ESSAYS ON IRRELEVANT AND IGNORED INFORMATION

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ZUSAMMENFASSUNG

Diese Dissertation besteht aus drei unabhängigen Abhandlungen über Verhaltensforschung und experimentelle Ökonomie. Der erste Aufsatz untersucht, warum Menschen Informationen über die Konsequenzen ihres Handelns für andere vermeiden, indem er theoretische Vorhersagen über die Hauptmotive der Informationsvermeidung miteinander vergleicht und Experimente zu deren Unterscheidung konzipiert. Der zweite Aufsatz stellt Ergebnisse eines Experiments vor, in dem untersucht wird, ob die Möglichkeit, über eigene Gewinne nichts zu wissen, altruistisches Verhalten fördern kann. Der dritte Aufsatz löst und testet experimentell ein globales Spiel-Modell spekulativer Angriffe, bei dem die Agenten wählen können, ob siekostenpflichtig eine auszahlungsirrelevante Ankündigung ("Sonnenfleck") lesen möchten.

Schlüsselwörter: Informationsvermeidung, moralischer Spielraum, Sonnenflecken, globale Spiele, Experimente

ABSTRACT

This thesis consists of three self-contained essays on behavioral and experimental economics. The first essay investigates why people avoid information regarding the consequences of their actions on others by comparing theoretical predictions of the main motives behind information avoidance and designing experiments to distinguish them. The second essay presents the results of an experiment which examines whether the chance of remaining ignorant about own payoffs can promote altruistic behavior. The third essay solves and tests experimentally a global-games model of speculative attacks where agents can choose whether to read, at a cost, a payoff-irrelevant (sunspot) announcement.

Keywords: information avoidance, moral wiggle room, sunspots, global games, experiments

Baraye madaram, Pari.

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The work of this thesis is based on the following publications:

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Preprint. Can be found in chapter 1 of this dissertation.

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Preprint. Can be found in chapter 3 of this dissertation.

AUTHOR'S CONTRIBUTION TO THE PUBLICATIONS

Contribution to the papers in this thesis are:

1. Defining the research problem, motivating the problem, defining the methodology, conducting the literature review, designing the experiment, coding the experiment, performing experiments, analyzing data, writing the results, co-writing the paper.
2. Single-author paper.
3. Defining the research problem, defining the methodology, developing the model, solving the equilibrium, simulating the equilibrium solution for comparative statics, designing the experiment, coding the experiment, performing experiments, analyzing data, writing the results, co-writing the paper.

INTRODUCTION

Consistent with the standard theory, there are countless situations in which information is sought after and is relevant. The focus in this dissertation is, however, on the opposite phenomena – on situations in which information is either (1) undesirable (information avoidance) or (2) irrelevant (sunspots). To investigate these situations, this dissertation uses methods from behavioral and experimental economics.

The first line of research deals specifically with information avoidance. People often avoid information about the consequences of their actions, even when it is free and could improve decision-making. Information avoidance is widespread and leads to reduced responsibility in settings such as corruption (Dana, 2006; Simon, 2005), spread of disease (Sullivan, Lansky, & Drake, 2004), environmental pollution (Rayner, 2012), and even atrocities (Cohen, 2001). For instance, in corporate scandals, ranging from Bernie Madoff's Ponzi scheme to corruption at FIFA (the international governing body of soccer), it is difficult to imagine how so many people could have failed to notice the unethical behavior (Bazerman & Sezer, 2016). However, despite the recent growing theoretical and experimental literature on information avoidance (Gino et al., 2016; Golman, Hagmann, & Loewenstein, 2017), we know very little about the motives behind information avoidance.

Two chapters stem from my research on information avoidance. The first chapter, which is a joint work with Alexander Nesterov, investigates why people avoid information. People frequently avoid information about the consequences of their actions and behave selfishly. Dana, Weber, and Kuang (2007) study an experimental situation in which a "dictator" facing the option to lower her own payoff is initially uncertain about whether that sacrifice will help or hurt the recipient but can click a button to reveal this information. Many dictators will avoid this costless information, and as a result, significantly fewer dictators take the simple steps necessary to guarantee a fair outcome than do in a baseline dictator game with full information. Most of the literature presumes that information avoidance here is conscious, and terms it *willful ignorance* or *strategic ignorance* (Bartling, Engl, & Weber, 2014; Gino et al., 2016; Grossman, 2014; Grossman & van der Weele, 2017; Kajackaite, 2015; Fong & Oberholzer-Gee, 2011). In this chapter, we test this presumption. If information avoidance is strategic then the revelation decision can be affected by the payoff-relevant changes in the environment, but should not be affected by the payoff-irrelevant changes. The first experimental change we make is a payoff-irrelevant change of the timeline of decision-making. In the original setting of Dana, Weber, and Kuang (2007) and all of its replications, the dictator learns the payoff-maximizing option *before* he faces the revelation choice. In contrast to this timeline, in our setting the dictator initially does not know which option will give him the higher payoff, and he learns this only *after* he has made the revelation choice. If information avoidance is strategic then this delay in learning which of the two options gives the higher payoff should not make any significant difference between treatments. Our first result indicates that voluntary revelation leads to a significant increase in selfish choices only in the before treatment. In the next experiment we implement a payoff-relevant change. In the original setting of Dana, Weber, and Kuang (2007), the probability of hurting the recipient by choosing the higher payoff is 50%. We change this probability to

1%, 25%, and 99% and find that the rate of information avoidance does not significantly change. In sum, we see that the payoff-relevant change does not affect the revelation decision, while the payoff-irrelevant change does. These findings are inconsistent with the presumption that information avoidance is strategic and support the anchoring explanation behind information avoidance. Instead of strategically protecting the self-image, the subjects might be myopically reacting to the information that grabs their attention.

The second chapter investigates whether people avoid information selflessly. Despite the recent growing literature on the adverse impact of information avoidance (for a literature review see Gino et al. 2016; Golman, Hagmann, & Loewenstein 2017), can information avoidance help us make more altruistic choices? For example, after learning about a product with positive externalities, a consumer may avoid learning how much it costs so that she does not hesitate to act altruistically. I manipulate the original setting of Dana, Weber, and Kuang (2007) such that a "dictator" facing the option to help the recipient is initially uncertain as to whether that option will lower or raise her own payoff but can click a button to reveal this information. I find that although about one-third of dictators avoid information about their own payoffs, the overall rate of altruistic choices does not significantly change compared to a baseline dictator game with full information. But this result could be driven since dictators dislike too much uncertainty about their own payoffs. In the next experiment, I change the underlying uncertainty. In our game, the probability of lowering own payoff by helping the recipient is 50%. I change this probability to 99%, in which a dictator knows that lowering her own payoff will almost surely help the recipient. I find that the rate of altruistic choices does not change significantly as the level of uncertainty decreases. These results suggest that although a few people may let go of learning the costs and choose the environmentally friendly options, the overall rate of environmentally friendly consumption choices does not change, regardless of whether there is an upfront concealment about costs or not.

Not only are there situations in which information is undesirable, but there are also situations in which information is irrelevant. For example, at least 90 percent of foreign exchange dealers rely on technical analysis that is without regard to any relevant underlying economic or fundamental analysis (Lui & Mole, 1998; Oberlechner, 2001; Taylor & Allen, 1992). Creditors facing a coordination problem when a borrower is in distress may be tempted to follow signals that provide no information about the fundamentals affecting payoffs ("sunspots"), fearing similar actions by others. Although in a global game with public sunspots, sunspots matter, in a global game in which intrinsic private signals guarantee equilibrium uniqueness, sunspots do not matter (Heinemann & Illing, 2002). The existence of sunspot equilibria only in the public signals of global games raises the question of whether real agents would actually coordinate on following sunspots and under which conditions they might do so.

The third and last chapter of the dissertation, which is a joint work with Frank Heinemann, tests whether extrinsic signals can also affect behavior if these signals are not public and if the underlying game has a unique equilibrium. To achieve this goal, we use an augmented global game, where players have the option to purchase a payoff-irrelevant public signal, that is, a sunspot, before they decide whether to invest in the project. We introduce a grain of doubt about the rationality assumption defining Nash equilibria by assuming that each agent behaves as if he or she expects that some of the other agents are naïve followers, who always choose to buy the sunspot message and follow the action it indicates. Our model predicts that (1) agents follow sunspots for some range of intrinsic signals, (2) the set of signals for which subjects follow sunspot messages increases as their private signals become noisier, and (3) agents expect more players to follow sunspots than actually do follow them.

To test our predictions, we use an experiment similar to Heinemann et al., (2004), where subjects can decide between two options (A or B) and where the payoff from B depends positively on whether the number of other subjects who choose B exceeds an exogenously given hurdle. Subjects receive either a public or private signals about the hurdle for success. After receiving their signals, subjects can individually decide whether to read a costly sunspot message that says either “Choose A” or “Choose B.” This message is the same for all agents who read it: it is randomly drawn with 50% probability for each of the two texts, and subjects are informed about the random nature of these messages. Although most groups converge to classical global-game strategies that neglect sunspots, we find that about one-third of groups eventually coordinate on sunspots, which is inconsistent with the standard theory. Elicited beliefs reveal that subjects overestimate the number of subjects who follow sunspots by about 100% on average. This is in line with the assumptions of our extended global game and presumably drives subjects to follow sunspots. From our theoretical analysis and the experiment we conclude that in environments with high strategic uncertainty, payoff-irrelevant signals can affect behavior even if they are costly to obtain and not expected to be publicly observed.

CHAPTER 1. INFORMATION AVOIDANCE IS NOT STRATEGIC

with Alexander Nesterov

1.1 Introduction

Imagine that you enter a clothing store to buy a shirt. Hesitating between two seemingly identical shirts of different brands, you may simply select the cheapest one. Then, while standing in the line for the cashier, you start pondering about what would cause this price difference. Could it be that the technology is not environmentally friendly? Maybe workers have poor working conditions or, perhaps, maybe they even use child labor? Each of these issues is important to you and may affect your choice. You could reach for your phone and figure out if any of them are true, but at the same time, you feel reluctant to do so, although the answer is only a few seconds away. You pay for your shirt and leave the store.

So why exactly were you reluctant to reveal the truth? In this paper we study motives behind *information avoidance* — the tendency to avoid information that otherwise would be essential for payoff-relevant decisions. Information avoidance is widespread and leads to reduced responsibility in settings such as corruption (Dana, 2006; Simon, 2005), spread of disease (Sullivan et al., 2004), environmental pollution (Rayner, 2012), and even atrocities (Cohen, 2001). For instance, in corporate scandals, ranging from Bernie Madoff's Ponzi scheme to corruption at FIFA (the international governing body of soccer), it is difficult to imagine how so many people could have failed to notice the unethical behavior (Bazerman & Sezer, 2016).

Figure 1-1 Payoff tables for Full information and Hidden information

Full information

		Dictator	Recipient
Dictator's choice	A	6	1
	B	5	5

Hidden information

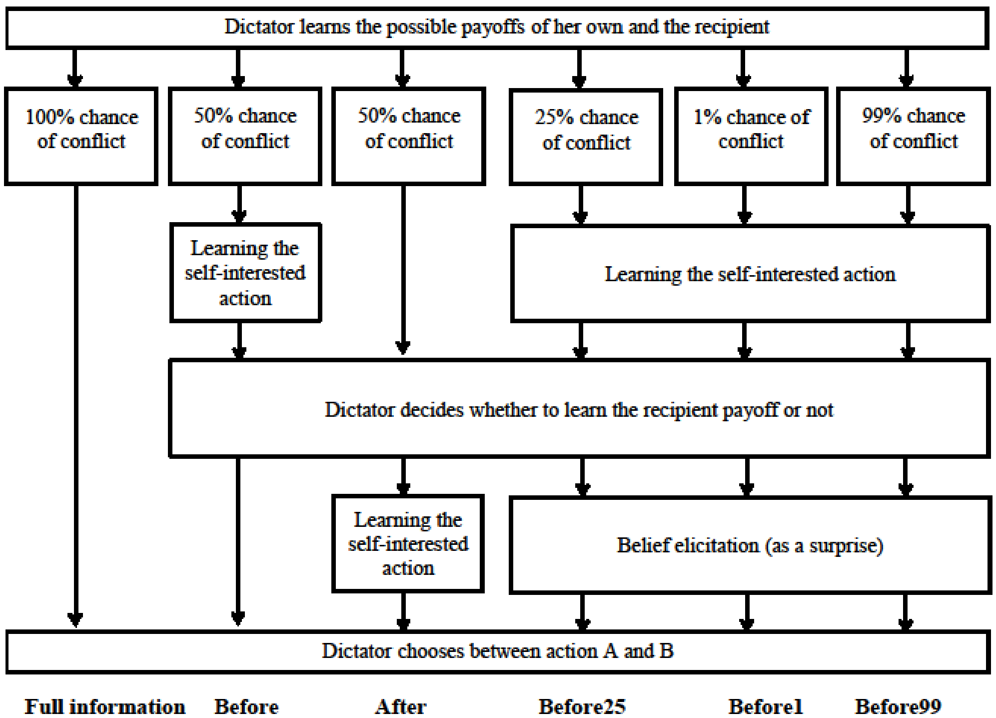
		Dictator	Recipient
Dictator's choice	A	6	1 or 5
	B	5	5 1

Notes. In the Full information treatment the dictator knows his payoffs and the recipient's payoffs. In the Hidden information treatment the dictator initially knows his own payoffs and does not know the recipient's payoffs; the probability that the payoffs are in conflict is 50%.

The standard tool to study information avoidance in the lab is the seminal experiment in Dana, Weber, & Kuang (2007) (hereafter, DWK). The experiment is based on a binary dictator game and has two treatments: Full information treatment and Hidden information treatment presented in Figure 1-1. In each treatment the dictator chooses between option A that gives him \$6 and option B that gives him \$5. The payoffs of the recipient differ between the two treatments. In the Full information treatment the payoffs of the recipient are in conflict with the payoffs of the dictator: the recipient gets only \$1 for A and \$5 for B. Thus, option A gives (6,1) and appears to be selfish, while option B gives (5,5) and is rather altruistic. In the Hidden information treatment the payoffs of the recipient are initially unknown, but it is common knowledge that they can be either conflicting as before or aligned: the payoffs are swapped such that option A gives (6,5) and option B gives (5,1). Conflicting and aligned payoffs are equally likely. Crucially, the dictator can choose to reveal this hidden information at no cost and only then choose option A or B.

The dictators behave strikingly differently in these two treatments: the share of selfish choices in the Hidden information treatment is almost twice as high as in the Full information treatment. This change is attributed to information avoidance: around half of the dictators choose not to reveal the truth and select option *A*, which gives them a higher payoff.

Figure 1-2 Overview of the Experimental Treatments



Notes. The Full information treatment is the binary dictator game, all other treatments are versions of the Hidden information treatment where we vary timing (Before vs. After) or probability of conflicting payoffs (Before vs. Before25, Before1, Before99). The dictator may reveal the true case at zero cost or proceed without revealing.

In the words of our example above, where options *A* and *B* are the two shirts, in both treatments you know that *A* is cheaper. You also know that one of these two shirts imposes a negative externality on others. If you knew that the shirt that does so is *A*, as in the Full information treatment, you would probably choose B. However, if you do not know which of the two shirts it is, then you may avoid learning the truth and you go for A.

Why exactly did the dictators avoid the truth? Following DWK most of the literature presumes that the information avoidance here is conscious, and terms it as *willful ignorance* or *strategic ignorance* (Bartling, Engl, & Weber, 2014; Gino et al., 2016; Grossman, 2014; Grossman & van der Weele, 2017; Kajackaite, 2015; Fong & Oberholzer-Gee, 2011). In this paper we want to test this presumption relying on the following argument. If information avoidance is strategic, then the revelation decision can be affected by the payoff-relevant changes in the environment, but should not be affected by the payoff-irrelevant changes. In our experiments we implement both these changes and see that the payoff-relevant change does not affect the revelation decision, while the payoff-irrelevant change does.

The first experimental change we make is a payoff-irrelevant change of the timeline (see Figure 1-2 for an overview of all our treatments). In the original setting of DWK and all of its replications, the dictator learns that A gives him the higher payoff *before* he faces the revelation choice (we refer to this setting as to the Before treatment). In contrast to this timeline, in our setting the dictator initially does not know whether A or B will give him the higher payoff, and he learns this only *after* he has made the revelation choice (the After treatment). If information avoidance is strategic then this delay in learning which of the two options gives the higher payoff should not make any significant difference to the Before and After treatments.

Our first result indicates that voluntary revelation leads to a significant increase in selfish choices *only* in the Before treatment. In the Before treatment dictators avoid the information in over 34% of cases and choose the selfish option in over 58% of cases, almost double the rates in the After treatment: 16% of information avoidance choice and 34% of selfish choices. The latter 34% of selfish choices in the After treatment do not significantly differ from 29% in the dictator game with complete information (the full information treatment).

Continuing our example, if you do not yet know the prices of the two shirts, then you are more likely to reveal the truth, for example, by reading a news article about the working conditions of various brands. And once you learn the information, you might be trapped: when you see that the cheaper shirt A causes negative externality then you cannot ignore this information anymore, and you opt for B. While if you knew the prices first then you might have simply decided not to read the same news article.

Our first result is inconsistent with the presumption that information avoidance is strategic. Varying the timeline of revelation should not matter for a strategic decision-maker. Two particular motives that are likely to ignore such a change in timing are the self-image motive and the default effect motive. The self-image motive is a person's desire, not necessarily to be altruistic, but to appear as such – both in the eyes of others and for themselves (Broberg, Ellingsen, & Johannesson, 2007; Dana, Cain, & Dawes, 2006; Dana et al., 2007; Grossman & van der Weele, 2017; Lazear, Malmendier, & Weber, 2012). People also avoid information since there is a psychological cost associated with changing the default of not receiving information (Grossman, 2014). In our experiment, the payoff-relevant information and the strategy set in both the Before treatment and the After treatment are the same: the dictator is initially aware of a 50% chance that the payoffs are in conflict and can remain ignorant about the recipient's payoff in both treatments. Therefore, in each treatment, the dictator can protect her self-image by avoiding the information. Similarly, in each treatment the default option is to avoid the information, and therefore the default effect motive has the same prediction for both.

However, the first result is consistent with a non-strategic motive behind information avoidance: anchoring.[1] This explanation suggests that the dictator gives a higher weight to the details that he sees relative to the details that are hidden. This makes the dictators more selfish in the Before treatment where the recipient's payoffs are initially hidden compared to the Full information treatment where both payoffs are shown. Similarly, in the After treatment both payoffs are initially hidden and thus receive the same weight. Hence, anchoring predicts a smaller share of information avoidance and selfish choices in the After treatment than in the Before treatment, it also predicts the same share of selfish choices in the After treatment and in the Full information treatment. Both predictions are consistent with our results.

The second experimental change is the change of the probability that payoffs are in conflict in the Before treatment. The probability that the payoffs are in conflict takes four

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[1] In the previous version of this paper we also considered another motive that is independent of the timing variation, wishful thinking, which eventually did not find support in the experimental data (Moradi & Nesterov, 2018).

values: 1% in the Before1 treatment, 25% in the Before25 treatment, 50% in the standard Before treatment, 99% in the Before99 treatment.

As the probability of conflict changes, the expected costs and benefits of revelation may change as well, and different motives behind information avoidance have different predictions. If the default costs cause information avoidance, then as the probability increases from 0 to 50% the expected value of the information increases as the uncertainty about the state increases, while the default costs remain fixed. Similarly, as the probability increases from 50% to 100%, the expected value of the information decreases as certainty increases.[2] Hence, the default cost motive predicts that dependence between information avoidance and the probability is U-shaped. In other words, information avoidance is correlated with certainty: the more the dictator is certain about the state, the less he needs the information. We should expect the lowest degree of information avoidance in the Before treatment, and the highest – either in the Before1 treatment or in the Before99 treatment.

If the image concerns cause information avoidance, then the role of the probability is more ambiguous and depends on the choice of the model. Feiler (2014) proposes a simple model predicting that as p increases from 0 to 100%, information avoidance increases. This result is based on an implicit assumption that when the dictator does not reveal, he does not incur image costs. At the same time, if the dictator reveals and discovers

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[2] This implies that some subjects will choose option B without revealing. In the Before99 treatment 5 out of 66 subjects follow this strategy, but this is not significantly higher than 2 out of 77 in the Before1 treatment and 3 out of 88 in the Before treatment.

conflicting payoffs he incurs image costs from choosing the selfish option A or enjoys the image benefits from choosing the fair option B. Alternatively, if he discovers aligned payoffs, he receives a mild benefit from choosing the dominating option A. As the probability increases, the expected costs of revelation become higher as conflict grows more likely, while non-revealing always gives a safe option with fixed utility. Hence, we should expect the lowest degree of information avoidance in the Before1 treatment, and the highest – in the Before99 treatment.

Grossman & van der Weele (2017) and its earlier version, van der Weele (2012) propose a self-signaling model of information avoidance where the role of the probability is ambiguous. On the one hand, as the probability increases, the "guilt" from avoiding information increases as ignorance sends a worse signal about one's level of altruism. (This is different from the assumption of no image costs from non-revealing in Feiler, 2014) On the other hand, as the probability increases, the information becomes less desirable as it more likely contains the "altruistic" news (same as in Feiler 2014). In van der Weele (2012) the second effect dominates the first and the prediction is the same: there is more information avoidance when conflict is more likely.[3]

Feiler (2014) finds evidence contrary to this prediction: when subjects are given a series of DWK games with varying probabilities, information avoidance increases as the probability decreases. That is, people seem to avoid information more when this is less likely to hurt the recipient. However, Grossman & van der Weele (2017) argue that the

[3] A more general model of Grossman & van der Weele (2017) does not have this prediction.

within-subjects environment of Feiler (2014) with multiple periods deviates from the environment of the self-image model. In the between-subjects design, van der Weele (2012) finds no significant difference when the probability from the original 50% increases to 80%.[4]

We find that as the probability of conflict changes, the rate of information avoidance does not significantly change. For all probabilities of conflicting payoffs of 1%, 25%, 50%, and 99%, the rate of information avoidance does not differ significantly from approximately one-third (34%, 25%, 34%, and 38%, respectively).

These findings do not support the default costs explanation and the self-image explanation. As we dramatically change the level of uncertainty (the probability increases from 1% to 50% and decreases from 99% to 50%), the stakes of ignoring or revealing the information should also dramatically increase, leading to a significant difference between the treatments. However, we cannot formally reject that the default costs explain information avoidance as we only find a null result. Similarly, the self-image explanation as in the model of Feiler (2014) and van der Weele (2012) is not supported but is also not rejected formally. We do not find that information avoidance significantly increases with the probability, but we also do not find a significant decrease as Feiler (2014) did.

The anchoring explanation is consistent with our evidence: given the same framing, subjects seem to pay little attention to the expected costs and benefits of ignorance.

[4] In our reduced model the self-image motive predicts the same rate of information avoidance for all probabilities: the costs and the benefits of information avoidance are linear in probability, and thus they cancel out.

Together with our first experimental finding, this supports the anchoring explanation behind information avoidance. Instead of strategically protecting the self-image, the subjects might be myopically reacting to the information that grabs their attention. Put more mildly, even if self-image concerns play a role in information avoidance, they are non-robust and can be neutralized by making the situation more complex.

The paper is structured as follows. The next section presents the experimental design and procedures. Section 3 provides a theoretical framework with testable predictions for each motive to guide our understanding of information avoidance. Section 4 presents the experimental results, and section 5 concludes.

1.2 Experiment

1.2.1 Design

The experiment has six treatments, displayed in Figure 1-2. The first two treatments exactly replicate the DWK experiment, while four additional treatments feature variations of the timeline and the underlying probability. The After treatment tests the robustness of DWK's information avoidance result when dictators do not know their self-interested option by varying the decision-making timeline in the Before treatment. The Before1, Before25, and Before99 treatments are designed to further compare the predictions of the different motives for information avoidance by changing the underlying probability of conflicting payoffs.

1. *Full information.* This treatment is an exact replication of the DWK's baseline treatment. The payoffs, as shown to the participants, are presented in Fig.0. Dictators choose between A and B by clicking on two of the letters. If the dictator (Player X) chooses option A, she receives 6 and the receiver (Player Y) receives 1. If the dictator chooses option B, both players receive 5. In the Full information treatment, the relationship between options and outcomes is transparent. While the dictators were making their choices, recipients were asked to make the same decision hypothetically, as if they were a dictator.

Figure 1-3 Before treatment payoff table

Player X's choices

A	X:6	Y:?
B	X:5	Y:?

Left

A	X:6	Y:1
B	X:5	Y:5

Right

A	X:6	Y:5
B	X:5	Y:1

Notes. The Before treatment is a replication of DWK's Hidden information treatment: the dictator initially knows his own payoffs and does not know the recipient's payoffs; the probability that the payoffs are in conflict is $p = 50\%$. *The dictator may reveal the true case at zero cost or proceed without revealing.*

2. *Before.* This treatment replicated the "hidden information" treatment of DWK. Participants were presented with two versions of the game as displayed in Figure 1-3. In both games, if the dictator chose A, she would receive her highest payoff and if she chose B, she would receive a lower payoff, thus option A is her self-interested option. The recipient's payoffs from these options were uncertain. In game "Left" (with conflicting payoffs as in the Full information treatment), the recipient would receive his lowest payoff if the dictator chose option A, and a smaller amount if the dictator chose B. In the

game “Right” (with nonconflicting payoffs), the recipient would get the opposite payoffs. Participants were told that the actual game they were playing was randomly selected with equal probability. The dictator could reveal which game was being played by clicking a “Reveal” button, which did not entail any costs. Participants were informed that the dictator’s revelation decision would not be disclosed to the recipient. In the Before treatment, the dictator is presented with her self-interested option, option A, *before* she is presented with the choice of learning of the recipient’s actual payoff.

Figure 1-4 After treatment payoff table

Player X’s choices		
A	X:6	Y:?
B	X:5	Y:?

Top Left

A	X:6	Y:1
B	X:5	Y:5

Top Right

A	X:6	Y:5
B	X:5	Y:1

Bottom Left

A	X:5	Y:1
B	X:6	Y:5

Bottom Right

A	X:5	Y:5
B	X:6	Y:1

Notes. In the After treatment the dictator initially does not know his payoffs and the recipient’s payoffs, i.e., which of the four games is played. All four games are equally likely, the probability that the payoffs are in conflict is $p = 50\%$*. The dictator may reveal the recipient’s payoffs (i.e., whether the game is Left or Right) at zero cost or proceed without revealing. The dictator is then shown his payoffs (i.e., whether the game is Top or Bottom).*

3. *After.* This treatment differed from the Before treatment in that the order of observing the self-interested option and the information choice was reversed. The participants were presented with four versions of the game as displayed in Figure 1-4. Two games, called top games, are identical to the games in the Before treatment. In the top games, the self-interested option is option A. The other two games, called bottom games, only differ from the top games in that the self-interested option is B. Participants were told that the actual

game they were playing had been randomly selected from the four games with equal probability. Whether the game would be in the left or right column (i.e., what the recipient's payoff is) was never revealed publicly. But the dictator could either reveal this by clicking a "Reveal" button or could decide not to reveal it by clicking "Continue." In the After treatment, dictators needed to click on a "Continue" button to choose information avoidance whereas in the Before treatment they did not need to click any button. This maintained the possibility of subjects not knowing their self-interested option at the time of the information choice. Grossman (2014) found that such deviation does not produce significantly different results along several key measures.

Figure 1-5 Example of information shown to dictators based on revelation choice.

(Revealed)

A	X:6	Y:1
B	X:5	Y:5

(Not revealed)

A	X:6	
B	X:5	

To be certain participants fully understood that the "Reveal" button depicted both players' payoffs and that the "Continue" button only showed the own payoff, in a quiz before the start of the experiment questions about these two buttons were included. After the dictator makes her revelation decision (and independent of her choice), she knows whether she is playing a game at the top or the bottom row i.e., she knows her own payoff from each option. Conditional on the revelation choice, participants observed the same payoff matrix in both treatments, as shown in the example in Figure 1-5. In the After treatment, the dictator is presented with information regarding the self-interested option only *after* she has been presented with the information choice.

4. *Before25*. This treatment differed from the Before treatment in that the probability of the game (with conflicting payoffs as in the Full information treatment) being played was 25% instead of 50%. After participants made the revelation choice, they were asked to state their beliefs incentivized by the binary scoring rule on three matters to earn 1 euro for each: (1) the likelihood of their actual game being the conflict game, (2) the likelihood of another dictator's game being the conflict game, (3) and the likelihood of another dictator choosing to reveal and choosing option B (the altruistic option).

