Discontinuous and Continuous Stochastic Choice and Coordination in the Lab*

Maxim Goryunov† Alexandros Rigos‡

First version: September 5, 2019
This version: August 31, 2020

Abstract

Coordination games have multiple equilibria under complete information. However, recent theoretical advances show that if players are uncertain but can acquire information about a payoff-relevant state of the world, the number of equilibria depends on whether they can implement strategies (stochastic choice rules) discontinuous in the state. We experimentally test these results in a two-player investment game. Through a minimal visual variation in the design (our treatment) we prompt participants to play strategies whereby their probability to invest is either continuous or discontinuous in the payoff-relevant state. When participants use continuous strategies, average behavior is consistent with play in the risk-dominant equilibrium, the unique theoretical prediction. When they use discontinuous strategies — in which case there are multiple equilibria — average behavior is closer to the payoff-dominant equilibrium strategy. Additionally, we extend the theory to heterogeneous populations: the set of equilibria monotonically decreases in the proportion of players who use continuous strategies.

Keywords: Coordination; Global games; Information acquisition; Continuous stochastic choice; Visual information; Experiment; Perception
JEL classification: C92, C72, D83

---

*We would like to thank Pol Campos-Mercade, Stephen Morris, Alexander Nesterov, Jakub Steiner, and Erik Wengström for their comments and suggestions at various stages of this paper. We also thank audiences at LGTC2019, Lisbon Meetings 2019, the Fall 2019 CNEE Workshop and seminar participants at Edinburgh and Lund. Goryunov is grateful to CERGE-EI Foundation for the Career Integration Fellowship. Rigos is grateful to Erik Mohlin and Handelsbankens Forskningsstiftelser (grant #P2016-0079:1).

†Nazarbayev University, Kabanbay Batyr Ave 53, 010000 Nur-Sultan, Kazakhstan, maxim.goryunov@nu.edu.kz

‡Department of Economics, Lund University School of Economics and Management, Box 7082, 220 07, Lund, Sweden; alexandros.rigos@gmail.com.

1 Introduction

Coordination games are typically ridden with multiple equilibria when information about payoffs is complete. However, in recent work, Morris and Yang (2019, MY hereafter) argue that when information is endogenously acquired, the number of equilibria is tightly connected to the technology of information acquisition that is available to the players. In particular, MY show that, in the limit of zero information frictions, a unique equilibrium exists whenever it is sufficiently harder for players to distinguish states that are nearby than ones that are further apart, and that equilibrium multiplicity persists otherwise.

The main goal of this paper is to investigate MY's insight in the lab. Our contribution is threefold. First, we provide experimental evidence of participant behavior in accordance with the theoretical results of MY: When unable to tell apart nearby states, subjects' average behavior is consistent with the risk-dominant equilibrium strategy, MY's unique equilibrium prediction. When equipped with a technology that allows them to tell apart nearby states, average behavior is closer to the payoff-dominant equilibrium strategy. Second, we introduce a new experimental design that is based on a visual presentation of the state space and the density function. This allows us to circumvent the language of distributions and conditional probabilities when communicating with subjects. Third, in our theoretical contribution, we extend the intuition of MY to heterogeneous populations that consist both of players who can and of players who cannot distinguish nearby states.

The strategic environment for our experiment is a two-player game in which each player chooses between a safe action (abstain) and a risky action (participate) simultaneously with her opponent. Abstaining yields a fixed payoff that is independent of the state of the world and of the opponent's action. The payoff from participation monotonically decreases in the state of the world and (weakly) increases if the opponent also participates. In this setting, a strategy is a rule that tells a player with what probability to participate as a function of the state of the world. In the theoretical model, there are two types of players. We call a player a *"sharp"* type if she can tell apart two states of the world that are arbitrarily close together and a *"fuzzy"* type if she cannot. A sharp player can use strategies that are discontinuous in the state of the world. In particular, a sharp player uses step functions that prescribe her to participate if and only if the state of the world is below some cutoff of her choice. First-best responses always fall into this class of strategies. In contrast, a fuzzy player — due to her inability to tell apart nearby states — is restricted to playing continuous strategies.[1] Each of the two theoretical player types corresponds to one of our experimental conditions, to which we return shortly.

[1] In the language of MY, a sharp player has an information acquisition technology with Cheap Perfect Discrimination whereas a fuzzy player's technology exhibits Infeasible Perfect Discrimination.

In our experimental design, information is communicated to participants in a purely visual manner. On their computer screens, participants are presented with a rectangle which represents the uniform distribution over the state space — an interval — along with numerals for the horizontal coordinates of the interval's endpoints. The state of the world is revealed to the participants as a dot that is displayed inside the rectangle for a short amount of time. The dot's horizontal coordinate is the value of the payoff-relevant state. Even though participants can observe the dot, its exact position is not communicated to them. So, they can have only a rough estimate of the state.

We conduct two between-subject treatments, which correspond to the two theoretical player types. Before the dot is displayed on their screen, participants are prompted to place a vertical line at any horizontal position within the rectangle, hence breaking it into two regions. In our *Line Treatment* (LT), the line remains displayed while the dot is displayed. In the *No Line Treatment* (NLT), the line disappears before the dot is displayed.

We expect participants to be affected by the treatment in the following way. In the Line Treatment, participants should be able to tell whether the dot is to the left or to the right of the line they placed and, thus, implement discontinuous *cutoff* strategies. They can easily achieve this by placing the line at their desired cutoff position and subsequently conditioning their choice to participate or to abstain on the dot's position relative to the line — just like the sharp types of the model. In contrast, in the No Line Treatment the line and the dot are never displayed at the same time. So, it should be nearly impossible for NLT participants to sharply change their behavior around any particular cutoff and the strategies they can implement have to be continuous — just like the theoretical fuzzy types.

Our first hypothesis is about the internal validity of our design, following from the analysis of the previous paragraph. Adopting a regression discontinuity design (RDD) we show that our treatments do, indeed, work as we intended. Subjects' probability to participate is discontinuous around the line position in the LT but continuous in the NLT. At the same time, we find that even though it is discontinuous, the participation probability in the LT approaches neither one to the immediate left nor zero to the immediate right of the line. Thus, we think that a heterogeneous population model is best-suited for the analysis of the LT, as some participants may fail to use cutoff strategies even with the help of the line (partial compliance).

We derive predictions for participants' strategic behavior in each treatment by solving the game for equilibrium, while allowing for heterogeneous populations which consist of both sharp and fuzzy players. This heterogeneity is essential in order to analyze cases in which subjects do not always comply with treatment, as in our LT (see above). We show that in the limit where information frictions disappear — i.e., when fuzzy players' strategies approach step functions — the set of possible equilibria shrinks monotonically as the proportion of fuzzy types in the population increases. As in MY, when the population consists of only sharp types, there is a continuum of Pareto-ranked equilibria. In fact, any state for which the complete information game has no dominant strategy can serve as the cutoff in a symmetric equilibrium. In the polar opposite case where the population consists solely of fuzzy types, there is a unique equilibrium cutoff which corresponds to the risk-dominant equilibrium of the complete information game. This is the two-player equivalent of the Morris and Yang (2019) Laplacian selection result: each player best responds to a uniform belief about her opponent's participation probability.

Our predictions for participant behavior are supported by the experiment data. The average position where participants in the NLT place the line is very close to (almost coincides with) the cutoff of the risk-dominant equilibrium strategy, as predicted by the theoretical model for a uniform population of fuzzy types. As for the LT, the theoretical prediction is less clear since our heterogeneous population model does not select a unique equilibrium. Notwithstanding, we find that participants in the LT are overall more likely to take the risky participate action than the ones in the NLT: the treatment effect on the likelihood of participation reaches 20 percentage points for some regions of the state space. Moreover, by observing the size of the discontinuity in the participation probability around the line position, we estimate the proportion of fuzzy types among LT participants — or, rather, the average LT participant's probability of failure to implement a cutoff strategy. We find that LT participants' average line position is consistent with them playing the strategy of the most efficient equilibrium (the one with the highest cutoff) that is permitted by the heterogeneous population model, given our estimated proportion of fuzzy types.

Two features of our design distinguish our approach from those of earlier experiments on coordination games with incomplete information. The first one has to do with the demands that the design puts on participants' inference capabilities. In the literature on global games experiments, pioneered by Heinemann, Nagel, and Ockenfels (2004), the state of the world is communicated to participants in the form of a signal whose value is equal to that of the state plus some zero-mean noise. In contrast, we take advantage of the fact that the theoretical results (both ours and those of MY) are detail-free: they do not depend on particular functional forms but only on whether or not local discrimination is feasible. This allows us to let the process of signal acquisition and inference from it take place entirely in the participants' minds, sparing the details of how exactly this happens — as long as the technologies with which we provide them satisfy our theoretical requirements concerning local discrimination. In doing so, we do not require participants to know how to properly use Bayes' rule or to have a notion of conditional probability whatsoever. In this regard, our approach is similar in spirit to Dean and Neligh (2019) whose participants' information acquisition cost is the intrinsic cost of counting how many balls displayed on their screen are of a particular color.

Second, our design relies on the observation that, for continuous distributions, the probability of an event equals the integral of the density function over this event and, therefore, the "area under the density function" as well. We visually present to participants the graph of the density function over the set of potential outcomes and rely on the intuitive notion of realizations being "equally likely" anywhere in this area. This allows us to do away with the language of probability altogether and at the same time communicate the exact probability distribution accurately. In our experiment we employ the uniform distribution, but the approach can be extended to any continuous distribution in a straightforward manner. We hope that these two features of our experimental framework can prove useful for the study of information processing beyond our investment game.

We begin by setting up the theoretical framework in Section 2 and proceed to describe our experimental design and its implementation in Section 3. The analysis of the experimental data is carried out in Section 4, and in Section 5 we relate our findings to those in the literature. Section 6 concludes.

2 Theoretical Model

In this section we theoretically study the game we used in our experiment and derive predictions for the behavior of the experiment participants. Our model is a simplified version of Morris and Yang (2019), extended to heterogeneous populations. Allowing heterogeneous players enables us to study the implications for equilibrium selection brought about by the co-existence of individuals who use discontinuous strategies with others who use continuous strategies. We set up the model so as to closely match the game that our participants played. Our results, though, hold for more general payoff structures.

2.1 The Game

Two players are considering participating in a project. Each player $i \in \{1,2\}$ chooses $a_i \in \{0,1\}$ independently from and simultaneously with her opponent. The action $a_i = 0$ corresponds to abstaining from whereas $a_i = 1$ corresponds to participating in the project. Abstention is a safe action and yields a payoff normalized to zero. Each player's payoff from participation depends on the realization of a random variable θ (the state of the world) and the other player's action. The state of the world θ represents the "difficulty" of the project. The players share a common prior that θ is uniformly distributed on the interval $[0,A]$. Player i's payoff from participating (playing $a_i = 1$) when her opponent plays a_j is

$$\max\{(1+a_j)e-\theta,0\}-t, \tag{1}$$

where $t > 0$ is a required initial investment cost and e is the exogenous effectiveness that each participating player brings to the project: higher total effectiveness leads to a higher income. We assume that $t < e < (A+t)/2$. This ensures that the state space has three regions: (i) $\theta \in [0, e-t]$, where $a_i = 1$ is a dominant action, (ii) $\theta \in (e-t, 2e-t)$ where there is no dominant action, and (iii) $\theta \in [2e-t, A]$ where $a_i = 0$ is a dominant action.

Prior to choosing their actions the players do not know the value of θ. They can, however, acquire information about it and choose an action based on the information they find. Any information acquisition strategy that player i might follow will ultimately result in a stochastic choice rule $s_i : \mathbb{R} \to [0,1]$, where $s_i(\theta)$ denotes the probability with which player i participates in the project conditional on the state of the world being θ. Henceforth, we use the terms *strategy* and *rule* interchangeably to refer to such functions s. As in MY, we restrict players' strategies to be Lebesgue-measurable and non-increasing (a.e.): a player's likelihood to participate cannot increase as the difficulty of the project increases.

The exact information acquisition technology (i.e. cost) is not modeled. Instead, each player is restricted to choose from a particular family of rules, depending on her type (see 2.3). The restrictions imposed are closely tied to the properties of cost functions used by MY (see also Pomatto, Strack, and Tamuz 2018).

2.2 Minimal Belief

An important quantity for the analysis is the belief of player i that her opponent plays $a_j = 1$, conditional on the state of the world being θ. We denote this belief by $b_j(\theta) \in [0,1]$. Given b_j, player i maximizes her expected payoff:

$$U(s_i, b) = \int_0^A s_i(\theta)\left[b_j(\theta)\max\{2e-\theta, 0\} + (1-b_j(\theta))\max\{e-\theta, 0\} - t\right]\frac{1}{A}\,\mathrm{d}\theta. \quad (2)$$

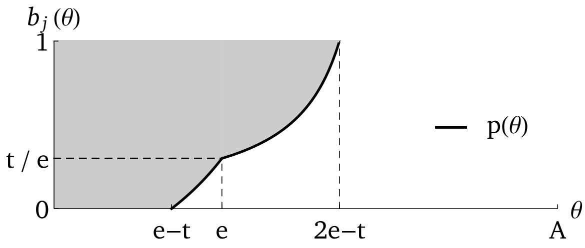
Due to the nature of the game, a higher $b_j(\theta)$ increases the payoff that player i receives from participating when the state is θ. In particular, at state θ, $a_i = 1$ is a best action for player i iff

$$b_j(\theta)\max\{2e-\theta, 0\} + (1-b_j(\theta))\max\{e-\theta, 0\} - t \geq 0$$

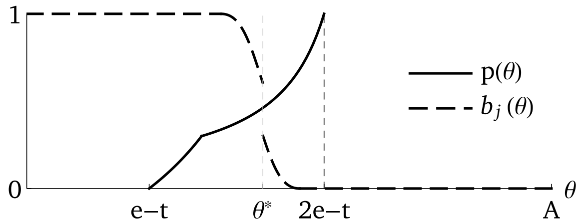
or

$$b_j(\theta) \geq \frac{t - \max\{e-\theta, 0\}}{\max\{2e-\theta, 0\} - \max\{e-\theta, 0\}} =: p(\theta). \quad (3)$$

Figure 1a plots $b_j(\theta)$ as a function of θ. If the belief $b_j(\theta)$ lies in the shaded region ($b_j(\theta) > p(\theta)$), then the best action for player i is to participate. When $\theta \in [e-t, 2e-t]$, the minimal belief for participation $p(\theta)$ lies in $[0,1]$ and the corresponding complete information game has two equilibria in pure strategies (both players participate or both players abstain).



(a) If $(\theta, b_j(\theta))$ is in the shaded region, $a_i = 1$ is the best action.



(b) For this b_j, the optimal response is to participate if and only if $\theta < \theta^*$.

Figure 1: Best action given the state and the belief about opponent taking action $a_j = 1$

Under our assumption that strategies are non-increasing, any plausible (i.e., equilibrium) belief b_j held by player i should also be non-increasing. Therefore, for any such belief there is a unique state $\theta^* \in [e-t, 2e-t]$ with the property that $b_j(\theta) \geq p(\theta)$ for all $\theta < \theta^*$ and $b_j(\theta) \leq p(\theta)$ for all $\theta > \theta^*$. So, the best a player can do (disregarding information costs) is to participate iff $\theta < \theta^*$, i.e., to play $s^*(\theta) = \mathbb{1}_{\{\theta<\theta^*\}}$. Figure 1b depicts this. The extent to which a player can actually implement this rule will depend on her *type*.

