivated beliefs. To do so we use causal mediation analysis, a type of analysis that tries to go beyond establishing a causal link between treatment and outcome by identifying the *mechanisms* through which the treatment affects the outcome (Celli, 2022). In Section 3.1, we show that investors invest significantly more under limited liability, yet this result could be driven by the change in investors' private incentives, their motivated beliefs, or both reasons combined. To disentangle the impact of motivated beliefs from the impact 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:

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

$$Inves_{b,r} = \beta_0 + \beta_1 \times \widehat{Prob_{b,r}} + \beta_2 \times MH_{b,r} + u_{b,r}. \quad (6)$$

In the first stage (Eq. 5), $Prob_{b,r}$ captures investor b's belief about the success probability of the investment in round r, $MH_{b,r}$ is a dummy variable that takes value 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 used in the Dot Spot matrices.[24] In the second stage (Eq. 6), $Invest_{b,r}$ 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.

This model allows us to identify the *indirect effect* of the treatment on investments which is 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

[23] In Table G.5 we replicate Columns (3) and (4) of Table 5 using only the data coming from matrices ranging from 190 to 210 dots, the results are qualitatively identical to those of Table 5.

[24] We fold in both *MA* and *DF* treatments into the dummy MH because they are statistically indistinguishable (recall Result 1 and Result 2). In Table H.1 of Appendix H we show the coefficients for all the dot spot dummies.

liability has on beliefs. Our main assumption is that the number of red dots, $Dots_{b,r}$, affects the investment decision only by shifting subjects' beliefs.[25]

Table 6: First Stage Regressions for *Prob*.

	(1)	(2)	(3)
	Prob	*Prob*	*Prob*
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)
.	.	.	.
.	.	.	.
.	.	.	.
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

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

Note: 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 and moral hazard on investment mediated by beliefs among those investors whose beliefs are affected by moral hazard (see, e.g., Imai et al., 2011).[26] In contrast, the complier average direct treatment effect (CADE) captures all causal mechanisms of limited liability and moral hazard 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 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

[25] 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.

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

Table 7: Second Stage with Instruments for *Prob*

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

Note: Robust standard errors clustered at the investor level in parentheses.

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

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

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

by approximately 1.1 percentage points in all three specifications. This effect is statistically significant at the 1% level. The direct treatment effect (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 effect, 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.[27]

Overall, the results in Tables 6–8 indicate that moral hazard 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 and moral hazard.

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 and moral hazard.

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), which occurs when agents derive utility from future utility flows. In our setup, this channel would result in subjects forming overoptimistic beliefs about the future.[28] Furthermore, as shown in Brunnermeier and Parker (2005), if subjects are excessively optimistic due to anticipatory utility, they might strongly prefer positively skewed assets such as our limited liability investments.

The second channel to form motivated beliefs in our experiment is self-image concerns (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. For example, in the *MA* treatment, investors can make large gains at low risk. However, they also know that a loss-taking subject will cover most of the losses if the investment fails. This possibility creates mental discomfort in the investor, who wishes to maintain a positive self-image while *also* 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 determine 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 as investors are not matched to any loss-taker. If anticipatory utility is the channel through which motivated beliefs

[27] 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 I.1) or only the incentivized beliefs data (Appendix I.2). Additionally, we compare the results of Table 7 to different (non-instrumented) specifications including a linear or logit regression using both the ambiguity and uncertainty data (Appendix I). The results across all of these exercises corroborate the validity of our IV approach.

[28] 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.

	(1)	(2)	(3)	(4)
	Prob	*Prob*	*Prob*	*Prob*
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)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
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

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

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

are formed in our setup, then there should be no difference in the reported success likelihoods between the *MA* and *NM* treatments. However, if self-image concerns are the channel at work, then we should observe investors reporting lower success likelihoods in *NM* than in *MA*. Furthermore, if motivated beliefs were solely due to self-image concerns, then 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).[29] 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* (Hypothesis H5 in Table 1), 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.

Furthermore, the relative sizes of the coefficients for the treatment dummies of *NM* and *MA* in Table

[29] In Table J.1 of Appendix J we detail the investment and beliefs of subjects for the different dot spot matrices in the sessions that include the NM treatment across treatments.

Table 10: Effect of of the *NM* and *MA* Treatments on Investment.

	(1)	(2)	(3)	(4)
	Invest	*Invest*	*Invest*	*Invest*
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)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
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

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

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

10 match the mediation analysis estimates 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 due to motivated beliefs (indirect effect), while two-thirds are caused by monetary incentives (direct effect, captured by the treatment dummy *NM*). The qualitative matching of results in Table 8 and Table 10 validates the IV approach from Section 3.3, and shows the robustness of our results and experimental design.

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

Under limited liability, motivated beliefs are only formed when moral hazard is present. [H5]

3.5 Motivated Beliefs and Social Preferences

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. Yet, 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 note that subjects invest significantly *more* when there is moral hazard than when there is not (rejecting Hypothesis H6 in Table 1). This is an unexpected outcome. Result 4 indicates that investors form motivated beliefs because they care about the impact of potential losses on third parties. However, when comparing *MA* and *NM*, we observe that investors take larger risks for the same incentive structure when third parties can be negatively affected.

Table 11: Effect of Treatments and Exogenously Given Risk on Investment.

	(1)	(2)	(3)	(4)
	InvestR	*InvestR*	*InvestR*	*InvestR*
RMA	11.42***	11.42***		
	(1.430)	(1.434)		
RNM	13.60***	13.60***	2.180**	2.180**
	(1.618)	(1.622)	(0.970)	(0.974)
success_10%	1.685***	1.685***	2.278***	2.278***
	(0.430)	(0.431)	(0.592)	(0.594)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
success_100%	99.95***	99.95***	99.93***	99.93***
	(0.0495)	(0.0497)	(0.0744)	(0.0747)
Constant	-8.291***	-11.81	-1.016**	-4.679
	(0.966)	(21.46)	(0.481)	(23.59)
N	1782	1782	1188	1188
adj. R^2	0.757	0.781	0.745	0.782
Controls	No	Yes	No	Yes

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

Note: Regression of the investment in the objective risk treatment (*InvestR*). The reference treatment for the first two columns is RBL. For the last two columns, it is RMA. Robust standard errors clustered at the investor level in parentheses.

Our interpretation of this result is that motivated beliefs are formed unconsciously and, consequently, exacerbate the already excessive risk-taking caused by limited liability. Because subjects are unaware that they are forming biased beliefs, they respond to their excessive optimism in the same way as they would to any other change in beliefs: by investing larger amounts whenever the expected returns are higher. We confirm this interpretation by comparing the investment of subjects in the *objective risk* task that subjects played before every treatment. Recall that, as described in Section 2.3, in the objective risk task subjects make investment decisions for 11 different assets, each with a given probability of success (0%, 10%, 20%, ..., 100%) and the same payoff structure as the corresponding treatments with uncertainty. We denote the objective risk treatments corresponding to *NM*, *MA*, and *BL* treatments as *RNM*, *RMA*, and *RBL*, respectively. Because in the objective risk task the success probabilities of investments are exogenously given, there is no room for subjects to form motivated beliefs. Therefore, if subjects care about the negative impact of their decisions on third parties (i.e., hold social preferences), they should invest less in the *RMA* treatment compared to the

RNM treatment.