5. *Before1*. This treatment differed from the Before25 only in that the probability of conflicting payoffs was 1%.

6. *Before99*. This treatment differed from the Before25 only in that the probability of conflicting payoffs was 99%.

We did not elicit participants' beliefs in earlier treatments in order to keep the design as close as possible to the moral wiggle room design of DWK. In Before25, Before1, and Before99 treatments, however, we were only interested in information avoidance choices and these choices were not affected by belief elicitation.

The extreme probabilities in the Before99 and Before1 almost eradicate the uncertainty in the Before treatment while still keeping the possibility of information avoidance. While other studies have looked at some more intermediate levels (van der Weele, 2012, and Feiler, 2014, look at an 80% probability of conflicting payoffs), the extreme probabilities allow us to have a pure test of the impact of the level of uncertainty on information avoidance.

1.2.2 Procedures

The experiment took place at the Experimental Laboratory at the Technical University of Berlin from July 2016 to August 2017. Randomization across the three treatments occurred at the participant level using ORSEE (Online Recruitment System for Economic Experiments; Greiner, 2015), which excludes those who had previously participated in an experiment related to charitable giving. The sessions were one-shot, between-subjects, gender balanced, with at least 16 participants present. Most of the participants were undergraduate and master's students from the Technical University of Berlin. The interface was programmed using the z-Tree software package (Fischbacher, 2007). Experimental instructions are provided in the Appendix.

Participants were instructed that they would be playing a game with another person in the room with whom they had been randomly and anonymously matched. Upon arriving at the experiment, participants sat at computer terminals, and the instructions were read aloud. After participants had been told which role they had been assigned, they were allowed to make a (for the recipients, hypothetical) choice. Unless otherwise noted, the screen progression and layout reproduced the DWK interface as faithfully as possible. The text of the general instructions was reproduced almost verbatim, as were the treatment-specific instructions in the replication treatments.

Participants completed a brief quiz to make sure they understood the instructions. The quiz was administered just before the start of the experiment, so participants were unlikely to forget. The answers were read aloud; the participants were then asked whether they had any doubts or questions.

We conducted 33 sessions. A total of 736 students participated across the five treatments with exactly half (368) playing the role of a dictator (Player X). On average, participants earned 10.70 euro, including a 5 euro show-up fee and incentive payment for the belief elicitation. Sessions lasted approximately 20 minutes.

1.3 Theory

Now we present our theoretical framework and predictions. We are interested in the behavior of the dictator in a binary dictator game with incomplete information and voluntary revelation. We sketch a decision-making model that incorporates three motives for information avoidance: *self-image, anchoring*, and *default effect*. In such settings the dictator might care about the signal she is sending via his action about his type (both to himself and to the observer): whether his action makes him look like a "selfish" type or rather like a "good" type (self-image motive). If the dictator gets to see his payoffs first, she might be conditioned to pay more attention to her payoffs than to the receiver's payoffs (anchoring motive). In addition, by default the payoffs of the recipient are hidden and choosing otherwise is associated with a cost of changing the default (default effect motive).

We find the equilibrium behavior in the three settings: the Full information setting (Proposition 1), the Before setting (Proposition 2), and the After setting (Proposition 3).

Then we present the model predictions regarding the behavior of subjects in our experiments.

1.3.1 Model

The dictator is endowed with the level of altruism, β, that is distributed according to cumulative density $F(\beta)$ on $[0,1]$. The distribution of types is commonly information and has a probability mass of zero, $F(\beta = 0) = \varepsilon$. We call these dictators with $\beta = 0$ as "selfish" types, while those dictators with $\beta > 0$ is referred to as to "altruistic" type. To keep the model linear we assume a uniform distribution for "altruistic" types $\beta > 0$, $F(\beta) = \varepsilon + (1 - \varepsilon)\beta$.

The dictator faces a choice between two payoff-relevant options, A and B, that determine his payoff and the payoff of the recipient. Before making the decision, the dictator will know his own payoffs for each of the two options $X_A = \overline{X}$ and $X_B = \underline{X}$ ($\Delta X \equiv \overline{X} - \underline{X} > 0$).[5] The dictator does not know the payoffs of the recipient Y_A, Y_B, but only knows the possible values that these payoffs can take: $Y_A \in \{\underline{Y}, \overline{Y}\}$ and $Y_B = \{\underline{Y}, \overline{Y}\} \backslash Y_Y$, ($\Delta Y \equiv \overline{Y} - \underline{Y} > 0$). There are two possible states of the world: the payoffs X and Y are either conflicting $Y_A = \underline{Y}$ (and thus $Y_B = \overline{Y}$) or nonconflicting $Y_A = \overline{Y}$ (and thus $Y_B = \underline{Y}$). We

[5] In the model we always assume that option A gives the dictator the highest payoff, although in the After setting the dictator does not know in advance. This is without loss of generality since options A and B are ex-ante symmetric.

denote this by the variable $conflict \in \{0,1\}$. The probability of conflicting payoffs is $\Pr(conflict = 1) = p, p \in [0,1]$.

Before choosing between A and B the dictator chooses whether to reveal the recipient's payoffs or not, we denote this revelation action by variable $r \in \{0,1\}$, where $r = 1$ means that the dictator reveals and $r = 0$ means that he remains ignorant.

The timing of the Before setting is as follows (see also Figure 1-8).

1. Dictator learns his type β and the setting $\{\underline{X}, \overline{X}\}, \{\underline{Y}, \overline{Y}\}, p$; Nature chooses $conflict \in \{0,1\}$ based on prior p.
2. Dictator learns $X_A \in \{\underline{X}, \overline{X}\}$.
3. Dictator decides whether to reveal $r \in \{0,1\}$ and in the latter case learns Y_A.
4. Dictator chooses action $a \in \{A, B\}$ and receives his payoff.

The timing for the Full information setting and the After setting is different. In the Full information setting $p = 1$ and $reveal \equiv 1$ (payoffs are always conflicting and there is no hidden information) and thus stages 2 and 3 take place simultaneously.[6] In the After setting the timing is the same as in the Before setting but stages 2 and 3 are swapped: first the dictator decides whether to reveal or not to reveal, and then he learns his own payoffs X_A and X_B.

[6] As there is no revelation decision in the Full information setting, there is no default effect. Similarly, as both payoffs are shown at the same time, there is no anchoring.

For each setting we make a technical assumption that in equilibrium there is at least one type $\beta > 0$ that chooses the selfish option A and at least one type $\beta > 0$ that chooses a prosocial option B. This assumption allows us to focus only on the interesting case where the strategy is not trivial.

1.3.1.1 Full information setting

The dictator's utility from taking action a is a sum of his payoff and the recipient's payoff weighted by β:

$$U(\beta|a) = X_a + \beta Y_a - c_a,$$

where the costs to self-image c_a when choosing action a is proportional to the likelihood that a "selfish" type will choose the same action a and proportional to the likelihood that a "altruistic" type will choose a different action $a' \neq a$.

More formally, $c_a = s\Pr(\text{"selfish" plays } a)\Pr(\text{"altruistic" plays not } a)$, where $s \in [0, \Delta X]$ is the highest possible self-image cost and is the same for each type,[7] the term $\Pr(\text{"selfish" plays } a) = \Pr(\beta = 0)\Pr(a|\beta = 0)$ is the probability that a dictator has type $\beta = 0$ and chooses action a, and the last term $\Pr(\text{"altruistic" plays not } a) =$

[7] We assume that $s \leq \Delta X$ as otherwise there will also be an equilibrium where each type $\beta > 0$, including arbitrarily small types, chooses the prosocial option B. In this equilibrium, choosing A instead of B brings ΔX and incurs the highest possible cost s.

$\Pr(a')\Pr(a'|\beta > 0)$ is the probability that a dictator has type $\beta > 0$ and chooses any action a' other than a.[8]

The "selfish" type $\beta = 0$ chooses A as it gives a higher payoff and this is all that matters for this type.

Now consider the "altruistic" types. Let us imagine that there is a cutoff β_0 such that each "altruistic" type $\beta \in (0, \beta_0)$ chooses option A, while each type $\beta \in (\beta_0, 1]$ chooses option B. When choosing A each "altruistic" type incurs the self-image costs from pooling with all "selfish" types while $(1-\varepsilon)(1-\beta)$ of "altruistic" types choose a different strategy, thus $c_A = s\varepsilon(1-\varepsilon)(1-\beta)$ and utility from choosing A and B for $\beta > 0$ is as follows:

$$U(\beta|A) = \overline{X} + \beta\underline{Y} - s\varepsilon(1-\varepsilon)(1-\beta),$$

$$U(\beta|B) = \underline{X} + \beta\overline{Y}.$$

The indifferent type β_0 receives the same utility from options A and B: $U(\beta_0|A) = U(\beta_0|B)$ and thus:

[8] Alternatively, the costs c_a can be modeled as a posterior probability that the dictator has type $\beta = 0$ after he chooses action a, $c_a = s\Pr(\beta = 0|a)$, or as a posterior estimate of the dictator's type $c_a = sE((1-\beta)|a)$, as in Grossman & van der Weele (2017). Both approaches will make the image costs c_A of choosing the selfish option A decreasing in the cutoff value (e.g., β_0 for the Full information setting), but our model makes this dependence linear and thus more tractable.

$$\beta_0 = \frac{\Delta X - s\varepsilon(1-\varepsilon)}{\Delta Y - s\varepsilon(1-\varepsilon)}. \tag{1}$$

The next proposition shows that this strategy is the unique equilibrium in the Full information setting.

Proposition 1. In the Full information setting there is a unique symmetric equilibrium in pure strategies $a^*(\beta)$ characterized by a cutoff β_0: all less altruistic types $\beta \in (0, \beta_0)$ choose the selfish action $a^*(\beta) = A$, all more altruistic types $\beta \in (\beta_0, 1]$ choose the altruistic action $a^*(\beta) = B$; type $\beta = 0$ chooses $a^*(0) = A$.

Proof. We first show that $a^*(\beta)$ is an equilibrium. At $a^*(\beta)$ for each type $\beta > 0$ the utility difference between choosing A and B is as follows:

$$U(\beta|A) - U(\beta|B) = \Delta X - s\varepsilon(1-\varepsilon) - \beta\Delta Y - \beta_0 s\varepsilon(1-\varepsilon).$$

Due to that the utility difference monotonically decreases in β and equals zero at the cutoff β_0, each type $\beta > 0$ finds $a^*(\beta)$ to be optimal.

Now we show that this equilibrium is unique. Let there be a different equilibrium where some "altruistic" types choose A and some "altruistic" types also choose B (by assumption we have both). For each type $\beta > 0$ the utility difference between choosing A and B is $U(\beta|A) - U(\beta|B) = \Delta X - \beta\Delta Y - c_A$, where c_A is a constant and thus the utility difference again monotonically decreases in β. Therefore, if some type β prefers A, each lower type $\beta' < \beta$ also prefers A, and if this type β prefers B then each higher type

$\beta'' > \beta$ also prefers B. Let $\hat{\beta}_0$ be the lowest type that chooses B, then type $\hat{\beta}_0$ is at most indifferent between choosing A or B, and each type β below $\beta < \hat{\beta}_0$ prefers A, $U(\beta|A) \geq U(\beta|B)$. And thus the level $\hat{\beta}_0$ is the desired threshold level β_0 given by equation (1).

1.3.1.2 Before setting

In the Before setting prior to taking the payoff-relevant action a the dictator takes the revelation action r, together these two actions constitute a strategy $\sigma = \{a, r\}$. In the Before setting the dictator's decisions are affected by four different motives: inequality aversion, self-image concerns, the anchoring bias, and the default effect. Combining all these motives, the expected utility from playing $\sigma = \{a, r\}$ is as follows:

$$E(U(\beta|\{a, r\})) = X_a + (\beta - \alpha(1-r))E(Y_a|r) - E(c_a) - dr,$$

where $\alpha \in [0,1]$ in $(\beta - \alpha(1-r))$ reflects the anchoring bias that comes from showing the dictator his own payoffs at the time of the revelation decision. If the dictator does not reveal ($r = 0$), then his altruism level is decreased by α, but if the dictator reveals ($r = 1$), then anchoring bias disappears. The last term dr reflects the default effect of not revealing: if the dictator does not reveal ($r = 0$), then he follows the default option and incurs zero costs, but if he reveals ($r = 1$), then he incurs costs $d \geq 0$.

We will show below that the unique equilibrium in this game has the same nature as in the case of Full information: there is a cutoff β_1 such that each type below the cutoff does not reveal and chooses A, and each type above the cutoff reveals and chooses the pro-social option (in particular, if the payoffs are aligned, he chooses B).

The $\beta = 0$ type is not subject to either anchoring or default costs and is therefore indifferent between revealing or not and always chooses option A. We assume that $\beta = 0$ dictator chooses to reveal with probability $\frac{1}{2}$.[9]

To calculate the self-image costs for type $\beta > 0$ first consider the case if the dictator reveals. If payoffs are in conflict then by choosing A he pools with all "selfish" types that revealed, while all "altruistic" types that revealed choose B. Thus, his self-image costs are the highest: $c_A(r = 1, conflict = 1) = s$. In contrast, if he chooses B he incurs zero costs $c_B(r = 1, conflict = 1) = 0$ as each "selfish" type chooses A. If payoffs are aligned then by choosing A he incurs zero costs $c_A(r = 1, conflict = 0) = 0$ as all "altruistic" types will choose the same (the self-image costs of choosing B are also zero, but B is dominated by A).

Now consider the case if the dictator does not reveal. If he chooses A then he pools with $\varepsilon/2$ of selfish types while $(1-\varepsilon)(1-\beta_1)$ of altruistic types choose a different strategy (i.e., to reveal), $c_A(r = 0) = s\frac{\varepsilon}{2}(1-\varepsilon)(1-\beta_1)$. (Again option B is dominated by A.)

We can order the self-image costs depending on the strategy. The most costly to self-image is to reveal and then, in the event of conflicting payoffs, to choose A, $c_A(r = 1, conflict = 1) = s$. It is slightly less costly to remain ignorant and then choose A, $c_A(r = 0) = s\frac{\varepsilon}{2}(1-\varepsilon)(1-\beta_1)$. Finally, the action that is least costly to self-image is

[9] The assumption about the equal split is not critical and can be generalized to an arbitrary share μ as is done in Moradi & Nesterov (2018).

reveal and choose prosocially (B in the case of conflicting payoffs and A otherwise), these costs are zero.10

The next proposition shows that in the Before setting there exists a generally unique equilibrium characterized by a cutoff value β_1: all "altruistic" types below β_1 choose not to reveal and choose option A, types above β_1 choose to reveal and choose the prosocial action.

Proposition 2. In the Before setting there exists a unique symmetric equilibrium in pure strategies $\sigma^*(\beta) = \{r^*(\beta), a^*(\beta)\}$ characterized by a cutoff β_1 (such that $0 < \beta_1 \leq 1$): all less altruistic types $\beta \in (0, \beta_1)$ do not reveal and choose the selfish action ($\sigma^*(\beta) = \{0, A\}$), all more altruistic types $\beta \in (\beta_1, 1]$ reveal and choose the altruistic action ($\sigma^*(\beta) = \{1, a_Y\}$ where $a_Y = B$ when $conflict = 1$ and $a_Y = A$ otherwise). The cutoff equals

$$\beta_1 = \frac{\Delta X + \frac{d}{p} - s\frac{\varepsilon(1-\varepsilon)}{2}}{(1-\alpha)\Delta Y - s\frac{\varepsilon(1-\varepsilon)}{2}}. \tag{2}$$

[10] 97% of our observations are consistent with one of these three strategies. Each other strategy (not reveal and choose B, reveal and in case of no conflict choose B) is dominated by at least one of the three considered strategies, and this holds for each type β. The only exception is when default cost d and probability of conflict p are both sufficiently high: then for altruistic types the optimal strategy is not to reveal and choose B. In our Before99 treatment among 66 subjects only 5 used this strategy, while 29 revealed and chose B (see Figure 1-12).

Proof. We first show that σ^* is an equilibrium. In σ^* the expected utility of type $\beta > 0$ from choosing $\{0, A\}$ is as follows: $E(U(\beta|\{0,A\})) = \overline{X} + \beta(1-\alpha)(p\underline{Y} + (1-p)\overline{Y}) - ps\frac{\varepsilon(1-\varepsilon)}{2}(1-\beta_1)$, and the expected utility from choosing $\{1, a_Y\}$ is as follows: $E(U(\beta|\{1,a_Y\})) = p\underline{X} + (1-p)\overline{X} + (1-\alpha)\beta\overline{Y} - d$. The utility difference is monotonically decreasing in β: $E(U(\beta|\{0,A\})) - E(U(\beta|\{1,a_Y\})) = p\Delta X - \beta(1-\alpha)p\Delta Y - ps\frac{\varepsilon(1-\varepsilon)}{2}(1-\beta_1) + d$, and equals zero at the cutoff level β_1. Therefore, each type below β_1 prefers not to reveal and chooses A, while each type above β_1 reveals and chooses the prosocial action a_Y, and σ^* is an equilibrium. We show that the equilibrium is unique using the same argument as for the Full information setting. Let $\hat{\beta}_1$ be the lowest type such that each type $\beta \in (\hat{\beta}_1, 1]$ above it reveals and chooses B (by assumption we have at least one such type $\beta = 1$) and type $\hat{\beta}_1$ is at most indifferent between choosing A and B: $E(U(\hat{\beta}_1|\{0,A\}) \geq E(U(\hat{\beta}_1|\{1,a_Y\}))$. Then, for each $\beta \in (0, \hat{\beta}_1)$ we get $E(U(\hat{\beta}|\{0,A\}) \geq E(U(\hat{\beta}|\{1,a_Y\}))$. And thus the level $\hat{\beta}_1$ is the desired threshold level β_1 given by equation (2). Q.E.D.

1.3.1.3 After setting

In the After setting the game is essentially the same as in the Before setting except for that there is no anchoring ($\alpha = 0$) and thus the expected utility of type β from choosing strategy $\{a, r\}$ is as follows:

$$E(U(\beta|\{a,r\})) = X_a + \beta E(Y_a|p,r) - c_a - dr,$$

We get an immediate result for this setting simply by letting $\alpha = 0$ in Proposition 2.

Proposition 3 In the After setting there exists a unique symmetric equilibrium in pure strategies $\sigma^*(\beta) = \{r^*(\beta), a^*(\beta)\}$ characterized by a cutoff β_2 (such that $0 < \beta_2 \leq 1$): all less altruistic types $\beta \in (0, \beta_2)$ do not reveal and choose the selfish action ($\sigma^*(\beta) = \{0, A\}$), all more altruistic types $\beta \in (\beta_2, 1]$ reveal and choose the altruistic action ($\sigma^*(\beta) = \{1, a_Y\}$ where $a_Y = B$ when $conflict = 1$ and $a_Y = A$ otherwise). The cutoff equals

$$\beta_2 = \frac{\Delta X + \frac{d}{p} - s\frac{\varepsilon(1-\varepsilon)}{2}}{\Delta Y - s\frac{\varepsilon(1-\varepsilon)}{2}}. \tag{3}$$

1.3.2 Model predictions

Next, using the results above we formulate predictions for the experiment. We first show predictions for the moral wiggle room: whether there are more prosocial choices in the Full information setting than in the hidden information setting. Next, we group the predictions based on our two key questions: whether information avoidance in the moral wiggle room is strategic and whether it depends on underlying probability.

1.3.2.1 <u>Is there moral wiggle room?</u>

To answer this question we need to consider the difference between the cutoff for the Full information setting (β_0) and the cutoffs for the Before setting (β_1) and the After setting (β_2). First observe that $\beta_1 \geq \beta_2$:

$$\beta_1 - \beta_2 = \left(\Delta X + \frac{d}{p} - s\frac{\varepsilon(1-\varepsilon)}{2}\right)\left(\frac{1}{(1-\alpha)\Delta Y - s\frac{\varepsilon(1-\varepsilon)}{2}} - \frac{1}{\Delta Y - s\frac{\varepsilon(1-\varepsilon)}{2}}\right) > 0,$$

and this difference is zero only if the second factor is zero, which occurs only when $\alpha = 0$.[11]

Next, observe that $\beta_2 \geq \beta_0$:

$$\beta_2 - \beta_0 = \frac{\frac{d}{p}(\Delta Y - s\varepsilon(1-\varepsilon)) + s\frac{\varepsilon(1-\varepsilon)}{2}(\Delta Y - \Delta X)}{(\Delta Y - s\frac{\varepsilon(1-\varepsilon)}{2})(\Delta Y - s\varepsilon(1-\varepsilon))} > 0,$$

as the denominator is positive and both parts in the nominator are positive. This difference is zero only if both $d = 0$ and $s = 0$.

Thus, we see that our model predicts moral wiggle room in the Before setting and in the After setting whenever at least one of the three motives is present: either self-image costs ($s > 0$), or default effect ($d > 0$), or anchoring ($\alpha > 0$).

1.3.2.2 Is information avoidance strategic?

If information avoidance is strategic and is driven exclusively by the combination of image concerns and the default effect, while anchoring is irrelevant ($\alpha = 0$), then $\beta_1 = \beta_2$ and the model predicts the same share of information avoidance in the Before setting and in the After setting. More generally, our model predicts that there is more

[11] The first factor is not zero as $s \leq \Delta X$ by assumption.

information avoidance in the Before setting than in the After setting ($\beta_1 > \beta_2$) if and only if anchoring is present ($\alpha > 0$).

1.3.2.3 Does information avoidance depend on the underlying probability?

Now we study the role of the probability of conflicting payoffs p by comparing the series of Before treatments for $p = .01$ (Before1), $p = .5$ (Before), $p = .25$ (Before25) and $p = .99$ (Before99) using the results of Proposition 2. As equation (2) shows, β_1 is decreasing in p in the entire domain whenever default costs are present ($d > 0$).

The default costs play a crucial role as these are the only costs in the model that do not depend on the probability of conflict p while the other costs (and benefits) of revealing are all in expectation. Indeed, if the dictator reveals and then chooses the prosocial action, he sacrifices ΔX with probability p. If the dictator does not reveal and chooses A then with probability p he sacrifices the benefit for the recipient ΔY and also incurs self-image costs c_A. As probability p increases this tradeoff between expected costs and the benefits of revelation becomes larger, while the default costs d remain fixed and become relatively less relevant. Therefore, keeping everything else fixed, with larger p revelation becomes less costly and the model predicts a higher share of revelation.

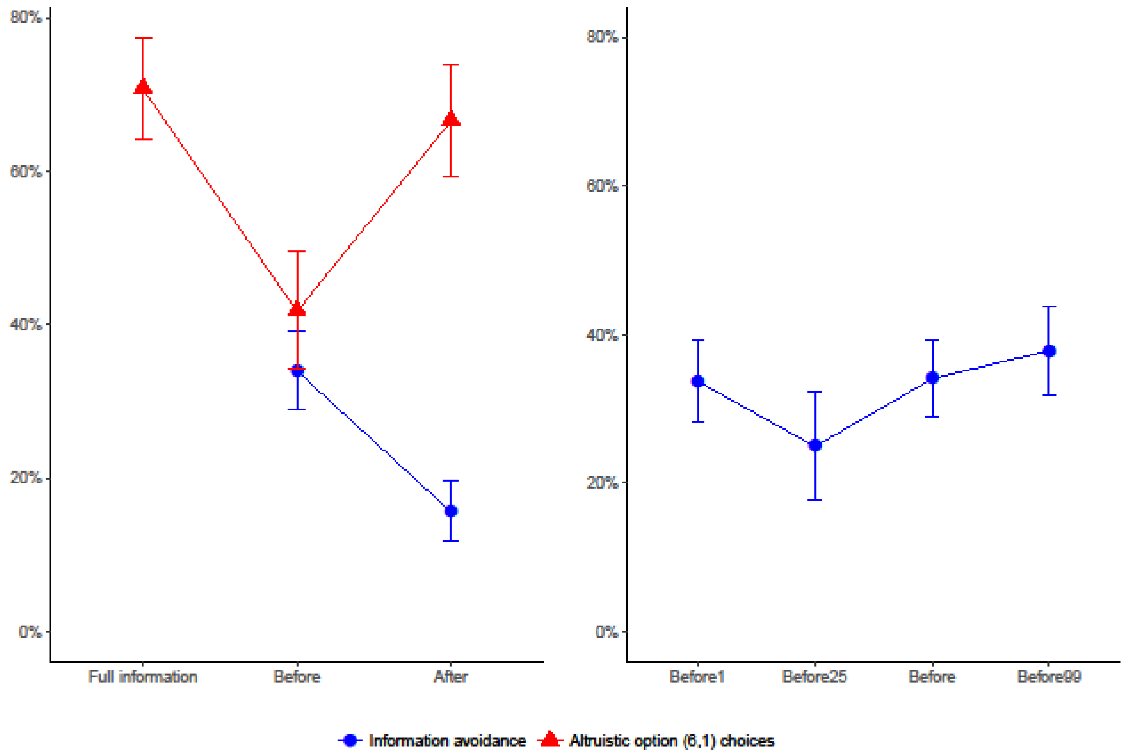
1.4 Experimental Results

Figure 1-6 displays the rates of information avoidance choices and selfish choices in all treatments. For the rate of information avoidance choices, we consider games with both conflicting and nonconflicting payoffs. For the rate of selfish choices, we only consider games with conflicting payoffs. In the Before1, Before25, and Before99 treatments, we do not report the rate of selfish choices since the prior belief elicitation might have an effect on their selfish choices. We provide detailed results of the treatments in the Appendix.

1.4.1.1 Is information avoidance strategic?

In the Full information treatment, 29% (14 out of 48) of dictators choose the selfish option. When the self-interested option is presented before the information choice, dictators are significantly more likely to choose the selfish option [$\chi^2(1)$ = 7, p = 0.01], consistent with DWK's result. They choose the selfish option in 58% (25 out of 43) of cases in the Before treatment. However, the rate of selfish choices drops to 33% (14 out of 42) of cases in the After treatment [$\chi^2(1)$ = 4, p = 0.04]. This rate of selfish choices in the After treatment does not differ significantly from the rate of selfish choices in the Full information treatment [$\chi^2(1)$ = 0.04, p = 0.8].

Figure 1-6 Information avoidance and selfish behavior by treatment.



"Information avoidance choices" is the fraction of subjects choosing not to "Reveal." "Selfish option (6,1) choices" is the fraction of subjects who played the game with conflicting payoffs and chose the action with the payoff of (6,1) instead of (5,5). The error bars represent $+/-1$ *standard error.*

Information avoidance choices drive the treatment difference in the selfish behavior between the Before and the After treatment. The rate of dictators choosing information avoidance in the Before treatment is 34% (30 out of 88), which is significantly greater [$\chi^2(1)$ = 7, p = 0.008] than the 16% (14 out of 89) rate in the After treatment. Most of those choosing information avoidance (90%) choose the selfish option and there is no significant difference between treatments. Dictators who choose to reveal the recipient's payoff in the Before and After treatment, choose the selfish option at the rate of 39% (11 out of 28) and 25% (9 out of 36), respectively, which does not differ significantly [$\chi^2(1)$

= 0.9, p = 0.3]. Thus, there is no significant difference between dictators' selfish choices conditional on their information avoidance choice. Relative to the After treatment, the significantly higher rate of information avoidance choices in the Before treatment leads to the significantly higher rate of selfish choices.

Hence, the increased selfish choices due to moral wiggle room found by DWK and replicated in the Before treatment depends on whether participants know their self-interested option. Relative to the Full information treatment, the rate of selfish choices in the After treatment changes slightly, from 29% to 33%. The information avoidance choice only leads to a significant increase in selfish choices when it is presented after the announcement of the self-interested option.

1.4.1.2 Does information avoidance depend on the underlying probability?

In the Before treatment, 34% (30 out of 88) of dictators choose to avoid information. Changing the underlying probability from 50% to 25% does not change the behavior of dictators significantly. In the Before25 treatment, 25% (9 out of 36) of dictators choose to avoid information [$\chi^2(1)$ = 0.60, p = 0.4]. As the probability of conflicting payoffs increases to more extreme values, the rate of information avoidance does not change significantly; it remains at approximately one-third. The rate of dictators choosing information avoidance is 38% (25 out of 66) in the Before99. In the Before1 treatment, the rate is 34% (27 out of 77), which does not differ significantly [$\chi^2(1)$ = 0.1, p = 0.7].