2.3 Player Types

Players can be of two types — termed *"sharp"* and *"fuzzy"* — based on their information acquisition technology. The players' types are independently drawn from the same distribution: a player is fuzzy with probability q and sharp with probability $1-q$. On the one hand, each of the two types finds focusing her attention on any part of the state space equally difficult.[2] On the other hand, the two types differ in their ability to tell apart nearby states.

Sharp players are endowed with an information acquisition technology that allows them to sharply distinguish nearby values of θ. So, they can behave differently at two different states that are arbitrarily close to each other (e.g. participate for sure at θ' and abstain for sure at $\theta' + \varepsilon$ for arbitrarily small $\varepsilon > 0$). That is, sharp players are able to implement discontinuous strategies.[3] We restrict sharp players to use *cutoff strategies*.[4] The cutoff strategy at ψ is denoted by σ_ψ and has a step-function form: $\sigma_\psi(\theta) = \mathbb{1}_{\{\theta\leq\psi\}}$. Figure 2 depicts cutoff strategies for various values of ψ.

In contrast, fuzzy players have an information acquisition technology that only gives them access to strategies that are continuous in θ. This means that they cannot sharply change the probability with which they participate from one state to states arbitrarily close

[2]This relates to the translation insensitivity property of the cost functional in MY.

[3]This relates to a sharp player's cost functional satisfying what MY call Cheap Perfect Discrimination.

[4]In fact, the analysis of 2.2 shows that cutoff strategies are optimal among the set of all strategies. Nevertheless, we impose this restriction to avoid unnecessary complexity.

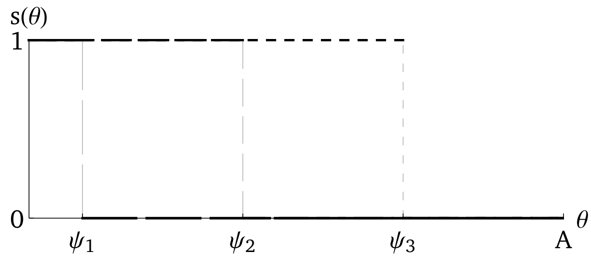


Figure 2: Different strategies for a sharp player (cutoff strategies)

to it. Moreover, even though fuzzy players cannot distinguish nearby states, they are still able to distinguish states that are far apart. So, they can set their participation probability to one for small θ (e.g. in the region where participation is dominant) and to zero for large θ (e.g. in the region where abstention is dominant) but have to vary this probability continuously in-between.[5]

With the above in mind, fuzzy players' strategies are assumed to have an exogenously given "shape" $\varrho : \mathbb{R} \to [0,1]$, which is a non-increasing, absolutely continuous function and satisfies

$$\varrho(\theta) \begin{cases} = 1, & \theta \leq 0 \\ \in (0,1), & \theta \in (0,\delta) \\ = 0, & \theta \geq \delta \end{cases}.$$

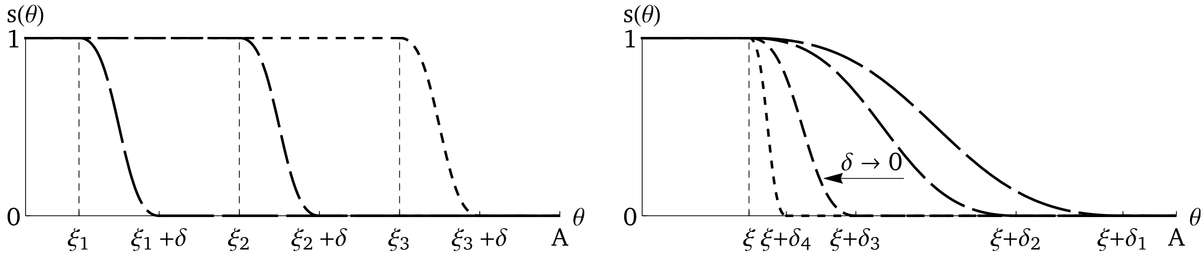
The exogenous parameter $\delta > 0$ is the width of the region in which the fuzzy player's decision is actually "fuzzy" and is a measure of how difficult it is for her to distinguish nearby states. As she finds it equally difficult to focus her attention on any part of the state space, the fuzzy player can choose to "place" this shape (translate ϱ) at any position ξ. So, fuzzy players are restricted to use strategies of the form $\tau_\xi(\theta) = \varrho(\theta - \xi)$. Such strategies are depicted in Figure 3a for given δ and different values of ξ.

Much in line with the global games literature, and in the spirit of MY, we focus on the limit where information frictions disappear, i.e., when $\delta \to 0$. In this limit, the fuzzy strategy τ_ξ converges to the cutoff strategy σ_ξ. This is shown in Figure 3b. The only — yet crucial — difference is that while τ_ξ is (absolutely) continuous, σ_ξ is not.

Equilibrium

Given the restrictions imposed on strategies, the decision problems of sharp and fuzzy types boil down to the choice of cutoffs, i.e., down to $\max_{\psi \in \mathbb{R}} U(\sigma_\psi, b)$ and $\max_{\xi \in \mathbb{R}} U(\tau_\xi, b)$,

[5]This relates to a fuzzy player's cost functional satisfying what MY call Infeasible Perfect Discrimination. In fact, Pomatto, Strack, and Tamuz (2018) show that if nearby states are hard to distinguish, optimal choice rules are Lipschitz continuous.



(a) Strategies at varying ξ for given δ (b) Strategies for fixed ξ as $\delta \to 0$

Figure 3: Different strategies for a fuzzy player

respectively. As a solution concept we use symmetric Bayesian Nash equilibrium. The symmetry requirement is natural in this environment and comes from the two players' roles being symmetric and the assumption that their types are drawn independently from the same population. In particular, we have the following characterization.

Definition 1 (Monotone symmetric Bayesian Nash equilibrium). *A* monotone symmetric Bayesian Nash equilibrium — *or simply* equilibrium — *is a tuple* $(\widetilde{\psi}, \widetilde{\xi}, \widetilde{b}) \in \mathbb{R} \times \mathbb{R} \times [0,1]^{[0,A]}$ *such that*

1. $\widetilde{\psi} \in \arg\max_{\psi \in \mathbb{R}} U(\sigma_\psi, \widetilde{b})$,
2. $\widetilde{\xi} \in \arg\max_{\xi \in \mathbb{R}} U(\tau_\xi, \widetilde{b})$,
3. *and* $\widetilde{b}(\theta) = (1-q)\sigma_{\widetilde{\psi}}(\theta) + q\tau_{\widetilde{\xi}}(\theta)$.

We show that the presence of fuzzy types limits the set of possible equilibria. More specifically, as the share of fuzzy types increases, the set of equilibria decreases.

Proposition 1. *When information frictions disappear ($\delta \to 0$), the set of equilibria is characterized by the set of possible cutoffs θ^* that satisfy*

$$q - q^2/2 \leq p(\theta^*) \leq 1 - (q - q^2/2).$$

For each such θ^*, the assessment $(\widetilde{\psi}, \widetilde{\xi}, \widetilde{b}) = (\theta^*, \theta^*, \mathbb{1}_{\{\theta \leq \theta^*\}})$ is a monotone, symmetric Bayesian Nash equilibrium.

Corollary 1. *In the limit where $\delta \to 0$,*

1. *When $q = 1$, there is a unique equilibrium. It is characterized by $p(\theta^*) = 1/2$.*
2. *When $q = 0$ there are multiple equilibria. In fact, any θ^* with $p(\theta^*) \in [0,1]$ characterizes an equilibrium.*
3. *As q increases, the set of equilibria decreases (in the set-inclusion sense).*

According to Corollary 1, the two cases studied by MY appear as special cases of our model. When $q = 1$, both players definitely follow continuous strategies. This corresponds MY's Infeasible Perfect Discrimination case and in the limit where information frictions disappear ($\delta \to 0$) the equilibrium is unique: the risk-dominant equilibrium (Laplacian selection). When $q = 0$, both players can choose any cutoff strategy and there are multiple equilibria: the coordination problem manifests itself in the information acquisition (or belief formation) stage. When $q \in (0, 1)$, the set of equilibrium cutoffs is a neighborhood of the risk-dominant cutoff (the one with $p(\theta^*) = 1/2$). In Section 4 we will use Proposition 1 and Corollary 1 to derive hypotheses about our participants' strategic behavior in each of the treatments.

3 Experimental Design

Our goal is to uncover how different technologies of information acquisition affect the way participants play the coordination game. In particular, we want to test the prediction of Proposition 1 that when the information acquisition technology only allows continuous choice rules the Laplacian equilibrium is selected. Additionally, we aim to understand how participants behave when the theory gives multiple (equilibrium) predictions and to what degree their choice to take the risky action or not is affected by the type of strategies that are available.

To this end, we design a between-subject laboratory experiment that induces participants to use either continuous or discontinuous choice rules with minimal variation between treatments. In this section, we first present the basic idea of the design that allows us to achieve that. We then proceed to discuss the details of how we implemented the design in the lab.

3.1 Design of the Main Task

Participants in the experiment are randomly matched in pairs to play a coordination game isomorphic to the one studied in Section 2. Each of the participants has a choice of two actions: either participate (P) in a project or abstain (A). If she chooses to abstain, she receives a known payoff t. If she chooses to participate, she brings an amount of effectiveness e (which is also known) into the pair's project. The project succeeds if the combined effectiveness of the pair exceeds the value of a variable θ, the project's difficulty. In this case, a subject who chose P receives a payoff equal to the difference between the pair's combined effectiveness and the project's difficulty. Otherwise, she receives a payoff of zero. The difficulty θ (the state of the world) is drawn from the uniform distribution over $[0, 3000]$

		Player 2	
		P	A
Player 1	P	$(\max\{2000-\theta,0\},\max\{2000-\theta,0\})$	$(\max\{1000-\theta,0\},300)$
	A	$(300,\max\{1000-\theta,0\})$	$(300,300)$

Table 1: Payoff matrix

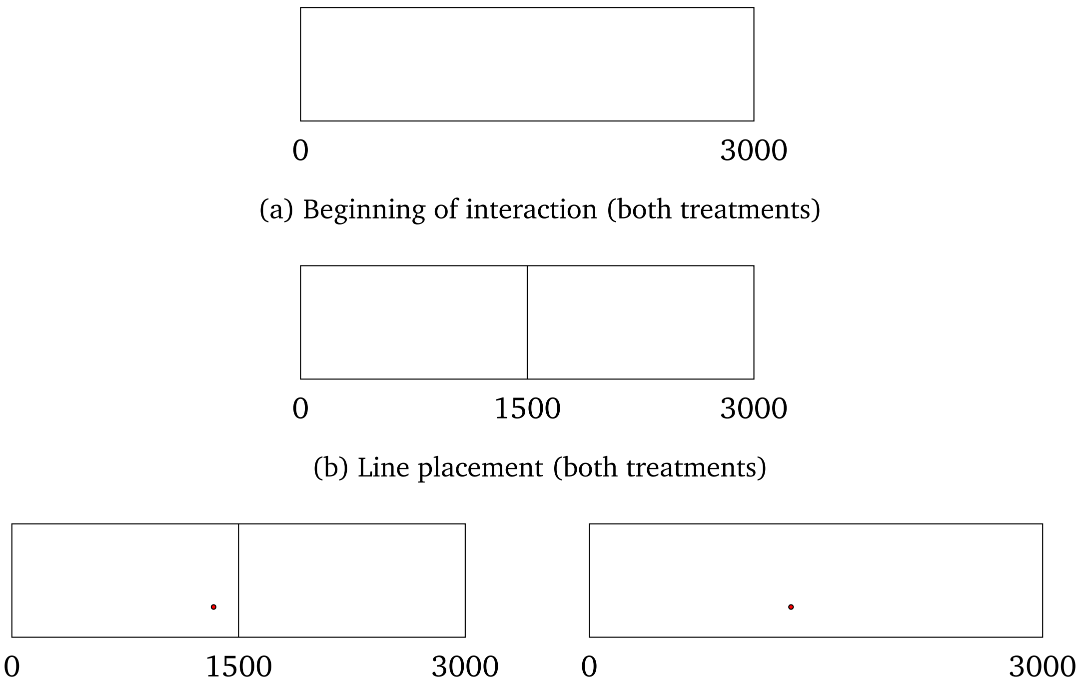
and its realization is unknown to the participants ex ante. Table 1 summarizes the payoffs in our experiment, where we set $t = 300$ and $e = 1000$. This choice of parameters splits the state space into three regions. Participation is the dominant action for $\theta \in [0,700]$ and abstention for $\theta \in [1700,3000]$, while no action is dominant in-between.

The novelty of our design lies in how we provide participants with information about θ. At the beginning of the interaction, each participant sees on her screen a rectangle that represents the uniform distribution of θ over the interval $[0,3000]$. At the leftmost and rightmost points of the rectangle the values of the extreme coordinates (0 and 3000) are shown (as seen in Figure 4a). Information is provided to participants via a dot that is displayed at a randomly drawn position within the rectangle for a limited amount of time (approx. 70 milliseconds) and then disappears. The dot's horizontal coordinate is the project's difficulty θ. We inform subjects that all points are equally likely, thus effectively communicating that θ is uniformly distributed. Subjects are prompted to choose their action after that.

In order to induce participants to use choice rules that are continuous or discontinuous in the state θ, we implement two treatments termed *Line Treatment* (LT) and *No Line Treatment* (NLT) that vary minimally from each other. In both treatments, prior to playing the coordination game, participants position a vertical line in the rectangle at the point of their choice (as shown in Figure 4b). Our treatment variation is that while in the LT the line stays on the screen until the participant chooses her action (including *while* the dot is displayed), in the NLT the line *disappears three seconds before* the dot is displayed.

Figure 4 illustrates our design. Panels 4a and 4b are common in both treatments and show an instance of a participant's screen before and after she places the line (we arbitrarily placed the line at 1500 as an example). Panels 4c and 4d show instances of participants' screens in the two treatments while the state is being revealed ($\theta = 1335$ in the examples). In the NLT the line is no longer displayed, while in the LT it is still displayed.

We expect that in the NLT (Figure 4d) the participants cannot tell apart nearby realizations of θ. Therefore, this technology should induce participants to use continuous choice rules, like those of "fuzzy" players in our theoretical model (see also Morris and Yang 2019). For this case, Proposition 1 predicts that in the limit of zero information frictions, Laplacian selection takes place: there is a unique equilibrium in which subjects take the risky action



(a) Beginning of interaction (both treatments)

(b) Line placement (both treatments)

(c) State revelation (Line Treatment)

(d) State revelation (No Line Treatment)

Figure 4: Illustration of the experimental design

to participate if and only if θ is below a cutoff ($\theta < 1400$ given our parameters). Since it is impossible to identify the state exactly, our participants are not quite at the frictionless limit. Because of this — and of experimental noise — we expect that participation probability may not drop all the way from zero to one at the 1400 position as would be the case with a perfectly executed cutoff strategy.