Table 11 presents regressions of the investment in the objective risk task ($InvestR$) in the *RBL*, *RMA*, and *RNM* treatments on dummies for each of the possible given success probabilities ($success\_x\%$), for each treatment, and on the other controls used in previous tables. The first two columns use *RBL* as the reference treatment, while columns (3) and (4) compare the investment in *RMA* and *RNM* using *RMA* as the reference. As expected, the investment in *RMA* is lower than in *RNM*. This indicates that subjects are more reluctant to invest when losses might harm a third party, which is in line with common models for social preferences (e.g., Fehr and Schmidt, 1999). Such social preferences should also lead to subjects to lower investments in MA than in NM. However, columns (3) and (4) of Table 10 show the opposite effect – when the signal is ambiguous, social preferences backfire as subjects form motivated beliefs to self-justify any risk-taking that may harm others, which results in an *increase* in risk-taking. This unexpected effect of social preferences suggests that motivated beliefs are formed unconsciously, and shows that the impact of motivated beliefs on investment in the *MA* treatment is bigger than the negative impact of other-regarding preferences visible in the *RMA* treatment.

To clarify the different effects of moral hazard and limited liability just described, Figure 4 illustrates the differences in investment between the treatments *NM*, *MA*, and *BL* under objective and ambiguous probabilities. The left panel shows the differences across the treatments with ambiguous signals as reported in Table 10 and the reasons for such differences. In it, we show that for subjective risk, the total effect of limited liability and moral hazard (i.e., the difference between *BL* and *MA*) is larger than the effect of limited liability alone, which is the difference between *BL* and *NM*. This is because the positive effect of motivated beliefs on investment exceeds the negative effect of social preferences. The right panel presents the same triangulation as the left one, but uses the data from the objective risk round reported in Table 11.[30] Here the total effect of limited liability and moral hazard (i.e., the difference between *RBL* and *RMA*) is smaller than the effect of limited liability alone, which is the difference between *RBL* and *RNM*), because social preferences lead to a reduction of investment when its failure harms another subject.

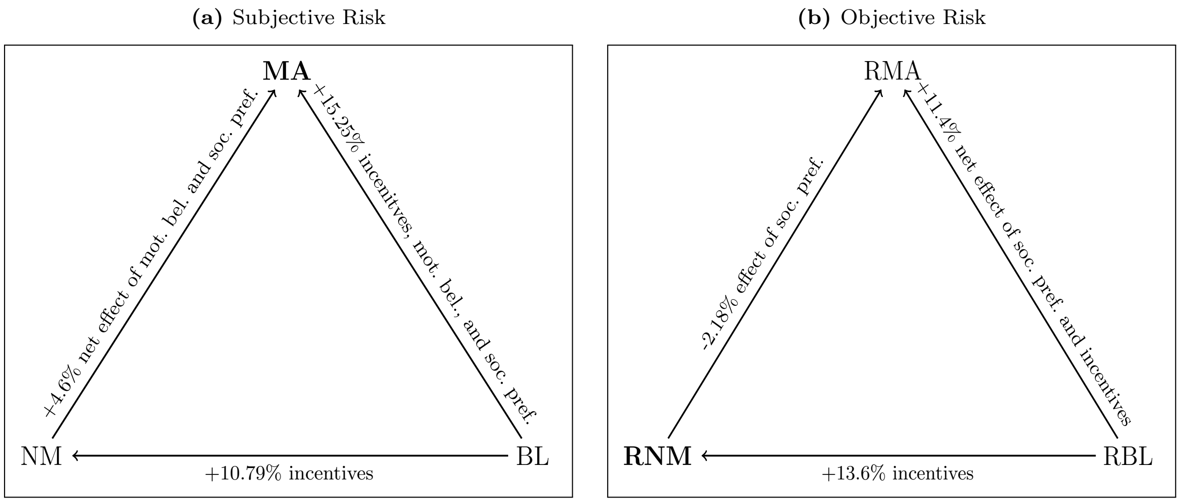
Overall, the results from Tables 9, 10, and 11 lead us to conclude that the need to self-justify risky behavior in situations with moral hazard results in *higher investments* than in situations without moral hazard. This is because when moral hazard is present, social preferences push subjects to form motivated beliefs which lead them to unconsciously increase their risky investment. These results show how vulnerable subjects are to the formation of motivated beliefs and point to the importance of understanding how motivated beliefs are formed and how decision-makers can bias or de-bias themselves. Such consequences should be accounted for in mechanism design and in the regulation of incentive structures (e.g., Schwardmann and Van der Weele, 2019; Bridet and Schwardmann, 2020) and can be summarized in the following result:

Result 5 *Social Preferences can Backfire*

When moral hazard is present, motivated beliefs result in higher risky investments, which would not occur absent the need of investors to self-justify their actions. [H6 rejected]

[30] Notice that the changes across vertices can be either positive or negative and that the numbers do not add up, as they come from separate regressions.

Figure 4: Triangulation of Changes in Investment



Note: Figure showing the differences in investment across treatments. In the left panel, subjects form beliefs about the success probabilities of the investment. In the right panel, the success probabilities are exogenously given. In BL and RBL subjects have full liability. In NM and RNM subjects have limited liability but no moral hazard. In MA and RMA subjects have both limited liability and moral hazard. The arrows point in the direction of the change in investment. For both figures, in bold the treatment with the highest investment.

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 (e.g., Cheng et al., 2015; Barberis, 2013).

We set up a within-subject experimental design to study the impact of limited liability and moral hazard on motivated beliefs. In it, participants invest under full and limited liability. Under full liability, the investors bear the full cost of any losses from the investment. However, under limited liability, a third party absorbs most of the losses if the investment fails, creating a situation of moral hazard similar to that described in Barberis (2013). Importantly, before each investment, subjects receive a noisy signal about its success potential and are asked to express their perceived likelihood of success. Because the signals provided in the different treatments are "informationally identical," we can observe the difference in beliefs for the same investment opportunity under different conditions.

The results indicate that, for the same investment opportunity, participants are more optimistic and invest larger sums under limited liability with moral hazard than under full liability. That is, we detect the formation of motivated beliefs under limited liability. However, motivated beliefs could come from different channels in our setup. To pin down the specific channel, we implement a limited liability treatment without moral hazard in which investment losses have limited liability but no impact on third parties. The results show that in the absence of moral hazard, subjects do not exhibit motivated beliefs. Moreover, the results show that subjects invest more when their actions impact third parties than when they do not. This paradoxical behavior can only be explained if motivated beliefs unconsciously drive participants to excessive optimism about their investments. Ironically, these optimistic beliefs (which are used to justify morally questionable actions) lead subjects to make even larger investments. Finally, using mediation analysis (Imai et al., 2011, 2013), we quantify the impact of motivated beliefs on subjects' investment decisions and show that about one-third of the increase in investment under limited liability is due to motivated beliefs.

According to Barberis (2013), subprime securitization is a particularly ripe environment for forming motivated beliefs and excessive risk-taking. The reason is that subprime-linked products are highly complex, offering traders at banks' mortgage desks enough belief "wiggle room" to manipulate their beliefs and justify their excessive risk-taking. Gino et al. (2016) argue that the formation of motivated beliefs depends 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 small amount of ambiguity can lead to the formation of self-serving beliefs.