Thus, for all the 1%, 25%, 50%, and 99% probabilities of conflicting payoffs, the rate of information avoidance remains around one-third. This result suggests that the probability of conflicting payoffs does not impact the information avoidance behavior.

As the previous result suggests, changing the underlying uncertainty does not significantly change the rate of information avoidance. The rate of information avoidance choices in the Before treatment with a high level of uncertainty is 34% (30 out of 88). This rate does not differ significantly from the rates in treatments with a low level of uncertainty, the Before99 and the Before1 treatments [$\chi^2(1)$ = 0.1, p = 0.8 and $\chi^2(1)$ = 0, p = 1].

We estimated the impact of the introduction of the self-interested option after the revelation choice, the probability, and uncertainty on information avoidance by means of a linear regression (Table 1-1). Model 1 considers the effect of our main variables of interest in the linear regression alone, showing that the After dummy decreases the rate of information avoidance choices by 53% (P = 0.011). Responses in the questionnaire revealed that when the self-interested option is introduced after the revelation choice, dictators show a higher concern over recipients' payoffs. Compared to that, dictators who see their own self-interested option initially show a more self-regarding behavior.

Models 2 and 3 examine the role of gender by introducing the female dummy. Model 2 shows that the order dummy has a robust impact on information avoidance when including the gender of subjects. For female subjects the rate of information avoidance is higher by 61% (P=0.0065) than for males.

Examining the role of gender highlights the strong impact of the order dummy. The After dummy decreases the chance of information avoidance by 65% (P=0.0482). Model 3 shows that this is not due to having a different ratio of gender in the After treatment.

Table 1-1 Treatment effects on the likelihood of information avoidance.

	Dependent variable:			
	Information Avoidance			
	(1)	(2)	(3)	(4)
After	-0.161**	-0.172**	-0.227**	
	(0.063)	(0.087)	(0.109)	
Probability	0.001	0.0005	0.0005	
	(0.001)	(0.001)	(0.001)	
Belief				0.001
				(0.001)
Uncertainty	-0.040	-0.012	-0.012	-0.102
	(0.055)	(0.077)	(0.077)	(0.089)
Female		0.156***	0.127*	
		(0.057)	(0.066)	
After*Female			0.108	
			(0.128)	
Constant	0.331***	0.264***	0.278***	0.320***
	(0.051)	(0.059)	(0.061)	(0.068)
Observations	356	258	258	179
R^2	0.032	0.055	0.057	0.011
F Statistic	3.935***	3.650***	3.058**	0.943

The dependent variable is a dummy that is equal to 1 when information is avoided. The independent variables are the dummy variable after, probability, belief, uncertainty, and the dummy of female. OLS estimates with robust standard errors in parentheses. Using logit and probit regressions we obtain qualitatively the same results. $^{***}P < 0.01$, $^{**}P < 0.05$, $^{*}P < 0.10$.

Model 1 further shows that the probability and the uncertainty have a weak effect that is not significant. This indicates that we cannot reject the hypothesis that probability and uncertainty make a significant difference in the rate of information avoidance. Model 4 shows that considering subjective beliefs instead of probabilities does not change this result.

Hence, we observe that the predictions of the anchoring model are the closest to the results of the experiment. This result suggests that DWK's information avoidance result may be driven not by self-image. Instead of strategically trying to protect self-image, the subjects may be naively reacting to any relevant information that grabs their anchoring. Put differently, even if self-image concerns play a role in information avoidance, they can be neutralized by making the situation more complex. Subjects are not strategic in the protection of their self-image.

1.5 Conclusion

In the present experiments we allow subjects to avoid information but we vary the timing and the probability of conflict. We find that information avoidance is sensitive with respect to the timing of the revelation decision (Before and After treatments) and not sensitive with respect to the probability of conflict (Before, Before1, Before25, Before99 treatments). Both results suggest that when deciding whether to avoid information the subjects in our experiments do not engage in strategic thinking but act rather myopically. These findings contradict the leading explanation of information avoidance in prosocial settings (a combination of self-image and default effect) and support the anchoring motive: subjects become more selfish when their payoffs are shown and the recipients' payoffs remain hidden.

Our paper has an implication for the design of information structures for cases with a conflict of interest. In various real-life situations, informed experts make suggestions to uninformed customers. This is, for example, the case for highly specialized experts like doctors, financial advisers, headhunters, and lawyers. When making this binding choice on behalf of the customer, the expert faces several incentives, which are not necessarily aligned: the benefit to the customer (the quality or fitness of the product) and the benefit to the expert (commission paid for a specific product compared to other products). As in our setting, the information about the quality of the product and the attached commission can initially be hidden and revealed by the expert (e.g., for a doctor prescribing a drug, both her patient's diagnosis and the drug producer's incentive program might be relevant and initially unknown). Our results suggest that if the information about the commission is revealed first then it might have a detrimental effect on the expert's incentives to learn the information on the quality of the product and, as a consequence, may lead to poor advice.

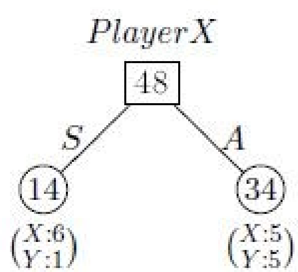
Our results also suggest that the rate of information avoidance does not depend on how likely the conflict of interest is, and this holds for a wide range of probabilities of conflict. Hence, informing the expert about the likelihood of the negative externality imposed by his actions does not help to mitigate information avoidance. Similarly, raising one's subjective belief about this likelihood should not have an effect. This is in line, for instance, with the evidence from genetic testing among individuals at risk of Huntington disease. As the probability of disease as assessed by clinicians rises all the way up to 99%, not only a patient's own reported probability changes very little, staying close to 40% on average, but also patients avoid getting tested: less than 5% of patients ever have the test (Oster, Shoulson, & Dorsey, 2013).

In real life, an expert makes the revelation decisions repeatedly and even if he remains ignorant, there is a chance that he will eventually learn. There is also a chance that the expert will suffer from giving a poor advice in the long run: one cannot fool everybody all the time, including oneself. These aspects might alleviate the human tendency to avoid relevant information in prosocial settings. The impact of these and similar aspects on the human tendency to avoid relevant information in prosocial settings is an open question and requires further research.

1.6 Appendix

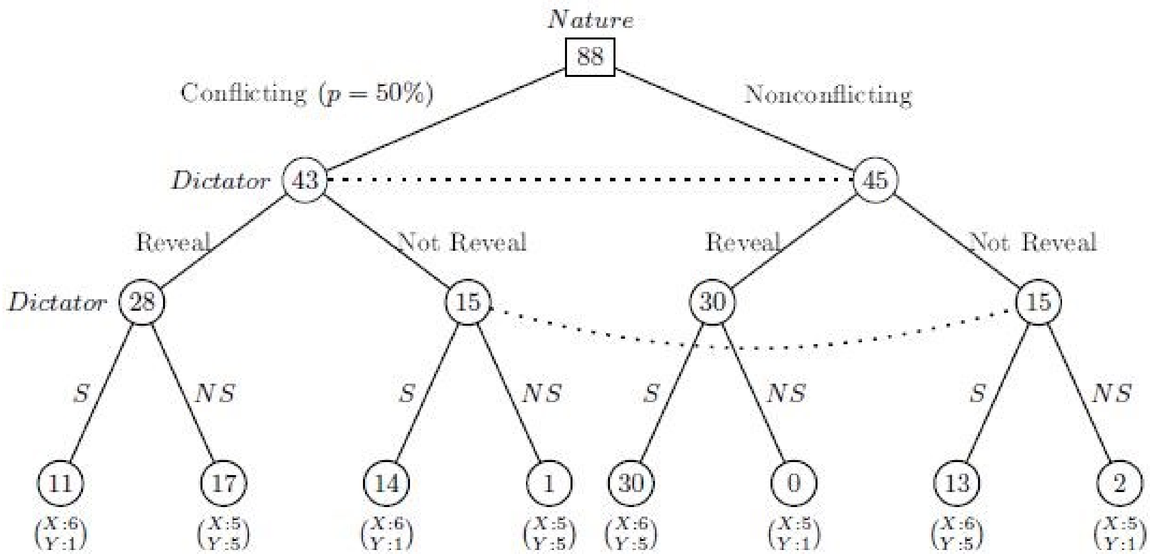
1.6.1 Game trees with results

Figure 1-7 Full information treatment



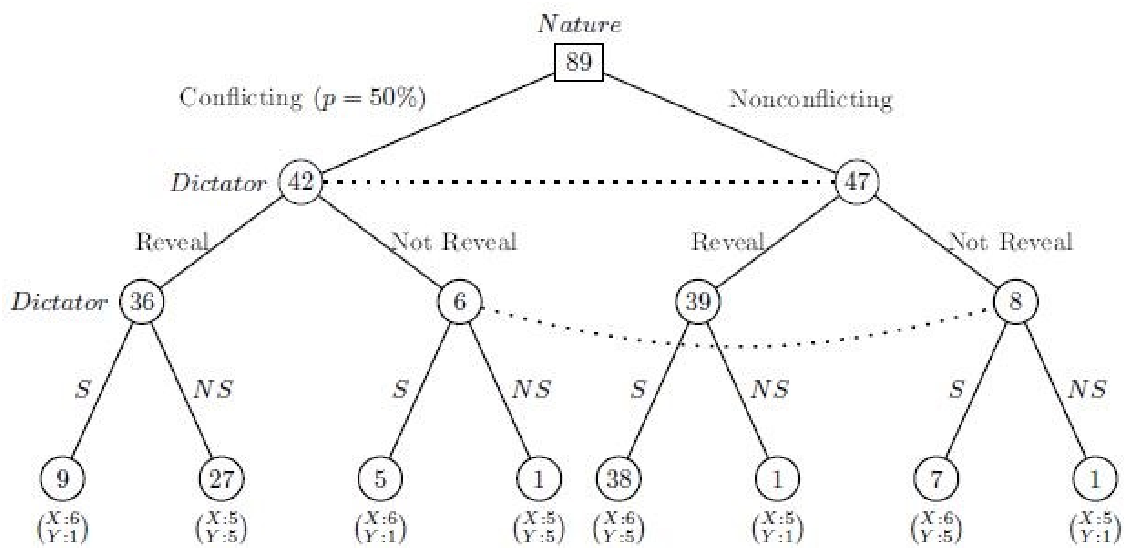
Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

Figure 1-8 Before treatment



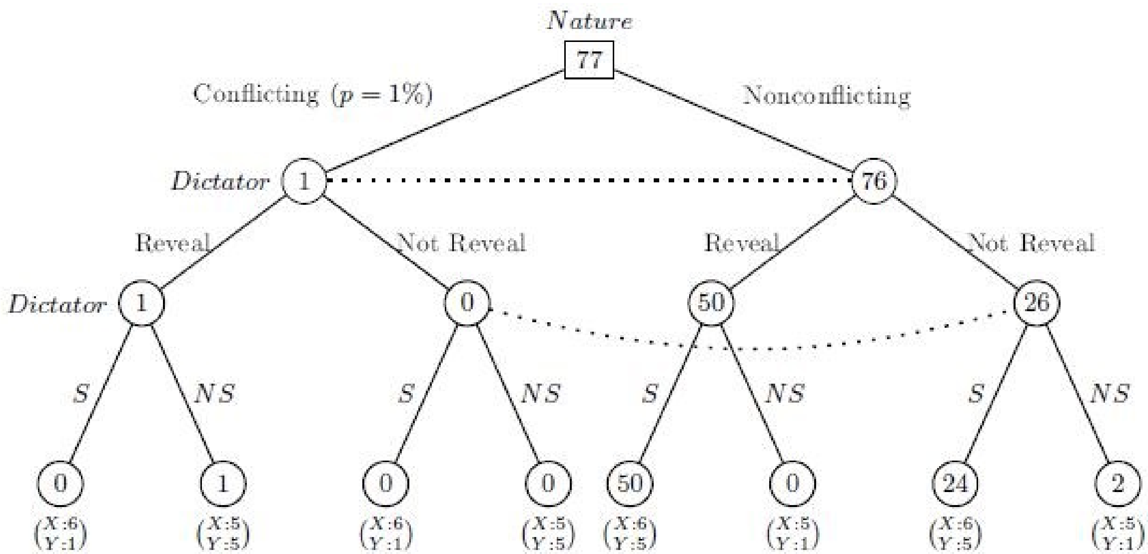
Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

Figure 1-9 After treatment



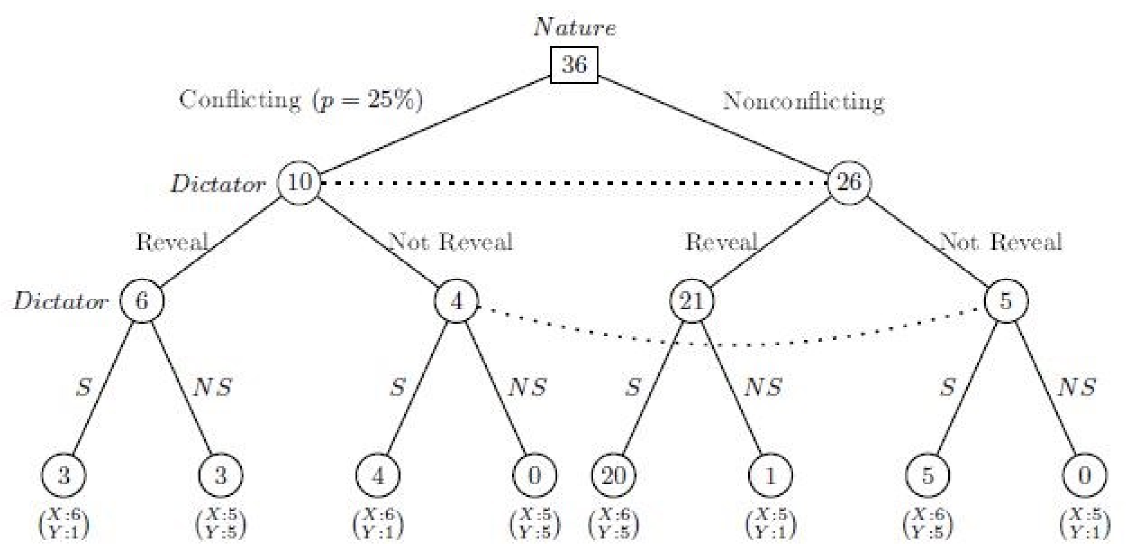
Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

Figure 1-10 Before1 treatment



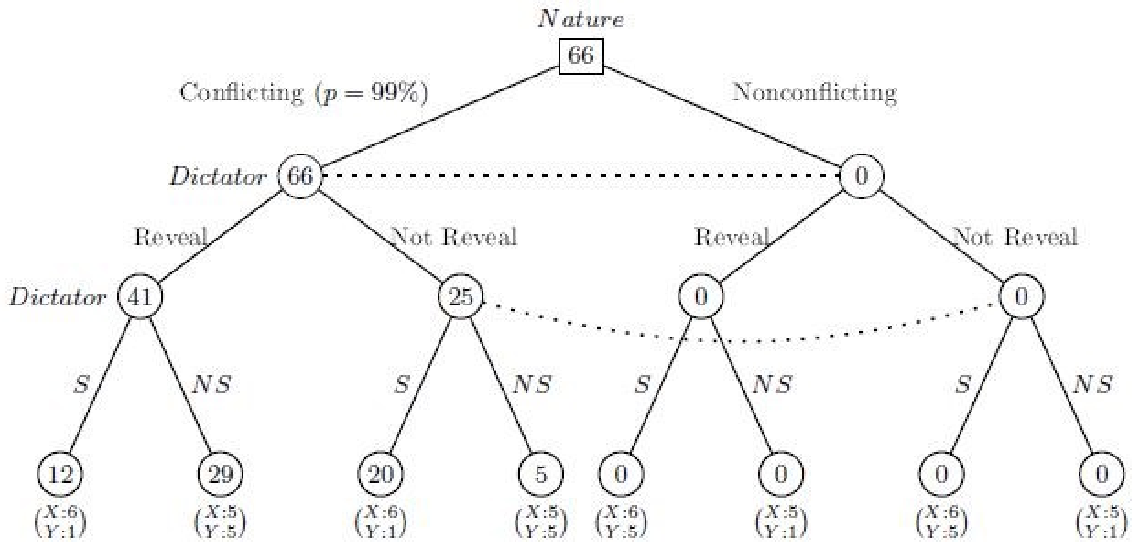
Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

Figure 1-11 Before25 treatment



Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

Figure 1-12 Before99 treatment



Notes: The number inside each node shows the number of subjects. The dictator chooses either Selfish (S), i.e., maximizing her own payoff, or Non-Selfish (NS).

1.6.2 Instructions

1.6.2.1 [All treatments]

This is an experiment in the economics of decision-making. You will be paid for your participation in the experiment. The exact amount you will be paid will depend on your and/or others' decisions. Your payment will consist of the amount you accumulate plus a 5€ participation bonus. You will be paid privately in cash at the conclusion of the experiment. If you have a question during the experiment, raise your hand and an experimenter will assist you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Please put away all outside materials (such as book bags, notebooks, etc.) before starting the experiment. Participants who violate the rules will be asked to leave the experiment and will not be paid.

In this experiment, each of you will play a game with one other person in the room. Before playing, we will randomly match people into pairs. The grouping will be anonymous, meaning that no one will ever know which person in the room they have played with. Each of you will be randomly assigned a role in this game. Your role will be player X or player Y. This role will also be kept anonymous. The difference between these roles will be described below. Thus, exactly one half of you will be a Player X and one half a Player Y. Also, each of you will be in a pair that includes exactly one of each of these types. The game your pair will play will be like the one pictured below. Player X will choose one of two options: “A” or “B.” Player Y will not make any choice. Both players will receive payments based on the choice of Player X. The numbers in the table are the payments players receive. The payments in this table were chosen only to demonstrate how the game works. In the actual game, the payments will be different. For example, if player X chooses “B” then we should look at the right square for the earnings. Here, Player X receives 3€ and Player Y receives 4€. Note that player X’s payment is in the lower-left corner of the square, player Y’s payment is in the upper-right corner.

Player X’s choices	A	X:1	Y:2
	B	X:3	Y:4

At this point, to make sure that everyone understands the game, please answer the following questions:

In this example, if Player X chooses “B” then:

Player X receives __

Player Y receives __

In this example, if Player X chooses "A" then:

Player X receives __

Player Y receives __

<answers read aloud>

1.6.2.2 [Before, Before1, Before25, Before99 treatments]

The actual game you will play will be one of the two pictured below. Note that both games are the same except that Player Y's payments are flipped between the two. Note that in both games, Player X gets his or her highest payment of 6 by choosing A. In the game on the left, this gives Player Y his or her lowest payment of 1. In the game on the right, this gives Player Y his or her highest payment of 5. In both games, if Player X chooses B, he or she will get a lower payment of 5. In the game on the left, this gives Player Y the highest payment of 5. In the game on the right, this gives Player Y the lowest payment of 1.

Left

A	X:6	Y:1
B	X:5	Y:5

Right

A	X:6	Y:5
B	X:5	Y:1

You do not know which of the games you will be playing. However, note that for Player X, the payments will be identical. The only thing that differs is the payment for Player Y.

[*Before treatment:* The actual game you will play was determined by a coin flip before the experiment.]

[*Before25 treatment:* The actual game you will play was determined by two coin flips before the experiment. If both coin flips are heads (heads-heads), the actual game you will play is the left game. For all other cases of coin flips (heads-tail, tail-heads, and tail-tail), the actual game you will play is the right game.]

[*Before99 and Before1:* The actual game you will play was determined by a random draw using an urn with 100 balls consisting of [*Before99:* 1 Blue and 99 Black] [*Before1:* 99 blue and 1 black] balls. When the drawn ball is blue, the left game will be played. If the drawn ball is black, the right game shall be played. For each pair of players the game will be determined in this way.]

However, we will not publicly reveal which game you are actually playing. Before playing, Player X can choose to find out which game is being played, if they want to do so, by clicking a button. This choice will be anonymous, thus Player Y will not know if X knows which game is being played. Player X is not required to find out and may choose not to do so. When the game ends, we will pay each player privately.

Player X's choices	A	X:6	Y:?
	B	X:5	Y:?

At this point, to make sure that everyone understands the game, please answer the following questions:

In both games, which action gives player X his or her highest payment of 6?__

If Player X chooses B, then Player Y receives __

1. 5

2. 1

3. either 5 or 1

1.6.2.3 [After treatment]

The actual game you will play will be one of the four pictured below. Note that the TOP AND BOTTOM column games are the same except that Player X's payments are flipped between the two. Similarly, LEFT and RIGHT row games are the same except that Player Y's payments are flipped between the two.

Note that in games in TOP, Player X gets his or her highest payment of 6 by choosing A. In the TOP-LEFT game, this gives Player Y's lowest payment of 1, and in the game TOP RIGHT, the highest payment of 5. Note that in games in TOP, if Player X chooses B, he or she will get a lower payment of 5. In the game TOP LEFT, this gives Player Y the highest payment of 5, and in the TOP-RIGHT game, the lowest payment of 1.

Note that in games in BOTTOM, Player X gets his or her highest payment of 6 by choosing B. In the BOTTOM-LEFT game, this gives Player Y's highest payment of 5, and in the game BOTTOM RIGHT, the lowest payment of 1. In games in BOTTOM, if Player X chooses A, he or she will get a lower payment of 5. In the game BOTTOM LEFT, this gives Player Y the lowest payment of 1, Top Left

A	X:6	Y:1
B	X:5	Y:5

Top Right

A	X:6	Y:5
B	X:5	Y:1

Bottom Left

A	X:5	Y:1
B	X:6	Y:5

Bottom Right

A	X:5	Y:5
B	X:6	Y:1

You do not know which of the games you will be playing. The actual game you will play was determined by two coin flips (one for TOP vs BOTTOM, and one for LEFT vs. RIGHT) before the experiment. However, we will not reveal publicly which game you are actually playing.

Before playing, Player X can choose to find out which games from LEFT and RIGHT are being played, if they want to do so, by clicking a "Reveal Player Y's Payoff" button. Note that for Player X, the payments will be identical. The only thing that will differ is the payment for Player Y. This choice will be anonymous; thus, Player Y will not know if X knows which game is being played. Player X is not required to find out and may choose not to do so by clicking on the "Continue" button. After deciding to reveal or not, Player X will be informed which game(s) from TOP and BOTTOM is being played. This is independent of his or her actions. When the game ends, we will pay each player privately.

Player X's choices

A		Y:?
B		Y:?

At this point, to make sure that everyone understands the game, please answer the following questions:

In TOP games, which action gives player X his or her highest payment of 6? __

In TOP games, if Player X chooses B, then Player Y receives __

1. 5
2. 1
3. either 5 or 1

When player X clicks on "Reveal" button, his final payoff table will contain information about

1. Only player X's payoff
2. Only player Y's payoff
3. Both players' payoff

When player X does not click on the "Reveal" button, his final payoff table will contain information about

1. Only player X's payoff
2. Only player Y's payoff
3. Both players' payoff

CHAPTER 2. SELFLESS IGNORANCE: TOO GOOD TO BE TRUE

2.1 Introduction

After learning about a product with positive externalities, a consumer may avoid learning how much it costs so that she does not have to hesitate in acting altruistically. The consumer uses the ignorance about own payoffs to act selflessly. Despite the recent growing literature on the adverse impact of information avoidance (for the literature review see Gino et al. 2016; Golman, Hagmann, and Loewenstein 2017), we know little about the beneficial impact of information avoidance. Can ignorance help us make more altruistic choices?

The struggle between pro-self and pro-social behavior is at the core of many fundamental difficulties of our time, such as, for example, the reduction of air pollution and the redistribution of scarce resources. For the welfare of our societies, it is thus essential to investigate possible mechanisms such as ignorance about own payoffs to promote pro-social choices over selfish ones.

Drawing attention away from potential costs upfront is cheap and easy to implement. It may change people's behavior without forbidding any options. By providing information about an environmentally friendly product upfront, an altruistic consumer may prefer not to learn the cost of it. If such a mechanism works, it has a promising potential to impact on crucial matters like air pollution and environmentally friendly and sustainable consumption.

This paper relates to the recent growing literature on moral wiggle room. According to the concept of moral wiggle room, people might prefer to remain uncertain about the effect of their choices on others. In the seminal experiment of Dana, Weber, and Kuang (2007), a dictator facing the option to lower her own payoff is initially uncertain as to whether that sacrifice will help or hurt the recipient, but she can click a button to reveal this information.[12] The authors demonstrate that many dictators will avoid this information and, as a result, significantly fewer dictators choose the altruistic option in this game than in a baseline dictator game with full information.

The closest study to this paper is Kandul and Ritov (2017), who provide experimental evidence similar to our design. Although their data shows no treatment effect, they conclude that ignorance increases altruistic choices. We challenge this conclusion. As we describe below, although our experimental result is consistent with theirs, our interpretation is rather different. This paper also improves on theirs in terms of statistical power and also investigating the impact of the underlying uncertainty on information avoidance.

The interplay between information avoidance and uncertainty about own payoffs is important. Information avoidance is a choice to seek rather than reduce uncertainty (Hertwig & Engel, 2016). Many believe that uncertainty over the outcomes drives the

[12] This result has been widely replicated (Feiler, 2014; Grossman, 2014; Grossman & van der Weele, 2017; Larson & Capra, 2009; Regner & Matthey, 2012; van der Weele, 2012).

information avoidance behavior (Dana et al., 2007) since the uncertainty works as a veil of ignorance protecting the ego of the decision-maker from facing the reality of the consequences of her choices. Although the finding in the lab is inconsistent with this claim (Moradi & Nesterov, 2018), people seem to react to uncertainty about their own payoffs differently than to the uncertainty about others' payoffs (Exley 2016). Thus, it is not clear whether the uncertainty about own payoffs plays a key role in prosocial behavior.

The definition that reflects the uncertainty in the moral wiggle room is the following: Uncertainty of a random variable is the amount of information gained when it is realized. In information theory, this variation of uncertainty is called *information content* or *suprisal*. For example, a product with a 50% chance of being more expensive than a rival product has a higher level of uncertainty than a product with a 10% chance. While two products with a 10% or 90% chance have the same level of uncertainty. Since the term uncertainty has a broad meaning with distinct definitions, while terms can sometimes be used interchangeably (Epstein, 1999), we stick to the definition above whenever we mention uncertainty.

This paper presents an experiment that sheds light on whether ignorance can enhance altruistic behavior. We use the experimental design of Moradi and Nesterov (2018) to distinguish two distinct features about ignorance: the mere possibility of information avoidance in the own payoff, and the underlying uncertainty about own payoffs to answer two specific questions:

1. Does the possibility of ignorance regarding own payoffs enhance altruistic behavior?

2. Does the level of uncertainty about own payoffs impact altruistic behavior?

To investigate whether ignorance about own payoffs enhances altruistic behavior, we use a simple binary dictator game with hidden information, similar to the moral wiggle room game of Dana, Weber, and Kuang (2007). The ignorance game is a two-player game in which a dictator has a binary choice between two choices where one of them leads to a higher payoff for the recipient than the other, but the own payoff of the dictator is unknown. There are two possible states of the world. In the conflicting state, the altruistic choice leads to a lower own payoff, and in the nonconflicting state to a higher own payoff. All the dictators need to do is to click a button in order to find out whether the state is conflicting or nonconflicting.

The first experimental manipulation contrasts the possibility of remaining ignorant about own payoffs. In the full information treatment, subjects play a binary dictator game with a conflicting state, i.e., with no possibility of information avoidance. Whereas in the high uncertainty treatment, both conflicting and nonconflicting states of the world are equally likely and the choice to remain ignorant about own payoffs is introduced. Ignorance can only explain the difference between the two treatments if the high uncertainty treatment has a significantly higher rate of altruistic choices than the full information treatment.

We find that although about one-third of dictators avoid information about their own payoffs, the overall rate of altruistic choices does not significantly change between the full information treatment and the high uncertainty treatment. This result suggests that ignorance about own payoffs does not increase the altruistic behavior. Although approximately one-third of dictators choose to remain ignorant about their own payoffs, this does not significantly change the overall rate of altruistic choices from the full information treatment. The fact that some remain ignorant can be explained in that they are altruistic types who would choose altruistically even if they knew their own payoffs.