In contrast, in the LT (Figure 4c), although it is still impossible to infer the exact position of the dot, it should be much easier for participants to distinguish whether the state is to the left or to the right of the line. Thus, we expect them to be able to implement strategies discontinuous at the position of the line, like our theoretical "sharp" players. Proposition 1 does not give a clear-cut theoretical prediction on where one should expect the subjects to place the line, since even when only a small share of participants follow discontinuous strategies, there are multiple equilibria.

In order for our results to be interpretable, it is key that we induce continuous play in the NLT and discontinuous play in the LT. We empirically confirm this in Section 4.1.

3.2 Procedures

The experiment took place at the Laboratory for Experimental Economics (LEE) of Copenhagen University between May 7 and May 16, 2019. It was implemented in oTree

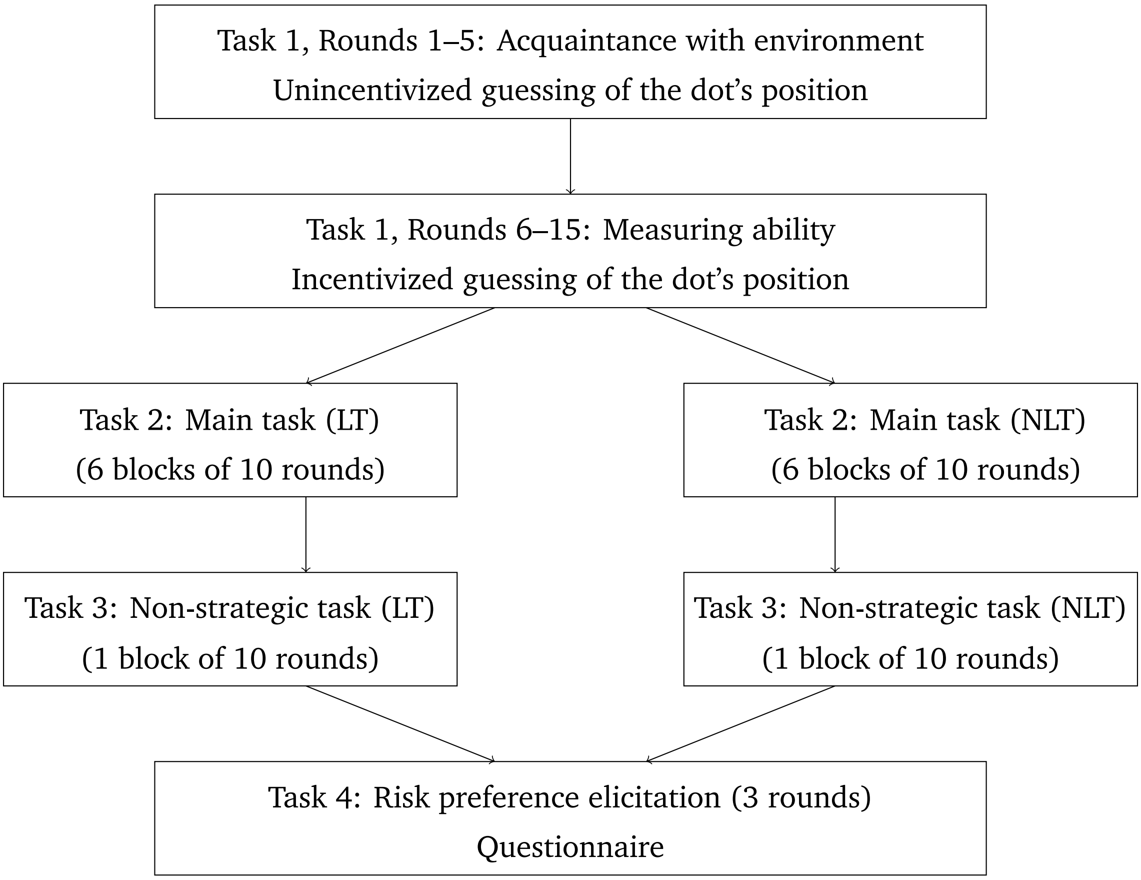


Figure 5: Outline of the experiment structure. In Tasks 2 and 3, participants chose line positions at the beginning of each block (1 block = 10 rounds). In Task 2, participants were randomly rematched within their matching groups after each block.

(Chen, Schonger, and Wickens 2016) and consisted of four tasks and a questionnaire. Seven sessions were attended by 186 participants most of whom were university undergraduates. Each session lasted approximately two hours and had between 24 and 28 participants. Details of the exact allocation of participants to treatments and payments are reported in Appendix C.1 (Table 8).

Upon entering the lab, each participant was assigned a computer and was handed instructions for the first task. Printed instructions for each subsequent task were handed after the previous task had finished. We used a between-subject design, with participants of both treatments being present in the laboratory at the same time. Because of this, only an introductory part of the instructions was read out loud whereas participants read the task instructions in private.[6] Clarifying questions were asked and answered, and control questions were checked also in private. We summarize the overall structure of the experiment in Figure 5.

[6]We provide the full instructions in Appendix D.

Task 1's purpose was to ensure that participants are familiar with the environment when they undertake the main task and consisted of 15 rounds. Participants were shown a rectangle (as described in 3.1) where in each round a randomly-positioned dot appeared for approximately 70 ms (as on the right-hand part of Figure 4). Participants' task was to guess the dot's horizontal coordinate. The purpose of the first five rounds was to train participants in spotting the dot within 70 ms and to familiarize them with the interface's dimensions. With that in mind, we gave them feedback (the exact horizontal coordinate of the dot) after each round but we did not provide them with incentives for rounds 1–5. The purpose of the final ten rounds of Task 1 was to measure participants' ability to spot the dot and accurately estimate its position. For this, participants were incentivized to give accurate guesses with closer guesses generating higher payoffs. Feedback for rounds 6–15 was provided only at the end of Task 1.

In Task 2, the core task of the experiment, we implemented the coordination game as described in Section 3.1. In each session, each of the two treatments was assigned half (or as close to half as possible) of the participants who remained in the same treatment throughout the experiment. Participants in each treatment (LT and NLT) were split into two matching groups. Each participant played the game for six blocks of ten rounds each and was randomly (re-)matched to a (potentially) new partner from her matching group at the beginning of each block. Matching groups were of size 6 or 8 so as to have four matching groups in each session while avoiding participants being re-matched to the same partner too often.

At the beginning of each block, participants chose their line positions, which stayed fixed for the duration of the block. After choosing the line position, when a participant was ready to start, she clicked a button (at this moment the line would disappear in the NLT), and three seconds later the dot indicating the state appeared for 70 ms. A few seconds later, participants were asked to choose between participation in the project and abstention. The line was present during state revelation and the decision process for participants in the LT but absent for those in the NLT. Each round corresponded to a different project and the dot's position (state of the world) was drawn independently across rounds and subject pairs. At the end of each block, participants received feedback on the play within the block (their and their partners' actions) along with the realized states of the world and payoffs.

After each block, each participant was rematched to a (potentially) new partner from the same matching group. we rematched the participants (within matching groups) to better preserve the spirit of a one-shot game. At the same time, there is potential for learning and convergence to different play across matching groups, especially in the LT where the theory predicts multiple equilibria. We, therefore, treat each matching group as a cluster. We introduced four matching groups per session in order to have a larger number of clusters.

Task 3 was a non-strategic version of the strategic Task 2 and had one block of ten rounds. Its purpose was to check whether (dis-)continuous play is driven purely by strategic uncertainty and to give us a measure of experimental noise in the absence of strategic considerations. Payoffs did not depend on other participants' actions but, instead, corresponded to the participant's partner abstaining from the project. Thus, under perfect information, it is optimal to play a strategy with a cutoff at 700. To avoid participants anchoring on particular cutoffs (e.g. 700) in the main task, we placed this task after the strategic one. We believe that such anchoring is less likely to occur if the non-strategic task follows the strategic one as there is an obvious unique optimal behavior in the non-strategic problem.

Finally, Task 4 consisted of three rounds of a short risk elicitation task inspired by the "bomb" task of Crosetto and Filippin (2013). The experiment concluded with a demographics questionnaire. We report summary statistics for demographics and risk in Appendix C.

Participants were paid for the sum of their earnings from one randomly drawn round from each task, except for Task 2 for which six rounds were drawn (one from each block). Payments took place in private at the end of the experiment and were made in cash. The average payment was 236 Danish kroner (approximately $35 at the time of the experiment).

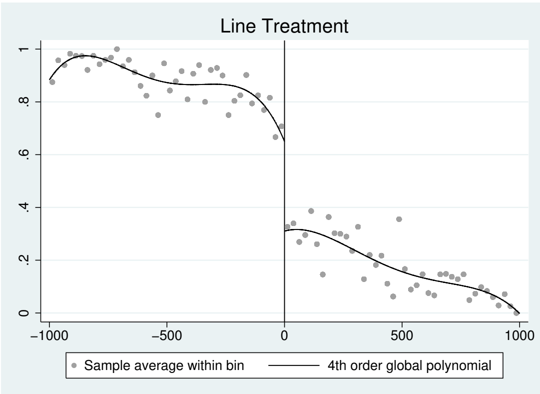
4 Results

We present the results of our experiment focusing on the behavior in the coordination game — Task 2 of our experiment. We first establish that our treatments work as we intended, i.e. that the play (probability of participation) is continuous in the No Line Treatment (NLT) and discontinuous in the Line Treatment (LT). We then study the difference in participant behavior between the two treatments, both in line placement and in the likelihood of taking the risky action to participate.

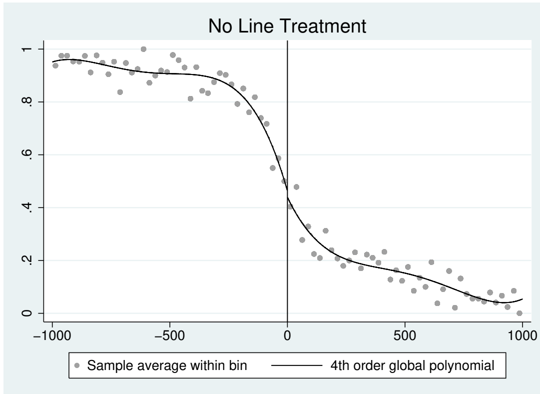
As participants were required to choose line positions at the beginning of each block of Task 2, these moments were salient opportunities for them to reconsider their strategies. However, over 70% of participants in either treatment fix their choice of line position from block 4 onwards. We report these results on the stabilization of line placement in Appendix C.2. With this in mind, our preferred estimates in what follows are the ones calculated with data from the last three blocks, after most learning has taken place. We also report the results for all six blocks for completeness.

4.1 Stochastic Choice (Dis-)Continuity: Internal Validity

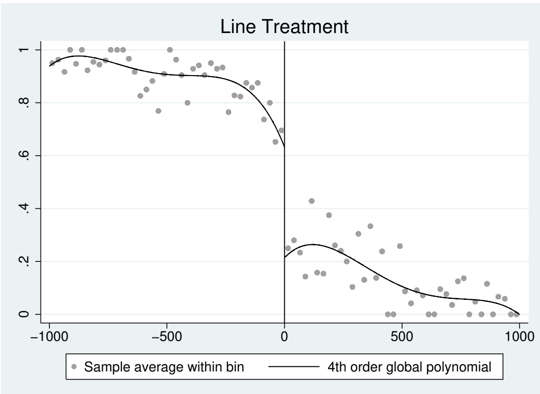
Our design is based on the premise that participants in the NLT are constrained to strategies in which their probability to take the risky action is continuous in the state of the world



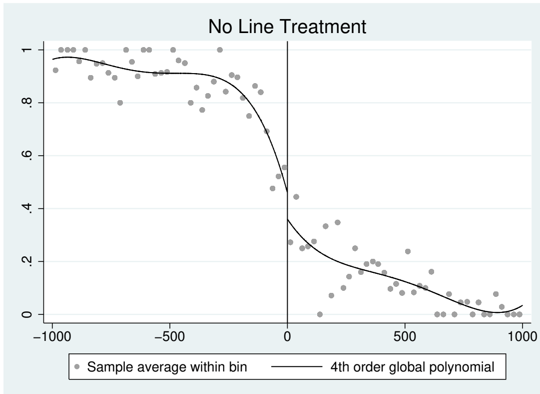
(a) All six blocks



(b) All six blocks



(c) Last three blocks



(d) Last three blocks

Figure 6: Estimate of participation probability conditional on the distance to the line in the main task (Task 2)

Table 2: Estimation of change in participation probability at the line position

	Line Treatment				No Line Treatment			
	All six blocks		Last three blocks		All six blocks		Last three blocks	
bandwidth	drop	p-value	drop	p-value	drop	p-value	drop	p-value
± 50	-0.21	0.313	-0.42	0.051	-0.145	0.307	-0.231	0.279
± 100	-0.284	0.032	-0.379	0.017	-0.026	0.877	-0.161	0.323
± 150	-0.333	0.003	-0.401	0.003	-0.001	0.812	-0.074	0.711
± 200	-0.325	<0.001	-0.393	0.001	-0.023	0.889	-0.081	0.718
± 250	-0.358	<0.001	-0.423	<0.001	-0.057	0.82	-0.116	0.477
± 300	-0.374	<0.001	-0.429	<0.001	-0.085	0.488	-0.143	0.26
± 350	-0.383	<0.001	-0.43	<0.001	-0.114	0.226	-0.175	0.106

(as they lack the visual help of the line while the dot is displayed), whereas participants in the LT are able to use strategies with a discontinuity at the line position of their choice. In what follows, we evaluate the validity of these assumptions for our participants.

We employ techniques developed for the Regression Discontinuity Design to test whether participant play exhibits a discontinuity around the line position each of them chose. The left-hand-side panels of Figure 6 present the probability with which participants in the LT took the risky action (participate), conditional on the relative position of the dot to the line. The sharp drop in probability at the line's position is visually apparent. The right-hand-side panels of Figure 6 present the corresponding results for the NLT. The gap in probability is almost absent when we look at all six blocks (top panel). A small gap appears when we focus on the last three blocks, but it is not statistically significant, as we show below.

To corroborate the graphical illustration with statistical evidence, Table 2 reports estimates of probability change around the line position. The estimate of the drop in probability is based on local linear regressions. We use Calonico, Cattaneo, and Titiunik (2014)'s estimation routine to obtain robust p-values. One can observe from the table that in the NLT the probability of participation in the project does not change for any bandwidth within 350 of the line position. This supports the hypothesis that participants in the NLT play continuous strategies, as we expected them. That is, our NLT worked as intended.

As for the LT, the drop in probability seems to be significant at all bandwidths, except for the smallest one. Within a distance of 50 from the line position, the drop in probability appears insignificant when we look at all six blocks and marginally significant when we look at the last three blocks only. However, the smallest bandwidth has, by construction, the smallest number of data points and, therefore, the largest standard errors. Further-more, the estimates are similar across all other bandwidths, both in terms of magnitude and significance.

We make two observations regarding the LT. First, the estimated size of the probability drop is larger when we focus on the last three blocks than when we use all six blocks. This suggests that participants take time to understand how to use and learn how to optimally position the line. This is consistent with our observation on line placement stabilization.

Second, although sizable (over 40 percentage points) the probability drop around the line position is not from one to zero. This is at odds with our theoretical prediction for the case where all players are sharp types ($q = 0$) and indicates that not all LT participants used the line as we intended. We thus deem behavior in the LT to be a mixture of continuous and discontinuous play and interpret the 40–43 p.p. drop as 40%–43% of participants following discontinuous strategies.[7] In Section 4.2 we explore to what degree the size of the gap and choice of line position are consistent with the theory we developed in Section 2.