However, even though the results of our experiment are robust and aligned with the theory, there are still some open questions. For instance, the relationship between beliefs and investment decisions remains ambiguous. Conducting an experiment that randomly assigns the order of screens for investment and beliefs or one where subjects are only asked to form beliefs and not invest might help to clarify this question. Similarly, one could adopt a design as in Gneezy et al. (2018), where subjects form beliefs before being informed of their treatment and then make investments. This might help to gain further insights into how beliefs impact investment decisions. Another valuable addition could be adding a measure of moral identity similar to that described in Aquino and Reed II (2002) or manipulating moral concerns by having a charity such as "Save the Children" take the losses instead of other laboratory subjects. Finally, given that the higher risk-taking in MA compared to MN goes against our prior expectations, testing the robustness of the result by replicating the experiment would be good. In light of the implications of motivated beliefs for investor behavior and the need for policymakers to address "bad beliefs", all of these extensions would not only be valuable contributions to academics but also to the regulatory debate.

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A Additional Variables

After the three treatments, subjects participate in a final block of 5 *parts*, that was 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 K.1 in Appendix K 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 $N_{i,r}$ and the actual number of red dots in the graphic ($A_{i,r}$).

For round r, we define overprecision as the difference between a subject's stated 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 is paid, 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 the answers of the subject are to the correct answers. Part 4 of the final block elicits risk and loss aversion using multiple price lists (see Tables K.4 and K.5 in Appendix K). 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 B.1.[31]

Two things are important to notice. First, the shown number of red dots 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 without having to worry about subjects recognizing this.

Table B.1: 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

Note: 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.

[31] 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 in BL due to a programming oversight, the matrices are different.

C 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, Table C.1 presents 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 matched treatments. As it is clear from the results, incentivizing beliefs does not seem to change the subjective probabilities reported by subjects.

Table C.1: Effects of Incentives on Beliefs

	120	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
BL = BL*	0.720	0.139	0.058	0.982	0.789	0.856	0.265	0.929	0.548	0.470
MA = MA*	0.023	0.459	0.144	0.918	0.018	0.635	0.802	0.587	0.213	0.938

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

The findings in Table C.1 are corroborated by Table C.2 which presents the results of regressing subjects' beliefs on a dummy for each of the different dot spots and a dummy that takes value 1 if the beliefs are not 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 indicate that incentives do not alter subjects' reported beliefs in either treatment (BL and MA). This result is reinforced by the results in Table C.3 where we find no significant interaction effects of the incentive dummy with treatment MA in comparison to BL.[32] As a robustness test, we exploit the within-subject aspect of our experiment to calculate the effect of the treatment on beliefs for each subject i and each matrix type ($m \in 120, 185, ..., 280$). 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 finds no statistical differences across $effect$ and $effect^{*}$ (p-value = 0.438).

Given these results, we conclude that incentives have no impact on the reported beliefs. Our results align with previous studies, such as 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.

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

Table C.2: Effect of incentives on beliefs.

	Baseline		Matches	
	(1)	(2)	(3)	(4)
	Prob	*Prob*	*Prob*	*Prob*
No Incentive	-2.422	-2.359	-3.917	-5.205*
	(2.622)	(3.071)	(2.697)	(2.851)
185.dots	16.89***	16.41***	23.19***	23.68***
	(2.232)	(2.210)	(2.231)	(2.261)
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
280.dots	81.36***	80.40***	80.25***	79.68***
	(2.391)	(2.526)	(2.001)	(2.114)
Constant	11.05	6.316	12.45	12.06
	(12.61)	(13.58)	(11.58)	(10.55)
N	1430	1340	1430	1340
Controls	Yes	Yes	Yes	Yes
Gender	No	Yes	No	Yes

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

Note: In all columns, the dummy variable (*No incentive*) 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 subject level in parentheses.

Table C.3: Interaction of incentives with *MA*

	(1)	(2)
	prob	prob
MA	4.398***	4.378***
	(1.337)	(1.339)
No Incentive	-2.952	-3.416
	(2.559)	(2.903)
No Incentive X MA	-0.341	-0.426
	(1.746)	(1.805)
185.dots	19.88***	19.84***
	(1.578)	(1.579)
.	.	.
.	.	.
.	.	.
280.dots	80.52***	79.67***
	(1.981)	(2.079)
Constant	9.995	7.161
	(10.46)	(10.46)
N	2860	2680
Controls	Yes	Yes
Gender	No	Yes

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

Note: In all columns, the dummy variable (*No incentive*) takes a value of 1 if the beliefs were not incentivized. The reference treatment is *BL*. Robust standard errors clustered at the subject level in parentheses.

D Experimenter Demand Effect

As a robustness test, Table D.1 replicates column (3) from Tables 3 and 5 but using only the first treatment of each session of investor subjects. This aggregates to 1070 observations across 107 subjects. The results show that while the treatment has a statistical effect at the 5% level for investments, we do not find statistical effects for the beliefs data. However, the lack of significant differences for beliefs is most likely due to the loss of power coming from reducing the total amount of observations by more than a factor of three. This suspicion is confirmed in Table D.2 where we reproduce column (3) from Tables 3 and 5 using all of the data, but show only the treatment dummies and the treatment order dummies for each session.

Table D.1: Replication of column (3) from Tables 3 and 5 using only the first treatments in a sessions.

	(1)	(2)
	Invest	*Prob*
MA	9.187**	3.228
	(4.031)	(2.464)
DF	9.140**	3.169
	(3.580)	(2.334)
185.dots	9.764***	17.26***
	(2.267)	(2.651)
190.dots	16.56***	26.97***
	(2.603)	(2.853)
195.dots	27.58***	35.02***
	(3.591)	(3.439)
199.dots	24.47***	32.82***
	(3.424)	(3.096)
201.dots	39.51***	43.57***
	(3.834)	(3.248)
205.dots	37.19***	40.93***
	(3.898)	(3.256)
210.dots	42.28***	43.46***
	(4.315)	(3.427)
215.dots	50.86***	53.20***
	(4.520)	(3.584)
280.dots	83.25***	76.40***
	(3.468)	(2.964)
Constant	-10.44	19.31
	(21.97)	(14.18)
N	1070	1070
adj. R^2	0.364	0.404
Personality Controls	Yes	Yes

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

Note: In Column (1), we reproduce Column (3) of Table 3 using only the first treatment in each session. In Column (2), we reproduce Column (3) of Table 5 using only the first treatment in each session. Robust standard errors clustered at the subject level in parentheses.

Table D.2: Replication of column (3) from Tables 3 and 5 showing the order dummies.