Although some may selflessly ignore learning their own payoffs and may choose altruistically, the key measure is the overall rate of altruistic choices. This point is downplayed in Kandul and Ritov (2017). The authors ran only two treatments similar to our full information and high uncertainty treatments.[13] Instead of comparing the result of altruistic choices between the two treatments, they compare the ratio of altruistic choices of dictators who chose to remain ignorant to the baseline. Kandul and Ritov (2017) conclude that "information avoidance can help to increase pro-social behavior—" without mentioning that the ratio of altruistic dictators is not large enough to generate a significant increase in the overall rate of altruistic behavior.

By running a power analysis beforehand, we choose the sample size according to the statistical power at the recommended level of 0.8. Thus, we can rely on the no-treatment effect of our results. Because of a similar design, if we assume the same effect size between our treatments and Kandul and Ritov (2017), the sample size has a statistical power at the level of 0.62. Kandul and Ritov (2017) did not vary the level of uncertainty.

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[13] Kandul and Ritov (2017) ran their experiment later than when we ran our main treatments, however, as they managed to publish sooner than us we therefore became aware of their results.

The second experimental manipulation varies the level of uncertainty about own payoffs. The low uncertainty treatment varies the likelihood of conflicting state in the high uncertainty treatment from 50% to the extreme likelihood of 99%. In this way, we make sure that the level of uncertainty regarding the own payoffs is trivial. If uncertainty about own payoffs plays no role in altruistic behavior, we should not expect to see any significant difference in the rate of altruistic choices between treatments. However, if we see significantly higher altruistic choices in the low uncertainty treatment compared to the high uncertainty treatment, then uncertainty should play a role in altruistic behavior.

We find that the rate of altruistic choices does not change significantly as the level of uncertainty decreases. Ignorance about own payoffs with either a high or a low level of uncertainty does not increase altruistic behavior.

Our result has an important policy implication. Imagine that a new environmental policy aims to increase the rate of a new environmentally friendly product by concealing its costs upfront. Our result suggests that although a few people may let go of learning the costs and choose the environmentally friendly options, the overall rate of environmentally friendly consumption choices does not change, regardless of whether there is an upfront concealment of costs or not.

The paper is structured as follows. The next section presents the experimental design and results. Section III concludes.

2.2 Experiment

Figure 2-3 displays the three treatments in the experiment. The full information treatment is a binary dictator game as a benchmark comparison. The next two treatments introduce the possibility of remaining ignorant of the own payoffs; one has a higher level of uncertainty than the other. Each treatment is described below.

1. Full information: This treatment exactly replicates DWK's baseline treatment. Dictators choose between two options A and B with conflicting payoffs as shown in Figure 1-2. Option A has a payoff of 6€ for the dictator and a payoff of 1€ for the recipient while option B has the same payoff of 5€ for both the dictator and the recipient.

Figure 2-1 Payoff of the full information treatment

Player X's choices	A	X:6	Y:1
	B	X:5	Y:5

2. High uncertainty: Participants were presented with the two versions of the game as in Figure 2-2. In both games option A has a payoff of 1€ for the recipient and option B has a 5€ payoff for the recipient. The dictator's payoffs from these options were uncertain. Participants were told that the actual game they were playing was randomly selected with equal probability. They were told that the actual game that they play would never be revealed publicly but the dictator could reveal them by clicking a button. The recipient would not be informed about the revelation choice of the dictator.

Figure 2-2 Payoffs of high uncertainty and low uncertainty treatments

Player X's choices

A	X:?	Y:1
B	X:?	Y:5

Left

A	X:6	Y:1
B	X:5	Y:5

Right

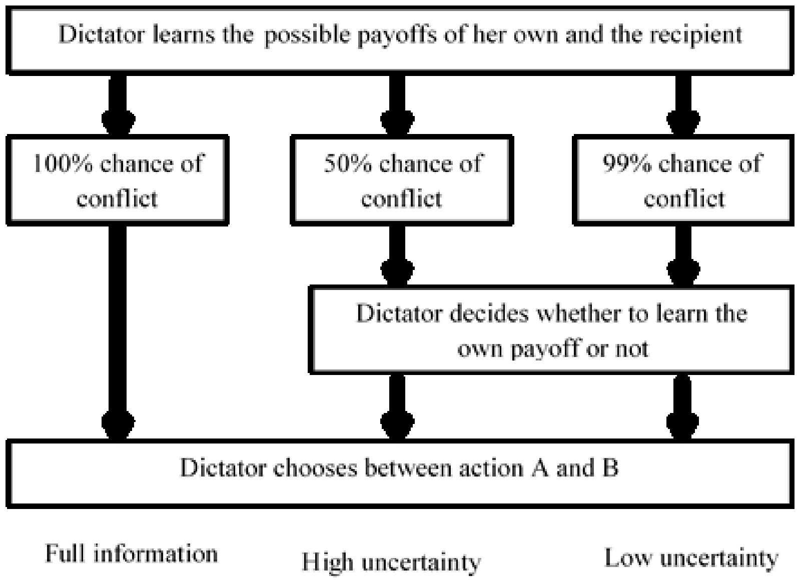
A	X:5	Y:1
B	X:6	Y:5

3. Low uncertainty: This treatment differed from the high uncertainty only in that the probability of the game with conflicting interests occurring was 99 percent instead of 50 percent.

Following the design of Moradi and Nesterov (2018), the extreme probability of 99 percent allows us to minimize the uncertainty while still keeping the possibility of information avoidance.

Participants completed a brief quiz to make sure they understood the instructions. The quiz was administered prior to the start of the experiment, so participants were unlikely to forget. The answers were read aloud; the participants were then asked whether they had any doubts or questions. Recipients made a hypothetical choice for the same game.

Figure 2-3 Overview of the Experimental Treatments



2.2.1 Hypotheses

Our design tests the two hypotheses listed below.

Hypothesis 1. The rate of altruistic choices between full information treatment and high uncertainty treatment does not differ.

Hypothesis 1 suggests that if ignorance about the own payoffs plays no role in altruistic behavior, we should not expect to see any significant difference in the rate of altruistic choices between treatments. Based on the other regarding payoff maximization, the rate of altruistic choices between full information and high uncertainty treatment does not differ.

Hypothesis 2. The rate of altruistic choices and also information avoidance choices between the high uncertainty treatment and the low uncertainty treatment does not differ.

This hypothesis allows us to examine the role of uncertainty in ignorance. An altruistic dictator would like to remain ignorant of her own payoff but does not like a high level of uncertainty about her payoffs. She may act altruistically in the low uncertainty treatment but not in the high uncertainty treatment.

2.2.2 Results

A total of 394 subjects participated across the three conditions, with exactly half (197) playing the role of dictator. A previous power analysis revealed that on the basis of the mean, between-groups comparison effect size observed in the Moradi and Nesterov (2018) study (d = .6), an approximate number of 43 dictators for the ignorance treatment would be needed to obtain statistical power at the recommended .80 level. Thus, all treatments have at least 43 observations.

On average, participants earned 9.70€, including a 5€ show-up fee. Sessions lasted approximately 20 minutes. The participants were recruited via the online recruitment system ORSEE (Greiner, 2015). The experiment was implemented by a z-Tree software (Fischbacher, 2007).

Result 1. Ignorance about own payoffs does not significantly increase the altruistic choices.

Figure 2 depicts the rates of information avoidance choices and altruistic choices in all treatments. In the full information treatment, 34 out of 48 dictators (71%) choose the altruistic action. This is not significantly different from the rate of altruistic choices in the high uncertainty treatment, in which 32 out of 44 (73%) dictators choose the altruistic choices ($X^2(1) = 0, p = 1$). In the low uncertainty treatment, 28 out of 48 dictators (58%) choose the altruistic action. This is not significantly different from the rate of altruistic choices in both the high uncertainty treatment ($X^2(1) = 2, p = 0.2$) and the full information treatment ($X^2(1) = 1, p = 0.3$).

The result suggests that ignorance about own payoffs with either a high or low uncertainty does not significantly impact the rate of altruistic choices. Thus, we cannot reject the first hypothesis.

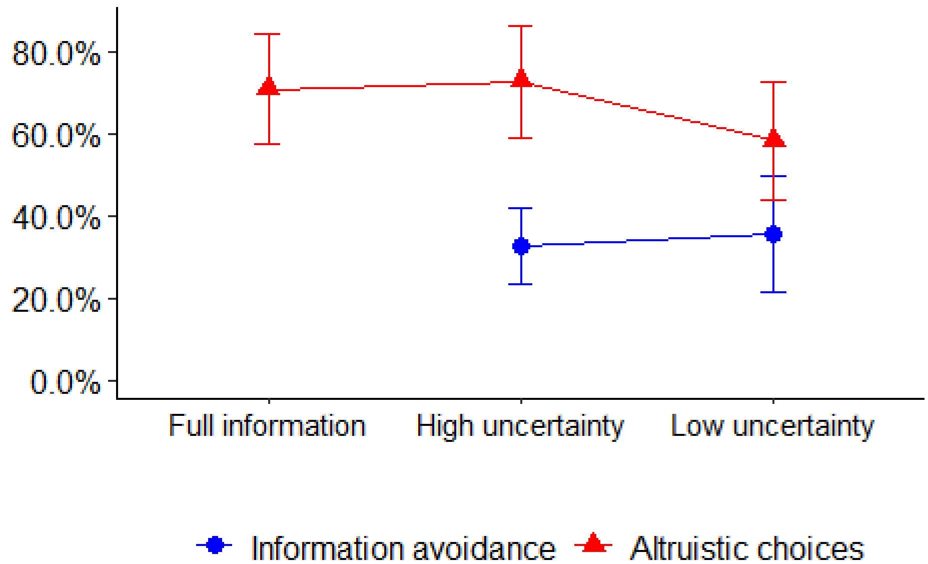
Result 2. In total, approximately one-third of dictators avoid information about their own payoffs in both ignorance treatments.

In the high uncertainty treatment, 33 out of 101 dictators (32%) choose to avoid information regarding their own payoffs. Of these 33 dictators, 27 (82%) choose the altruistic action. Although in the conflicting interests games, 14 out of 44 (32%) avoid information about their own payoffs and choose the altruistic option B, their rate is not large enough to yield a significant difference in the rate of altruistic choices between Full information treatment and the high uncertainty.

In the low uncertainty treatment, 17 out of 48 dictators (35%) choose to avoid information about their own payoffs, which is not significantly different from the high uncertainty treatment ($X^2(1) = 0.02, p = 0.9$).

Out of 17 dictators who choose to avoid information about their own payoffs, only nine of them (53%) choose altruistically in the low uncertainty treatment, which is significantly different from the high uncertainty treatment ($X^2(1) = 3, p = 0.07$).

Figure 2-4 Altruistic choices and information avoidance by treatment.



"Altruistic choices" is the fraction of subjects who played the game with conflicting interests and chose the action B. "Information avoidance choices" is the fraction of subjects choosing not to reveal their own payoffs. The error bars represent +/- 95% confidence interval.

The low uncertainty in the low uncertainty treatment has a two-sided effect on selfish and altruistic-type dictators who sort into information avoidance. First, the expected cost of not revealing and then choosing altruistically decreases for selfish-type dictators as the probability of conflicting games increases. That is because the selfish types care only about their own payoffs. The uncertainty is so low that selfish-type dictators do not bother revealing the information. This increases the rate of selfish types among dictators who choose to avoid information.

Consistent with this explanation, the rate of dictators who choose to avoid information and choose the non-altruistic option significantly increases from 4% (2 out of 44) in the high uncertainty treatment to 16% (8 out of 48) in the low uncertainty treatment ($p = 0.09, Fisher's\ exact\ test$).[14] The dictators' questionnaire provides supporting evidence. Most of the dictators who remain ignorant and choose the non-altruistic option state that they were certain of their own payoffs.

Another impact of the low level of uncertainty is that altruistic dictators may avoid information. The uncertainty might help altruistic dictators appear to be a selfless altruistic person when she voluntarily remains ignorant about her own payoff. But, when the uncertainty is almost removed, as in the low uncertainty treatment, it is much harder to keep an image of selfless altruism when she almost surely knows her own payoffs. Then, the information avoidance choice loses its attractiveness for an altruistic type.

Consistent with this explanation, the rate of dictators who choose to avoid information and select the altruistic option significantly decreases from 32% (14 out of 44) in the high uncertainty treatment to 19% (9 out of 48) in the low uncertainty ($\mathrm{X}^2(1) = 4, p = 0.05$).

2.3 Conclusion

The idea moral wiggle room suggests that information avoidance can lead, or can at least "license," people to take selfish actions (Dana et al., 2007). In other words, information avoidance serves as a situational justification for people's selfishness. In contrast to this approach. Kandul & Ritov (2017) believe that "that the same mechanism of information

[14] Since the expected number of observations is small, Fisher's exact test was used.

avoidance can help to increase pro-social behavior." This paper provides evidence that in the context of moral wiggle room, information avoidance does not increase the pro-social behavior. We also find that changing the underlying uncertainty of information avoidance also does not help to increase the pro-social choices.

Although the classic design of moral wiggle room and its variation used here is similar to many real-life situations, it certainly does not include many factors. For example, in our experiment the possibility of a conflict of interest is salient. In the real world, consumers may not think in terms of certain probabilities when forming an idea about costs, because there are many other dimensions of the product that they may take into consideration. In such contexts, further studies are needed to investigate whether information avoidance can promote altruistic behavior.

2.4 Appendix

2.4.1 Instructions

<u>[All treatments]</u>

This is an experiment in the economics of decision-making. You will be paid for your participation in the experiment. The exact amount you will be paid will depend on your and/or others' decisions. Your payment will consist of the amount you accumulate plus a 5€ participation bonus. You will be paid privately in cash at the conclusion of the experiment. If you have a question during the experiment, raise your hand and an experimenter will assist you. Please do not talk, whisper, or try to communicate with other participants during the experiment. Please put away all outside materials (such as book bags, notebooks, etc.) before starting the experiment. Participants who violate the rules will be asked to leave the experiment and will not be paid.

In this experiment, each of you will play a game with one other person in the room. Before playing, we will randomly match people into pairs. The grouping will be anonymous, meaning that no one will ever know which person in the room they have played with. Each of you will be randomly assigned a role in this game. Your role will be player X or player Y. This role will also be kept anonymous. The difference between these roles will be described below. Thus, exactly one half of you will be a Player X and the other half a Player Y. Also, each of you will be in a pair that includes exactly one of each of these types. The game your pair will play will be like the one pictured below. Player X will choose one of two options: “A” or “B.” Player Y will not make any choice. Both players will receive payments based on the choice of Player X. The numbers in the table are the payments players receive. The payments in this table were chosen only to demonstrate how the game works. In the actual game, the payments will be different. For example, if player X chooses “B,” then we should look at the right square for the earnings. Here, Player X receives 3€ and Player Y receives 4€. Note that player X’s payment is in the lower-left corner of the square, player Y’s payment is in the upper-right corner.

Player X’s choices			
	A	X:1	Y:2
	B	X:3	Y:4

At this point, to make sure that everyone understands the game, please answer the following questions:

In this example, if Player X chooses "B" then:

Player X receives __

Player Y receives __

In this example, if Player X chooses "A" then:

Player X receives __

Player Y receives __

<answers read aloud>

[Full information Treatment]

The actual game you will play is pictured below. Note that in this game, Players X gets the highest payment of 6€ by choosing A, but this gives Player Y the lowest payment of 1€. However, if player X chooses B player X will get a lower payment of 5€ while Player Y will also get a payment of 5€. Since we will only play this game once and will then end the experiment, please take a minute to think about the game.

Player X's choices	A	X:6	Y:1
	B	X:5	Y:5

[High uncertainty and low uncertainty treatments]

The actual game you will play will be one of the two pictured below. Note that both games are the same except that Player X's payments are flipped between the two. Note that both games are the same except the amounts for Player X have been exchanged. Player X will receive his highest payout (6€) if he selects A in the game LEFT or B in the game RIGHT. Otherwise, Player X will receive his lowest payout (5€). Player Y receives his highest payout (5€) in both games if B is selected and the lowest payout (1€) if A is selected.

Left

A	X:6	Y:1
B	X:5	Y:5

Right

A	X5	Y:1
B	X:6	Y:5

You do not know which of the games you will be playing. However, note that for Player Y, the payments will be identical. The only thing that will differ is the payments for Player X.

[*High uncertainty treatment:* The actual game you will play was determined by a coin flip before the experiment.]

[*Low uncertainty treatment:* The actual game you will play was determined by a random draw using an urn before the experiment. The urn contains 100 balls consisting of 99 blue ball and 1 black balls. When the drawn ball is blue, the left game is played. If the ball is black, the right game is played.]

However, we will not publicly reveal which game you are actually playing. Before playing, Player X can choose to find out which game is being played, if they want to do so, by clicking a button. This choice will be anonymous; thus, Player Y will not know whether X knows which game is being played. Player X is not required to find out and may choose not to do so. When the game ends, we will pay each player privately.

Player X's choices	A	X:?	Y:1
	B	X:?	Y:5

At this point, to make sure that everyone understands the game, please answer the following questions:

In both games, which action gives player Y his or her highest payment of 5€?__

If Player X chooses B, then Player X receives __

i. 5€
ii. 6€
iii. Either 5€ or 6€.

<answers read aloud>

CHAPTER 3. SUNSPOTS IN GLOBAL GAMES

With Frank Heinemann

3.1 Introduction

Global games are a selection device in coordination games with strategic complementarities that are used for modeling financial intermediation and bank runs, attacks on pegged currency exchange rates, and investments with external returns to scale. Take, for example, a borrower who has financed an investment with multiple short-term credits. If creditors refuse to roll over their claims, the borrowing costs may rise to the extent that the borrower becomes insolvent, in which case withdrawing credit is the optimal decision. However, the same borrower might be able to serve all debt under its old conditions if creditors extend their maturities, which may leave all of them with higher returns than withdrawing.

Creditors facing a coordination problem when a borrower is in distress may be tempted to follow signals that provide no information about fundamentals affecting payoffs ("sunspots"), fearing similar actions by others. For example, at least 90 percent of foreign exchange dealers rely on technical analysis (Lui & Mole, 1998; Oberlechner, 2001; Taylor & Allen, 1992). Technical analyses of financial markets provide forecasts of asset prices and give trading advice based on the history of price movements but without regard to any underlying economic or fundamental analysis.

Creditors may use sunspot signals to coordinate their decisions of whether to roll over or foreclose the loan, expecting similar strategies by other creditors who are getting the same signals. If the underlying game has multiple equilibria and signals are publicly observed, any mapping from signals into the set of equilibrium strategy combinations of the game without sunspot signals is an equilibrium of the game with such signals. If it assigns different actions for different realizations of the signal, it is called a sunspot equilibrium. Here, the expectation that the signal determines the outcome of the game is self-fulfilling. Such self-fulfilling expectations are akin to those faced by the depositors of a bank that is vulnerable to a run (Diamond & Dybvig, 1983) or by traders in foreign exchange markets who secure their positions against a devaluation and, thereby, create the pressure that may lead to a devaluation (Morris & Shin, 1998). All of these are examples of coordination games with strategic complementarities. The existence of sunspot equilibria raises the question of whether real agents would actually coordinate on following sunspots and under which conditions they might do so.

Public announcements play a key role in coordination games. They may coordinate expectations and thereby stabilize a currency or prevent a bank run, but they may also coordinate expectations on the unfavorable equilibrium that are associated with a devaluation or bank run. Applying global games, Morris & Shin (1998, 2003) show that common knowledge about payoffs is responsible for equilibrium multiplicity. If agents possess sufficiently precise private signals about payoffs, the equilibrium of an otherwise identical game is unique. Consequently, Morris and Shin argue that the mere presence of public signals destabilizes an economy by allowing for self-fulfilling beliefs and reducing the predictability of behavior and final outcome.

The literature on coordination games with strategic complementarities has focused on intrinsic signals that provide information about the fundamentals affecting payoffs. Intrinsic public signals may lead to overreactions that are eventually detrimental to welfare (Morris & Shin, 2002), or even to equilibrium multiplicity, while intrinsic *private* signals stabilize markets and may prevent multiplicity as in a global game (Morris & Shin, 1998, 2003). Extrinsic public signals (sunspots) allow for sunspot equilibria if the respective game without these signals has multiple equilibria. In a global game in which intrinsic private signals guarantee equilibrium uniqueness, sunspot equilibria do not exist (Heinemann & Illing, 2002).

The empirical validity of these results has been tested in various experiments: Cabrales, Nagel, & Armenter, (2007) and Heinemann, Nagel, & Ockenfels (2004) test global-game predictions in binary-action coordination games with public and private signals and show that observed behavior is close to the predictions of the theory of global games. Heinemann et al. (2004) find only small differences in behavior between treatments with public and private signals, which indicates that the theory of global games can also be used as a selection device for games with multiple equilibria. They show that subjects coordinate on threshold strategies such that they choose one action if the public signal is below the threshold and the other action if the public signal is above the threshold. Nevertheless, different groups of agents coordinate on different thresholds that are distributed between the thresholds derived from global-game selection and payoff-dominant equilibrium. Arifovic & Jiang (2014) show that the provision of extrinsic public signals may give rise to sunspot equilibria in those games in which different groups of agents are likely to coordinate on different equilibria. The explanation of the impact of sunspots seems to be subjects' perceived strategic uncertainty. Heinemann, Nagel, & Ockenfels (2009) show that those games in which different groups of agents are likely to arrive at different outcomes are also the games in which subjects are most uncertain about the likely strategies of other agents. The results from Arifovic & Jiang (2014) indicate that if strategic uncertainty is high, salient but fundamentally uninformative public signals can be used as focal points to coordinate expectations and behavior in one or the other action.

Fehr, Heinemann, & Llorente-Saguer (2018) show that sunspot signals may affect behavior, even if the sunspots are not publicly observed and sunspot-driven behavior is not an equilibrium. Their underlying coordination game, however, has a continuum of equilibria, which implies large strategic uncertainty. In financial markets, on the other hand, traders usually possess some private information or idiosyncratic opinions about the shadow value of a currency or about the riskiness of a bank. Such private signals accompany a unique equilibrium in which sunspots should not matter. The potential impact of sunspots under public signals and the similarity of behavior under public and private signals in the absence of sunspots raises the question of whether extrinsic signals may also affect behavior if subjects have intrinsic private information and the game, thus, has a unique equilibrium.

In this paper, we test whether extrinsic signals can also affect behavior if these signals are not public and if the underlying game has a unique equilibrium. To achieve this goal, we use an augmented global game, where players have the option to purchase a payoff-irrelevant public signal, called a sunspot, before they decide whether to invest in the project. We introduce a grain of doubt about the rationality assumption defining Nash equilibria by assuming that each agent behaves as if he or she expects that some of the other agents are naïve followers who always choose to buy the sunspot message and follow the action that it indicates. Our model predicts that (1) agents follow sunspots for some range of intrinsic signals, (2) the set of signals for which subjects follow sunspot messages increases as their private signals become noisier, and (3) agents expect more players to follow sunspots than actually do follow sunspots.

To test our predictions against the standard theory, we use an experiment, similar to those mentioned above, where subjects can decide between two options (A or B) and where the payoff from B depends positively on whether the number of other subjects who choose B exceeds an exogenously given hurdle. Subjects receive either public or private signals about the hurdle for success. After receiving their signals, subjects can individually decide whether to read a sunspot message that says either "Choose A" or "Choose B." This message is the same for all agents who read it, it is randomly drawn with 50% probability for each of the two texts, and subjects are informed about the random nature of these messages. We introduce a small cost for reading this message so that we can identify subjects who condition their actions on this message. The signals that subjects received about fundamentals were either public (common information treatment) or private, for which we distinguished private signals with low and high noise.

In all treatments, the vast majority of subjects used threshold strategies, i.e., invested for low signals, did not invest for high signals, and eventually followed the sunspot message for intermediate signals without any overlap. In about one-third of the groups, following the sunspot message is eventually the most likely strategy for some range of intermediate signals. Since most groups converge to classical global-game strategies that neglect sunspots, the comparative statics of the sunspot global-game solution with respect to the level of signal precision cannot be confirmed. Consistent with the predictions, however, we find that the set of signals for which subjects may follow sunspot messages gets larger if the precision of private signals decreases, while there is no significant difference between treatments with private signals of high precision and fully informative public signals. Thus, in contrast to the classical global-game prediction, it is not the noise per se but the size of the noise that affects the power of sunspots.

Consistent with our motivation of subjects following sunspots because they fear others will follow the sunspot, we find that subjects expect, on average, twice as many players to follow a sunspot than actually do. We conclude that in environments with high strategic uncertainty, payoff-irrelevant signals can affect behavior even if they are costly to obtain and not expected to be publicly observed.

Section 3.2 explains the coordination game with sunspots. Section 3.3 lays out the experimental design and results. Section 3.4 concludes the paper.

3.2 Coordination game with sunspots

We investigate a coordination game in which players can choose whether to invest in a project or not. Depending on market fundamentals, the investment only pays off if sufficiently many players invest. This is the standard coordination game introduced by Morris & Shin (2004). In our augmented game, players have the option to purchase a payoff-irrelevant public signal, called a sunspot, before they decide whether to invest in the project. We solve this model for two distinct cases: (A) an infinite number of agents; and, (B) a finite number of agents.

First, we solve this model for the case with an infinite number of agents to compare our results to the theoretical literature on global games. In most of the theoretical literature on global games, it is assumed that there are infinitely many agents. Since we test the predictions of the model in a laboratory experiment, we also provide the solution for a finite number of agents. Thus, we can directly compare the predictions with empirical results from the experiment.

3.2.1 Infinite number of agents

There is a continuum of infinity many agents indexed by i, who have to decide simultaneously whether to invest in a project or not. The project outcome depends on the proportion of agents who invest, denoted by A and on an exogenous state variable denoted by θ. Investment is successful if $A \geq \theta$, that is, if the proportion of agents who invest is larger than the required threshold. The return of a successful investment for each agent who invests is 1. If the investment is not successful, the payoff from investing is 0.

The payoff of not investing is $\lambda \in (0,1)$, and can be regarded as the opportunity cost of investment. The payoffs are summarized in Table 3-1 .

Table 3-1 Investment game payoff

	$A \geq \theta$ (Project succeed)	$A < \theta$ (Project fails)
Invest	1	0
Not Invest	λ	λ

Let us now extend this game by introducing a payoff-irrelevant message (sunspot). The sunspot message, s, is a random variable with two possible realizations: $s =$ "$invest$" with probability q and $s =$ "$not\ invest$" with probability $1 - q$. The sunspot message can only be observed by an agent after paying a cost *c*. Agents who do not purchase the sunspot message will not be informed about its realization. The message will be the same for all agents who purchase it.

Each agent makes two decisions: (1) whether to buy the sunspot message and (2) whether to invest or not. When deciding on their investment, agents do not know the proportion of agents who have bought the sunspot message. Thus, a strategy consists of a decision as to whether to buy the sunspot message and whether to invest (conditional on the sunspot message if it is bought or unconditional if it is not bought). As sunspot messages are salient messages mapping into the second-stage action space ("invest" versus "not invest"), we focus on strategies that follow the sunspot message if it is bought. While theoretically, an agent may buy the sunspot message and then choose the action that is opposed to the sunspot message, this is counter-intuitive and violates previous tests of behavior under payoff-irrelevant messages (see Duffy & Fisher, 2005, or Fehr, Heinemann, & Llorente-Saguer, 2012, for examples). As messages are costly, the strategy to buy the sunspot message and then decide for or against investment, irrespective of the sunspot message's content, is dominated by not buying the sunspot message.

This leaves us with three strategies that an agent may choose in the first stage of the game: In addition to "invest" and "not invest," independently of the sunspot realization, the agent may choose "follow," where she follows the recommendation of the sunspot message. If an agent chooses to follow, she pays a cost of c, invests if $s = "invest$," and does not invest if $s = "not\ invest$."