Having established the internal validity of our experimental design, we now turn to study how the qualitative difference between the strategies available in the two treatments (discontinuous versus continuous) affects participants' choices in the coordination game. We first study line placement and then the choice to participate in the project (risky action).

4.2 Line Placement

Given the parameters of our experiment, the theory predicts that when all players are fuzzy ($q = 1$) there is a unique equilibrium characterized by a cutoff at position 1400. As argued in Section 3.1, this makes 1400 the relevant prediction for the cutoff in the No Line Treatment (NLT). At the same time, a value close to it — 1500 — is very salient in our design as it splits the state space in half. In what follows, we use the chosen line position as a proxy for participants' intended cutoff, and aim to test whether participants' choices are consistent with the theoretical predictions.[8]

In Figure 7 we present block by block the average line position chosen by participants in the two treatments along with 95% confidence intervals based on standard errors clustered by matching group. Observing the figure, one can see that participants of both treatments

[7]"Continuous play" here can also be the result of experimental noise due to, e.g., some players playing randomly, not fully understanding the interaction, or not spotting the line, behaviors which can be safely assumed to not vary discontinuously around the line position. Appendix B.2 shows that in the absence of strategic considerations (Task 3) the size of the discontinuity in the LT is much larger but still smaller than one. This suggests that at least part of the discrepancy in gap size can be attributed to strategic uncertainty, albeit not all.

[8]Indeed, in Appendix B.1 we provide evidence showing that the line position is a good proxy for participants' intended cutoffs even in the NLT (where the line disappears).

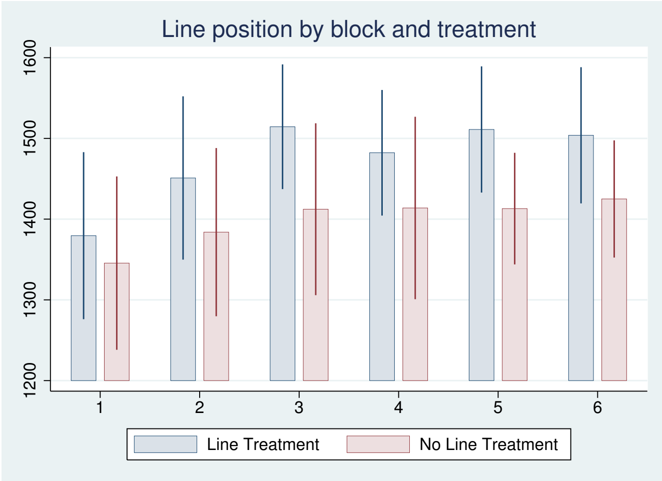


Figure 7: Average line position across treatments by block with 95% confidence intervals. Observations are clustered at the matching group level.

start with placing the line at relatively low positions of the state space. However, the average position increases quickly in the next two blocks and stabilizes from the third block onwards. Moreover, one can observe that the average line position on which participants settle in the NLT is close to 1400 — our theoretical prediction — whereas in the Line Treatment (LT) it is somewhat higher, close to 1500.

These observations are corroborated by Table 3, in which we report average line positions along with the respective p-values for the null hypotheses that the average line position is at 1400 and at 1500. In the LT, starting from block 3 onwards we can reject the hypothesis that the average line position is at 1400, thus Laplacian selection has little bite when at least some subjects have access to discontinuous strategies. In the NLT, where subjects are constrained to play continuous strategies, one cannot reject that the average line position is at 1400, the value Laplacian selection predicts.

Moreover, we can use these data to determine whether average participant behavior in the LT is consistent with our theoretical findings. As the average line position in the LT is very close to 1500, both visually and statistically, we focus on this value. According to our theoretical analysis, 1500 can be an equilibrium cutoff only when the minimal belief $p(\theta)$ at this point is below the upper bound established in Proposition 1, i.e. only when

$$p(1500) = \frac{t}{2e - 1500} \leq 1 - (q - q^2/2).$$

Thus, the share of the sharp players (who play discontinuous strategies) $1 - q^*$ should be at least $\sqrt{0.2} \approx 0.44$. This value, although slightly larger, is very close to the drop in the probability of participation around the line in the LT (see 4.1). In other words, the average line position in LT is very close to the maximal (the most Pareto-efficient) equilibrium in the

Table 3: Test for specific average line positions with p-values (two-tailed t-test)

	Line treatment			No Line Treatment		
	Line position	=1400 p-value	=1500 p-value	Line position	=1400 p-value	=1500 p-value
Block 1	1380	0.676	0.026	1346	0.293	0.008
Block 2	1451	0.296	0.314	1384	0.744	0.032
Block 3	1514	0.007	0.693	1412	0.807	0.098
Block 4	1482	0.04	0.63	1414	0.796	0.123
Block 5	1511	0.009	0.764	1413	0.69	0.018
Block 6	1504	0.02	0.923	1425	0.47	0.044
Blocks 1-6	1474	0.045	0.444	1399	0.977	0.018
Blocks 4-6	1499	0.015	0.979	1417	0.615	0.029

Table 4: Difference in line position between No Line and Line Treatments by block

block #	1	2	3	4	5	6	1-6	4-6
ATE	-34.00	-67.09	-102.16	-68.39	-98.04	-78.87	-74.76	-81.76
p-value	0.618	0.332	0.104	0.301	0.048	0.137	0.148	0.101

game of mixed player types given our estimate of the share of sharp players ($\sim$ 40–43%). Whether subjects play the maximal equilibrium given their ability to use the tools available to them (the line) or focus on the most salient features of the game or, even, modify their use of the tools to make the two coincide is a question we cannot answer with our data. We believe, however, it is an interesting avenue for future research.

We conclude our analysis of the line position by statistically testing whether the line positions in the two treatments are identical. Table 4 summarizes the difference in the average line positions between the two treatments. Our main treatment of interest is the NLT because it is where the theoretical prediction is unique. Thus, we view the LT as a baseline, and report the treatment effects of the NLT relative to the LT. We compute p-values using the randomization inference technique which is particularly suited for the analysis of experiments and has good finite-sample properties. Since our clusters are the matching groups in the sessions, we re-randomize treatment across them. We perform 10,000 permutations of the treatment indicator, independently for each block. During the first blocks of the task, LT participants change their line position by more than their NLT counterparts on average. This is reflected in the magnitude of the treatment effect increasing with experience. The magnitude is relatively large and covers 7%–10% of the state-space region where no action is dominant (the interval $(700, 1700)$). However, except for block 5, the treatment effect is not statistically significant at the 5% level.

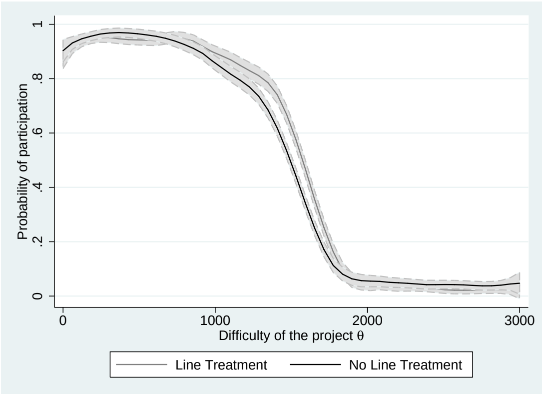
Summarizing, our analysis of line placement shows that NLT participants behave (on average) in accordance with the Laplacian selection equilibrium, thus giving support to MY's theoretical results. In particular, when the information acquisition technology only permits continuous choice rules — as is arguably the case in many real-world settings — the risk-dominant equilibrium is likely to be a good prediction of market participant behavior. As for the LT, where some participants use sharp thresholds, the theory offers multiple predictions. We provide suggestive evidence that in this case participants are more willing to take the risky action and to coordinate on more Pareto-efficient equilibria.

4.3 Action Choice

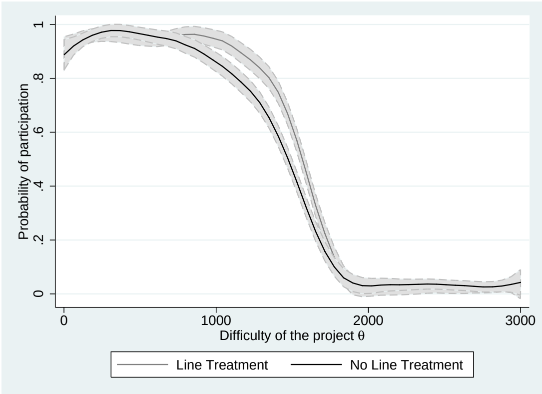
We now turn to investigate how the likelihood with which participants choose the risky action (to participate) in the LT differs from that in the NLT. For this, we use the data on the realized state θ and the choice of action (either participate or abstain), thus, this slice of our data can be viewed as state-dependent stochastic choice data (e.g. see Caplin, Dean, and Leahy 2018). Figure 8 presents non-parametric estimates of the probability of participation as a function of the state of the world for the two treatments. The left-hand panel shows the results using data from all six blocks whereas the right-hand panel focuses only on the last three blocks, when the choice of line placement for a large portion of our participants has stabilized.

The region of state-of-the-world realizations θ where no action is dominant — and hence induces a coordination problem — is $(700, 1700)$. Figure 8 shows that in this region participants are more likely to take the risky action in the LT than in the NLT. Visually, the graph of the estimated probability to take the risky action in the LT appears shifted to the right of that in the NLT. This is in agreement with the difference between average line positions in the two treatments. In other words, providing players with more information (in particular, with the ability to tell apart nearby states) leads them to take the risky action more, on average.

Investigating further, we split the state space into bins of size 100 and estimate the probability of taking the risky action conditional on the state of the world θ being within a given bin. We cluster standard errors at the matching group level. Figure 9 presents the results. Marks on the horizontal axes refer to the bins' centers. For conciseness, we only report the results for bins between 900 and 1800. The estimated probability of taking the risky action outside this interval does not differ across treatments and approaches the corner values (1 to the left and 0 to the right).

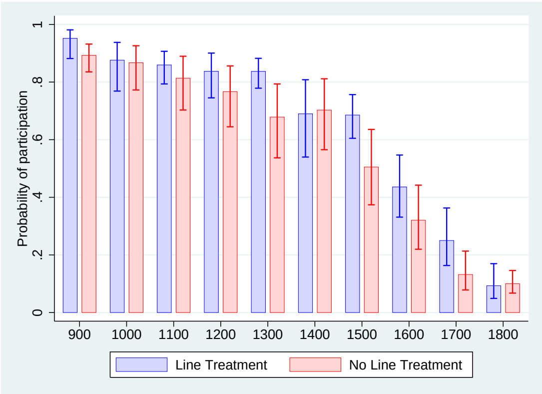


(a) All six blocks

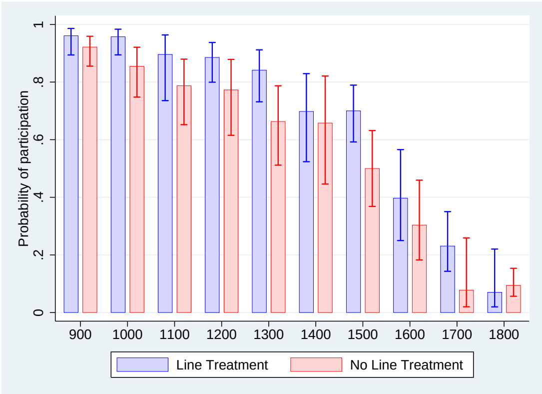


(b) In the last three blocks

Figure 8: Non-parametric estimate of probability of participation conditional on the state of the world, with confidence intervals



(a) All six blocks



(b) Last three blocks

Figure 9: Estimates of participation probability conditional on the state of the world by bins of 100, with 95% confidence intervals

Table 5: Difference in the probability of participation by bins

	All six blocks		Last three blocks	
Bin	Treatment effect	p-value	Treatment effect	p-value
(850, 950)	-0.059	0.057	-0.039	0.187
(950, 1050)	-0.009	0.858	-0.103	0.023
(1050, 1150)	-0.046	0.364	-0.109	0.135
(1150, 1250)	-0.071	0.247	-0.113	0.105
(1250, 1350)	-0.159	0.020	-0.178	0.026
(1350, 1450)	0.013	0.877	-0.040	0.729
(1450, 1550)	-0.180	0.016	-0.200	0.014
(1550, 1650)	-0.115	0.119	-0.093	0.351
(1650, 1750)	-0.118	0.040	-0.153	0.029

As one can observe in Figure 9, for almost all depicted bins the probability of taking the risky action is higher in the LT and the effect size is up to 20 percentage points. The difference is highest for the bin centered on 1500, which corresponds to the middle of the state space in our experiment. The only exception is the bin centered around 1400, where the treatment effect appears to be zero. However, this estimate is the least precise.

To further support the above discussion on the treatment effect, we estimate the following regression model:

$$a_{imjr} = \sum_{s=1}^{29} \Big[\alpha_s \mathbb{1}_{\{100s-50 \leq \theta_{imjr} < 100s+50\}} + \beta_s \text{NLT}_i \mathbb{1}_{\{100s-50 \leq \theta_{imjr} < 100s+50\}} \Big] + \varepsilon_{imjr}. \tag{4}$$

In the equation, $a_{imjr} = 1$ if subject i from matching group m chose to participate in the project in round r of block j and $a_{imjr} = 0$ otherwise; $\text{NLT}_i = 1$ if the participant i was assigned to the NLT and $\text{NLT}_i = 0$ if she was assigned in the LT, while the indicator function $\mathbb{1}_{\{\cdot\}}$ tracks into which bin the state θ_{imjr} fell for subject i in round r of block j.

The results are shown in Table 5. We use very conservative standard errors, clustered at the matching-group level (6 or 8 participants per group). Despite that, the differences appear to be significant for a substantial number of bands, although not across the board. Note also that the treatment effect appears stronger (larger in absolute value) and reaches up to 20 p.p. when we focus on the latter blocks, after learning has taken place.

These cross-treatment differences in participation probability can be reconciled with the differences in line placement we found in 4.2 (70–100 points of the state space). Assuming participation probability declines at a constant rate over [700,1700], the 70–100 shift in average cutoff corresponds to a probability of participation reduced by 7–10 p.p., which is not far from our estimates.

The results further support our previous analysis. Participants in the LT — who have more accurate information than their NLT counterparts — take the risky action more often and for larger values of the state of the world (project's difficulty). They thus appear to be playing strategies closer to the one prescribed by the Pareto-efficient equilibrium.

5 Relation to the Literature

The theoretical literature on "global games" began with the seminal contribution of Carlsson and van Damme (1993) who start with the observation that when the payoffs of a 2×2 game with strategic complementarities are common knowledge, the game has multiple strict equilibria. They then proceed to show that if players receive (exogenous) idiosyncratic noisy signals about the game's payoffs (instead of payoffs being commonly known), only the risk-dominant equilibrium survives iterated deletion of dominated strategies in the limit where the noise vanishes. Some early applications of this stark result are reviewed in Morris and Shin (2000).