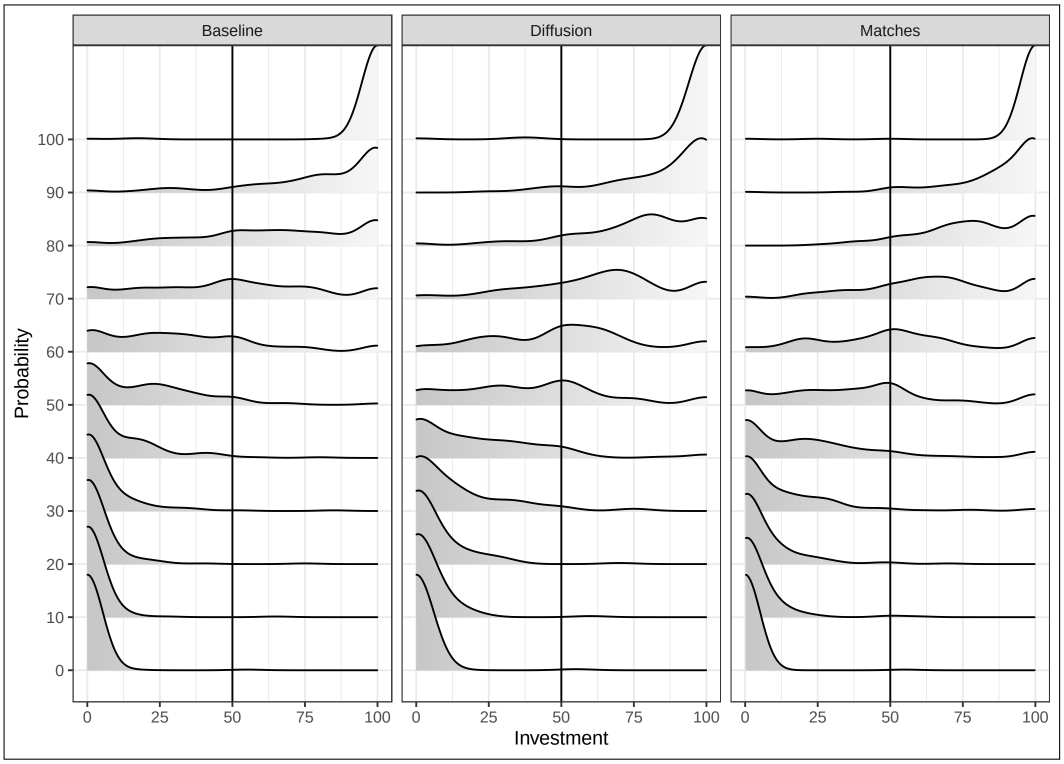
	(1)	(2)
	Invest	*Prob*
MA	13.23***	4.114***
	(1.470)	(0.892)
DF	10.81***	3.171***
	(1.458)	(1.129)
MA DF BL	1.314	0.133
	(5.057)	(2.775)
DF MA BL	2.932	2.772
	(4.612)	(2.517)
BL MA NM	4.504	3.299
	(4.624)	(2.492)
MA NM BL	6.842	4.675*
	(4.637)	(2.427)
Constant	-9.140	2.156
	(18.64)	(10.81)
N	3480	3480
adj. R^2	0.368	0.444
Gender	Yes	Yes
Personality Controls	Yes	Yes

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

Note: In Column (1) we reproduce Column (3) of Table 3, showing only the treatment and order dummies. In Column (2) we reproduce Column (3) of Table 5, showing only the treatment and order dummies. Baseline dummy is *BL MA DF*. Robust standard errors clustered at the subject level in parentheses.

E Risk

Figure E.1: Investments for Given Probabilities in Risk Part



Note: The figure shows the density estimates of investment made by all investors for each given probability of success. The shading of the distribution gets lighter as the investment gets higher. We present the results for all three treatments.

In each treatment *MA*, *DF*, and *BL*, subjects take part in a risky investment task in which the probabilities for success of the investment are explicitly given, which we call *RMA*, *RDF*, and *RBL*, respectively. Figure E.1 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 E.1 indicate that investors understood the incentives, as they tend to invest more for higher success probabilities.

Figure E.1, and the means reported in Table E.1 show that subjects invest significantly more in the limited liability treatments than in the *Baseline*. The average investment is 32.85% in (*RBL*), 41.73% in (*RMA*), and 41.5% in (*RDF*). In line with this, the investment in the limited liability treatments is also higher for most success probabilities. The only exception arises at the extreme probabilities of 0% and 100%, where investors tend to invest either nothing or their entire endowment independent of the treatment. Finally, a within-subject Wilcoxon signed-rank test comparing the total investments made in the three treatments (Table E.2) confirms that investments *RMA* and *RDF* are significantly higher than in *RBL* (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, *RMA* and *RDF*. Not only

Table E.1: Mean Investments in Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
RBL	32.85	.51	1.39	2.72	4.64	8.25	17.83	32.88	48.00	66.36	80.83	97.97
	(38.76)	(4.76)	(6.32)	(8.46)	(11.14)	(13.72)	(20.35)	(27.52)	(29.82)	(28.37)	(24.60)	(12.81)
RMA	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)
RDF	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)

Note: 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 E.2: Wilcoxon Signed-Rank Tests for Risk Part

	Total	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
p-value RBL = RMA	<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 RBL = RDF	<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 RDF = RMA	0.434	0.993	0.562	0.728	0.460	0.635	0.345	0.522	0.392	0.288	0.219	0.186

Note: 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.

are the total investment levels in these treatments similar, but also the investments for a given success probability (Table E.1). A within-subject Wilcoxon signed-rank test comparing the *total* amount invested in both treatments confirms this result, as the null hypothesis of no difference cannot be rejected (p-value = 0.434). This result is also confirmed in Table E.3, where we regress the amount invested (*InvestR*) for each possible endogenously given probability (*success_x*%) and see that there is a strong positive and significant difference of MA and DF with respect to BL, but no difference between RMA and RDF.

Comparing how much subjects invest in the ambiguity and risky treatments "for the same probability" is complicated since in the risky treatments, subjects invest under eleven different situations where p = [0%,10%,...,90%,100%], while in the ambiguity treatments, subjects report their subjective probabilities using integers (i.e., they can enter 101 different probabilities). To overcome this problem we create the variable $inv'_{i,p',t}$ which captures the average investment made by subject i in treatment t for an interval around the risk investment probability p = [0%,10%,...,90%,100%].[33] This allows us to compare the investment that subject i made in treatment t for the objective probability p ($inv_{i,p,t}$) to its ambiguous "similar" counterpart ($inv'_{i,p',t}$).

Figure E.2 plots the difference between the investment under ambiguity and the investment under

[33]To create $inv'_{i,p',t}$, we average all the investments of subject i in treatment t that she made within each interval $[p-5,\, p+4]$. So, for example, to compare the investment done with a given p=40% to $inv'_{i,40,t}$, we average across all investments for which the subjects stated a probability of success in the interval [35%, 44%). Of course, $p = 0\%$ and $p = 100\%$ are compared to the smaller intervals [0%, 4%) and [95%,100%], respectively.

Table E.3: Effect of Treatments and Exogenously Given Risk on Investment.