3.2.1.1 Common information game

If the state of the economy θ is common information, the game has a unique equilibrium or multiple symmetric pure-strategy Nash equilibria, depending on the value of θ:

If $\theta \leq 0$ the equilibrium is unique: nobody buys the sunspot message, everyone invests and investment is successful;

If $\theta > 1$ no one buys the sunspot message and no one invests;

If $\theta \in (0,1]$ there are up to three pure-strategy equilibria characterized by self-fulfilling beliefs:

1. all agents invest without buying the sunspot message,

2. nobody buys the sunspot message and nobody invests, and

3. everyone buys the sunspot message and follows its prescription. This equilibrium exists if the cost of the sunspot message is sufficiently small:

$$c \leq min\{(1-q)\lambda,\ q(1-\lambda)\}. \tag{4}$$

Proof. Payoffs for the unconditional equilibrium strategies are obvious. If all agents condition their investment on the sunspot message, their expected payoffs are $q + (1 - q)\lambda - c$. An agent who deviates to not buying the sunspot message and not investing receives λ, an agent who deviates to not buying and investing has an expected payoff q. Thus, for $c \leq min\{(1-q)\lambda,\ q(1-\lambda)\}$, no agent has an incentive to deviate. QED

The sunspot message may serve as a means to coordinate actions, which may seem valuable to agents of the game if they cannot make up their minds as to how to behave without such a coordinating device or if they believe that other agents will follow the sunspot message.[15]

The efficient equilibrium is, of course, to invest without buying the sunspot message, whenever $\theta \leq 1$. However, for $\theta > 0$, buying and following the sunspot message yields a higher expected payoff than not buying and not investing. This raises the question of

[15] Arifovic and Jiang (2014) have actually shown that for some values of θ, subjects may coordinate on following salient extrinsic messages, if these messages are provided to all agents at no cost.

whether real agents would actually coordinate on following the sunspot message and for which states of θ they might do so.

In order to address this question, we compare the predictions of two theories, the theory of global games predicts that agents will not follow the sunspot message. Our own theory assumes that agents exogenously believe some others will follow sunspots, which leads them to follow sunspots themselves for some range of states that are strictly interior to the set of states for which the common-information game has multiple equilibria.

The reason for this comparison is that Heinemann et al. (2004) show that subjects in laboratory experiments treat coordination games with public information about the state of the economy as similar to a global game with private information about the state. Furthermore, Heinemann et al. (2009) show that behavior in a coordination game with common information can be described by the equilibrium of a global game. As we will discuss in the next part, the global-game extension of the common-information game described above has a unique equilibrium in which sunspots are ignored. Thus, we test this prediction against the prediction of a model that embeds the global game as a special case but could explain sunspot-following behavior as well.

3.2.1.2 Sunspot global game

The state variable θ follows a normal distribution with mean y and precision α (that is, with a variance of $1/\alpha$). Agents do not observe θ. Each agent observes a noisy private signal about it:

$$x_i = \theta + \epsilon_i$$

where ϵ_i is i.i.d. and normally distributed with mean 0 and precision β. After realizing the noisy signal, agents decide whether to invest, follow, or not invest.

Morris & Shin (2004) show that for sufficiently precise signals ($\alpha^2/\beta \leq 2\pi$) the game without sunspots has a unique equilibrium. As Heinemann & Illing (2002) point out, the introduction of sunspot variables does not change this result, because the unique equilibrium can be derived by the iterative elimination of dominated strategies. Thus, in a global game, agents ignore the sunspot messages even when they come at no cost. In equilibrium, agents play a threshold strategy with a threshold signal x^*, such that agents with lower signals invest, agents with higher signals do not invest, and an agent with the marginal signal x^* is indifferent. Thus, there is no equilibrium in which agents buy and follow the sunspot message for any signal.

Experiments on global games have shown that there are little behavioral differences between coordination games with multiple equilibria in which the underlying state is common information and their respective global-game versions with private signals and a unique equilibrium (Heinemann et al., 2004).

Heinemann et al. (2009) argue that a global-game equilibrium can be used as a descriptive theory of behavior under strategic uncertainty in a coordination game with multiple equilibria. This would not be true if actual agents follow sunspots, because in a global-game equilibrium, sunspots are ignored. Thus, if we observe agents following sunspots, we would need another theory, potentially embedding a global-game equilibrium as a special case, to describe such behavior. For this reason, we introduce a simple extension of a global game that may eventually account for sunspot-following behavior in a coordination game.

3.2.1.3 Extended global game with exogenous beliefs in sunspots

Based on our motivation that agents may believe that others are following sunspots, we introduce a grain of doubt about the rationality of the assumption defining Nash equilibria. Namely, we assume that each agent behaves as if he or she expects that a proportion $p \in [0,1)$ of agents are naïve followers, who always choose to buy the sunspot message and follow the action that it indicates, while the proportion $1 - p$ of agents are expected to choose rationally between invest, not invest, and follow, depending on their information about fundamentals of the game and given their belief in a proportion p of naïve followers.

Note that it is not necessary that the naïve followers *actually* exist. If agents believe in the existence of some naïve followers, their best response may be to follow the sunspot themselves, provided their signal about fundamentals is critical. For $p = 0$, we are back to the standard global game in which equilibrium strategies ignore sunspots.

The presumed presence of some naïve followers can make a difference in intermediate states of the world: for some signals, the expected share of rational investors is so close to the expected hurdle of success that the sunspot message is expected to determine whether the hurdle is passed or not. For such signals, agents may be prompted to follow the signal themselves. Rational agents best respond to everybody else. Hence, they account for the widespread belief that sunspots may affect the outcome in intermediate states, and may themselves decide to follow the sunspot for some intermediate signals.

If we restrict ourselves to the three strategies "invest," "follow," and "not invest," the extended global game is supermodular and we can focus on the threshold equilibria for which agents switch from one strategy to the next if the private signal surpasses the respective threshold. If there is a unique threshold equilibrium, a supermodular game does not have any other equilibria. We first solve for an equilibrium strategy characterized by two thresholds in posterior beliefs about the fundamental: the investing switching point, ξ^I , and the not-investing switching point, $\xi^N > \xi^I$. These thresholds are such that agents invest without buying the sunspot message if their posterior estimate of the underlying fundamental is below ξ^I, they do not buy the sunspot message and do not invest if their posterior is above ξ^N, and they buy and follow the sunspot message for posterior beliefs between the two switching points. At the switching points, agents are indifferent between the neighboring strategies, which give the equilibrium conditions determining the two thresholds. After solving for an equilibrium, we identify conditions for its uniqueness.

Under Bayes' theorem, agent i's posterior belief about θ follows a normal distribution with mean

$$\xi_i = \frac{\alpha y + \beta x_i}{\alpha + \beta} \tag{5}$$

and precision $\alpha + \beta$. If agents use a switching strategy as described above, they do not buy the sunspot message and invest if the private signal x_i is smaller than

$$x^I(\xi^I, y) = \frac{\alpha + \beta}{\beta} \xi^I - \frac{\alpha}{\beta} y. \tag{6}$$

They do not buy the sunspot message and do not invest if the private signal x is larger than

$$x^N(\xi^N, y) = \frac{\alpha + \beta}{\beta} \xi^N - \frac{\alpha}{\beta} y. \tag{7}$$

They buy and follow the sunspot message if the private signal is between x^N and x^I.

Since we have an infinite number of agents, the probability of a private signal falling in any of these three regions is almost certainly identical to the proportion of agents who receive signals in the respective region. This allows us to denote two critical values of fundamentals at which the project is *expected* to be in the margin between failing and succeeding when the sunspot message is: (a) "invest," by ψ^N ; and, (b) "non invest," by ψ^I.

While these threshold states ψ^N and ψ^I depend on strategies characterized by the critical values for beliefs ξ^N and ξ^I, the optimal strategies depend on the fundamental states for which investment can be expected to succeed. We now solve for the equilibrium, which is a vector of threshold states and threshold signals, such that threshold signals are a best response to threshold states and threshold states are derived from the proportion of investors following the respective threshold strategy plus naïve followers.

In each case, we derive two equations that solve two pairs of unknowns: (ξ^N, ψ^N) when the sunspot message is "invest" and, (ξ^I, ψ^I) when the sunspot message is "not invest."

<u>The Sunspot message is "invest"</u>

If the sunspot message is "invest" then all agents whose posterior beliefs are below ξ^N will invest. Hence, an agent who believes in a proportion *p* of naïve followers, expects a critical state to success, $\psi^N = f + p$, where f is the proportion of agents who are expected to invest resulting from the switching strategy around ξ^N; and p is the proportion of naïve followers. At this state, the probability of receiving a signal below x^N is given by $Prob(x_i < x^N|\psi^N) = \Phi(\sqrt{\beta}(x^N - \psi^N))$, where $\Phi(.)$ is the cumulative distribution function for the standard normal.[16] Thus, the proportion of agents expected to invest because of a signal below x^N is $\Phi(\sqrt{\beta}(x^N - \psi^N))\,(1-p)$. This determines the expected marginal threshold to success as the value ψ^N that solves

$$\begin{aligned} \psi^N &= \Phi(\sqrt{\beta}(x^N - \psi^N))\,(1-p) + p \\ &= \Phi(\sqrt{\beta}(\frac{\alpha+\beta}{\beta}\xi^N - \frac{\alpha}{\beta}y - \psi^N))\,(1-p) + p. \end{aligned} \tag{8}$$

[16] $Pr(x_i < x|\theta,\psi) = Pr(\theta + \epsilon_i < x|\theta,\psi) = Pr(\sqrt{\beta}\epsilon_i < \sqrt{\beta}(x-\psi)) = \Phi(\sqrt{\beta}(x-\psi))$

At switching point ξ^N, an agent is indifferent between following and not investing. The expected payoff from following is $qProb(\theta < \psi^N|\xi^N) + (1-q)\lambda - c$, because "following" implies a successful investment whenever $\theta < \psi^N$ (recall that q is the probability that the sunpot message is "invest"). Since the conditional density over θ is normal with mean ξ^N and precision $\alpha + \beta$, this indifference condition is given by [17]

$$q\Phi(\sqrt{\alpha+\beta}(\psi^N - \xi^N)) + (1-q)\lambda - c = \lambda, \tag{9}$$

which implies

$$\psi^N = \xi^N + \frac{\Phi^{-1}(\lambda + \frac{c}{q})}{\sqrt{\alpha+\beta}}. \tag{10}$$

This gives us our second equation. Replacing ψ^N in equation (5) by (7) and rearranging the terms gives

---

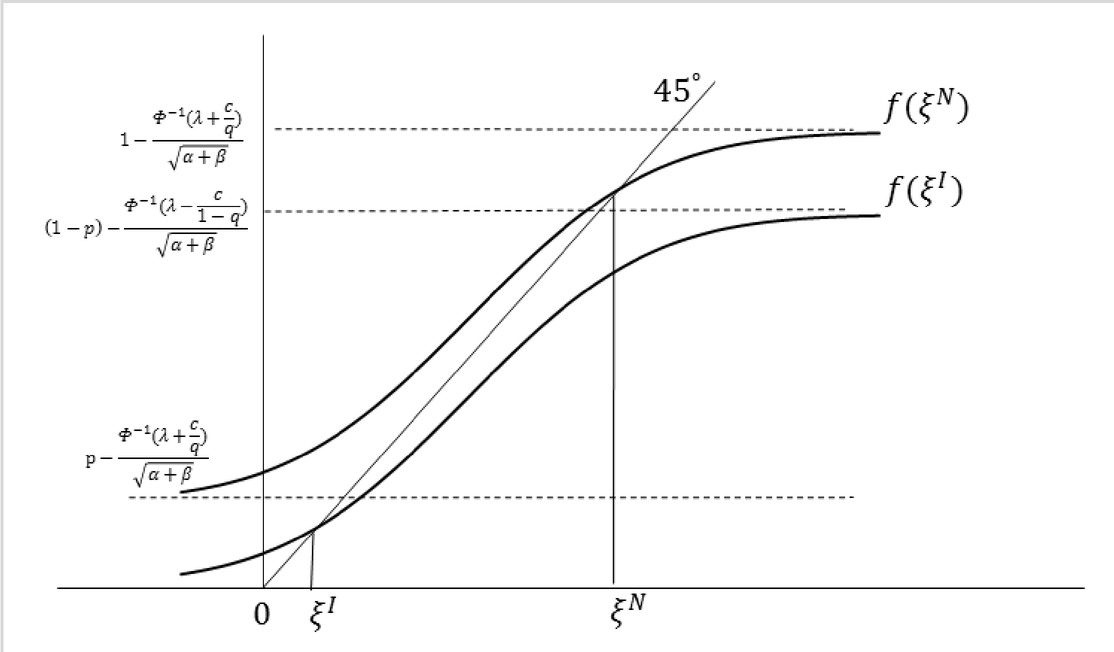
[17] $\theta = \xi + u_i$, where $u_i \sim N(0, \frac{1}{\alpha+\beta})$. Therefore $Pr(\theta < \psi|\xi,\psi) = Pr(\xi + u_i < \psi|\xi,\psi) = Pr((\sqrt{\alpha+\beta}u_i < \sqrt{\alpha+\beta}(\psi - \xi)) = \Phi(\sqrt{\alpha+\beta}(\psi - \xi))$

$$\xi^N = \Phi\left(\sqrt{\beta}\left(\frac{\alpha}{\beta}(\xi^N - y) - \frac{\Phi^{-1}(\lambda + \frac{c}{q})}{\sqrt{\alpha + \beta}}\right)\right)(1 - p) + p - \frac{\Phi^{-1}(\lambda + \frac{c}{q})}{\sqrt{\alpha + \beta}} \tag{11}$$

Figure 3-1 shows that the switching point ξ^N is obtained as the intersection between the 45° line and a linear transformation of a cumulative normal distribution. Equation (11) has a unique solution if the expression on the right-hand side has a slope that is less than 1 everywhere. The slope of the right-hand side is given by $(1 - p)\phi(\alpha/\sqrt{\beta})$ where ϕ is the density of the standard normal evaluated at the appropriate point. Since $\phi \leq 1/\sqrt{2\pi}$, a sufficient condition for a unique solution for ξ^N is given by

$$\frac{\alpha}{\sqrt{\beta}} \leq \frac{\sqrt{2\pi}}{1 - p}. \tag{12}$$

Figure 3-1 Default points $\boldsymbol{\xi^N}$ and $\boldsymbol{\xi^I}$.



Since α is the precision of the ex-ante distribution of θ, while β is the precision of private signals, the condition in equation (12) is satisfied whenever private signals are sufficiently precise relative to the underlying uncertainty of the fundamental.

<u>The sunspot message is "not invest"</u>

If the sunspot message is "not invest" the critical value of the fundamentals at which the project is expected to be in the margin between failing and succeeding was denoted as ψ^I. At this state, the proportion of agents expected to invest because of a signal below x^I is $\Phi(\sqrt{\beta}(x^I-\psi^I))(1-p)$. This determines the expected marginal threshold to success if the sunspot message is "not invest" as the value ψ^I that solves

$$
\begin{aligned}
\psi^I \quad &= \Phi(\sqrt{\beta}(x^I - \psi^I))(1-p) \\
&= \Phi(\sqrt{\beta}(\frac{\alpha+\beta}{\beta}\xi^I - \frac{\alpha}{\beta}y - \psi^I))\,(1-p).
\end{aligned}
\tag{10}
$$

At the switching point ξ^I, an agent is indifferent between following and investing. The payoff from following is $qProb(\theta < \psi^N|\xi^I) + (1-q)\lambda - c$, because "following" implies a successful investment whenever $\theta < \psi^N$. The payoff from investing is $qProb(\theta < \psi^N|\xi^I) + (1-q)prob(\theta < \psi^I|\xi^I)$, because the investment is also successful for a sunspot saying "not invest," if the state is below ψ^I. The indifference condition between following and investing at a posterior of ξ^I is, thus, given by

$$
(1-q)\lambda - c = (1-q)\Phi\left(\sqrt{\alpha+\beta}(\psi^I - \xi^I)\right), \tag{13}
$$

which implies

$$
\psi^I = \xi^I + \frac{\Phi^{-1}(\lambda - \frac{c}{1-q})}{\sqrt{\alpha+\beta}}. \tag{14}
$$

This gives us our second equation. Replacing ψ^I in Equation (10) by (14), and rearranging terms gives

$$\xi^I = \Phi\left(\sqrt{\beta}\left(\frac{\alpha}{\beta}(\xi^I - y) - \frac{\Phi^{-1}\left(\lambda - \frac{c}{1-q}\right)}{\sqrt{\alpha+\beta}}\right)\right)(1-p) - \frac{\Phi^{-1}(\lambda - \frac{c}{1-q})}{\sqrt{\alpha+\beta}}. \tag{15}$$

The point ξ^I is obtained as the intersection between the 45° line and a linear transformation of a cumulative normal distribution (see Figure 3-1). Inequality (12) also ensures the uniqueness of ξ^I.

There is a region of signals for which agents follow the sunspot message if and only if

$$\Delta = \xi^N - \xi^I > 0.$$

Theorem 1. If $\frac{\alpha}{\sqrt{\beta}} \leq \frac{\sqrt{2\pi}}{1-p}$ and $p > 0$, there is a $c^{max} > 0$, such that for all $c < c^{max}$, there is an unique equilibrium where agents follow sunspots when their posterior beliefs are contained in an interval (ξ^I, ξ^N), with $\Delta = \xi^N - \xi^I > 0$.

Proof:

We first show the existence of the equilibrium and then its uniqueness. The proof of existence is structured in three steps.

1. For $\mathrm{p} = 0$ and $\mathrm{c} = 0$, there is no sunspot region. Equations (11) and (15) become identical and since each has a unique solution under condition (12), this implies $\xi^\mathrm{N} = \xi^\mathrm{I}$.

2. Total differentiation of (11) w.r.t. ξ^N and p gives $\frac{d\xi^N}{dp} = \frac{1-\Phi(\cdot)}{1-(1-p)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)}$, which is positive for $\frac{\alpha}{\sqrt{\beta}} \leq \frac{\sqrt{2\pi}}{1-p}$. Total differentiation of (11) w.r.t. ξ^N and c gives $\frac{d\xi^N}{dc} = \frac{-[(1-p)\phi(\cdot)\sqrt{\beta}+1]\frac{1}{\sqrt{\alpha+\beta}}\cdot\frac{1}{q\phi(\cdot)}}{1-(1-p)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)}$, which is negative under the same condition. Similarly, equation (15) yields $\frac{d\xi^I}{dp} = \frac{-\Phi(\cdot)}{1-(1-p)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)} < 0$ and $\frac{d\xi^I}{dc} = \frac{[(1-p)\phi(\cdot)\sqrt{\beta}+1]\frac{1}{\sqrt{\alpha+\beta}}\cdot\frac{1}{(1-q)\phi(\cdot)}}{1-(1-p)\frac{\alpha}{\sqrt{\beta}}\phi(\cdot)} > 0$. This establishes that the sunspot region widens in p and shrinks in c.

3. Thus, for $p > 0$ and $c = 0$, $\xi^N > \xi^I$. For any given value of $p > 0$, if c rises to $(1-q)\lambda$, then Equation (15) implies that ξ^I converges to infinity. If c rises to $(1-\lambda)q$, then Equation (11) implies that ξ^N converges to minus infinity. Hence, for $c \rightarrow \min\{(1-q)\lambda, q(1-\lambda)\}$, $\xi^I > \xi^N$. As (8) and (13) are continuous in c, there exists a $c^{max} \epsilon (0, \min\{(1-q)\lambda, q(1-\lambda)\})$, for which $\xi^I = \xi^N$.

Uniqueness.

Equations (11) and (15) characterize the equilibrium thresholds. Assuming $\frac{\alpha}{\sqrt{\beta}} \leq \frac{\sqrt{2\pi}}{1-p}$, equation (11) has at most one solution, because the derivative of the left-hand side with respect to ψ^N is 1 while the derivative of the right-hand side is smaller than $(1-p)\frac{\alpha}{\sqrt{\beta}\sqrt{2\pi}}$. The same argument guarantees that there is at most one solution ψ^I to equation (15). Thus, if a threshold equilibrium exists, it is unique. Because the game is supermodular, a unique threshold equilibrium implies that there is no other equilibrium. Q.E.D.

3.2.1.4 Global-game selection

Global-game equilibria are used for two purposes: (1) as a descriptive theory for heterogeneous behavior under strategic uncertainty that arises, in particular, in early rounds of a repeated coordination game before agents learn the strategies of others and coordinate their actions; (2) as a refinement predicting one particular equilibrium in the common information game. This refinement is given by the global-game selection (GGS), the limiting equilibrium for private signals becoming infinitely precise. Having derived the equilibrium conditions for finite signal precision, we can now investigate how the thresholds to the sunspot region are affected by $\beta \to \infty$. We will use the GGS as a benchmark for testing the theory in the laboratory. Very precise signals may prevent subjects from following the sunspot or may reduce the sunspot region to an extent that it disappears in the limit. But, the sunspot equilibrium still exists with a very high level of signals precision and, as we show below, the size of the interval of posteriors for which agents follow the sunspot is bound away from zero.

Let us see what happens in the limit when the private signals become very precise, and noise becomes negligible. This corresponds to the case where $\beta \to \infty$. From (11), threshold ξ^N satisfies[18]

[18] Note that $\Phi(-\Phi^{-1}(z)) = 1 - z$.

$$\xi^N \to \overline{\xi^N} = p + (1-p)\Phi\left(-\Phi^{-1}\left(\lambda + \frac{c}{q}\right)\right) = p + (1-p)\left(1 - \lambda - \frac{c}{q}\right). \quad (16)$$

By equation (10), we have

$$\psi^N \to \overline{\xi^N} = p + (1-p)\,(1 - \lambda - \frac{c}{q}). \quad (17)$$

Similarly, from (15), threshold ξ^I converges to

$$\xi^I \to \overline{\xi^I} = (1-p)\Phi\left(-\Phi^{-1}\left(\lambda - \frac{c}{1-q}\right)\right) = (1-p)\left(1 - \lambda + \frac{c}{1-q}\right). \quad (18)$$

By equation (14), we have

$$\psi^I \to \overline{\xi^I} = (1-p)\left(1 - \lambda + \frac{c}{1-q}\right). \quad (19)$$

The difference between equations (17) and (19), gives us the sunspot region at its limit. Thus, the widths of the sunspot region, Δ, converges to

$$\Delta \to \overline{\Delta} = p - c\,\frac{1-p}{q\,(1-q)}. \quad (20)$$

The sunspot region remains positive at its limit as long as the cost of the sunspot is sufficiently small:

$$c^{max} = q\,(1-q)\,\frac{p}{1-p}. \tag{21}$$

The analysis of this limiting case demonstrates that, even when information concerning the underlying fundamental becomes very precise, if the costs of sunspots are sufficiently small, agents will still coordinate on sunspots for some critical values of the fundamental.

3.2.2 Finite number of agents

In applying the model to our experiment, it is convenient to redefine the state variable θ as the number of agents necessary for the success of the investment, because the experiment will have a finite number of agents N. This alters the equilibrium conditions slightly. In this subsection, we provide the solution of the model for a finite number of agents who simultaneously decide whether to invest, follow, or not invest. In the experiment, the payoffs of the game are 58 experimental currency units (ECU) if an investment is successful, 8 ECU if not, and 33 ECU if a player does not invest. So, the profit from an investment being successful is 50 ECU and the opportunity costs for trying to get this profit are 25 ECU. Normalizing payoffs such that the gain from the success of an investment is 1 as in Table 3-1, leads to $\lambda = .5$. The costs of reading the sunspot message were 1 ECU, which amounts to $c = .02$.

3.2.2.1 Common information game

If the number of agents needed for success, θ, is common information, the game can have a unique or multiple symmetric pure-strategy Nash equilibria as in the case with infinitely many agents:

If $\theta \leq 1$, investing is the dominant strategy. Nobody buys the sunspot message, everyone invests and investment is successful;

If $\theta > N$, not investing is the dominant strategy, no one buys the sunspot message and no one invests;

If $\theta \in (1, N]$ there are up to three pure-strategy equilibria characterized by self-fulfilling beliefs: everyone invests, no one invests, and everyone follows the sunspot provided $c \leq min\{(1-q)\lambda, q(1-\lambda)\}$.

3.2.2.2 Global-game with exogenous beliefs in sunspots

As explained in the previous section, we assume that each agent expects that a number $p \in \{0,1, \dots, N\}$ of the other agents are naïve followers, who always choose to buy the sunspot message and follow the action that it indicates, while $1-p$ agents are expected to choose between invest, not invest, and follow, depending on their information about the fundamentals of the game and given their belief in *p* naïve followers.

Applying the global-game approach, assume that state θ follows a normal distribution with mean y and precision α (that is, with a variance of $1/\alpha$). Conditional on state θ, each agent i observes a noisy signal x_i with mean θ and variance β.

They buy and follow the sunspot message if and only if the private signal is between x^N and x^I. A risk-neutral player who receives the marginal signal x^N is indifferent between following and not investing, provided all other agents excluding naïve followers choose to not invest if and only if their signal is above x^N. If the sunspot message is "invest," the probability that the investment is successful is given by the probability that at least $\hat{\theta} - 1 - p$ out of other $N - 1$ non-naïve agents get signals below x^N and choose to follow, where $\hat{\theta}$ is the smallest integer above θ.This can be described by the binomial distribution. The probability that agents get signals below x^N, $Prob(x < x^N|\theta)$, is equal to $\Phi\left((x^N - \theta)\sqrt{\beta}\right)$, where Φ is the standard normal cumulative function. Thus, x^N is the signal x that solves

$$q \int_{-\infty}^{N} f(\theta|x^N)\left(1 - Bin\left(\hat{\theta} - 2 - p, N - 1 - p, \Phi(\sqrt{\beta}(x^N - \theta))\right)\right) d\theta + (1 - \mathrm{q})\lambda - c = \lambda, \tag{22}$$

where $f(\theta|x^N)$ is the normal distribution with mean $(\alpha y + \beta x^N)/(\alpha + \beta)$ and precision $\alpha + \beta$ and Bin is the cumulative binominal distribution. Note that $f(\theta|x^N) = \phi\left(\sqrt{\alpha + \beta}(\theta - \xi^N)\right)$ and $x^N(\xi^N, y) = \frac{\alpha+\beta}{\beta}\xi^N - \frac{\alpha}{\beta}y \Leftrightarrow \xi^N = \frac{\beta\, x^N + \alpha\, y}{\alpha+\beta}$.

In equilibrium at signal x^I, agents are indifferent between following and investing. Thus x^I is the signal x that solves

$$\begin{aligned} q\int f(\theta|x^I)\left(1 - Bin\left(\hat{\theta} - 2 - p, N - 1 - p, \Phi(\sqrt{\beta}(x^N - \theta))\right)\right) d\theta + (1-\mathrm{q})\lambda - c \\ = \mathrm{q}\int f(\theta|x^I)\left(1 - Bin\left(\hat{\theta} - 2 - p, N - 1 - p, \Phi(\sqrt{\beta}(x^N - \theta))\right)\right) d\theta \\ +(1-\mathrm{q})\int f(\theta|x^I)\left(1 - Bin\left(\hat{\theta} - 2, N - 1 - p, \Phi(\sqrt{\beta}(x^I - \theta))\right)\right) d\theta. \end{aligned} \tag{23}$$

Equations (22) and (3) characterize the equilibrium threshold signals. We can simplify these equations to:

$$\int_{-\infty}^{N} f(\theta|x^N)\left(1 - Bin\left(\hat{\theta} - 2 - p, N - 1 - p, \Phi(\sqrt{\beta}(x^N - \theta))\right)\right) d\theta = \lambda + \frac{c}{q}, \tag{24}$$

and

$$\int_{-\infty}^{N} f(\theta|x^I)\left(1 - Bin\left(\hat{\theta} - 2, N - 1 - p, \Phi(\sqrt{\beta}(x^I - \theta))\right)\right) \int d\theta = \lambda - \frac{c}{1-q}. \tag{25}$$

3.2.2.3 <u>Global-game selection</u>

For β converging to infinity, the equilibrium conditions (21) and (22) characterize the GGS that we can use as a refinement theory for the common-information game. Hence, we refer to these thresholds as the "sunspot global-game selection" for the game with common information.

From Basteck, Daniëls, & Heinemann (2013), we know that the GGS can be derived by decomposing the game into two smaller games, in which agents simply decide between the neighboring strategies "invest" and "follow" and between "follow" and "not invest." The GGS of a binary action game is the best response to a uniform distribution of the proportion of other agents taking either action (Morris & Shin, 2003).

So, suppose an agent has a uniform distribution on the number A of the $N-p-1$ other agents who invest unconditionally, while the others are following sunspots. If the message is "invest" all of the other agents invest and the investment is successful if $\hat{\theta} \leq N$. If the message is "not invest" the investment is successful if $1 + A \geq \hat{\theta}$. Here, the success probability is $\frac{N-p-\hat{\theta}+1}{N-p}$.