Morris and Yang (2019) show that a result similar to that of Carlsson and van Damme (1993) holds when information is endogenously acquired and stochastic choice is continuous (players cannot tell apart nearby states), while it fails to hold if players can implement discontinuous stochastic choice rules. With this, they point out the importance of continuity of stochastic choice for equilibrium selection (Mathevet 2010, provides a general principle, while Mathevet and Steiner 2013, emphasize the importance of translation insensitivity in obtaining such results).

In Section 2, our theoretical model extends the intuition of MY to heterogeneous populations of players and generates two results. On the one hand, even a small amount of "sharp" players (who can tell apart nearby states) is enough to restore equilibrium multiplicity. On the other hand, the set of equilibria admitted when there is a positive fraction of sharp players is "around" (a neighborhood of) the risk-dominant equilibrium. Taken together, these results show that MY's prediction is robust to small amounts of sharp players.

There are a number of experimental studies that investigate the effect of information frictions on participant behavior in coordination games. Heinemann, Nagel, and Ockenfels (2004) pioneered this literature, which largely focuses on the global games framework. In their experiment subjects play a speculative attack game in two different treatments: one in which the state is common knowledge (for which the theory predicts multiple equilibria) and one in which each participant receives a noisy private signal about the state (with a unique equilibrium prediction). They find that participants in both treatments follow cutoff strategies. Yet, in the common information treatment the cutoff is closer to that of the payoff-dominant equilibrium while in the private information treatment it is closer to the cutoff of the risk-dominant equilibrium. Cornand (2006) examines the Heinemann, Nagel, and Ockenfels (2004) result in the presence of two signals which, depending on the treatment, are either both public, or one is public and one is private. She finds that participants tend to play the risky action more frequently in the treatment with two public signals, leading to Pareto superior outcomes.

Our experimental findings (Section 4) parallel those of the aforementioned studies. In our environment too, the equilibrium selection result provides a good prediction for participants' play when the theoretical conditions for its application are satisfied. Moreover, our results conform to a behavioral regularity present in these studies: When multiple equilibria are predicted by the theory, participants tend to play strategies that lead to more efficient outcomes, compared to the risk-dominant equilibrium (rather than less efficient play).

Szkup and Trevino (2015) conduct an experiment on global games where they allow participants to increase the precision of their signals by incurring costs. They find that participants who acquire — or are exogenously given — more precise signals tend to choose thresholds that correspond to more efficient equilibria of the complete-information game. Although this finding goes against the authors' comparative statics predictions, it goes in the same direction as our experimental result: more accurate information (like the one in our Line Treatment) shifts participant behavior towards more efficient outcomes.

Our approach is different from the existing literature in that we depart from the global games structure of information provision (state + noise) and let participants' minds "choose signals." We hope that this environment is more natural for the participants and that it can induce them to behave as they would when faced with coordination problems outside the lab. This approach is similar to Dean and Neligh (2019) whose design is based on displaying blue and red balls, with the fraction of red balls representing the state of the world. They focus on the implications of information frictions in a decision problem, whereas we study the strategic implications of information acquisition.

A separate but related strand of literature studies how "noise" in the sense of deviations from equilibrium (or simply from prevailing behavioral rules) matters for equilibrium selection and convergence of play. For instance, Mäs and Nax (2016) and Lim and Neary (2016) study prevailing behavioral deviations and the resulting equilibrium selection in coordination games with complete information.

6 Conclusion

In this paper we experimentally investigate participant behavior in a two-player coordination game of incomplete information under different information structures. To this end, we employ a novel design that relies on a graphical presentation of the state space. The design allows us to accurately communicate probability distributions to participants while bypassing the language of probability that some participants may find inaccessible. We believe that our approach can be useful to other experimenters aiming to conduct studies in incomplete information environments. For example, it can be used for experiments on beauty contests (à la Morris and Shin 2002) to communicate signals following (truncated) normal distributions.

With a small variation in our experimental design we are able to investigate how participant behavior is affected by two different information technologies: one that generates strategies (stochastic choice rules) continuous in the state of the world and one that generates discontinuous strategies. We find that when participants can only play continuous strategies the theoretical equilibrium selection result of Morris and Yang (2019) is a good prediction for participants' behavior. When participants can use discontinuous strategies — in which case multiple equilibria are predicted by the theory — participants behave in a way consistent with play in more efficient equilibria. Interestingly, experimental studies in global games (Heinemann, Nagel, and Ockenfels 2004; Cornand 2006) also find similar results which suggests that the tendency for efficiency when multiple equilibria are present might be a behavioral regularity.

Finally, we provide an extension of Morris and Yang (2019)'s theoretical result to heterogeneous populations, showing that the set of equilibria is continuously decreasing in the proportion of players that use continuous strategies. While this shows that even a small number of "sharp" players who can use discontinuous strategies suffices to establish multiple equilibria, the set of equilibria admitted is always a neighborhood of the risk-dominant equilibrium. Therefore, MY's prediction is "robust" to small amounts of sharp players.

An avenue for future research is to study how larger groups of participants (rather than pairs) play similar coordination games under the two information structures. Another one is to investigate comparative statics with respect to the payoff structure. This could help identify which elements of the game can induce participants to behave even more efficiently when the theory predicts multiple equilibria.

References

Calonico, S., M. D. Cattaneo, and R. Titiunik (2014). “Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs”. *Econometrica* 82 (6), pp. 2295–2326.

Caplin, A., M. Dean, and J. Leahy (2018). “Rational Inattention, Optimal Consideration Sets, and Stochastic Choice”. *The Review of Economic Studies* 86 (3), pp. 1061–1094.

Carlsson, H. and E. van Damme (1993). “Global Games and Equilibrium Selection”. *Econometrica* 61 (5), pp. 989–1018.

Chen, D. L., M. Schonger, and C. Wickens (2016). “oTree—An Open-Source Platform for Laboratory, Online, and Field Experiments”. *Journal of Behavioral and Experimental Finance* 9, pp. 88 –97.

Cornand, C. (2006). “Speculative Attacks and Informational Structure: an Experimental Study”. *Review of International Economics* 14 (5), pp. 797–817.

Crosetto, P. and A. Filippin (2013). “The “Bomb” Risk Elicitation Task”. *Journal of Risk and Uncertainty* 47 (1), pp. 31–65.

Dean, M. and N. L. Neligh (2019). “Experimental Tests of Rational Inattention”. *Columbia University Discussion of Economics Working Papers* (21).

Heinemann, F., R. Nagel, and P. Ockenfels (2004). “The Theory of Global Games on Test: Experimental Analysis of Coordination Games with Public and Private Information”. *Econometrica* 72 (5), pp. 1583–1599.

Lim, W. and P. R. Neary (2016). “An Experimental Investigation of Stochastic Adjustment Dynamics”. *Games and Economic Behavior* 100, pp. 208–219.

Mäs, M. and H. H. Nax (2016). “A Behavioral Study of “Noise” in Coordination Games”. *Journal of Economic Theory* 162, pp. 195–208.

Mathevet, L. (2010). “A Contraction Principle for Finite Global Games”. *Economic Theory* 42 (3), p. 539.

Mathevet, L. and J. Steiner (2013). “Tractable Dynamic Global Games and Applications”. *Journal of Economic Theory* 148 (6), pp. 2583–2619.

Mattsson, L.-G. and J. W. Weibull (2002). “Probabilistic Choice and Procedurally Bounded Rationality”. *Games and Economic Behavior* 41 (1), pp. 61–78.

Morris, S. and H. S. Shin (2000). *Global Games: Theory and Applications*. Cowles Foundation Discussion Papers 1275R. Cowles Foundation for Research in Economics, Yale University.

Morris, S. and H. S. Shin (2002). “Social Value of Public Information”. *The American Economic Review* 92 (5), pp. 1521–1534.

Morris, S. and M. Yang (2019). “Coordination and Continuous Stochastic Choice”. *Available at SSRN: https://ssrn.com/abstract=2889861*.

Pomatto, L., P. Strack, and O. Tamuz (2018). "The Cost of Information". *arXiv preprint arXiv:1812.04211*.

Szkup, M. and I. Trevino (2015). "Costly Information Acquisition in a Speculative Attack: Theory and Experiments". *NYU working paper*.

Appendices

A Proof of Proposition 1

Begin by defining

$$\Delta_1(\theta) := \max\{e-\theta, 0\} - t \quad \text{and} \quad \Delta_2(\theta) := \max\{2e-\theta, 0\} - t.$$

Given this, player i with a belief b_j about her opponent's participation is faced with the following decision problem:

$$\max_{s \in \mathscr{S}_t} \int_0^A s(\theta)\left[b_j(\theta)\Delta_2(\theta) + (1-b_j(\theta))\Delta_1(\theta)\right]\frac{1}{A}\,\mathrm{d}\theta.$$

Where $\mathscr{S}_t$ is the set of stochastic choice rules that are available to her type. Notice that when $\theta \in (e-t, 2e-t)$ — i.e., in the area of interest where the complete information game has multiple equilibria — $\Delta_1(\theta) < 0$ and $\Delta_2(\theta) > 0$.

We proceed by calculating best responses to a belief b_j for each of the two types.

Sharp Type

The decision problem facing a sharp player is

$$\max_{\psi \in \mathbb{R}} \int_0^A \sigma_\psi(\theta)\left[b_j(\theta)\Delta_2(\theta) + (1-b_j(\theta))\Delta_1(\theta)\right]\frac{1}{A}\,\mathrm{d}\theta$$

or

$$\max_{\psi \in [0,A]} \int_0^\psi \left[b_j(\theta)\Delta_2(\theta) + (1-b_j(\theta))\Delta_1(\theta)\right]\frac{1}{A}\,\mathrm{d}\theta$$

We already showed in Section 2.2 that the best a player can do when her belief is b_j is to play strategy $\mathbb{1}_{\{\theta \leq \theta^*\}}$ where θ^* is the unique state $\theta^* \in [e-t, 2e-t]$ with the property that $b_j(\theta) \geq p(\theta)$ for all $\theta < \theta^*$ and $b_j(\theta) \leq p(\theta)$ for all $\theta > \theta^*$. Since sharp types can use strategies of this type (cutoff strategies), the best response of a sharp player is to use the cutoff ψ^* with the property

$$\lim_{\theta \nearrow \psi^*} b_j(\theta) \geq p(\psi^*) \geq \lim_{\theta \searrow \psi^*} b_j(\theta), \tag{5}$$

where $p(\psi^*)$ is the minimal belief at ψ^* defined in (3).

Fuzzy Type

The decision problem facing a fuzzy player is

$$\max_{\xi\in\mathbb{R}} \int_0^A \tau_\xi(\theta)\big[b_j(\theta)\Delta_2(\theta)+(1-b_j(\theta))\Delta_1(\theta)\big]\frac{1}{A}\,\mathrm{d}\theta$$

or

$$\max_{\xi\in\mathbb{R}} \int_0^{\xi} \big[b_j(\theta)\Delta_2(\theta)+(1-b_j(\theta))\Delta_1(\theta)\big]\mathrm{d}\theta + \int_{\xi}^{\xi+\delta} \varrho(\theta-\xi)\big[b_j(\theta)\Delta_2(\theta)+(1-b_j(\theta))\Delta_1(\theta)\big]\mathrm{d}\theta.$$

Taking a first order condition and using that $\varrho(0)=1$ and $\varrho(\delta)=0$ yields that the optimal choice of ξ should satisfy

$$-\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta-\xi^*)\big[b_j(\theta)\Delta_2(\theta)+(1-b_j(\theta))\Delta_1(\theta)\big]\mathrm{d}\theta = 0$$

When δ is small, the ξ^* a fuzzy player chooses in her best response must fall in the range $[e-t, 2e-t-\delta]$. This is a result of participation being dominant when $\theta < e-t$ and abstention when $\theta > 2e-t$, along with the fuzzy player's ability to place all the varying part of the shape ϱ within the region $[e-t, 2e-t]$ (since $\delta < t$). Using this, along with the fact that

$$p(\theta) = \frac{-\Delta_1(\theta)}{\Delta_2(\theta)-\Delta_1(\theta)}$$

in this region, allows us to re-write the FOC as

$$\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta-\xi^*)(\Delta_2(\theta)-\Delta_1(\theta))(p(\theta)-b_j(\theta))\,\mathrm{d}\theta = 0. \tag{6}$$

Equilibrium

Let $\widetilde{b}$ be the equilibrium belief, while $\widetilde{\psi}$ and $\widetilde{\xi}$ are the equilibrium strategies for the sharp and fuzzy types, respectively. Since each of the two types is constrained to a particular class of strategies, the equilibrium belief $\widetilde{b}$ of a player about her opponent's strategy should be of the form

$$\widetilde{b} = (1-q)\sigma_{\widetilde{\psi}} + q\tau_{\widetilde{\xi}}$$

for some $\widetilde{\psi}, \widetilde{\xi} \in \mathbb{R}$. Therefore, we only need to calculate best responses to beliefs of the above form.

Starting from the sharp type, her best response ξ^* to the equilibrium belief $\widetilde{b}$ is given by condition (5):

$$\lim_{\theta \nearrow \psi^*} \widetilde{b}(\theta) \geq p(\psi^*) \geq \lim_{\theta \searrow \psi^*} \widetilde{b}(\theta)$$

and as $\psi^* = \widetilde{\psi}$ in equilibrium, we have:

$$\lim_{\theta \nearrow \widetilde{\psi}} \widetilde{b}(\theta) \geq p(\widetilde{\psi}) \geq \lim_{\theta \searrow \widetilde{\psi}} \widetilde{b}(\theta). \tag{7}$$

Now we turn to calculating the fuzzy type's best response ξ^* to the equilibrium belief $\widetilde{b}$. Condition (6) gives:

$$\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)(\Delta_2(\theta) - \Delta_1(\theta))(p(\theta) - \widetilde{b}(\theta))\,\mathrm{d}\theta = 0.$$

Notice that in the integral of the above equation, $\varrho'(\theta) < 0$ and $\Delta(\theta) := \Delta_2(\theta) - \Delta_1(\theta) > 0$ for all values of $\theta \in [\xi^*, \xi^* + \delta]$. So, in order for the integral to evaluate to zero, it must be that $\widetilde{b}(\xi^*) > p(\xi^*)$ and $\widetilde{b}(\xi^* + \delta) < p(\xi^* + \delta)$. That is, $\widetilde{\psi} \in (\xi^*, \xi^* + \delta)$.