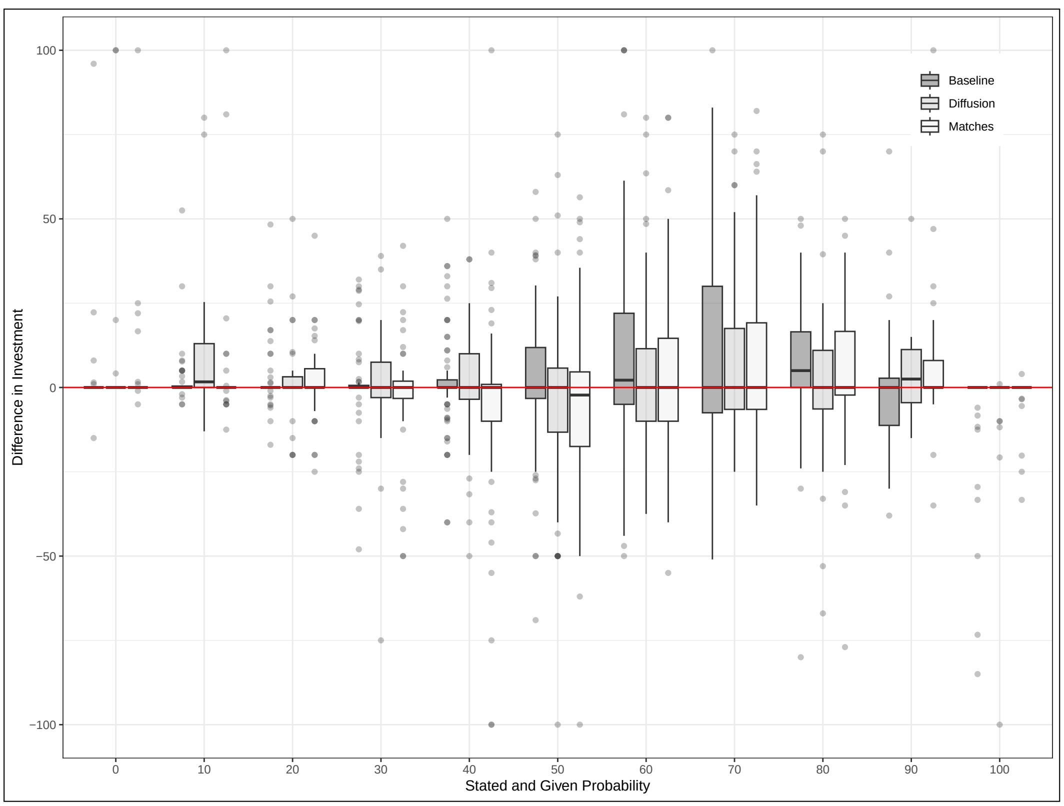
	(1)	(2)
	InvestR	*InvestR*
RMA	9.278^{***}	
	(1.215)	
RDF	9.736^{***}	0.458
	(1.240)	(0.792)
success_10%	2.088^{***}	2.625^{***}
	(0.438)	(0.598)
success_20%	3.792^{***}	4.556^{***}
	(0.676)	(0.822)
success_30%	8.046^{***}	10.17^{***}
	(1.140)	(1.476)
success_40%	15.60^{***}	19.84^{***}
	(1.800)	(2.418)
success_50%	30.44^{***}	37.67^{***}
	(2.295)	(2.932)
success_60%	42.45^{***}	48.99^{***}
	(2.565)	(2.904)
success_70%	55.95^{***}	61.44^{***}
	(2.715)	(2.862)
success_80%	70.15^{***}	74.62^{***}
	(2.608)	(2.500)
success_90%	81.97^{***}	85.62^{***}
	(2.496)	(2.275)
success_100%	96.03^{***}	96.31^{***}
	(2.072)	(2.047)
Constant	3.602	-1.096
	(16.66)	(19.30)
N	2640	1760
adj. R^2	0.742	0.757
Controls	Yes	Yes
Gender	Yes	Yes
All treatments	Yes	No

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

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

uncertainty for the *similar probability* of success ($diff_{i,p,t} = inv'_{i,p',t} - inv_{i,p,t}$) for all p and t, where the larger $diff_{i,p,t}$, the larger the investment under ambiguity. Two things pop out immediately: first, the median $diff_{i,p,t}$ across most treatments and probabilities is zero. This means that once we control for beliefs, subjects are generally consistent in their investments across risk and ambiguity settings. Nonetheless, there is an evident asymmetry above and below 50% across all three treatments. Subjects are fairly consistent in their investment for probabilities below 50%, but for probabilities above 50% (excluding 100%), there is higher variance in $diff_{i,p,t}$, with subjects tending to invest more in ambiguous situations than uncertain situations. In Table E.4 we regress $diff_{i,p,t}$ on dummies for treatment, personality traits, order dummies, and a dummy for each probability p. Column (1) uses all of the observations, column (2)uses data for probabilities greater than $p > 50\%$, and the third column only uses data for probabilities less than $p < 50\%$. The results show that the difference in investment is significantly lower in *MA* than in *BL*. That is, in the *MA* treatment, subjects invest relatively less under ambiguity than under uncertainty conditional on the probabilities of success. We see no difference across treatments in any of the other treatments or specifications. The personality traits of subjects do not have any statistical relevance, so we omit them from Table E.2.

Figure E.2: Difference between investments in risky and ambiguous treatments.



Note: Box plots showing the difference in investment under the uncertain and ambiguous treatments for "similar" likelihoods of success ($diff_{i,p,t} = inv'_{i,p',t} - inv_{i,p,t}$). The horizontal axis shows the eleven uncertain probabilities while the vertical axis shows the difference.

Table E.4: Differences in investment between risky and ambiguous treatments.

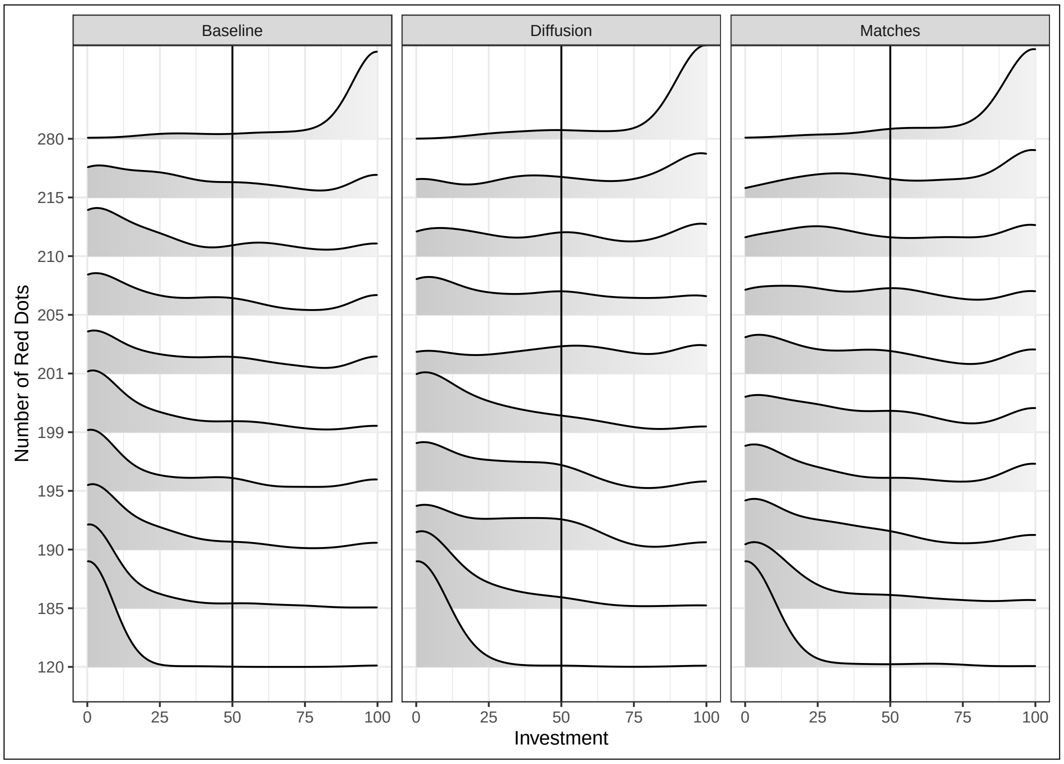
	(1)	(2)	(3)
	$diff$	$diff$ ($p \geq 50\%$)	$diff$ ($p < 50\%$)
MA	-2.384**	-1.994	-1.445
	(1.084)	(1.842)	(1.237)
DF	-1.583	-2.516	0.826
	(1.483)	(2.616)	(1.642)
Constant	8.261	-7.356	34.37*
	(13.94)	(17.13)	(19.73)
N	1886	772	805
adj. R^2	0.048	0.066	0.041
Controls	Yes	Yes	Yes
Probability Dummies	Yes	Yes	Yes
Gender	No	No	No

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

Note: The dependent variable in all columns is $diff_{i,p,t} = inv'_{i,p',t} - inv_{i,p,t}$. Column (1) uses all of the data, Column (2) uses the data for cases where $p \geq 50$, and Column (3) the data for $p < 50$. In all cases, we use all personality controls except for gender. Robust standard errors clustered at the subject level in parentheses.