In the limit, for $\beta \to \infty$, an agent is indifferent between investing and following if and only if

$$q + (1-q)\frac{N-p-\hat{\theta}+1}{N-p} = q + (1-q)\,\lambda - c.$$

$$\Leftrightarrow \frac{N-p-\hat{\theta}+1}{N-p} - \lambda + \frac{c}{1-q} = 0 \tag{26}$$

As $\hat{\theta}$ is a natural number and the agent has almost perfect information about the state, the critical signal x^I, at which an agent switches from investing to following is the integer $\hat{\theta}$, at which the left-hand side of (26) changes its sign, which is the largest integer x^I with $x^I \leq \left(1 - \lambda + \frac{c}{1-q}\right)(N - p) + 1$.

Similarly, suppose an agent has a uniform distribution on the number A of the $N - p - 1$ other agents who follow sunspots, while the others are not investing. If the message is "invest" the investment is successful if $A + p + 1 \geq \hat{\theta}$. Thus, the probability of an investment being successful given $1 + p \leq \hat{\theta} \leq N$ if the message is "invest" is $\frac{N-\hat{\theta}+1}{N-p}$. If the message is "not invest" nobody invests and the success probability is 0 for $\hat{\theta} \geq 1 + p$.

Hence, in the limit, for $\beta \to \infty$, an agent is indifferent between following and not investing if and only if

$$q\,\frac{N-\hat{\theta}+1}{N-p} - q\,\lambda - c = 0. \tag{27}$$

As $\hat{\theta}$ is a natural number and agents are almost perfectly informed about the state variable θ, the threshold signal x^N is given by the integer $\hat{\theta}$ at which the left-hand side of (27) changes its sign, which is the largest integer x^N with $x^N \leq N - \left(\lambda + \frac{c}{q}\right)(N - p) + 1$.

A positive sunspot region requires $x^I < x^N$, which is equivalent to $c < c^{max}$.

If the costs of reading the sunspot message are higher, e.g., for $p = 0$, agents directly switch from "invest" to "not invest." The respective threshold signal x^*, at which they are indifferent, is given by the best response to a uniform distribution on the number of other non-naïve players investing. For $1 \leq \hat{\theta} \leq N$, the probability of success is $\frac{N-\hat{\theta}+1}{N-p}$ if the sunspot is "invest" and $\frac{N-p-\hat{\theta}+1}{N-p}$ if the sunspot is "not invest." Hence, an agent is indifferent between investing and not investing if and only if

$$q\frac{N-\hat{\theta}+1}{N-p}+(1-q)\frac{N-p-\hat{\theta}+1}{N-p}-\lambda=0 \tag{28}$$

As $\hat{\theta}$ is a natural number and agents are almost perfectly informed about the state variable θ, the threshold signal x^* is given by the integer $\hat{\theta}$ at which the left-hand side of (28) changes its sign, which is the largest integer x^* with $x^* \leq N-(1-q)p-(N-p)\lambda+1$.

In the next section, we calculate the theoretical predictions for the experiment.

3.2.2.4 Theoretical predictions for the experiment

A set of parameters governs the theoretical model: $\Theta=\{N,q,y,\alpha,\beta,\lambda,c\}$. For the experiment, the parameters chosen are

$$\Theta=\{8,0.5,4.5,0.16,\beta,0.5,0.02\}$$

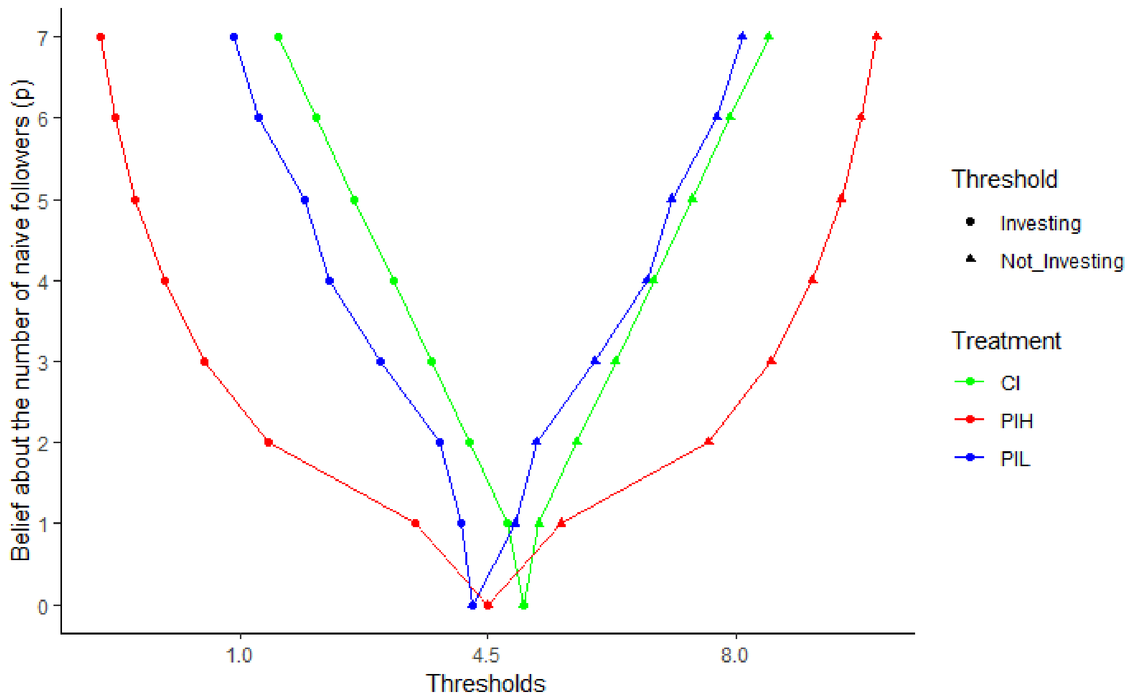
where β varies across treatments: $\beta=4$ for a private information treatment with low noise (PIL) and $\beta=0.25$ for a private information treatment with high noise (PIH). In common information (CI) treatment, θ is common knowledge. The state θ is drawn from a normal distribution with mean $y = 4.5$ and a standard deviation of $1/\alpha^2 = 2.5$. The opportunity cost of investing is $\lambda = .5$. The costs of reading the sunspot message are set at $c = 0.02 < min\{(1-q)\lambda,\, q(1-\lambda)\}$.

For these parameters, the region of multiple equilibria in the common information game is $\theta \in (1{,}8]$. If it is common knowledge that all agents believe that a number p of the other agents will buy and follow the sunspot (independent of their signals), the thresholds of the global game with exogenous beliefs in sunspots open an interval of private signals, for which agents follow the sunspot. These thresholds are indicated by the solutions to (25) and (26) and are displayed in Figure 3-2 for different values of p. The limit case with *p=0* resembles the standard global-game equilibrium, in which no agent follows the sunspot message. Given these parametric assumptions, we can characterize the predictions of the model in the form of the five main hypotheses to be tested in our experiment.

Hypothesis 1: Choices are consistent with threshold strategies.

Hypothesis 1 establishes that subjects will use threshold strategies either switching directly from “invest” to “not invest” or with two thresholds, a smaller one, x^I, where they switch from “invest” to “follow” and a larger one, x^N, where they switch from “follow” to “not invest.” Such threshold strategies are predicted by the theory of global games with and without exogenous beliefs in sunspots.

Figure 3-2 Equilibrium predictions for threshold signals



Hypothesis 2: Sunspot messages will be ignored for all signals.

The standard theory of global games predicts a direct switch from "invest" to "not invest," while our extended global game predicts the existence of an intermediate region, in which subjects follow the sunspot for any $p \geq 1$. Thus, given that H1 is not rejected, Hypothesis 2 discriminates between the two models.

Hypothesis 3: The set of signals for which subjects follow sunspot messages in the PIH treatment is greater than in the CI and PIL treatments.

Hypothesis 4: The set of signals for which subjects follow sunspot messages in the CI treatment is about the same as in the PIL treatment.

If H2 is rejected, we can test for the comparative statics properties of the equilibrium of the global game with exogenous beliefs in sunspots. Figure 3-2 shows the threshold signals at which agents switch between not investing and following the sunspot and between following and investing without looking at the sunspot. The sunspot region in the middle widens as the expected number of naïve followers increases. Between treatments, the sunspot region is wider under the high noise of the private signal (PIH) than in the other two. Thresholds of the PIL treatment are always a bit higher than under common information (CI), but the difference is numerically small. Figure 3-2 depicts the thresholds in PIH and PIL and also in the limit case, the GGS, as a refinement of the CI treatment. For the selected parameters the sunspot region is larger in PIH than in CI and PIL, which implies hypotheses 3 and 4.

Hypothesis 5: On average, subjects expect more players to follow sunspots than actually do follow sunspots.

Finally, the extended global game assumes that all agents behave as if they exogenously believe in some others following sunspots, while in fact all agents best respond to this belief and follow sunspots only for intermediate signals. Thus, the extended game implies that agents (on average) believe that more players follow sunspots than actually do. In the experiment, we elicit beliefs about the total number of players following sunspots. Thus, we can directly test whether this assumption holds.

3.3 The Experiment

We present the results of a series of laboratory experiments designed to test the implications of the sunspot model described in section 2 in comparison to the standard global-game equilibrium. The experiment was conducted at the Experimental Laboratory at Berlin University of Technology from February to May 2016. Subjects were recruited using ORSEE (Greiner, 2004). Most of the subjects were undergraduate students from the university. Sessions were computerized using a z-Tree program (Fischbacher, 2007).

The main experimental studies that relate to our paper are Cabrales et al. (2007) and Heinemann et al. (2004). In particular, our experimental design is closely related to the work of Heinemann et al. (2004) who test the predictions of the model by Morris & Shin (1998) in the laboratory and find that, on average, 92% of observed strategies are consistent with the use of undominated threshold strategies.

The analysis of the results will first address the hypotheses stated in the previous section. This will be followed by a convergence analysis and some additional results that enrich the predictions of our model.

3.3.1 Experimental design

We implemented a between-subjects design that allowed us to directly compare the behavior of subjects across treatments. There were three main treatments: Common Information (CI), Private Information with Low noise signal (PIL), and Private Information with High noise signal (PIH).

Overall, we ran eight sessions with 16 or 24 subjects each, leading to a total of 176 subjects. Subjects were randomly assigned to groups of eight who played the respective game for 12 or 15 periods. Subjects of different groups never interacted with each other, so that the groups give us independent observations. The first two sessions (one with CI and one PIH) had only 12 periods and were completed faster than we expected. We decided to run the remaining sessions with 15 rounds to collect more observations. Table 1-1 summarizes our experimental design.

Table 3-2 Experimental design

Treatment	Signal	Sessions	Total Groups (12 periods, 15 periods)	Subjects
CI	Common information	3	8 (3, 5)	64
PIL	Private information with precision of β=4	2	6 (0, 6)	48
PIH	Private information with precision of β=0.25	3	8 (2, 6)	64
Total		8	22 (5, 17)	176

In each session, there were two or three groups of eight subjects who were randomly matched and remained for all periods. The game was explained using neutral terms. Subjects were told to choose between two actions, A or B, avoiding terminology such as “investment.” Before starting the first period, subjects had a chance to complete a quiz with the answers provided to make sure they understood the instructions. Each session lasted from 90 to 120 minutes and subjects earned, on average, 25€ including a 5€ show-up fee.

In each period, all subjects had to make decisions for 10 independent situations. In each situation each subject had to make three decisions:

- Whether to look at the message which contained either "choose A" ("not invest") or "choose B" ("invest") with equal probabilities. Subjects were informed that the message is random with 50% probability for both versions and that it is the same for all who look at it.
- Choose between A (not invest) or B (invest).
- Guess how many members of the subject's own group (including her- or himself) would look at the message.

For each situation, a state θ (called X in the experiment), the same for all group members, was randomly drawn from a normal distribution with mean 4.5 with a standard deviation of 2.5 (that is, $\alpha = 0.16$). In groups with CI, subjects were informed about θ. In sessions with PIL and PIH, this information was withheld; instead, each subject received a private signal from a normal distribution with a mean of θ and a standard deviation of 0.5 and 2 (that is, a precision of 4 and 0.25) accordingly. The state θ and private signals were displayed with three decimal digits. Looking at the message costed 1 experimental currency unit (ECU). The payoff for alternative A was 33 ECU. The payoff for alternative B was 58 if at least θ group members chose B and eight otherwise. The payoff for guessing the number of readers was also incentivized. For each guess, we paid subjects 12 ECU minus the absolute distance between their guess and the actual number of readers.

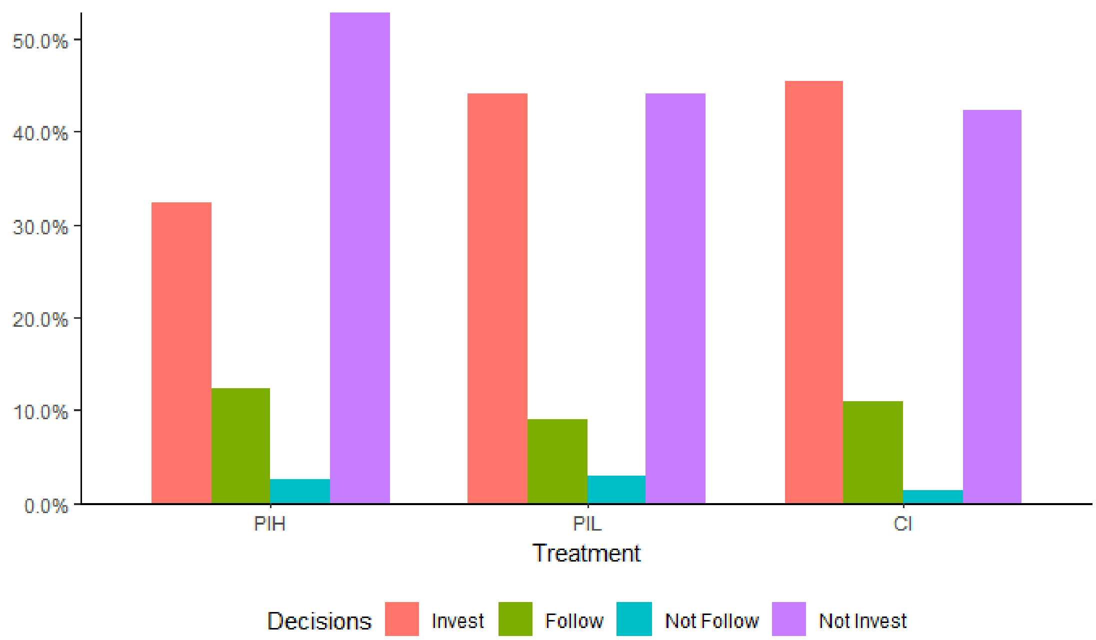
After all subjects in a session completed their decisions in one period, they were informed for each of the 10 situations about the true value of θ (along with their previous signal in treatments PIL and PIH), the text of the message, the number of group members that chose B, whether B was successful, their own payoff for each situation, and also the sum of their payoffs for the 10 situations of this round. They were not informed about how many subjects looked at the sunspot message, nor about their payoff from guessing this number. This information was only provided at the end of the experiment for the one period that was selected for payoffs. Information about previous periods could not be revisited. Subjects were allowed to take notes and many of them did. At the end of each session participants had to fill out a questionnaire.

The final payoff was based on the 10 situations in two randomly selected distinct periods: one period for the payoffs of the games and one period for payoffs from guessing the number of players who looked at the sunspot message. Subjects were paid in private, using the exchange rate of 22 ECU per 1 euro. All of these rules, including the distributions of state variable and signals (called “hint numbers” in the experiment), were described in the instructions (see Appendix) that were read aloud before the start of the experiment.

3.3.2 Results

Figure 3-3 depicts summary statistics for the relative frequencies by which subjects invested without looking at the sunspot message (“Invest”), neither looked at the message nor invested (“Not Invest”), followed the sunspot message (“Follow”), or looked at the sunspot message but took the opposite decision (“Not Follow”). While the theory section assumes that nobody would pay for a sunspot message and then choose the opposite action (“Not Follow”), we found that 2% of decisions actually did so. The reasons may be confusion or curiosity.[19]

Figure 3-3 The relative frequencies of decisions.



In all three treatments, about 10% of all decisions followed the sunspots. Under the high noise of the private signal (PIH), subjects decided more often to “not invest” and less often to “invest” than in the other two treatments. This is in line with previous results on

[19] Since we have a repeated game, subjects might also be interested in learning the sunspot message in order to detect whether the success of the investment was related to the message. Such knowledge might help them to improve their strategies in subsequent rounds. For this reason, we informed them all about the sunspot message during the information phase of each round (after decisions had been taken). It could, thus, not justify paying for the message.

threshold games that subjects are less inclined to take the risky action if there is larger uncertainty about the threshold.

Table 3-3 Blocks of three rounds

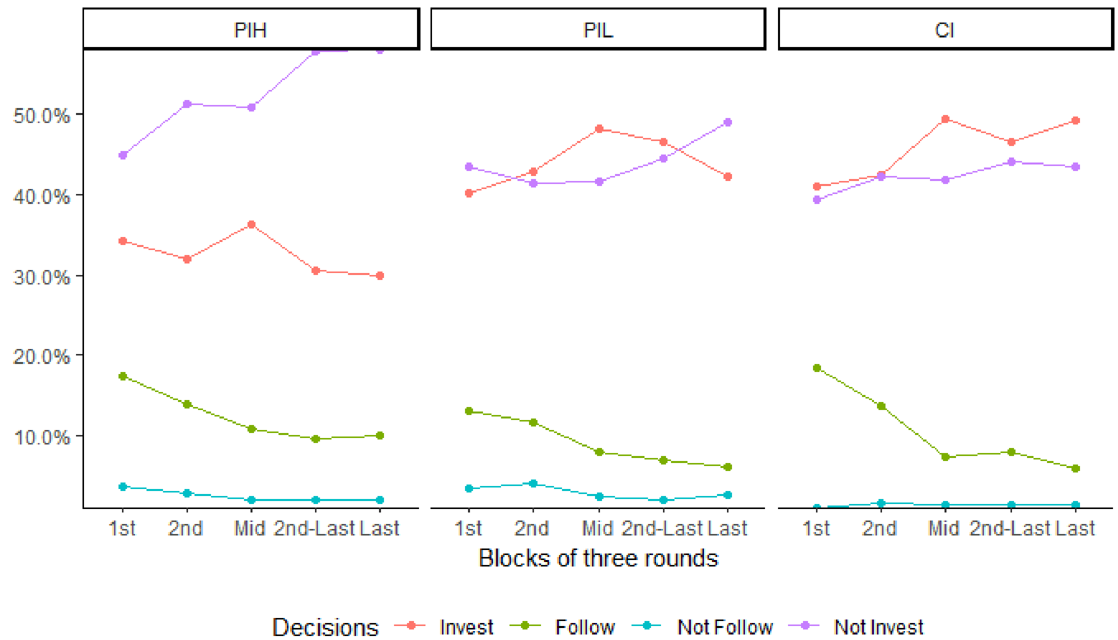
Block	Rounds	Groups
1^{st}	1 to 3	All groups
2^{nd}	4 to 6	All groups
Mid	7 to 9	Only 15-period groups
2^{nd}-last	Second last three rounds	All groups
Last	Last three rounds	All groups

To analyze time trends and learning or coordination effects, we categorize the data in blocks of three rounds. This way of categorizing the rounds serves two purposes. First, it enables us to analyze the data consistently for all groups without differentiating between groups with 12 or 15 rounds. Second, compiling three rounds of data brings a larger number of observations for tests and regression analyses than analyzing each period separately. This makes the regression analysis meaningful while still keeping a sense of time for convergence analysis. To compare subjects' early and late strategies between treatments, we categorize the data as described in Table 3-3. We refer to the first three rounds as the "1^{st} block," the second three rounds as "2^{nd}," the last three rounds as "Last," the second last three rounds as "2^{nd}-Last," and the remaining rounds (in treatments with 15 rounds) as "Mid."

Figure 3-4 shows how the relative frequencies of the four possible combinations of decisions changed over time. In all treatments, the proportion of decisions that followed the sunspots started to decrease from about 15% in the first block of periods to about

7.5% in the last block. The only other strong trend is the share of “Not Invest” in the PIH treatment, which increased from 45% in the first block to 58% in the last block.

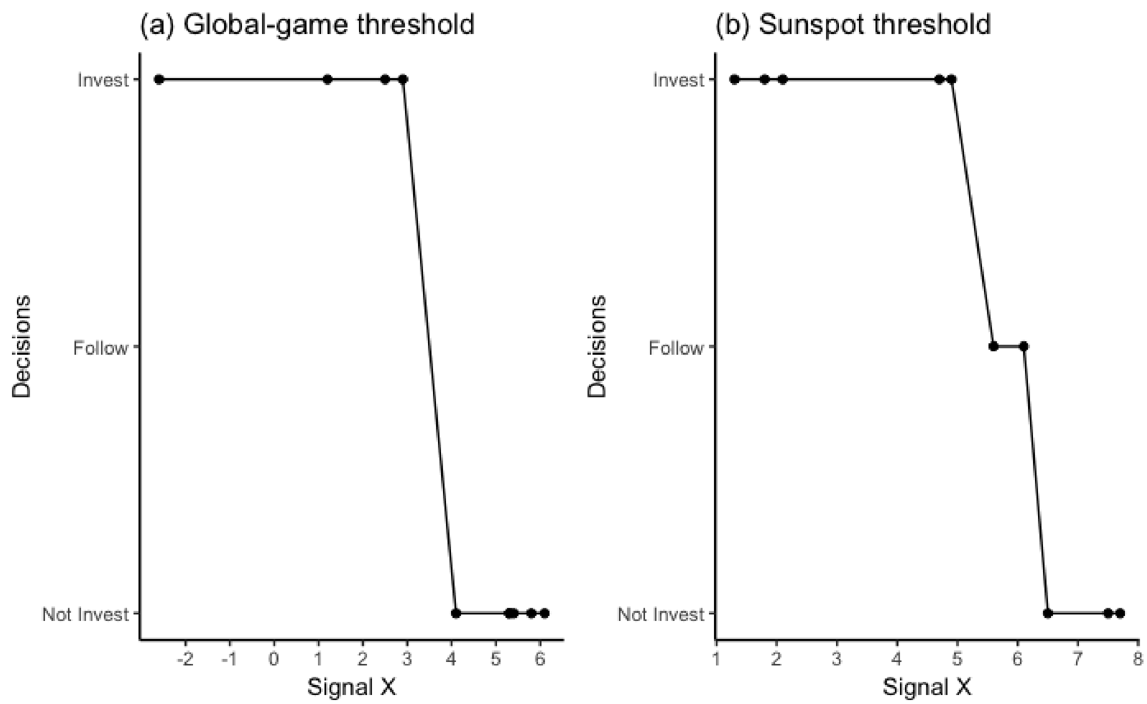
Figure 3-4 The relative frequencies of decisions in blocks of three rounds



The first hypothesis that we derived from the theories states that subjects use threshold strategies. Recall that in every round, subjects chose whether to purchase the message and also chose A or B for 10 randomly chosen unordered situations. We say that a subject’s strategy in a particular period is consistent with the threshold strategies if for low signals the subject invests without looking at the sunspot message, follows the sunspot message for medium signals, and neither looks at the sunspot messages nor invests for high signals without any overlap.

If a subject directly switches from “Invest” to “Not Invest” and does not look at sunspot messages for any signal, we call it “global-game” threshold strategy or, in short, “global-game strategy” as illustrated in panel (a) of Figure 3-5. If a subject follows a threshold strategy looking at sunspots for some intermediate signals, we call it a “sunspot” threshold strategy or in short “sunspot strategy” as illustrated in panel (b) of Figure 3-5.

Figure 3-5 Examples of global-game and sunspot strategies.

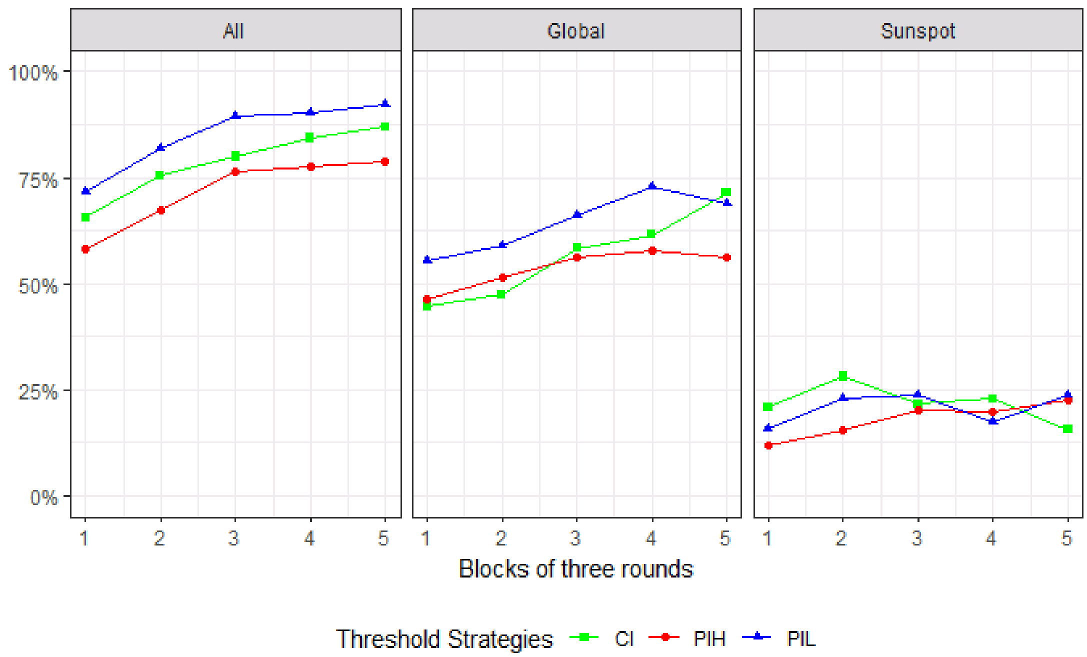


If a subject directly switches from “Invest” to “Not Invest” and does not look at sunspot messages for any signal, we call it “global-game” threshold strategy or, in short, “global-game strategy” as illustrated in panel (a) of Figure 3-5. If a subject follows a threshold strategy looking at sunspots for some intermediate signals, we call it a “sunspot” threshold strategy or in short “sunspot strategy” as illustrated in panel (b) of Figure 3-5.

Our first hypothesis claims that subjects use threshold strategies. We find strong support for this hypothesis in the data. We find that 78% of choices are consistent with threshold strategies. In particular, 58% of subjects use global-game thresholds, and 20% use sunspot thresholds.

Result 1 (threshold strategies) On average, 78% of strategies are consistent with threshold strategies, increasing to 85% in the last three periods.

Figure 3-6 Percentage of threshold strategies.



The ratio of threshold strategies is clearly smaller than in the experiment by Heinemann et al. (2004), where it was 92% on average. We attribute this to the more complicated set-up of our experiment with four possible combinations of choices instead of only two in their experiment. In fact, we find that 94% of strategies that ignored sunspots are threshold strategies, but only 60% of strategies did not ignore sunspots. The difference can be explained by the fact that following sunspot thresholds with two switching points is a less obvious strategy than following one threshold for a player who ignores sunspots.

In addition, subjects who do not use the threshold strategies might have thoughts that are unexplained by our theories and that may also lead them to pay for sunspot messages more often than subjects who behave consistently.

Figure 3-6 shows that the rate of threshold strategies increases over time from approximately 65% in the first three rounds to 85% in the last three rounds. This increase comes mainly from global-game strategies. Global-game strategies increase from approximately 50% in the first three rounds to 65% in the last three rounds. To determine the statistical significance of these findings we look into the regression analysis.

Table 3-4 shows OLS regressions of the impact of rounds on the likelihood of choosing threshold strategies in the different treatments. The dependent variable for the first three panels is the dummy variable of choosing a sunspot threshold strategy. In the last three panels, the dependent variable is the dummy variable of choosing a global-game threshold strategy. Since the observations within each group and also by every subject are not i.i.d, the standard errors are clustered at both the group level and the subject level. Logit and probit regressions yield the same qualitative results. The first panel compares the likelihood of choosing a sunspot strategy between CI (treatment dummy = 1) and PIH (treatment dummy = 0), second panel between PIH (treatment dummy = 1) and PIL (treatment dummy = 0), and the third panel between PIL (treatment dummy = 1) and CI (treatment dummy = 0).

Result 2 (Sunspot strategies) On average, 20% of strategies are sunspot threshold strategies.

Table 3-4 Threshold strategies and rounds.