When $\delta \to 0$, the values of $\Delta(\theta)$ and of $p(\theta)$ change infinitesimally in the range $\theta \in [\xi^*, \xi^* + \delta]$, since both functions are bounded by linear ones in $[e - t, 2e - t]$. So, they can be treated as constant in $[\xi^*, \xi^* + \delta]$. Moreover, as $\widetilde{\psi} \in (\xi^*, \xi^* + \delta)$, the values they take in this range are approximately $\Delta(\widetilde{\psi})$ and $p(\widetilde{\psi})$, respectively. With this, the FOC becomes

$$\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)\Delta(\widetilde{\psi})(p(\widetilde{\psi}) - \widetilde{b}(\theta))\,\mathrm{d}\theta = 0$$

or, since $\Delta(\widetilde{\psi}) > 0$ in this region,

$$\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)(p(\widetilde{\psi}) - \widetilde{b}(\theta))\,\mathrm{d}\theta = 0 \Rightarrow \int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)p(\widetilde{\psi})\,\mathrm{d}\theta - \int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)\widetilde{b}(\theta)\,\mathrm{d}\theta = 0 \Rightarrow$$

$$-\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)\widetilde{b}(\theta)\,\mathrm{d}\theta = p(\widetilde{\psi}) \Rightarrow -\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)\big((1-q)\mathbb{1}_{\{\theta \leq \widetilde{\psi}\}} + q\varrho(\theta - \widetilde{\xi})\big)\,\mathrm{d}\theta = p(\widetilde{\psi}) \Rightarrow$$

$$(1-q)(1 - \varrho(\widetilde{\psi} - \xi^*)) - q\int_{\xi^*}^{\xi^*+\delta} \varrho'(\theta - \xi^*)\varrho(\theta - \widetilde{\xi})\,\mathrm{d}\theta = p(\widetilde{\psi}).$$

In equilibrium, $\xi^* = \widetilde{\xi}$ and the integral in the above equation evaluates to $-1/2$. So,

$$(1-q)(1 - \varrho(\widetilde{\psi} - \widetilde{\xi})) + \frac{q}{2} = p(\widetilde{\psi}). \tag{8}$$

Notice that $\varrho(\widetilde{\psi}-\widetilde{\xi})$ is the equilibrium probability with which a fuzzy player participates when the state is $\theta=\widetilde{\psi}$.

Substituting (8) into (7), which ensures that sharp players are also best responding to $\widetilde{b}$, we get:

$$(1-q)+q\varrho(\widetilde{\psi}-\widetilde{\xi}) \;\geq\; (1-q)(1-\varrho(\widetilde{\psi}-\widetilde{\xi}))+\frac{q}{2} \;\geq\; q\varrho(\widetilde{\psi}-\widetilde{\xi}) \Rightarrow$$
$$(1-q)\frac{q}{2} \;\leq\; (1-q)\varrho(\widetilde{\psi}-\widetilde{\xi}) \;\leq\; (1-q)\Big(1-\frac{q}{2}\Big)$$

Finally, eliminating $\varrho(\widetilde{\psi}-\widetilde{\xi})$ by using (8), we get:

$$q-q^2/2 \;\leq\; p(\widetilde{\psi}) \;\leq\; 1-(q-q^2/2). \tag{9}$$

Any $\widetilde{\psi}$ that satisfies the above equation can be an equilibrium threshold. As $\widetilde{\psi}\in(\widetilde{\xi},\widetilde{\xi}+\delta)$, in the limit where $\delta\to 0$, it must be that $\widetilde{\xi}=\widetilde{\psi}$. Finally, in this limit the belief is $\widetilde{b}(\theta)=\lim_{\delta\to 0}(1-q)\sigma_{\widetilde{\psi}}+q\tau_{\widetilde{\psi}}=\mathbb{1}_{\{\theta\leq\widetilde{\psi}\}}$. □

B Supporting Evidence

B.1 Line Position as a Proxy for Intended Cutoff

In the analysis of Section 4, we assumed that participants in both treatments aim to use cutoff strategies and that they place the line at the position of their intended cutoff. We now explore whether this assumption is warranted. In particular, we measure the share of participants whose observed behavior is consistent with an intention to play a cutoff-at-line-position strategy, i.e. to switch from one action to the other at the position of the line. We use the "intention" qualifier because, given our design, we believe that participants in the NLT should not be able to play cutoff strategies exactly. Moreover, it is likely that participants make mistakes, even if their intention is to play a cutoff-at-line-position strategy (e.g. because they did not spot the dot at all in a specific round). This interpretation is closer to the idea of control cost of implementing the strategy (see for example Mattsson and Weibull 2002).

For the above reasons, we use four different measures of consistency of observed play with a cutoff-at-line-position strategy, based on different criteria. The shares of players that are found to qualify for each of our four criteria are reported in Table 6 by block and treatment. We also report more restrictive measures for which qualifying participants need to consistently satisfy the respective criteria during the last three, or during all six blocks. For the rest of this analysis, we refer to the case where a subject participates to the left of her line or abstains to the right of her line as a *mistake*.

Table 6: Share of subjects consistent with cutoff-at-line-position play

	No mistakes		No far mistakes		0–1 mistakes		0–1 far mistakes	
Block	LT	NLT	LT	NLT	LT	NLT	LT	NLT
1	0.367	0.344	0.467	0.552	0.533	0.615	0.644	0.750
2	0.444	0.448	0.533	0.625	0.711	0.677	0.778	0.802
3	0.533	0.490	0.622	0.708	0.722	0.760	0.811	0.865
4	0.567	0.469	0.656	0.688	0.778	0.719	0.811	0.813
5	0.589	0.542	0.667	0.719	0.789	0.802	0.856	0.875
6	0.563	0.533	0.644	0.760	0.756	0.833	0.844	0.865
All	0.156	0.063	0.233	0.240	0.244	0.208	0.333	0.500
4-6	0.344	0.240	0.444	0.469	0.478	0.479	0.622	0.708

Note: Mistakes refer to inconsistencies between cutoff-at-line-position play and observed play of participants. Far mistakes refer to mistakes that occur when the state is apart from the line by more than the average error in the incentivized rounds of Task 1, which was 166.

First, according to our most stringent criterion, a subject's behavior is consistent with a cutoff-at-the-line strategy if she always participates to the left of her line and never participates to the right of her line in a given block. As one can see from column *No mistakes* of Table 6, even under this very stringent definition, the share of participants whose behavior is indistinguishable from exact cutoff play, although starting relatively small, exceeds 50% in the latter blocks of the task.

Our second, less stringent criterion takes into account the fact that it is much harder to follow a cutoff strategy when the realized state is near the line position (especially in the NLT). In order to get a measure of what is "near" and what is "far," we use the data from the incentivized rounds of the guessing game in Task 1. We compute the average size of the error that participants made while trying to guess the position of the dot and find it equal to 166. Then, we turn a blind eye to the region within this average error from the line position and say that behavior is consistent with an (intended) cutoff strategy if the participant did not make any mistakes outside that region. Not surprisingly, with this measure the share of "consistent" subjects increases (column *No far mistakes*).

The third (column *0–1 mistakes*) and fourth (column *0–1 far mistakes*) criteria of consistency we employ respectively relax the first and the second definitions by allowing one mistake of the respective type (either "proper" or "far" mistake). Under these definitions around 80% of the participants behave in a way that resembles a cutoff-at-line-position strategy, switching from participation to abstention at their line position. This shows that the line position is a good approximation of the cutoffs for a large majority of the participants.

B.2 Non-strategic Task

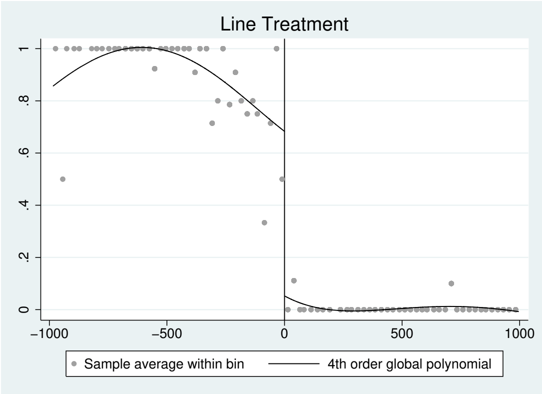
The analysis in this section concerns our participants' behavior in the non-strategic Task 3 of the experiment. Task 3 is identical to our main task (Task 2) but with the strategic interaction removed, while each participant gets payoff as if her partner is known to abstain from the project. The results from our analysis lend further support to the internal validity of our design, as they show that also in the absence of the strategic considerations, participants play continuous strategies in the NLT, and at least some subjects play discontinuous strategies in the LT.

Figure 10 and Table 7 report the results of regression discontinuity analysis at the position of the line in Task 3. Similarly to the strategic task, we observe that the probability of taking the risky action is continuous in the NLT and discontinuous at the line position in the LT. These results point towards the validity of our design.

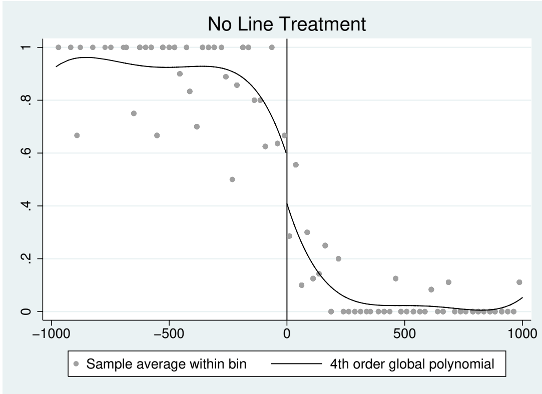
One interesting observation is the difference between strategic and non-strategic environments in the drop in the probability of taking the risky action around the line. The RDD results indicate that in the non-strategic environment this drop is close to 65 p.p. whereas in the strategic environment it is around 40 p.p. Although we do not have a firm theoretical foundation for this result, it might indicate that, rather than being unable to use the line, some participants chose to ignore it in the strategic treatment.

Table 7: Estimation of discontinuity at the line position in the non-strategic task

	Line Treatment		No Line Treatment	
bandwidth	drop	p-value	drop	p-value
± 50	-0.220	0.793	-0.303	0.456
± 100	-0.604	0.057	-0.172	0.572
± 150	-0.665	0.003	-0.237	0.355
± 200	-0.651	<0.001	-0.244	0.268
± 250	-0.649	<0.001	-0.256	0.213
± 300	-0.647	<0.001	-0.274	0.145
± 350	-0.653	<0.001	-0.286	0.101



(a) Line Treatment



(b) No Line Treatment

Figure 10: Estimate of participation probability conditional on the distance to the line in the non-strategic task (Task 3)

C Additional Data

C.1 Allocation of participants in treatments and payment data

Table 8: Experiment Overview

	Overall		Line Treatment			No Line Treatment		
Session	# P	Avg pay	# P	Matching group sizes	Avg pay	# P	Matching group sizes	Avg pay
1	28	247	14	8; 6	231	14	8; 6	263
2	28	241	14	8; 6	251	14	8; 6	231
3	26	233	12	6; 6	248	14	8; 6	220
4	24	230	12	6; 6	223	12	6; 6	236
5	26	242	12	6; 6	225	14	8; 6	256
6	26	228	12	6; 6	220	14	8; 6	236
7	28	233	14	8; 6	227	14	8; 6	239
All	186	236	90		232	96		240

Note: Average pay is reported in Danish kroner and rounded to the nearest integer. Column *# P* reports the number of participants. Column *Matching group sizes* reports sizes of groups within which the participants were rematched in Task 2.

Table 8 reports the number of participants, sizes of matching groups and average pay by session and treatment. In each session, 12 or 14 participants were assigned to each treatment, depending on attendance, in order to achieve as close to a 50-50 split as possible.

C.2 Choice Stabilization

Table 9: Stabilization of line position by block

	1	2	3	4	5	6
			Line Treatment			
In block	43.33	13.33	12.22	12.22	7.78	11.11
Cumulative	43.33	56.67	68.89	81.11	88.89	100
			No Line Treatment			
In block	42.71	18.75	7.29	3.13	10.42	17.71
Cumulative	42.71	61.46	68.75	71.88	82.29	100

Table 9 presents the shares of participants who do not change their line position from the specific block onwards by treatment. Note that in both treatments over 50% of participants fix the choice of the line position from block 2 onwards, and over 70% do so by block 4. Players also seem to settle on the line position somewhat faster in the Line Treatment, compared to the No Line Treatment, however, Wilcoxon rank-sum test of the stabilization block between two treatments has p-value of 0.781 indicating that the hypothesis of the same speed of stabilization in both rounds can not be rejected.

C.3 Summary Statistics

Table 10: Summary statistics by treatment

	LT	NLT	Total
Av. Mistake	166.56	169.87	163.04
Risk-aversion	987.98	990.90	984.88
Male (%)	38.80	39.78	37.78

Table 10 reports summary statistics. The first row — Av. Mistake — reports average distance between the dot position and the participant's guess in the ten incentivized rounds of the guessing game (Task 1). The next row reports our measure of risk-aversion based on Task 4. This task had three rounds, starting in the same way as all previous tasks 4a. At the beginning of each round a position of the dot is drawn but not revealed. Then, a line starts moving from the leftmost to the rightmost end of the rectangle. Participants can stop the moving line at any point, and once they decide to do so, the position of the dot is revealed. If the dot is to the right of the line, i.e. the line has not crossed the dot, the payoff is equal to the position of the line. If the line has crossed the dot, the payoff is zero. Thus, the dot acts like the hidden "bomb" of Crosetto and Filippin (2013). Our measure of risk-aversion is the median choice across three rounds. The last row reports the share of male participants (note that in the LT three participants chose not to report their gender).

D Experiment Instructions

In the following pages we provide the full sets of instructions participants received. We start with Task 1, which was the same for both treatments. For each of Tasks 2 and 3 we first provide the instructions for the Line Treatment and then for the No Line Treatment. Task 4, which was the same for both treatments, concludes. For the reader's convenience, we print labels in [square brackets] indicating in which treatment(s) the corresponding instruction pages were handed out. These labels were not printed on the instructions that participants received.

Welcome

Thank you for your participation in this economic experiment, in which you will have the chance to earn money. This experiment is run by the Laboratory for Experimental Economics (LEE). The CERGE-EI Foundation (USA) and Handelsbankens forskningsstiftelser (Sweden) have provided funds for this research.

For this experiment, you are paid money that you accumulate over decision tasks. The exact amount you receive will be determined during the experiment and will depend on your decisions as well as the decisions of others. You will be paid privately, in cash, at the conclusion of the experiment.

All monetary amounts you will see in this experiment will be denominated in *points*. We will convert *points* to DKK at the rate of

$$24 \textit{ points} = 1 \text{ DKK}.$$

We ask you not to communicate from now on. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc., you will be asked to leave and you will not be paid. We expect and appreciate your following of these rules.

The Experiment

All participants are present in the room. The experiment consists of 4 tasks. You will receive instructions for each task after the previous task is finished.

At the end of the experiment (after the fourth task) we will ask you to fill out a questionnaire. The data you will be asked for will be treated strictly confidentially and used for research purposes only.

We now ask you to read through the instructions of today's experiment. After you have read the instructions, you will have time to ask clarifying questions. We would like to stress that any choices you make in this experiment are entirely anonymous. Please do not touch the computer or its mouse until you are instructed to do so. Thank you.

All numerical examples in these instructions are used simply to provide examples and do not represent any hints or suggestions for how you should make your decisions during the experiment.

If you have a question please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

[Both Treatments]

Task 1

This task consists of 15 rounds. In this task your payoff will only depend on your own decisions. The decision you make in any one round does not affect any other round in any way.

- Rounds 1 to 5 are practice rounds, allowing yourself to familiarize with the experimental environment. Therefore, the decisions you make in rounds 1 to 5 **will not** affect your earnings in the experiment.
- Rounds 6 to 15 will affect your earnings in the following way: At the end of the experiment a computer will **randomly select one of rounds 6 to 15** and you will be paid for the amount of *points* that you earned in that round.