F Effect of Treatments on Investment

Figure F.1: Density of Investments for Each Type of Matrix



Note: The figure shows the density estimates of the investment made by all investors for each type of matrix. The shading of the distribution gets lighter as the investment gets higher. We present the results for all three treatments.

Table F.1: Wilcoxon Signed-Rank Tests for Investments

	Total	**120**	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
p*-value *BL* = *MA	**<0.001**	0.152	<0.001	0.014	0.014	<0.001	0.022	0.004	<0.001	<0.001	0.236
p*-value *BL* = *DF	**<0.001**	0.039	0.019	0.038	0.282	0.136	<0.001	0.010	<0.001	<0.001	0.026
p*-value *DF* = *MA	**0.254**	0.656	0.324	0.709	0.157	0.097	0.183	0.883	0.838	0.820	0.926

Note: 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.

Table F.2: Effect of Signals and Treatments on Investment with all dummies for the dot spot matrices.

	(1) *Invest*	(2) *Invest*	(3) *Invest*	(4) *Invest*
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

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

Note: 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 subject level in parentheses.

Table F.3: Linear specification of the Dot Spot matrices.

	(1)	(2)	(3)	(4)
	Invest	*Invest*	*Invest*	*Invest*
MA	12.94***	12.94***	13.37***	
	(1.399)	(1.400)	(1.469)	
DF	9.290***	10.57***	10.89***	-1.932
	(1.614)	(1.389)	(1.473)	(1.395)
Dots	0.571***	0.570***	0.566***	0.575***
	(0.0164)	(0.0167)	(0.0176)	(0.0194)
Constant	-83.72***	-81.85***	-89.46***	-77.11***
	(3.173)	(18.80)	(19.30)	(21.81)
N	3750	3750	3480	2140
adj. R^2	0.320	0.333	0.330	0.318
Controls	No	Yes	Yes	Yes
Gender	No	No	Yes	Yes
BL included	Yes	Yes	Yes	No

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

Note: Replication of Table 3 using a linear specification for the number of dots (*Dots*). This variable takes the value of the dots shown in each matrix instead of the dummy variables used in the original specification. Robust standard errors clustered at the subject level in parentheses.

Table F.4: Investment across treatments for informationally identical matrices.

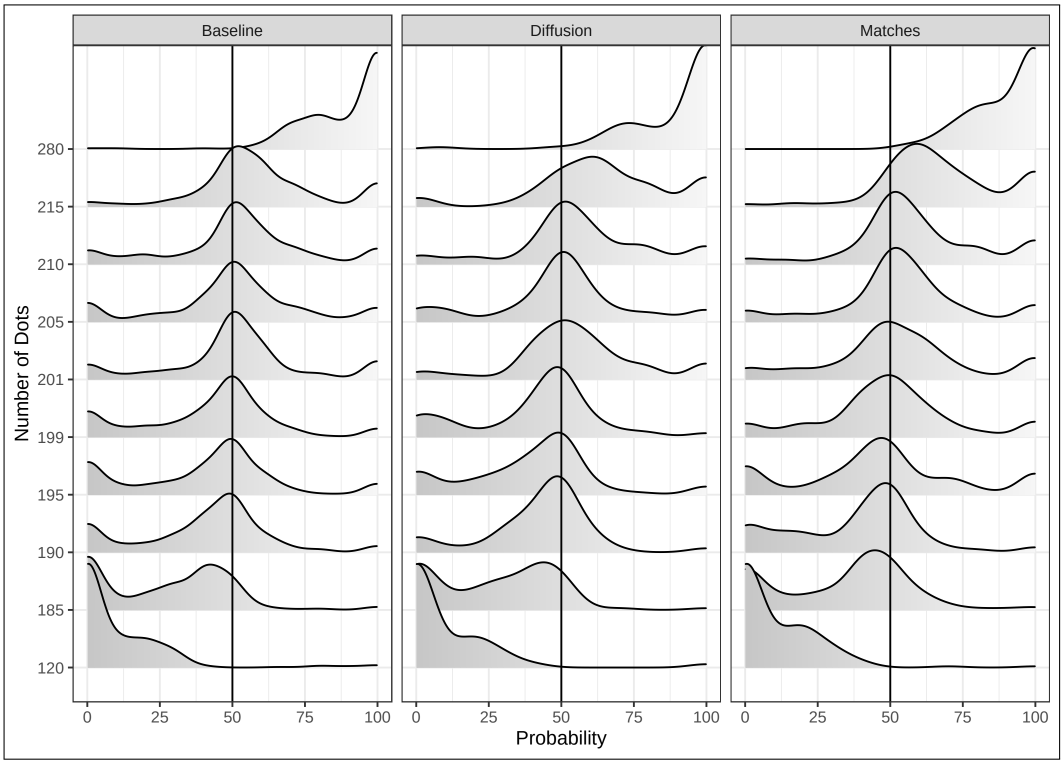
	(1)	(2)	(3)
	BL - MA	*BL - DF*	*MA - DF*
Raven	-0.0607	-0.383	0.171
	(0.543)	(0.693)	(0.605)
Overestimation	-0.617*	-0.240	0.572**
	(0.351)	(0.348)	(0.268)
Overplacement	0.299	0.243	-0.0503
	(0.555)	(0.477)	(0.388)
Overprecision	-0.221	-0.0327	0.173
	(0.162)	(0.187)	(0.131)
Risk aversion	-1.016**	-0.410	0.482
	(0.447)	(0.512)	(0.387)
Loss aversion	1.900**	0.818	-1.321**
	(0.876)	(0.784)	(0.653)
Female	0.888	-5.599	-5.753*
	(3.354)	(3.590)	(3.338)
Constant	-20.80	3.168	15.44
	(20.89)	(22.55)	(21.21)
N	741	432	441
adj. R^2	0.016	0.017	0.025
Session Fixed Effects	Yes	Yes	Yes

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

Note: In the first column, the dependent variable is the difference in investment between BL and MA when a subject sees matrices with the same number of dots. In the second column, the dependent variable is the difference in investment between BL and DF. The third column shows the difference between MA and DF. Robust standard errors clustered at the subject level in parentheses.

G Effect of Treatments on Beliefs

Figure G.1: Density of the Stated Likelihood of Success for Each Type of Matrix.



Note: The figure shows the density estimates of the likelihood of success stated by all investors for each type of matrix. The shading of the distribution gets lighter as the likelihood gets higher. We present the results for all three treatments.

Table G.1: Wilcoxon Signed-Rank Tests for Stated Likelihoods

	Total	**120**	**185**	**190**	**195**	**199**	**201**	**205**	**210**	**215**	**280**
***p*-value $BL = MA$**	**<0.001**	0.151	0.007	0.644	0.095	0.004	0.919	0.365	0.012	< 0.001	0.361
***p*-value $BL = DF$**	**0.035**	0.100	0.868	0.300	0.662	0.306	0.275	0.810	0.013	0.008	0.240
***p*-value $DF = MA$**	**0.139**	0.919	0.075	0.247	0.353	0.385	0.449	0.367	0.855	0.773	0.405

Note: Column $Total$ presents a Wilcoxon Signed-Rank Tests comparing investors' aggregate invested amount across treatments. All other columns present Wilcoxon Signed-Rank tests comparing the investments across treatments for each type of matrix.