	Choosing a sunspot or global-game threshold strategy					
	Sunspot PIH (1)	Sunspot PIL (2)	Sunspot CI (3)	Global PIH (4)	Global PIL (5)	Global CI (6)
Round	0.011***	0.003	-0.009**	0.008	0.013***	0.028***
	(0.004)	(0.003)	(0.003)	(0.005)	(0.003)	(0.006)
Constant	0.093***	0.186***	0.284***	0.477***	0.538***	0.355***
	(0.027)	(0.030)	(0.065)	(0.088)	(0.066)	(0.069)
Observations	912	720	888	912	720	888
R^2	0.015	0.001	0.007	0.004	0.014	0.054
F Statistic	13.833***	0.586	6.666***	3.737*	10.409***	50.783***

*Note: The dependent variable is the proportion of sunspot threshold strategies in the first three panels, and the proportion of global-game threshold strategies in the last three panels. The independent variable is the number of the round. The standard errors are clustered at both group level and subject level. OLS estimates with robust standard errors in parentheses. Logit and probit regressions yield similar results. Stars indicate significance levels: *p<0.1; **p<0.05; ***p<0.01.*

Our second hypothesis claims that sunspot messages are ignored for all signals as predicted by the standard theory of global games. The first three panels in Table 3-4 show how the share of sunspot threshold strategies in the different treatments depends on time, here, the period number. The constant plus the coefficient for "round" gives the estimated share in Round 1. The share of subjects who use sunspot threshold strategies in the first period is 10% in Treatment PIH, 19% in Treatment PIL, and 27% in Treatment CI. The constants are significant in all three treatments. The differences between the constants (and thereby the share of sunspot strategies in a hypothetical Period 0) are significant at p=.005 between PIH and CI and at p=.018 between PIH and PIL.

Result 3 (Sunspot convergence) The rate of sunspot threshold strategies in PIH increases over time, while it does not significantly change in PIL and it decreases in CI.

The rate of sunspot strategies shows different convergence trends in each treatment. The rate of sunspot strategies in the PIH treatment significantly rises by 1.1% ($p = 0.006$) for every round. This is surprising as one may expect that subjects eventually converge to the global-game equilibrium of not using sunspot strategies. While PIL does not show any significant trend, the rate of sunspot strategies in the CI treatment significantly falls by .9% ($p = 0.01$) for every round. Given that we have 12 to 15 rounds in each session, the share of sunspot strategies rises to more than 20% in PIH and falls below 20% in CI.

Our result suggests that the convergence analysis depends on the level of signal precision. Although the rate of sunspot strategies decreases over time when the state is common information, this may not be the case if there is private information. In fact, with a high level of noise, the rate of sunspot strategies may increase.

Result 4 (Global-game strategies) On average, 58% of strategies are global-game threshold strategies.

Panels 4 to 6 in Table 3-4 show OLS regressions where the dependent variable is the likelihood of choosing a global-game threshold strategy. The initial rates of global-game strategy in PIH, PIL, and CI treatments are 49%, 55%, and 38%. This rate is significantly larger in PIL than in CI ($p = 0.046$).

Result 5 (Global-game convergence) The rate of global-game threshold strategies in PIL and CI rises over time, while in PIH it does not significantly change over time.

Over time, the share of subjects who choose global-game strategies rises significantly by about 1.3% per round in PIL and by 2.8% per round in CI. Both trends are significant at ($p < 0.01$). This trend is significantly stronger in the CI treatment compared to both PIL ($p=.074$) and PIH ($p=.009$).

Thus, in treatments PIL and CI, the share of global-game strategies increases over time, while the share of sunspot strategies is constant or decreasing. In treatment PIH, the rate of sunspot strategies rises over time, while the rate of global-game strategies has no significant trend.

Our second hypothesis claims that sunspot messages are ignored as predicted by the standard theory of global games. Indeed, we find that 30% of subjects never buy any sunspot messages. However, the other 70% eventually pay for these messages and then follow them in 83% of these cases. We view this as sufficient evidence to reject Hypothesis 2. Hence, we now turn to an analysis of the values of the switching points and how they depend on treatments. As subjects have an incentive to coordinate their actions, individual thresholds of distinct subjects from the same group are not independent (except for the first period). Thus, we estimate the average switching points of all subjects in a matching group and treat this estimate as one independent observation. We will use these estimates to test whether groups converge to a global-game threshold or to sunspot thresholds. They will also allow us to test comparative statics predictions between treatments and the numerical prediction of the respective global-game equilibrium.

By fitting multinomial logistic functions to the pooled data from three periods of a whole group, we can estimate the probabilities with which subjects in this group and in these periods "invest," "not invest," "follow," or "not follow" conditional on the subjects' signals. In this way, the probability of each action varies between zero and 1 while the sum of all probabilities is equal to 1. The odds ratio for each strategy depends on the values of the explanatory variables through:

$$\ln\left(\frac{prob(Invest)}{prob(Not\ Invest)}\right) = a_I + b_I X$$

$$\ln\left(\frac{prob(Follow)}{prob(Not\ Invest)}\right) = a_F + b_F X$$

$$\ln\left(\frac{prob(Not\ Follow)}{prob(Not\ Invest)}\right) = a_{NF} + b_{NF} X$$

where X is the subjects' signal about the state. By fitting the pooled data of a whole group to a multinomial logistic function, we can compute the fitted probabilities as

$$prob(Invest) = \frac{e^{a_I + b_I X}}{1 + e^{(a_I + b_I X)} + e^{(a_F + b_F X)} + e^{(a_{NF} + b_{NF} X)}}$$

$$prob(Follow) = \frac{e^{a_F + b_F X}}{1 + e^{(a_I + b_I X)} + e^{(a_F + b_F X)} + e^{(a_{NF} + b_{NF} X)}}$$

$$prob(Not\ Follow) = \frac{e^{a_{NF}+b_{NF}X}}{1 + e^{(a_I+b_IX)} + e^{(a_F+b_FX)} + e^{(a_{NF}+b_{NF}X)}}$$

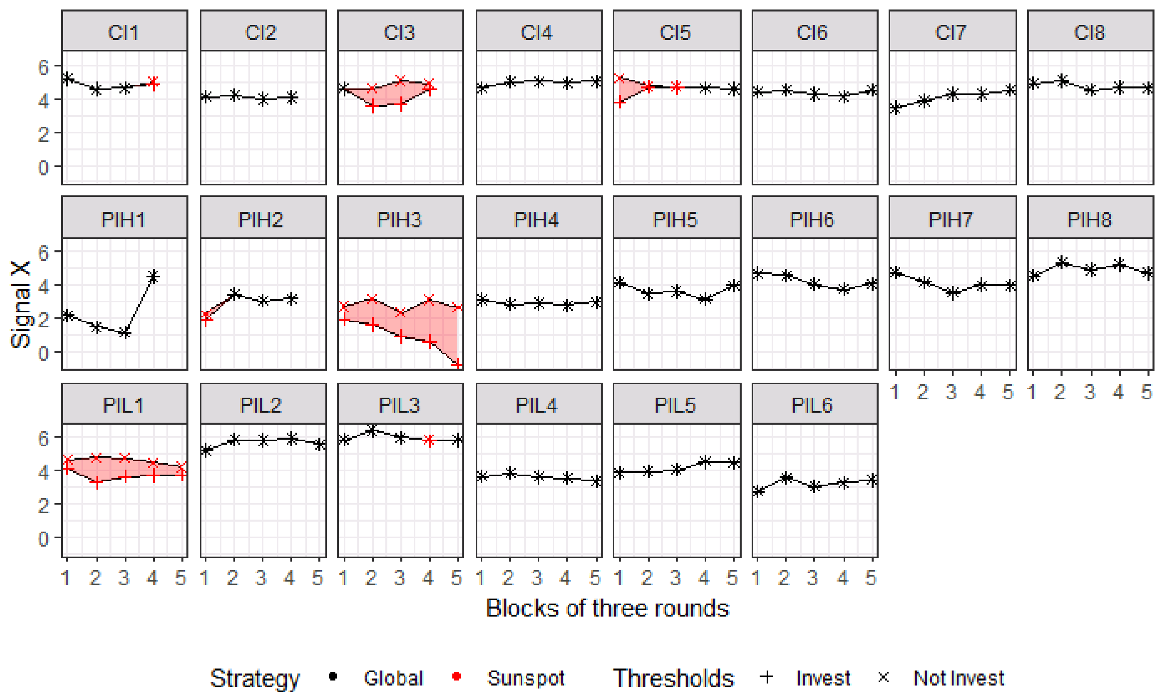
$$prob(Not\ Invest) = \frac{1}{1 + e^{(a_I+b_IX)} + e^{(a_F+b_FX)} + e^{(a_N+b_NX)}}$$

Extending the method employed by Heinemann, Nagel, and Ockenfels (2004) to four potential strategies, we estimate the switching points by the signals at which the most likely action changes from one to another. For low signals, $prob(Invest|X)$ is close to 1 but decreases in X. The probability not to invest rises from 0 to 1 and the probability to follow can eventually exceed both of them for some intermediate signals. If there is a range of signals for which $prob(follow|X) > \max\{prob(Invest|X), prob(Not-invest|X), prob(Not-follow|X)\}$, this range describes the sunspot region. The estimated threshold for switching from "invest" to "follow," X^I, is then given by the smallest value for which $prob(follow|X^I) = prob(Invest|X^I)$. The estimated threshold for switching from to "follow" to "not invest," X^N, is given by the largest value for which $prob(follow|X^N) = prob(Not-Invest|X^N)$.

If both $prob(Follow|X)$ and $prob(Not-follow|X)$ are smaller than $\max\{prob(Invest|X), prob(Not-invest|X)\}$ for all X, the group is said to follow a global-game threshold.

Figure 3-7 displays for each matching group the range of signals (vertical axis), for which the respective strategy is estimated to be most likely. Black curves indicate the evolution of switching points over the four (respectively 5) blocks of periods (horizontal axis). If there is only one switching point then subjects tend to switch from "invest" to "not invest" directly, that is, they coordinate on a global-game threshold strategy. If there are two switching points, the red region between them indicates the range of signals for which subjects are most likely to follow sunspot messages. All the estimated parameters are provided in Table 3-8 in the appendix.

Figure 3-7 Most likely strategies for every group.



Note: The most likely strategy, according to the multinomial logistic regression, is "invest" for signals below the invest threshold, "not invest" for signals above the not-invest threshold, and "follow the sunspot message" for signals in the red area between invest threshold and not-invest threshold.

Result 6 (Estimated thresholds) In approximately one-third of groups, there is a range of signals for which following sunspot messages is eventually the most likely action.

The results show strong differences between the groups in all three treatments. In approximately, one-third of groups, there is a region of signals for which following the sunspot is the most likely action in at least some periods. While groups PIL1 and PIH3 coordinate on sunspots for some range of signals in all blocks of three periods, other groups such PIL3, PIH2, CI1, CI3, and CI5 coordinate on sunspots for at least one block of three periods. The remaining groups (68%) always tend to switch directly from "invest" to "not invest."

The standard deviations of the fitted logistic functions, $\frac{\pi}{b_I\sqrt{3}}$, $\frac{\pi}{b_F\sqrt{3}}$, and $\frac{\pi}{b_{NF}\sqrt{3}}$ are measures of coordination within the group. The higher the parameters b_I, b_F, and b_{NF} are, the smaller the variation of thresholds is between different members of the same group. The overall standard deviation of the fitted logistic functions, $\sqrt{(\frac{\pi}{b_I\sqrt{3}})^2 + (\frac{\pi}{b_F\sqrt{3}})^2 + (\frac{\pi}{b_{NF}\sqrt{3}})^2}$ is an inverse measure of coodination within a group[20].

Result 7 (Coordination convergence) Overall, the coordination within groups increases over time in PIH and CI.

Comparing these estimates between blocks of the same group indicates that the overall standard deviation is decreasing over time in PIH and PIL (Table 3-5). In PIH and CI

[20] Note that if nobody buys a sunspot message then $prob(Follow) = 0$ and $\frac{\pi}{b_F\sqrt{3}}$=0.

treatments, the overall standard deviations within groups are significantly different from zero. Thus, there is room to improve the coordination. And the coordination does get to improve over time. However, in the PIL treatment, the overall standard deviation is never significantly different from zero. This suggests that in some groups there is a high level of coordination from the start.

Result. 8 (Relative frequency I) The set of signals for which subjects might follow sunspot messages in Treatment PIH is approximately three times larger than in treatments PIL and CI.

Table 3-5 The coordination within the group and the time.

	The standard deviation within groups		
	PIH	PIL	CI
	(1)	(2)	(3)
Time	-2.327***	-1.882	-1.755**
	(0.723)	(1.625)	(0.715)
Constant	16.341***	11.839	9.811***
	(3.381)	(7.368)	(2.795)
Observations	38	30	37
R^2	0.194	0.095	0.246
F Statistic	8.662***	2.929*	11.394***

*Note: The dependent variable is the overall standard deviation within a group. The independent variable is time as blocks of three rounds. The standard errors are clustered at the group level. OLS estimates with robust standard errors in parentheses.*p<0.1; **p<0.05; ***p<0.01*

Table 3-6 estimates the impact of signals and rounds on the likelihood of following the sunspot message. Here, we pool the data from all the groups to get an overall estimate of the likelihood subjects will follow the sunspots. The quadratic form of OLS is used because the extended global game predicts that subjects follow the sunspots at intermediate signals around the prior mean of 4.5 (see Figure 3-2). "Signal^2" is the squared deviation of signals from their mean, which is 4.5. In this regression, the linear term "Signal" is accordingly defined as the actual signal minus the prior mean. The OLS estimates show that the linear term is insignificant in all treatments. Thus, there is no bias in looking at sunspots for higher or lower signals.

Table 3-6 The likelihood of following the sunspot message, signal, and rounds.

	Probability to follow the sunspot		
	PIH	PIL	CI
	(1)	(2)	(3)
Signal2	-0.00043	-0.00306**	-0.00281***
	(0.00057)	(0.00125)	(0.00084)
Signal	-0.00658	-0.00203	-0.00156
	(0.00421)	(0.00461)	(0.00193)
Round	-0.00627**	-0.00665***	-0.01256***
	(0.00244)	(0.00075)	(0.00242)
Constant	0.17638***	0.16256***	0.22030***
	(0.03712)	(0.04163)	(0.04152)
Observations	9,120	7,200	8,880
R2	0.01088	0.01726	0.03232
F Statistic	33.43718***	42.12666***	98.82627***

Note: The dependent variable is the following sunspot dummy variable. The independent variables centered signal, centered signal squared, and rounds. OLS estimates with robust standard errors in parentheses. The standard errors are clustered at both the group level and the subject level. Same interpretation holds for logit and probit regressions.

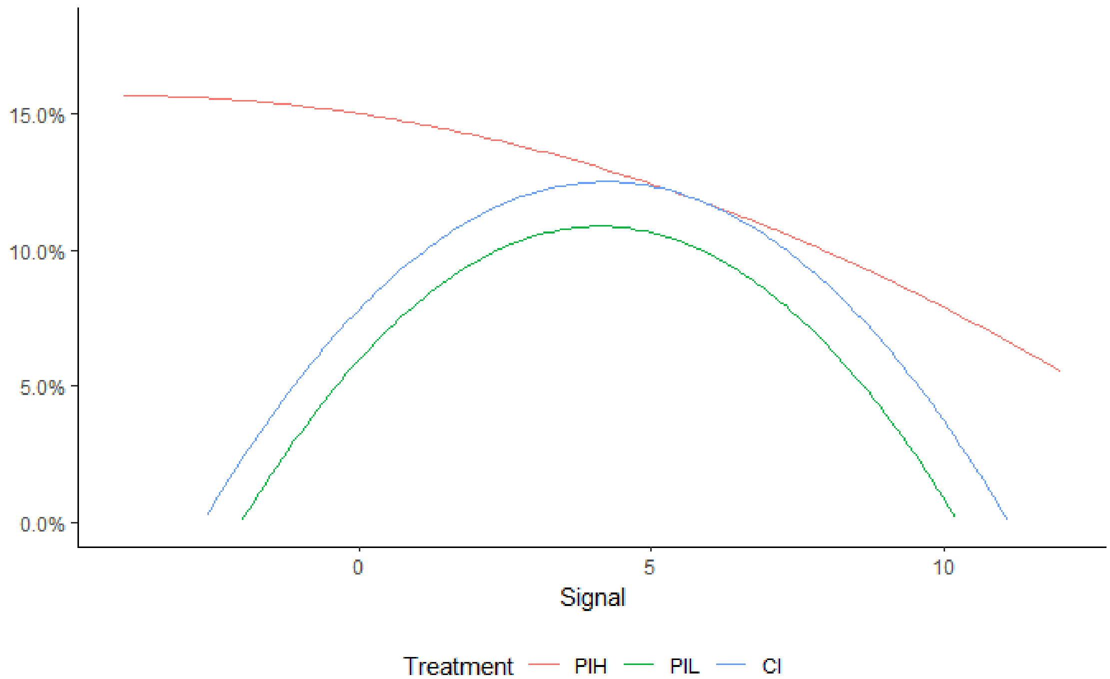
The quadratic term is significant for treatments PIL and CI with negative coefficients, which supports the predictions of the extended global game: the probability of following sunspots is hump-shaped around the prior mean. In Treatment PIH the coefficient of the quadratic term is also negative but insignificant. Here, subjects eventually look at sunspot messages irrespective of their signals. The round number has a significant and negative impact on the likelihood of following sunspots in all three treatments. This indicates that subjects tend to look at sunspots less frequently in the later periods, a finding that we have already seen in Figure 3-4.

Using the estimated coefficients, we can calculate the range of signals for which the probability of following sunspots is positive. For Treatment CI, this range shrinks from [-3, 11] in the first round to [0, 8] in Round 15. For Treatment PIL, the range is [-4, 13] in the first round and [1, 7] in Round 15. This range is largest in treatment PIH: due to the low coefficient on the quadratic term it is given by [-26, 19] in the first round and by [-20, 13] in Round 15. This range for the average rounds are depicted for every treatments in Figure 3-8. Thus, the qualitative comparative statics are consistent with Hypothesis 3.

There is no significant difference in the impact of the signal on the probability of following the sunspot between PIL and CI. Coefficients do not change significantly between CI and PIL treatments. This is consistent with Hypothesis 4.

Summarizing, we see that independent of the treatment only a minority of groups coordinates on a sunspot-threshold strategy. Nevertheless, about 20% of all subjects follow sunspot-threshold strategies and in treatments with CI or private information with low noise (PIL) the probability of subjects following sunspots is positive for a range of signals that is centered around the prior mean of signals. These are the situations with the highest strategic uncertainty.

Figure 3-8 Probability of following sunspot messages.



Note: The probability of following sunspot messages are based on estimated values for an OLS regression similar with averaged rounds.

As we argued in the theory section of this paper, the reason why subjects follow sunspots might be that they put an exogenous probability on other subjects following these sunspots. This reasoning implies that the expected number of subjects following sunspots is higher than the actual number of subjects who follow sunspots (Hypothesis 5).

Result. 9 (Belief overestimation) Subjects expect, on average, 1.79 players to follow sunspots while, on average, 0.87 players follow sunspots.

Table 3-7 Beliefs overestimation

	Beliefs overestimation		
	PIH	PIL	CI
	(1)	(2)	(3)
Signal	0.01851**	0.00313	0.03688**
	(0.00920)	(0.02265)	(0.01540)
Signal2	-0.00831***	-0.01539*	-0.01742**
	(0.00134)	(0.00927)	(0.00707)
Round	-0.02615*	-0.03020	-0.00651
	(0.01490)	(0.01920)	(0.02354)
Constant	1.28140***	1.11674***	1.08606***
	(0.21285)	(0.23877)	(0.25475)
Observations	9,120	7,200	8,880
R2	0.00964	0.01106	0.00951
F Statistic	29.58781***	26.82091***	28.40256***

Note: The dependent variable is the rate of belief overestimation. The independent variables centered signal, centered signal squared, and round. OLS estimates with robust standard errors in parentheses. The standard errors are clustered at both group level and subject level.

This general finding is consistent with Hypothesis 5. Of course, the degree to which subjects overestimate the number of followers differs between subjects and depends on the signals. While in 30% of all decisions subjects expect the right number of players to follow sunspots, in 53% of all decisions subjects overestimate the number of followers. In the remaining 17% of all decisions, subjects underestimate the number of followers. “Belief overestimation” is the difference between subjects’ stated beliefs about the number of followers and the actual number of followers.

Table 3-7 shows the impact of signals and rounds on this difference for all treatments. As in the regressions in Table 3-1, “signal” stands for the actual signal minus its prior mean of 4.5. In all treatments, the rate of belief overestimation is hump-shaped, as indicated by the significant negative coefficients on "signal^2". In treatments PIH and CI, subjects tend to overestimate the number of followers more for larger signals than for smaller signals. Although the coefficients for the round number are negative in all three treatments, they are insignificant in CI and PIL and only marginally significant in PIH. This indicates that belief overestimation is not strongly declining over time. Note that subjects did not get an immediate feedback about the number of followers. They could only infer this from their feedback about the total number of subjects who chose A or B in situations with different realizations of the sunspot message.

3.4 Conclusions

The theory of global games delivers a key solution to coordination games with strategic complementarities by assuming common knowledge of rationality. This paper makes three contributions in that regard. The first two are theoretical. By assuming that agents believe that some fraction of other agents naïvely follows sunspots, we provide a condition for a unique equilibrium in which agents follow costly sunspot messages even with private signals about fundamentals, while the standard theory of global games predicts that behavior is unaffected by sunspots when agents receive private information about fundamentals. Our second theoretical contribution is to address the role of transparency on the thresholds for sunspot-following behavior: under the assumption of an exogenously given belief in naïve sunspot followers, the range of signals for which otherwise rational agents choose to follow sunspots does not disappear if the precision of private signals converges to infinity. As long as the costs for obtaining sunspot messages are sufficiently small, there exists a positive range of fundamentals for which agents follow sunspots even with rather precise private information about these fundamentals. By means of simulation, we have shown that the range of signals for which subjects follow sunspots in equilibrium may widen if private signals get very imprecise. In this respect, transparency about fundamentals may reduce the impact of extrinsic signals on behavior and, thus, central banks or bank supervisors may want to provide sufficient information about economic fundamentals in order to avoid rumors or uninformative signals triggering currency or banking crises.

Our third contribution tests the predictive power of the extended global game in a laboratory experiment. In all information conditions, some subjects use global-game threshold strategies and may eventually coordinate on a common threshold strategy where they follow sunspot messages in situations with high strategic uncertainty. However, most groups converge to classical global-game strategies that neglect sunspots. The comparative statics of the sunspot global-game solution with respect to the level of signal precision cannot be confirmed. This is in line with other experiments on global games like Heinemann et al., (2004) or Szkup & Trevino (2017), who also find that the empirical evidence on responses to the precision of private information does not follow the comparative statics of global-game thresholds. In those papers, more precise information leads to a better coordination on the efficient action, which is “invest” in our game.

Elicited beliefs reveal that subjects overestimate the number of subjects who follow sunspots by about 100% on average. This is in line with the assumptions of our extended global game and presumably drives subjects to follow sunspots. Fearing that others follow sunspots eventually drives the coordination toward a sunspot threshold strategy, even though such a strategy is not a Nash equilibrium. From our theoretical analysis and the experiment we conclude that in environments with high strategic uncertainty, payoff-irrelevant signals can affect behavior even if they are costly to obtain and not expected to be publicly observed.

The overestimation of sunspot-following behavior and the actual proportion of subjects who follow sunspots are independent of the level of noise. Thus, no amount of transparency can prevent agents from following sunspots if they are fearful of others doing so. In this regard, the interaction between the fear that others might follow sunspots and the historic relation between sunspot messages and the final outcome as an indicator of the message's credibility becomes crucial, and how public announcements can influence this interaction is a key question for future research.

3.5 Appendix

3.5.1 Multinomial logistic estimation

Table 3-8 displays the results of multinomial logistic regressions to estimate parameters and standard deviation of individual thresholds in each group for every block of three rounds.

Table 3-8 Multinomial logistic regression

Group	Time	aI	bI	aF	bF	aNF	bNF	Overall sd

Group	Time	aI	bI	aF	bF	aNF	bNF	Overall sd
CI1	1	2.569	-0.497	0.666	-0.154	NA	NA	0.943
CI1	2	4.050	-0.891	2.349	-0.626	-4.203	0.322	2.059
CI1	3	6.807	-1.473	5.052	-1.214	1.691	-0.832	3.776
CI1	4	12.007	-2.424	7.906	-1.580	-5.132	0.371	5.291
CI2	1	3.166	-0.773	-2.400	-0.064	NA	NA	1.408
CI2	2	3.607	-0.863	-2.088	-0.251	NA	NA	1.629
CI2	3	5.264	-1.332	-1.889	-0.339	NA	NA	2.493
CI2	4	5.331	-1.316	-1.856	-0.580	NA	NA	2.608
CI3	1	6.650	-1.453	4.058	-0.890	2.649	-1.314	3.903
CI3	2	9.281	-2.334	4.219	-0.914	2.077	-1.033	4.917
CI3	3	8.011	-1.871	4.240	-0.838	4.310	-1.352	4.455
CI3	4	16.327	-3.434	10.128	-2.075	11.233	-2.586	8.657
CI4	1	2.525	-0.546	0.824	-0.342	-1.829	-0.170	1.209
CI4	2	7.853	-1.568	3.060	-0.667	3.618	-1.307	3.895
CI4	3	38.492	-7.663	30.624	-6.109	32.777	-7.426	22.303
CI4	4	39.369	-7.995	29.800	-6.160	8.592	-1.995	18.661
CI4	5	44.350	-8.820	3.310	-1.103	1.357	-0.955	16.214
CI5	1	4.168	-0.927	2.349	-0.448	1.971	-1.513	3.319
CI5	2	6.226	-1.316	3.677	-0.774	1.687	-0.648	3.008
CI5	3	11.953	-2.557	7.268	-1.552	6.790	-1.994	6.521
CI5	4	25.093	-5.413	11.450	-2.511	9.472	-2.657	11.848
CI5	5	29.423	-6.462	16.068	-3.629	21.232	-5.046	16.263
CI6	1	3.591	-0.818	0.553	-0.462	-1.265	-0.551	1.976
CI6	2	4.758	-1.069	NA	NA	NA	NA	NA
CI6	3	9.368	-2.196	0.323	-0.987	0.013	-0.916	4.672
CI6	4	4.329	-1.046	-2.082	-0.536	NA	NA	2.132
CI6	5	4.451	-1.121	NA	NA	NA	NA	NA
CI7	1	1.914	-0.555	0.720	-0.328	-1.826	-0.399	1.374
CI7	2	3.152	-0.817	0.803	-0.495	NA	NA	1.733

Group	Time	aI	bI	aF	bF	aNF	bNF	Overall sd
CI7	3	3.416	-0.803	1.205	-0.758	NA	NA	2.002
CI7	4	3.941	-0.923	2.400	-0.922	-1.915	-0.333	2.442
CI7	5	4.386	-0.975	2.452	-1.020	-1.213	-0.716	2.871
CI8	1	4.205	-0.858	2.268	-0.525	-1.226	-0.358	1.936
CI8	2	3.807	-0.754	1.551	-0.380	NA	NA	1.531
CI8	3	3.815	-0.846	1.463	-0.479	0.720	-0.566	2.041
CI8	4	6.542	-1.401	1.078	-0.490	0.448	-0.640	2.932
CI8	5	6.592	-1.422	2.536	-0.847	0.162	-0.955	3.466
PIH1	1	0.848	-0.394	-1.869	-0.114	NA	NA	0.744
PIH1	2	1.425	-0.983	-4.780	0.044	-9.460	0.541	2.037
PIH1	3	1.452	-1.302	-2.977	-0.695	-5.282	0.130	2.687
PIH1	4	1.107	-1.573	NA	NA	NA	NA	NA
PIH2	1	0.600	-0.282	0.392	-0.171	-1.188	-0.376	0.907
PIH2	2	1.882	-0.547	1.258	-0.385	-1.130	-0.480	1.494
PIH2	3	1.292	-0.424	0.100	-0.215	-0.464	-0.534	1.297
PIH2	4	1.991	-0.631	0.934	-0.417	-0.834	-0.247	1.444
PIH3	1	1.213	-0.526	0.708	-0.262	-4.346	-0.079	1.075
PIH3	2	2.088	-1.061	0.835	-0.265	-2.634	-0.105	1.993
PIH3	3	1.466	-1.065	0.844	-0.363	-2.689	-0.239	2.086
PIH3	4	2.593	-1.249	2.290	-0.737	-1.205	-0.469	2.764
PIH3	5	1.446	-1.053	1.753	-0.664	-2.678	-0.124	2.270
PIH4	1	1.950	-0.629	-0.184	-0.187	-0.134	-0.487	1.482
PIH4	2	1.898	-0.669	-0.431	-0.245	-1.835	-0.447	1.526
PIH4	3	2.623	-0.903	0.131	-0.503	-1.073	-0.563	2.134
PIH4	4	1.860	-0.669	-1.117	-0.268	-2.969	-0.253	1.386
PIH4	5	2.261	-0.762	-0.230	-0.353	-1.995	-0.317	1.628
PIH5	1	1.857	-0.449	0.280	-0.333	0.067	-0.596	1.482
PIH5	2	1.231	-0.355	0.110	-0.415	-1.200	-0.277	1.111
PIH5	3	1.961	-0.544	0.388	-0.368	0.100	-0.537	1.539
PIH5	4	2.065	-0.658	1.013	-0.451	-0.441	-0.513	1.720