This is how the input screen will look at the beginning of each round. Whenever you are ready, you can press the button "Click to flash the dot in 3 seconds." After you press the button, and after 3 seconds have elapsed, a dot will appear inside the box on the screen for 70 milliseconds (0.07 seconds). The Position of the dot is random and equally likely for any point inside the box. The Position of the dot in one round **does not** depend on the Position of the dot in any other round. It can happen that you may not be able spot the dot the first few times. Do not worry, you will be able to spot it after a few practice rounds.

[Both Treatments]

Your task is to guess the horizontal Position of the dot. The leftmost side of the box corresponds to 0, and the rightmost side of the box corresponds to 3000. After the dot disappears, you need to insert your Guess as a number between 0 and 3000, e.g., 23 or 2556.

After each of rounds 1 to 5, you will receive feedback specifying what the exact Position of the dot was and how far from it your Guess was. You will receive no feedback after rounds 6 to 15.

In each of rounds 6 to 15, you will be awarded *points* for your Guess. The closer your Guess is to the actual Position of the dot, the higher your earnings will be. Thus, your goal is to give your best guess of the horizontal Position of the dot. Specifically, the distance between the dot's actual horizontal Position and your Guess will be deducted from 500. Your payoff for the round will be the resulting number of *points*. If the difference between the dot's Position and your Guess is more than 500, your payoff for the round is 0 *points*. At the end of Task 1, you will receive feedback on all rounds 1 to 15.

At the end of the experiment, a computer will randomly select one out of rounds 6 to 15 for payment. You will receive *points* equal to your payoff from that round. You will not receive *points* for any of the other 14 rounds.

Example

Suppose that the dot's Position is 1555. After the dot disappears, you need to insert your Guess.

1. If your Guess is 1620, the difference between your Guess and the dot's Position is $1620 - 1555 = 65$, which is **less** than 500. Your payoff is $500 - 65 = 435$ *points*.

2. If your Guess is 1500, the difference between your Guess and the dot's Position is $1555 - 1500 = 55$, which is **less** than 500. Your payoff is $500 - 55 = 445$ *points*.

3. If your Guess is 1000, the difference between your Guess and the dot's Position is $(1555 - 1000) = 555$, which is **more** than 500. Your payoff is 0 *points*.

Are there any questions? If you have a question please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

Practice Questions

Before Task 1 begins, we ask you to answer some practice questions. This is done to make sure that everyone understands how payoffs are calculated. When you are done answering the questions, please raise your hand and an experimenter will come to your desk.

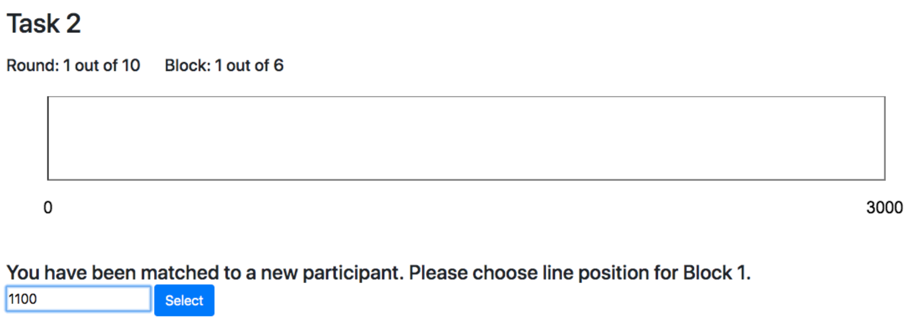
1. Suppose the dot's Position is 1324 and your Guess is 1310. What is your payoff (in *points*), if this round is selected for payment?

2. Suppose the dot's Position is 1575 and your Guess is 1600. What is your payoff (in *points*), if this round is selected for payment?

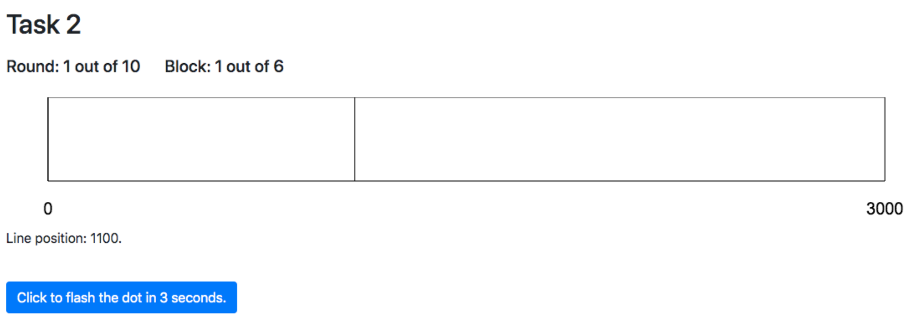
Task 2

This task consists of 6 blocks of rounds. Each block consists of 10 rounds. In this task your payoff will depend on your own decisions but also on the decisions of other participants. At the beginning of each block, **a computer will randomly pair you with one other participant** in the room. You will not know who your partner for the block is. Your partner will not know that he or she is paired with you.

At the beginning of each block, the input screen will contain a box, as in Task 1. However, this time there is a vertical line at position 0. You can move the line by inserting a number between 0 and 3000 into the box, as shown in the picture below. You can place the line at any position you want. Your choice of the line's position before round 1 of each block will be applied to all 10 rounds of that block. The line's position will not be used to determine your payoff in any way.

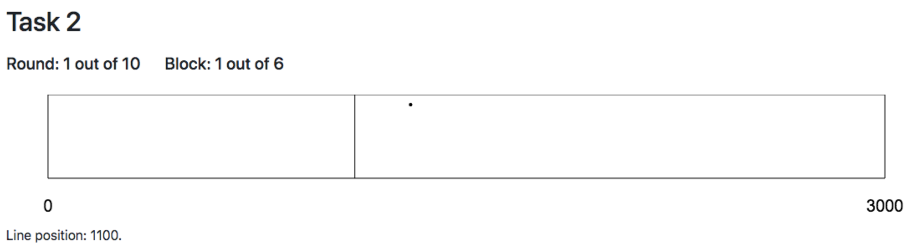


Once you have chosen the position of the line by clicking on the button "Select", the block begins.

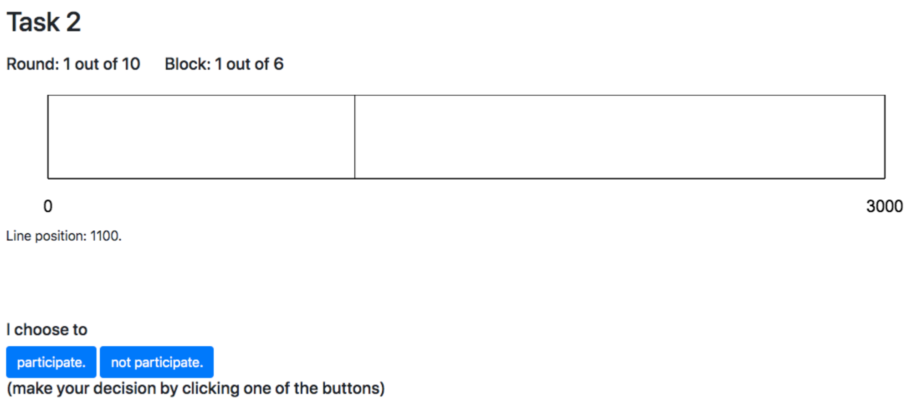


At the beginning of each round you press the button "Click to flash the dot in 3 seconds." Three seconds later, a dot will appear inside the box for 70 milliseconds (0.07 seconds).

The Position of the dot is random and equally likely for any point inside the box. It is the same for you and your partner.



A few seconds after the dot disappears, you will have to choose between two actions: **participate** or **not participate.**



Each round represents a project. The horizontal Position of the dot indicates the difficulty of the project. By choosing **participate,** each participant brings 1000 units of effort to the project. Choosing **not participate** brings 0 units of effort to the project. If the combined amount of units of effort of you and your partner exceeds or equals the number corresponding to the dot's Position, then the project **succeeds.** Otherwise, the project **fails.** If you **participate** and the project **succeeds,** you receive a number of *points* equal to the difference between your group effort and the project's difficulty. If you **participate** and the project **fails,** you receive 0 *points*. If you do **not participate,** you receive 300 *points*.

Thus,

- if the dot's Position is larger than or equal to 2000 and you decide to participate, you will receive 0 *points*. You will receive 300 *points* if you decide to not participate.
- if the dot's Position is larger than or equal to 1000 and less than 2000 and you decide

to participate, you will receive (2000 - dot's Position) *points* if your parter decides to participate, and you will receive 0 *points* if your partner decides to not participate. You will receive 300 *points* if you decide to not participate.

- if the dot's Position is smaller than 1000 and you decide to participate, you will receive (1000 - dot's Position) *points* if your partner decides not to participate, and you will receive (2000 - dot's Position) *points* if your partner decides to participate. You will receive 300 *points* if you decide to not participate.

Once you and your partner have chosen actions, the next round of the block will start. The block is completed after 10 rounds. After the end of round 10 of each block, you will receive feedback on the block. The feedback will specify the exact Position of the dot, your chosen action, the action chosen by your partner, and your earnings in each of the 10 rounds. The feedback will also specify the position of the line that you chose for the block.

After you observe the feedback, **you will be randomly rematched with a new partner,** and a new block will start, until 6 blocks have been completed.

At the end of the experiment, a computer will randomly select one round from each of the 6 blocks for payment. You will receive *points* equal to your payoff from those 6 rounds. You will not receive *points* for any of the other 54 rounds.

Are there any questions? If you have a question please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

Practice Questions

Before Task 2 begins, we ask you to answer some practice questions. This is done to make sure that everyone understands how the software operates and how payoffs are calculated. When you are done answering the questions, please raise your hand and an experimenter will come to your desk.

Suppose you are at the beginning of Task 2. Suppose also that you chose the line to be at 1100, and the randomly selected Position of the dot turned out to be at 1300.

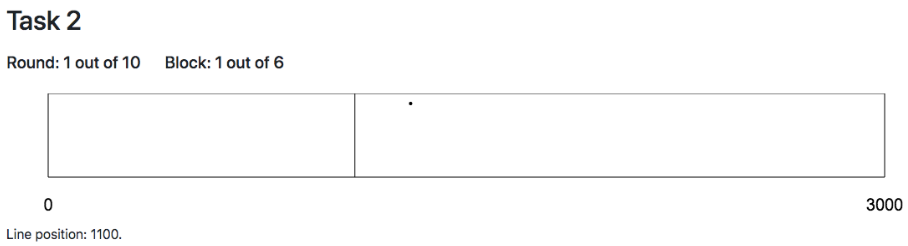
1. What will the screen look like **immediately before** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

2. What will the screen look like **immediately after** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

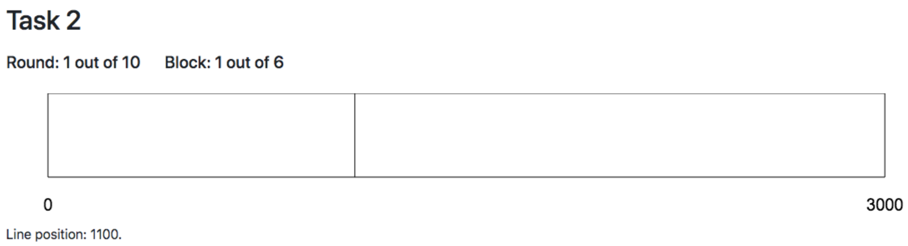
3. What will the screen look like **3 seconds after** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

4. What will the screen look like **3.5 seconds after** you press the button “Click to flash the dot in 3 seconds.”? (Select one of the figures below, A, B, or C)

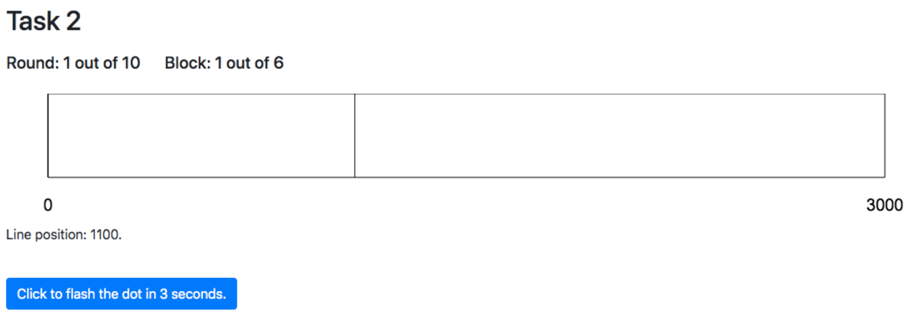
A)



B)



C)



5. Fill in the missing payoffs in the tables below.

Dot Position is 1900

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

Dot Position is 1400

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

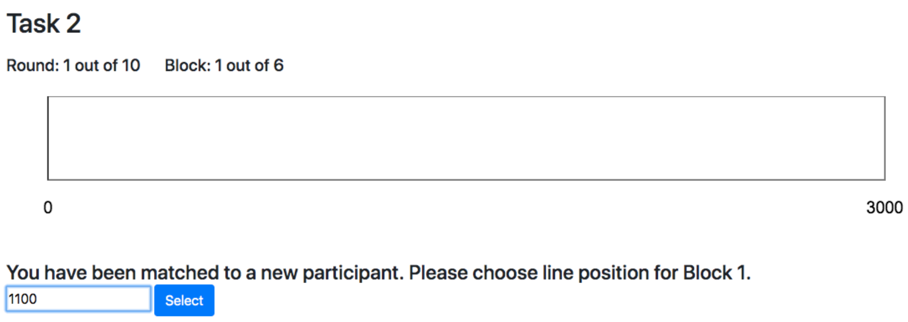
Dot Position is 600

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

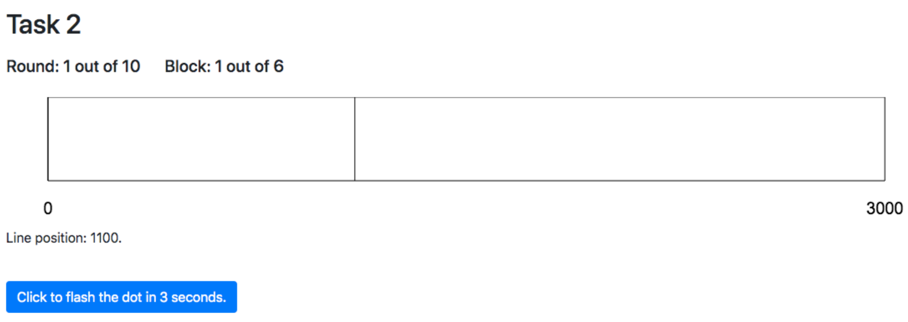
Task 2

This task consists of 6 blocks of rounds. Each block consists of 10 rounds. In this task your payoff will depend on your own decisions but also on the decisions of other participants. At the beginning of each block, **a computer will randomly pair you with one other participant** in the room. You will not know who your partner for the block is. Your partner will not know that he or she is paired with you.