Table G.2: Effect of Signals and Treatments on Beliefs showing the coefficients for all of the dot spot dummy variables.

	(1)	(2)	(3)	(4)
	Prob	*Prob*	*Prob*	*Prob*
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

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

Note: 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 subject level in parentheses.

Table G.3: Linear specification of the Dot Spot matrices.

	(1)	(2)	(3)	(4)
	Prob	*Prob*	*Prob*	*Prob*
MA	4.276***	4.278***	4.185***	
	(0.876)	(0.876)	(0.917)	
DF	1.866*	2.755***	3.192***	-0.957
	(1.019)	(1.035)	(1.108)	(1.202)
Dots	0.530***	0.530***	0.521***	0.525***
	(0.0148)	(0.0148)	(0.0156)	(0.0165)
Constant	-60.30***	-61.79***	-65.64***	-61.63***
	(3.146)	(10.74)	(11.10)	(11.24)
N	3750	3750	3480	2140
adj. R^2	0.414	0.417	0.420	0.434
Controls	No	Yes	Yes	Yes
Gender	No	No	Yes	Yes
BL included	Yes	Yes	Yes	No

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

Note: Replication of Table 5 using a linear specification for the number of dots (*Dots*). This variable takes the value of the dots shown in each matrix instead of the dummy variables used in the original specification. Robust standard errors clustered at the subject level in parentheses.

Table G.4: Difference in beliefs for informationally equivalent matrices.

	(1)	(2)	(3)
	BL - MA	*BL - DF*	*MA - DF*
Raven	0.211	0.914	0.292
	(0.367)	(0.587)	(0.486)
Overestimation	0.158	0.472	0.547**
	(0.168)	(0.341)	(0.225)
Overplacement	0.364	0.258	-0.129
	(0.281)	(0.346)	(0.290)
Overprecision	0.0321	0.0114	0.197
	(0.0875)	(0.119)	(0.119)
Risk aversion	-0.391	-0.535	-0.0666
	(0.317)	(0.355)	(0.235)
Loss aversion	-0.0280	-0.866*	-0.862
	(0.371)	(0.501)	(0.710)
Female	1.870	-1.781	-1.677
	(2.156)	(2.534)	(3.170)
Constant	-5.738	-9.531	6.411
	(13.13)	(19.59)	(16.62)
N	741	432	441
adj. R^2	-0.004	0.017	0.015
Session Fixed Effects	Yes	Yes	Yes

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

Note: The dependent variable is the difference between the reported beliefs for matrices with the same number of dots across treatments BL and MA in column (1), BL and DF in column (2), and MA and DF in column (3). Robust standard errors clustered at the subject level in parentheses.

Table G.5: Replication of Columns (3) and (4) from Table 5 using only the cases where the number of red dots ranges from 190 to 210.

	(1)	(2)
	Prob	*Prob*
MA	3.889***	
	(1.282)	
DF	3.427**	-0.650
	(1.453)	(1.400)
195.dots	4.156**	6.348***
	(2.000)	(2.295)
199.dots	4.298***	7.451***
	(1.553)	(2.129)
201.dots	13.43***	14.60***
	(2.025)	(2.053)
205.dots	12.03***	13.40***
	(1.812)	(2.119)
210.dots	15.66***	19.88***
	(1.917)	(2.089)
Constant	31.74**	36.92**
	(13.71)	(14.53)
N	2088	1284
adj. R^2	0.060	0.073
Personality Controls	Yes	Yes
Session Fixed Effects	Yes	Yes

Standard errors in parentheses

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

Note: Robust standard errors clustered at the subject level in parentheses.

H First Stage IV

Table H.1: First Stage Regressions for *Prob*.

	(1)	(2)	(3)
	Prob	*Prob*	*Prob*
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

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

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

I Alternative IV Specifications

I.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 I.1 and I.2 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.[34] 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 I.3 and I.4 show the second stage (eq. 6) using only MA or DF, respectively. 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 I.5 and I.6, respectively) are very similar to those of the pooled data (Table 8).

[34] 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).

Table I.1: First Stage Regressions for *Prob* using *BL* and *MA* data.

	(1)	(2)	(3)
	Prob	*Prob*	*Prob*
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

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

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

Table I.2: First Stage Regressions for *Prob* using *BL* and *DF* data.

	(1)	(2)	(3)
	Prob	*Prob*	*Prob*
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

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

Note: In all three columns the dummy for $Dots120$ is not included because of multicollinearity. Robust standard errors clustered at the subject level in parentheses.

Table I.3: Second Stage with Instruments for *Prob* using *BL* and *MA* data.

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

Note: Robust standard errors clustered at the subject level in parentheses.

Table I.4: Second Stage with Instruments for *Prob* using *BL* and *DF* data.

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

Note: Robust standard errors clustered at the subject level in parentheses.

Table I.5: Indirect (CACME) and Direct Treatment Effects (CADE) using *BL* and *MA* data.

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

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

Table I.6: Indirect (CACME) and Direct Treatment Effects (CADE) using *BL* and *DF* data.

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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

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

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

I.2 Incentivized Beliefs

In this section, we report the instrumental variable approach of Section 3.3 using only the data from sessions where beliefs were incentivized. In Table I.7 we run the first stage regression (eq. 5), in Table I.8 we run the second stage (eq. 6), and in Table I.9 we present the CACME and CADE results. Overall, the IV using only the incentivized data shows qualitatively identical results to using the non-incentivized results.

Table I.7: First Stage Regressions for *Prob*.

	(1)	(2)
	Prob	*Prob*
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

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

Note: Data include sessions with incentivized beliefs only . In all four columns, the dummy for $Dots120$ is not included because of multicollinearity. Robust standard errors clustered at the subject level in parentheses.

Table I.8: Second Stage with Instruments for Prob

	(1)	(2)
	Invest	*Invest*
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

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

Note: Data include sessions with incentivized beliefs only . Robust standard errors clustered at the subject level in parentheses.

Table I.9: Indirect (CACME) and Direct Treatment Effects (CADE)

	(1)	(2)
	Invest	*Invest*
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

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

Note: Data include sessions with incentivized beliefs only . Standard errors obtained from bootstrapping by resampling observations (with replacements) for 1,000 times. Bootstrap standard errors in parentheses.

I.3 Alternative Specifications

In this section, we check how robust the results of Table 7 are to alternative specifications. Table I.10 shows a linear regression of $Invest_{b,r}$ as dependent variable on $Prob_{b,r}$ and the two different treatments (MA and DF) separately along with all of the control variables used in column (3) of Table 7. The results of the regressions in Table I.10 are close to those of Table 7. That is, the effects of instrumented and non-instrumented beliefs on investments are very similar. Moreover, Table I.11 uses the data from the risk part of each treatment and regresses the investment of each investor b for a given risk. The results are again very similar to those of Table 7. Note, however, that the effect of exogenously given success probabilities (*given risk*) is significantly larger than the effect of subjective beliefs about success probabilities (*prob*). This may be due to the uncertainty about success probabilities in the ambiguous environment.