Group	Time	aI	bI	aF	bF	aNF	bNF	Overall sd
PIH5	5	4.962	-1.254	2.918	-0.921	2.210	-1.032	3.386
PIH6	1	3.033	-0.648	0.643	-0.498	0.229	-0.686	1.935
PIH6	2	3.818	-0.835	-0.239	-0.414	-0.019	-0.554	1.967
PIH6	3	5.180	-1.288	1.735	-0.811	0.167	-1.132	3.440
PIH6	4	5.404	-1.444	0.733	-0.610	-0.054	-0.879	3.260
PIH6	5	5.279	-1.296	0.518	-0.545	-0.676	-0.823	2.955
PIH7	1	1.534	-0.325	0.664	-0.142	-0.424	-0.169	0.712
PIH7	2	3.033	-0.728	1.093	-0.297	-0.389	-0.211	1.476
PIH7	3	2.982	-0.850	-0.137	-0.232	-1.481	-0.288	1.681
PIH7	4	6.498	-1.629	0.695	-0.402	1.194	-0.629	3.251
PIH7	5	4.376	-1.104	0.754	-0.417	-0.566	-0.448	2.290
PIH8	1	2.119	-0.469	-0.143	-0.151	-0.620	-0.427	1.182
PIH8	2	5.638	-1.055	0.326	-0.280	1.967	-0.809	2.464
PIH8	3	6.946	-1.417	-1.316	-0.332	NA	NA	2.640
PIH8	4	8.632	-1.655	1.706	-0.685	NA	NA	3.249
PIH8	5	11.169	-2.369	1.636	-0.725	NA	NA	4.494
PIL1	1	5.926	-1.364	2.134	-0.457	-1.850	-0.045	2.610
PIL1	2	5.962	-1.570	2.463	-0.509	-3.120	-0.054	2.995
PIL1	3	8.842	-2.004	6.471	-1.356	-0.071	-0.320	4.427
PIL1	4	11.451	-2.673	8.267	-1.822	-5.325	0.370	5.906
PIL1	5	9.967	-2.427	7.208	-1.696	-0.291	-0.289	5.395
PIL2	1	7.507	-1.433	4.717	-0.976	-1.403	-0.298	3.190
PIL2	2	13.146	-2.235	6.556	-1.194	2.319	-0.715	4.776
PIL2	3	15.172	-2.599	2.251	-0.585	4.692	-1.068	5.205
PIL2	4	16.997	-2.855	-0.104	-0.315	NA	NA	5.210
PIL2	5	40.521	-7.238	2.569	-0.483	19.816	-3.828	14.876
PIL3	1	7.876	-1.339	4.427	-0.817	3.914	-0.869	3.251
PIL3	2	26.362	-4.085	19.929	-3.145	22.906	-3.776	11.591
PIL3	3	19.992	-3.320	13.219	-2.378	14.321	-2.788	8.968
PIL3	4	55.190	-9.431	29.610	-5.033	-0.947	-0.320	19.398

Group	Time	aI	bI	aF	bF	aNF	bNF	Overall sd
PIL3	5	13.376	-2.286	4.459	-1.025	2.236	-0.826	4.784
PIL4	1	3.905	-1.061	1.230	-0.566	0.826	-0.754	2.575
PIL4	2	7.651	-1.978	1.694	-0.674	3.696	-1.298	4.462
PIL4	3	8.173	-2.235	3.040	-0.987	-1.423	-0.194	4.446
PIL4	4	4.405	-1.228	0.969	-0.665	1.310	-0.773	2.895
PIL4	5	7.322	-2.149	-0.692	-0.383	2.360	-0.964	4.328
PIL5	1	4.433	-1.138	1.065	-0.781	-0.542	-1.024	3.116
PIL5	2	12.001	-3.019	4.056	-1.612	2.546	-1.326	6.657
PIL5	3	16.371	-4.018	6.741	-2.336	NA	NA	8.429
PIL5	4	17.993	-3.953	9.128	-2.816	NA	NA	8.804
PIL5	5	26.235	-5.958	NA	NA	NA	NA	NA
PIL6	1	1.408	-0.505	-0.016	-0.403	-1.090	-0.384	1.364
PIL6	2	3.168	-0.881	1.169	-0.550	0.802	-0.520	2.107
PIL6	3	3.977	-1.293	-0.089	-0.504	-1.249	-0.539	2.701
PIL6	4	5.502	-1.659	1.991	-1.020	0.425	-0.797	3.817
PIL6	5	8.579	-2.484	1.497	-0.788	3.719	-1.621	5.567

3.5.2 Instructions

[All Treatments]

General information

This is an experiment in economic decision-making that gives you a chance to earn money. This will be paid to you privately at the end of the experiment. We ask that you do not communicate with each other from now on. If you have a question, please raise your hand.

You are randomly divided into three groups of 8 participants, which will persist for the duration of the experiment. The rules are the same for all participants. The experiment is divided into 15 independent rounds. Each round consists of a decision-making and an information phase. In the decision phase of each round you will be presented with 10 games in which you have to make three decisions each:

- whether to view a message,
- whether to choose A or B
- What is your guess about the number of participants in your group that read the message?

At the end of the 15 rounds, 2 rounds will be randomly chosen to determine your payouts.

Rules of the games:

The rules are the same in all games.

Random processes

In each game, a number X is randomly selected. This number X is the same for all participants in your group. The probability distribution of X looks like this:

Figure 1: Probability density function of X

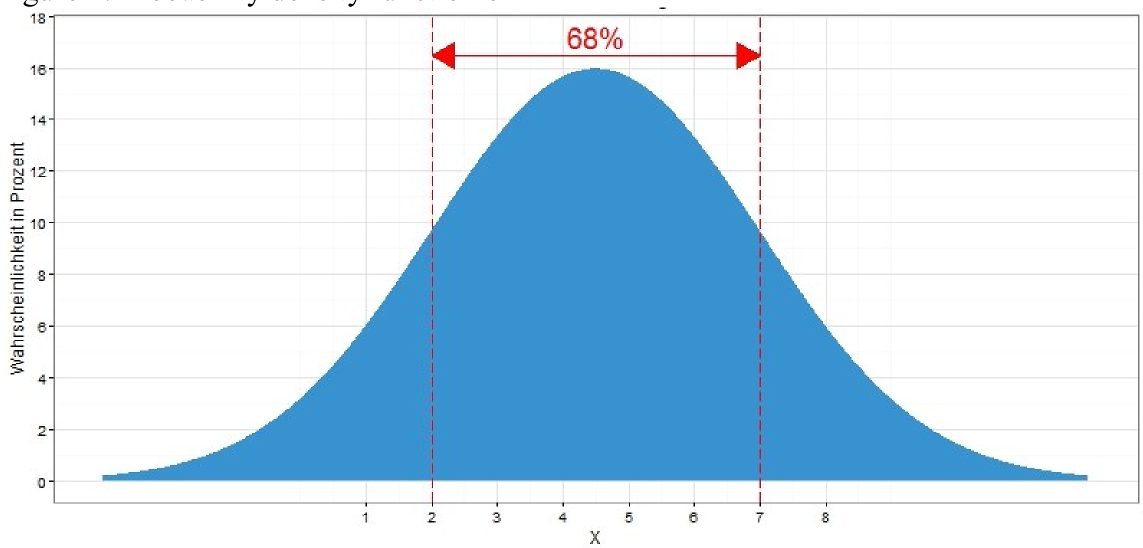


Figure 1 shows the density function of the number X. This density function is a normal distribution with expectation 4.5 and a standard deviation of 2.5. Figure 1 shows that in 68% of all cases, the number X is between 2 and 7. Numbers closer to 4.5 are more likely than numbers farther from 4.5.

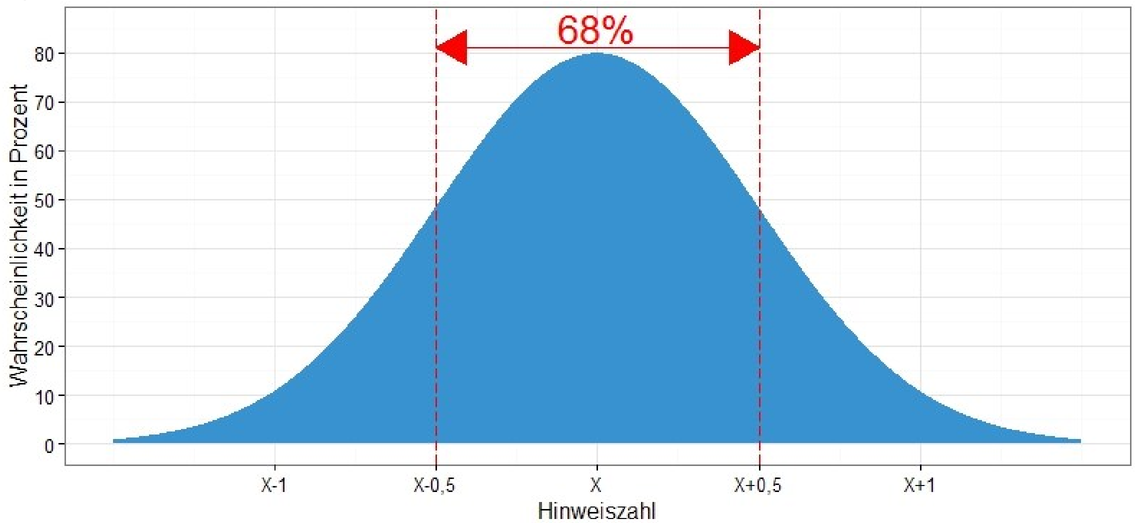
[Only in private treatments]

At the moment of your decision, you do not know what number X is drawn. However, each participant receives a hint about the unknown number X. A hint is a hint number that is normally distributed around the true number X.

The distribution of the hint numbers is a normal distribution with a mean value X and a standard deviation of [PIL: 0.5 /PIH: 2]. In 68% of cases, the hint number falls between [PIL: X-0.5 /PIH: X-2], and [PIL: X+0.5 /PIH:X+ 2].

This means that the hint number can take any value. However, the hint numbers closer to the unknown number X are more likely than the hints further away from X. If the *unknown number is X=4.32 then your hint number is taken from a distribution with mean 4.32 and standard deviation [PIL: 0.5 /PIH: 2]. So, with a probability of 68%, your hint number will be between [PIL: 3.82 and 4.82 /PIH: 2.32 and 6.32].*

Figure 2 shows the distribution of hints for any number X.



Conversely, the number X can take any value, but the numbers that are closer to your hint number are more likely than the numbers farther from the hint number.

The hint numbers are drawn independently from the same distribution for each participant. Therefore, different participants will usually receive different hint numbers.

[In all treatments]

In addition, the computer generates a message in each game. With a 50% probability, the message is “Choose A,” with a 50% chance the message is “Choose B.” You can view the message for a fee. The text of the message is the same for all participants who look at it.

The message is generated purely by chance and is independent of the number X [PIL and PIH: and the hint numbers].

Decisions:

Each participant has the opportunity to read the message by clicking on "Read message." This will cost 1 Experimental Currency Unit (ECU). The text is the same for all participants, but only those participants who pay 1 ECU can see it.

Each participant must choose between A and B.

Each participant makes a guess about how many of the 8 participants (including yourself) have selected "Read Message."

If you choose A, you will be credited ECU 33. The amount will be reduced to 32 ECU if you read the message. This payout is the same in all games, overall rounds, and for all participants.

If you choose B, your payout will depend on how many of the other participants have chosen B in the same game and how big the unknown number X is. If at least X members of your group opt for B then Action B is successful and you get 58 ECU. If less than X group members choose B, then B is unsuccessful and you receive 8 ECU. The payouts are reduced to 57 or 7 ECU if you have read the message.

Note:

If the unknown number X is less than or equal to 1, then action B succeeds regardless of the decisions of the other participants.

If the unknown number X is greater than 8, then action B is unsuccessful even if all 8 participants choose B.

[Only in CI: The number X is given with 2 decimal places. Since at least X participants must choose B to be successful, you must round X to the next highest whole number to get the required number of B decisions.]

In each game, you will also be asked how many of the 8 participants (including yourself) have chosen "Read message." Here, you can enter numbers from 0 to 8. You will get ECUs for your guess. The closer you are to the true number of people who have chosen "Read message" the more points you get. Your payout is:

12 ECU minus the absolute amount of the difference between your guess and the true number of participants who read the message

12 ECU -| *the true number of those who choose "Read message" - your guess* |.

For example, if you do not read the message, but suspect that 4 of the other participants have selected "Read message," while in fact, only 2 participants have read the message, the absolute difference is 2 and you will therefore receive 10 ECU for your guess.

If you have made your decisions for A or B and have entered your guesses, please click on the red OK button to submit your decision.

After all participants have made their decisions for the 10 games and clicked on the red OK button, the round is over and the next round follows.

At the end of the 15 rounds, one round is randomly selected. You will receive the payout of your decisions between A and B for this round. From the remaining 14 rounds, one more round is randomly selected in which you receive your payout for the guesses about the number of participants who have read the message.

The rounds to be paid out will be communicated to you after the 15 rounds have expired. The selection of the rounds to be paid out is purely random and does not depend on your decisions. That means any decision you make may be relevant to your fee.

Information after each round:

Each participant receives information about the 10 different games after each round:

[In PIL and PIH: your hint]

[In PIL and PIH: the previously unknown] number X,

the text of the message,

how many participants (including you) opted for B

whether action B was successful,

your own payout, which results from your decision between A and B,

You will not receive information about how many participants read the message. You will receive this information only after the last round and only for the round that will be paid out.

Example:

The number of participants is eight. The unknown number X that was drawn is 4.28.

The hint numbers of the participants are: 3 .12, 4.35, 3.96, 4.60, 3.88, 5.96, etc.

The message is “Select B.”

Three participants read the message. This will cost them 1 ECU each.

Two of the participants choose A, the other six take B.

In order to receive a positive payout, at least 4.28, i.e., 5 participants have to choose B. Since 6 participants have chosen B, each of the B-decision-makers receives 58 ECU. The participants who have chosen A receive 33 ECU. For those who read the message, the payouts are reduced by 1.

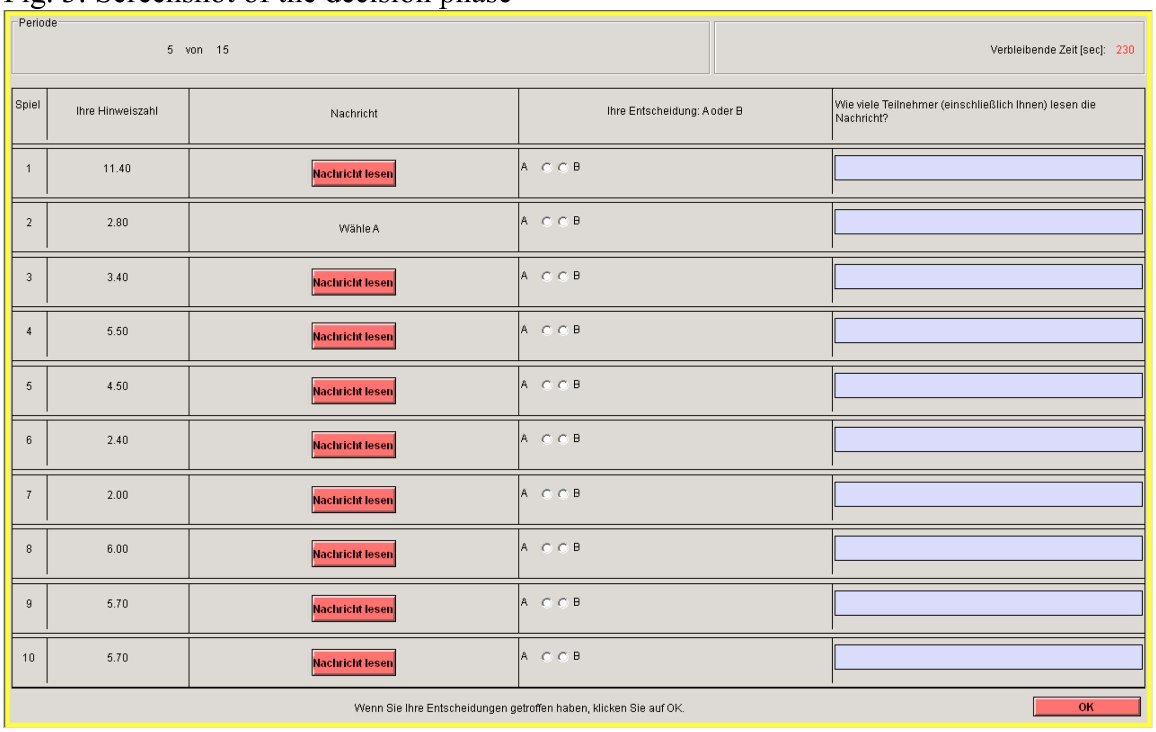
[In PIH and PIL: Keep in mind that you do not know the true value of X, but you will only get a hint number that approximates X. You should also note that the text of the message is neither related to the true value of X nor to the hint number. Therefore, you can never predict exactly how many of the other participants choose B.]

[In CI: Note that the text of the message is not related to the value of X.]

Instructions for the PC:

Each round is divided into a decision phase and an information phase. In the decision phase, the current number of rounds will be displayed on the screen in the header. Below is a table with 10 games. For each game you will be given the value of the [PIH and PIL: hint /CI: X] number. In the next column you have the possibility to read the message by clicking on the corresponding button. As soon as you click on the “Read message” button, you will see the text “Choose A” or “Choose B.” You cannot undo this decision. In the fourth column you have to choose between A and B. In the last column, enter your guess about the number of participants (including yourself) who have read the message. If you have made your decisions for all 10 games, please click the red OK button. You can change your decisions until you have clicked the OK button. If you have exceeded the time limit, you will be advised to make your decisions.

Fig. 3: Screenshot of the decision phase



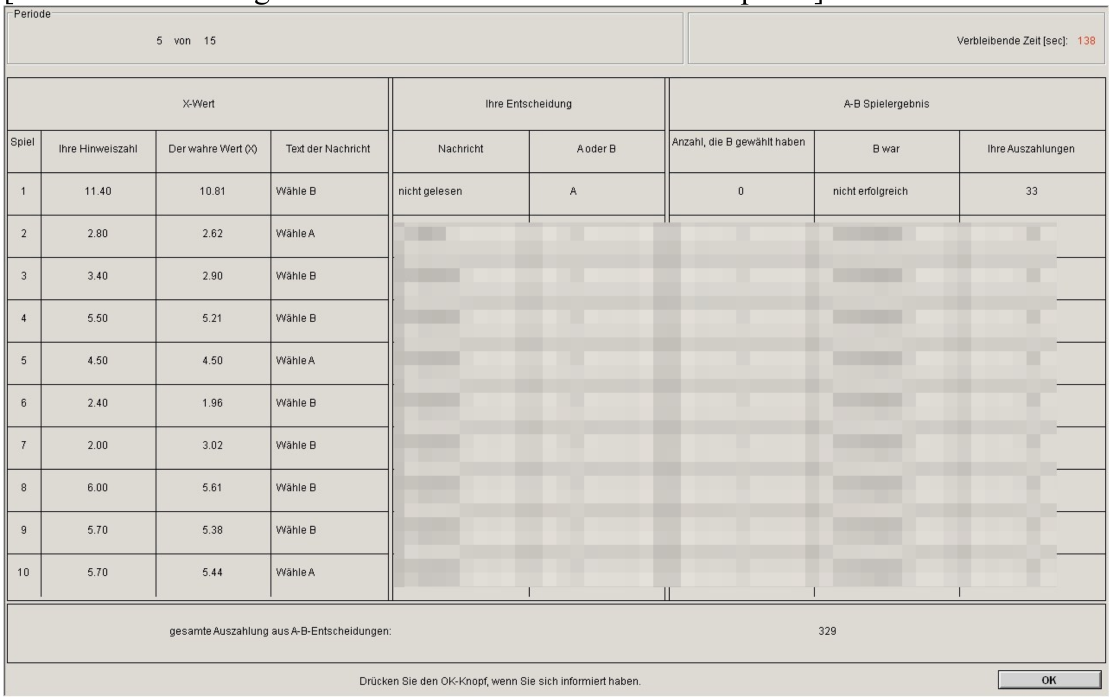
Once all participants have clicked the OK button, the decision phase of a round is completed and the information phase begins. A new table consisting of 3 parts will be displayed on your screen. The first part, titled “X value,” gives [PIH and PIL: your personal hint number,] the unknown value X and the text of the message for each game.

The next part, consisting of 3 columns, with the heading “your decision,” indicates whether you have read the message and whether you have chosen A or B.

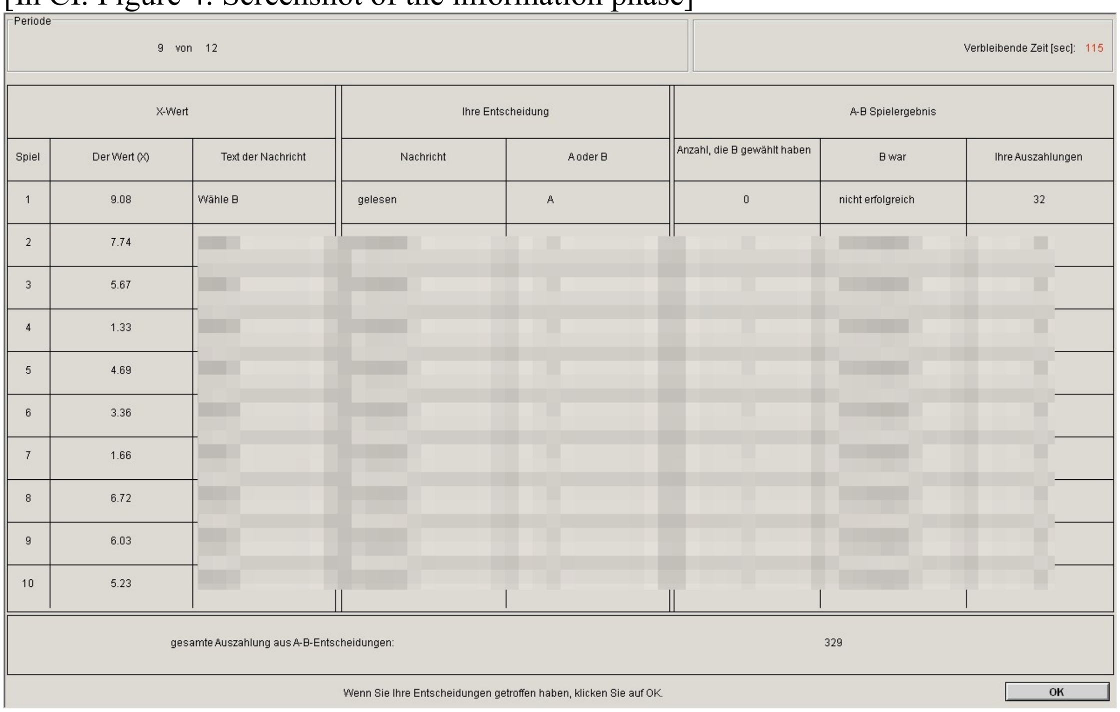
The last part titled “A-B game outcome” indicates the number of participants who have chosen B, whether B was successful, and your payoff for your decision between A and B (in ECU) in case this round will be selected to be paid out.

In the header of the screen, you will see a clock running backward. You have 120 seconds to look at the information. When the time is up, the next round starts. You can also finish the information phase in advance by clicking the gray Ok button. However, you can then no longer inform yourself about the result of the previous round.

[In PIH and PIL: Figure 4: Screenshot of the information phase]



[In CI: Figure 4: Screenshot of the information phase]



Questionnaire:

At the end of the experiment we kindly ask you to complete a questionnaire. Your personal information will be kept strictly confidential and will only be used for research purposes.

Payout:

At the end of the 15 rounds, one round is randomly selected for which you will receive the payout for your decisions between A and B. The cost of reading the message will be charged here. From the remaining 14 rounds, one more round is randomly selected for which you receive your payout for the guesses about the number of participants who have read the message.

The selection of the rounds to be paid out is purely random and does not depend on your decisions.

Your final payment is the sum of the payouts from the selected rounds. You will receive one euro for every 22 ECU.

Exercises:

To understand the game better, you should first answer the following questions. The correct answers will be provided below. If you have questions, please raise your hand and one of the instructors will help you.

1 The unknown number X is 5.48. Of the other 7 participants, 3 opt for A and 4 for B. You do not read the message.

a) What is your payout if you choose A? ____

b) What is your payout if you choose B? ____

2 The unknown number X is 2.69. You choose B. How many participants need to choose B for B to succeed? ____

3 [In PIH and PIL:] Your clue number is 7.14, you read the message and choose A. What is your payout? ____

4 You click on "read message" and assume that 2 other participants read the message as well. What is the expected number of participants (including you) who read the message?

5 You suspected that a total of 3 participants read the message. 5 participants (including you) read the message. What is your payout on the assumption? ____

Indicate whether the following statements are true or false:

6 All players reading the message see the same text.

7 The text of the message depends on the unknown number X

8 [In PIH and PIL:] The text of the message depends on your clue number.

9 The unknown number X is the same for all participants in your group.

10 [In PIH and PIL:] All participants receive the same clue number.

11 When I have made my 10 decisions between A and B and entered the 10 guesses, the decision phase is complete.

Solutions and explanations:

1 a) 33. The payout for A is always 33 (minus 1 if you read the message).

b) 8 . Since (with you) fewer than X participants have opted for B, B is not successful.

2 at least 3.

3 [In PIH and PIL:] 32. The payout for A is equal to 33 (minus 1 because you have read the message).

4 3. That is two others and you.

5 10. Five participants have read the message with you. You suspected 3. The Difference is 2. Your payout is therefore 12 - 2 = 10.

6 True. The text is the same for all participants.

7 Wrong. The text of the message is independent of X.

8 [In PIH and PIL:] Wrong. The text of the message is independent of your clue number.

9 True.

10 [In PIH and PIL:] Wrong. The numbers of the participants are drawn independently.

11 Wrong. To complete the decision phase, you still need to click on the red OK button click.

CONCLUSION

In the present experiments we allow subjects to either avoid undesirable information or obtain irrelevant information. In the first chapter, we find that information avoidance regarding the consequences of actions on others is sensitive with respect to the payoff-irrelevant changes of the timeline of decision-making and not sensitive with respect to the payoff-relevant changes of the underlying probability. This result suggests that when deciding whether to avoid information regarding the consequences of actions on others, people do not engage in strategic thinking but act rather myopically. While the same does not hold true for information avoidance regarding the consequences of actions on own payoffs. In the second chapter, we find that the chance of remaining ignorant about own payoffs does not lead to more prosocial choices.

Irrelevant information can be used as a coordination tool. Creditors facing a coordination problem when a borrower is in distress may be tempted to follow signals that provide no information about the fundamentals affecting payoffs ("sunspots"), fearing similar actions by others. The third chapter concludes that in environments with high strategic uncertainty, payoff-irrelevant signals can affect behavior even if they are costly to obtain and not expected to be publicly observed.

As I have shown, there are many situations that either directly address, or can be connected to ignored or irrelevant information. Given the diverse mechanisms leading to such situations, the literature on the topic has not been structured as a coherent body; nor, I suspect, can it or should it. Given the important consequences of ignored or irrelevant information, research on the mechanisms that produce it could have immediate and important policy applications—e.g., in overcoming resistance toward confronting the scientific evidence on climate change or in controlling the impact of biased or doctored news articles in times of financial crises.

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