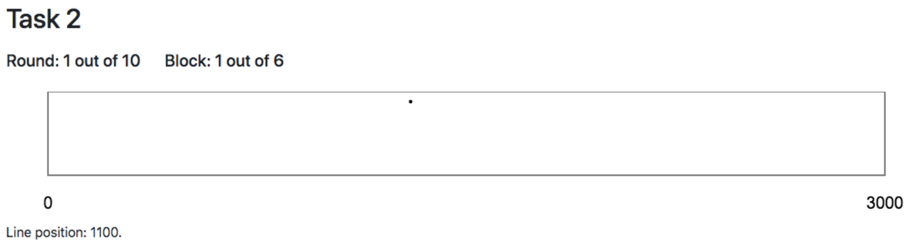
At the beginning of each block, the input screen will contain a box, as in Task 1. However, this time there is a vertical line at position 0. You can move the line by inserting a number between 0 and 3000 into the box, as shown in the picture below. You can place the line at any position you want. Your choice of the line's position before round 1 of each block will be applied to all 10 rounds of that block. The line's position will not be used to determine your payoff in any way.



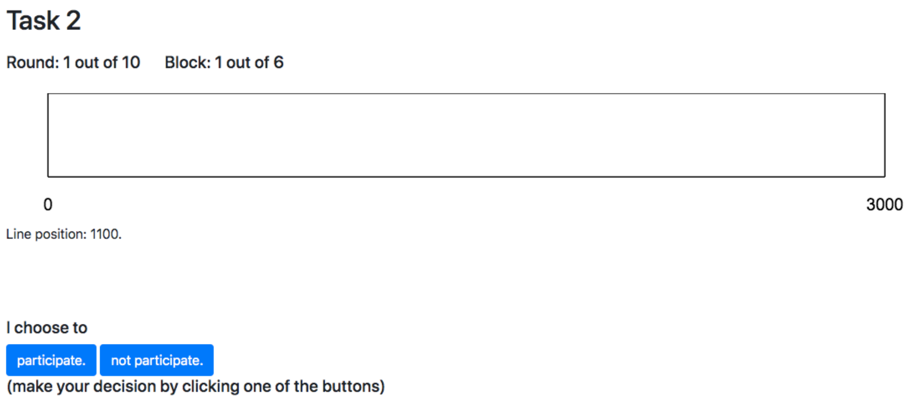
Once you have chosen the position of the line by clicking on the button "Select", the block begins.



At the beginning of each round you press the button "Click to flash the dot in 3 seconds." Once you press the button, the line will disappear. Three seconds later, a dot will appear inside the box for 70 milliseconds (0.07 seconds). The Position of the dot is random and equally likely for any point inside the box. It is the same for you and your partner.



A few seconds after the dot disappears, you will have to choose between two actions: **participate** or **not participate.**



Each round represents a project. The horizontal Position of the dot indicates the difficulty of the project. By choosing **participate,** each participant brings 1000 units of effort to the project. Choosing **not participate** brings 0 units of effort to the project. If the combined amount of units of effort of you and your partner exceeds or equals the number corresponding to the dot's Position, then the project **succeeds.** Otherwise, the project **fails.** If you **participate** and the project **succeeds,** you receive a number of *points* equal to the difference between your group effort and the project's difficulty. If you **participate** and the project **fails,** you receive 0 *points*. If you do **not participate,** you receive 300 *points*.

Thus,

- if the dot's Position is larger than or equal to 2000 and you decide to participate, you will receive 0 *points*. You will receive 300 *points* if you decide to not participate.
- if the dot's Position is larger than or equal to 1000 and less than 2000 and you decide

to participate, you will receive (2000 - dot's Position) *points* if your parter decides to participate, and you will receive 0 *points* if your partner decides to not participate. You will receive 300 *points* if you decide to not participate.

- if the dot's Position is smaller than 1000 and you decide to participate, you will receive (1000 - dot's Position) *points* if your partner decides not to participate, and you will receive (2000 - dot's Position) *points* if your partner decides to participate. You will receive 300 *points* if you decide to not participate.

Once you and your partner have chosen actions, the next round of the block will start. The block is completed after 10 rounds. After the end of round 10 of each block, you will receive feedback on the block. The feedback will specify the exact Position of the dot, your chosen action, the action chosen by your partner, and your earnings in each of the 10 rounds. The feedback will also specify the position of the line that you chose for the block.

After you observe the feedback, **you will be randomly rematched with a new partner,** and a new block will start, until 6 blocks have been completed.

At the end of the experiment, a computer will randomly select one round from each of the 6 blocks for payment. You will receive *points* equal to your payoff from those 6 rounds. You will not receive *points* for any of the other 54 rounds.

Are there any questions? If you have a question please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

Practice Questions

Before Task 2 begins, we ask you to answer some practice questions. This is done to make sure that everyone understands how the software operates and how payoffs are calculated. When you are done answering the questions, please raise your hand and an experimenter will come to your desk.

Suppose you are at the beginning of Task 2. Suppose also that you chose the line to be at 1100, and the randomly selected Position of the dot turned out to be at 1300.

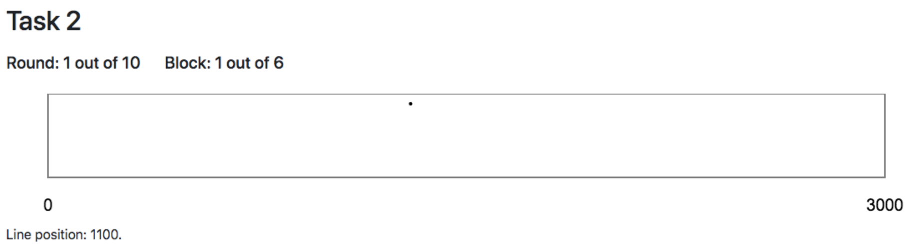
1. What will the screen look like **immediately before** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

2. What will the screen look like **immediately after** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

3. What will the screen look like **3 seconds after** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

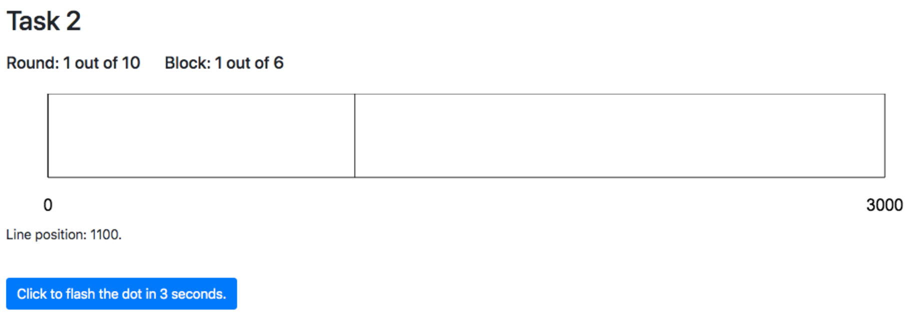
4. What will the screen look like **3.5 seconds after** you press the button "Click to flash the dot in 3 seconds."? (Select one of the figures below, A, B, or C)

A)



B)

C)



5. Fill in the missing payoffs in the tables below.

Dot Position is 1900

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

Dot Position is 1400

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

Dot Position is 600

Your decision	Your partner's decision	Your payoff	Your partner's payoff
participate	participate		
participate	not participate		
not participate	participate		
not participate	not participate		

Task 3

This task consists of 1 block of 10 rounds. In this task your payoff will only depend on your own decisions. **You will not be paired with any other participants.**

At the beginning of each block, the input screen will contain a box, as in Task 2. There is a vertical line at position 0. You can move the line by inserting a number between 0 and 3000 into the box, as shown in the picture below. You can place the line at any position you want. Your choice of the line's position before round 1 of the block will be applied to all 10 rounds of the block. The line's position will not be used to determine your payoff in any way.

Once you have chosen the position of the line by clicking on the button "Select", the block begins. At the beginning of each round you press the button "Click to flash the dot in 3 seconds." Three seconds later, a dot will appear inside the box for 70ms (0.07 seconds). The Position of the dot is random and equally likely for any point inside the box. A few seconds after the dot disappears, you will have to choose between two actions: **participate** or **not participate.**

Each round represents a project. The horizontal Position of the dot indicates the difficulty of the project. By participating, you bring 1000 units of effort to the project. If the amount of your effort exceeds or equals the number corresponding to the dot's Position, then the project is successful. Otherwise, the project fails. If you participate and the project succeeds, you receive a number of *points* equal to the difference between your effort and the project's difficulty. If you participate and the project fails, you receive 0 *points*. If you do not participate, you receive 300 *points*.

Thus,

- if the dot's Position is larger than or equal to 1000 and you decide to participate, you will receive 0 *points*. You will receive 300 *points* if you decide to not participate.

- if the dot's Position is smaller than 1000 and you decide to participate, you will receive (1000 - dot's Position) *points*. You will receive 300 *points* if you decide to not participate.

Once you have chosen your action, the next round of the block will start. The block is completed after 10 rounds. After the end of round 10, you will receive feedback on the block. The feedback will specify the exact Position of the dot, your chosen action, and your earnings in each of the 10 rounds. The feedback will also specify the position of the line that you chose for the block.

At the end of the experiment, a computer will randomly select one round from the block for payment. You will receive *points* equal to your payoff from this round. You will not receive *points* for any of the other 9 rounds.

If you are sure that you understand the above instructions, you can now click on the "Next Task" button on your screen. Otherwise, if you have a question, please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

Task 3

This task consists of 1 block of 10 rounds. In this task your payoff will only depend on your own decisions. **You will not be paired with any other participants.**

At the beginning of each block, the input screen will contain a box, as in Task 2. There is a vertical line at position 0. You can move the line by inserting a number between 0 and 3000 into the box, as shown in the picture below. You can place the line at any position you want. Your choice of the line's position before round 1 of the block will be applied to all 10 rounds of the block. The line's position will not be used to determine your payoff in any way.

Once you have chosen the position of the line by clicking on the button "Select", the block begins. At the beginning of each round you press the button "Click to flash the dot in 3 seconds." Once you press the button, the line will disappear. Three seconds later, a dot will appear inside the box for 70ms (0.07 seconds). The Position of the dot is random and equally likely for any point inside the box. A few seconds after the dot disappears, you will have to choose between two actions: **participate** or **not participate.**

Each round represents a project. The horizontal Position of the dot indicates the difficulty of the project. By participating, you bring 1000 units of effort to the project. If the amount of your effort exceeds or equals the number corresponding to the dot's Position, then the project is successful. Otherwise, the project fails. If you participate and the project succeeds, you receive a number of *points* equal to the difference between your effort and the project's difficulty. If you participate and the project fails, you receive 0 *points*. If you do not participate, you receive 300 *points*.

Thus,

- if the dot's Position is larger than or equal to 1000 and you decide to participate, you will receive 0 *points*. You will receive 300 *points* if you decide to not participate.

- if the dot's Position is smaller than 1000 and you decide to participate, you will receive (1000 - dot's Position) *points*. You will receive 300 *points* if you decide to not participate.

Once you have chosen your action, the next round of the block will start. The block is completed after 10 rounds. After the end of round 10, you will receive feedback on the block. The feedback will specify the exact Position of the dot, your chosen action, and your earnings in each of the 10 rounds. The feedback will also specify the position of the line that you chose for the block.

At the end of the experiment, a computer will randomly select one round from the block for payment. You will receive *points* equal to your payoff from this round. You will not receive *points* for any of the other 9 rounds.

If you are sure that you understand the above instructions, you can now click on the "Next Task" button on your screen. Otherwise, if you have a question, please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

[Both Treatments]

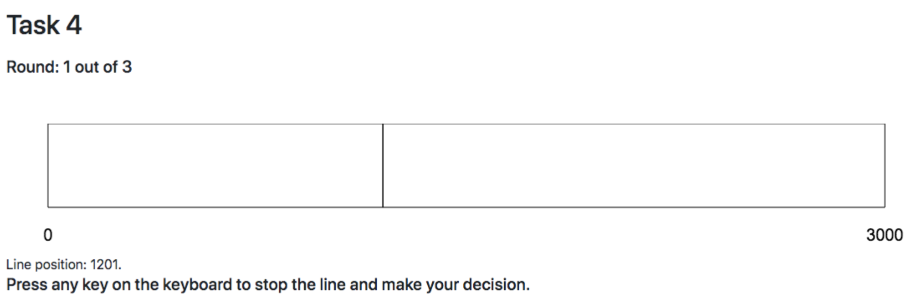
Task 4

This task consists of 3 rounds. In this task your payoff will only depend on your own decisions.

This is how the input screen will look at the beginning of each round. There is a vertical line at position 0 but this time you cannot move it.

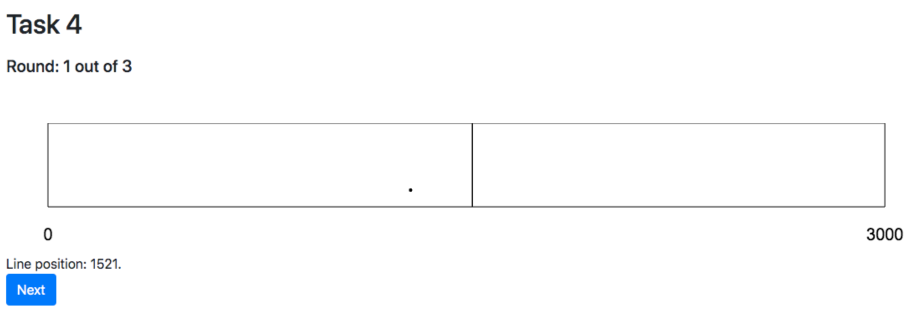
At the beginning of the round, a computer will secretly select the Position of the dot, which will not be revealed to you at this point. The Position of the dot is random and equally likely for any point inside the box. The Position of the dot in one round **does not** depend on the Position of the dot in any other round.

At the beginning of each round you press the button “Click for the line to start moving.” Once you press the button, the line will start moving from 0 at the left end of the box towards 3000 at the right end of the box at a constant speed. It will take approximately 90 seconds for the line to go all the way from 0 to 3000.



You can stop the line at any time you want by pressing any key on your keyboard. This will stop the line’s move immediately. A few seconds after you stop the line, the Position of the dot will be revealed to you.

[Both Treatments]



Your payoff for the round depends on whether the dot is to the left or to the right of the line.

- If the dot is on or to the right of the line, that is, if

$$\text{line Position} \leq \text{dot Position}$$

  at the end of the round, meaning that the line has not passed the dot while moving, your payoff is an amount of *points* equal to the horizontal Position of the line.

- If the dot is to the left of the line, that is, if

$$\text{dot Position} < \text{line Position}$$

  at the end of the round, meaning that line has passed the dot while moving, your payoff is 0 *points*.

Example

Suppose that the dot's Position is at 1425.

1. If you stop the line at 1783, the dot is to the left of the line. Your payoff is 0 *points*.
2. If you stop the line at 783, the dot is to the right of the line. Your payoff is 783 *points*.
3. If you stop the line at 1425, the dot is on the line. Your payoff is 1425 *points*.

At the end of the experiment, a computer will randomly select one round from Task 4 for payment. You will receive *points* equal to your payoff from this round. You will not receive *points* for any of the other 2 rounds.

Are there any questions? If you have a question please raise your hand and an experimenter will come to your desk. **Please do not ask any questions out loud.**

Practice Questions

Before Task 4 begins, we ask you to answer some practice questions. This is done to make sure that everyone understands how the software operates and how payoffs are calculated. When you are done answering the questions, please raise your hand and an experimenter will come to your desk.

1. How do you stop the line's move?
2. What is your payoff if you stop the line at 1025 and the dot's Position is 1200?
3. What is your payoff if you stop the line at 1200 and the dot's Position is 1200?
4. What is your payoff if you stop the line at 1200 and the dot's Position is 1025?