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, Tables I.12 and I.13 reproduce Tables I.10 and I.11, but using logistic models instead of linear regressions. Once again, the effect of given probabilities on investors' investment ("Given Risk" in Table I.12) is significantly larger than that of subjective probabilities ("Prob" in Table I.13).

Table I.10: Regressions for Investment on Stated Probability

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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)
Prob	0.976***	0.973***	0.977***
	(0.0239)	(0.0242)	(0.0266)
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

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

Note: Robust standard errors clustered at the investor level in parentheses.

Table I.11: Regressions for Investment on Given Probability

	(1)	(2)	(3)
	InvestR	*InvestR*	*InvestR*
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)
Given Risk	1.046***	1.046***	1.045***
	(0.0193)	(0.0193)	(0.0205)
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

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

Note: Robust standard errors clustered at the investor level in parentheses.

Table I.12: Logit regressions for Investment on Stated Probability

	(1)	(2)	(3)
	Invest	*Invest*	*Invest*
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)
Prob	0.0727***	0.0736***	0.0731***
	(0.00596)	(0.00619)	(0.00647)
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

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

Note: Robust standard errors clustered at the investor level in parentheses.

Table I.13: Logit regressions for Investment on Given Probability

	(1)	(2)	(3)
	InvestR	*InvestR*	*InvestR*
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)
Given Risk	0.0814***	0.0832***	0.0840***
	(0.00506)	(0.00529)	(0.00545)
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

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

Note: Robust standard errors clustered at the investor level in parentheses.

J Descriptive statistics for sessions with NM treatment only

Table J.1: Investments and Beliefs in sessions with NM treatment.

	Total	***120***	***185***	***190***	***195***	***199***	***201***	***205***	***210***	***215***	***280***
BL Invest	30.99	0.60	8.26	19.55	26.53	19.35	35.71	39.83	31.27	43.96	91.69
	(37.48)	(2.11)	(16.40)	(28.29)	(36.72)	(27.89)	(32.94)	(36.70)	(36.40)	(36.16)	(20.93)
BL Belief	46.72	8.50	26.48	41.67	42.90	43.32	52.17	53.40	52.30	62.50	89.13
	(30.12)	(10.68)	(20.54)	(24.84)	(29.26)	(22.15)	(26.84)	(25.40)	(23.02)	(21.75)	(15.77)
NM Invest	43.63	1.77	7.40	29.78	26.09	34.24	46.79	62.57	51.58	67.14	95.11
	(40.93)	(6.16)	(17.96)	(35.04)	(32.75)	(34.19)	(38.80)	(37.14)	(39.08)	(32.83)	(13.18)
NM Belief	49.01	10.00	19.75	38.30	38.75	42.48	51.31	64.42	56.88	64.16	92.49
	(30.77)	(10.22)	(19.16)	(22.95)	(21.28)	(22.15)	(24.65)	(25.29)	(26.47)	(21.15)	(9.80)
MA Invest	46.22	3.18	24.50	34.51	43.50	53.47	40.26	45.78	59.10	72.00	92.00
	(40.18)	(10.14)	(31.48)	(33.80)	(40.40)	(38.63)	(38.82)	(35.51)	(36.21)	(31.77)	(20.60)
MA Belief	51.25	11.96	33.72	41.77	44.66	53.92	52.47	53.23	61.46	72.16	92.42
	(29.90)	(11.89)	(22.33)	(21.59)	(27.33)	(25.79)	(26.29)	(24.20)	(22.71)	(19.3)	(9.36)

Note: Mean investments as a percentage share of the endowment and stated probabilities of success depending on the number of red dots. The column *Total* shows the aggregated average of all investments and stated beliefs in a treatment. Standard Deviations are shown in parentheses.

K 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 K.1). 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 K.1

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table K.1, 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 K.1 (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 K.1) and your amount to be invested equals 40% $\times$ 8 euro = 3.20 euro.
- If the computer randomly chooses *decision situation 9* for the payoff, the investment will be successful with a probability of 80% (see Table K.1) and your amount to be invested equals 70% $\times$ 8 euro = 5.60 euro.

In each situation you use a scroll bar to state the percentage of the endowment of 8 euro you want to invest, if this situation is paid off. As soon as you have made your eleven decisions, please click on "confirm entry". As long as you did not confirm your entries, you can change the 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 $\times$ 8 euro. Remember: In the end exactly one of the eleven rounds from both parts of block 1 is randomly chosen for your payoff.

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

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

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

By using the scroll bar you state which percentage share of your 8 euro you want to invest. Moreover, in each round of part 2 you will be asked 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 K.2). 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 K.2

In each of the 11 situations, you will be given a success **probability** of the investment. As you can see in Table K.2, this **success probability** increases from 0% (in decision situation 1) to 100% (in decision situation 11) in increments of 10 percentage points.

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

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

Specific instructions for Block 2 Part 2

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

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

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

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

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

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

Summary of Block 2

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

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

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

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

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

General Instructions for Block 3

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

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

For all type A the following holds:

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

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

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

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

Example:

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

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

For all type B the following holds:

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

For all type A and B the following holds:

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

Specific instructions for Block 3 Part 1

As in both previous blocks, part 1 again consists of **one round with 11 decision situations**, summarized in a table (see Table K.3). 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 K.3, 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 K.3

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 K.1. 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.

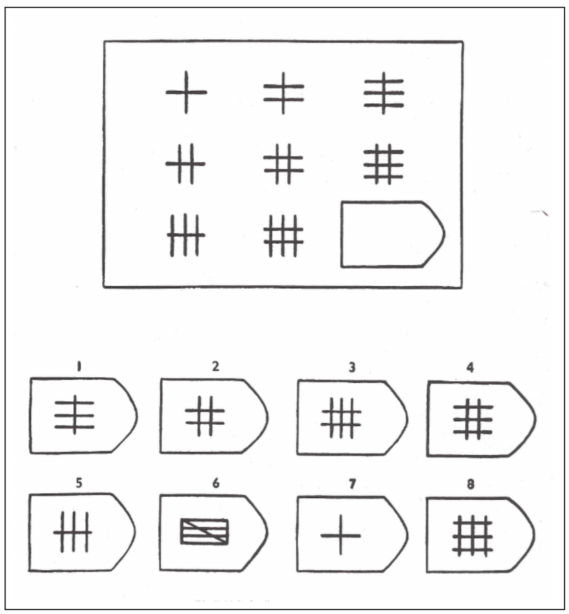


Figure K.1

You **choose the element** using a **drop-down list** (see Figure K.2). 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"

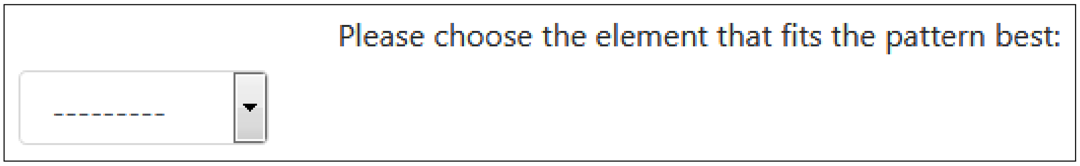


Figure K.2

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 K.4** and **Table K.5**, 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 K.4:

In the **lotteries** of Table K.4 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 K.4, **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 K.4): 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 K.4. 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 K.5:

In the **lotteries** of Table K.5 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 K.5, **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 K.5): 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 K.5. 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 K.4

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 K.5

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