

Selection through information acquisition in coordination games*

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Abstract

We investigate experimentally the role of costly information acquisition as a selection mechanism in coordination games with incomplete information. We find that subjects' behavior, conditional on their precision choice, varies along two dimensions. Higher precision choices lead to more coordination attempts (and successful coordination) and more predictable strategies than low precision choices. These differences in behavior are absent when information precision is exogenous, suggesting that information choices act as a selection device. We find that individual precision choices are stable and unaffected by others' past precision choices from the beginning of the experiment, suggesting that that selection is not driven by strategic anticipation but rather by unobserved heterogeneity in subjects' preferences. We show that these effects have significant payoff consequences.

Key words: information acquisition, selection, coordination games, experiments.

JEL codes: C72, C90, D82

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1 Introduction

In many economic situations decision makers spend a considerable amount of time and resources to acquire additional information in order to improve their understanding of the decision environment they face. Many of these environments are characterized by coordination motives that make agents want to take similar actions to others who hold different information from them.¹ Motivated by the ubiquity of these environments, an extensive theoretical literature analyzes private information acquisition and its impact on economic outcomes in coordination settings with incomplete information (e.g., Colombo et al. (2014), Myatt and Wallace (2015), Szkup and Trevino (2015), or Yang (2015)). However, there is little empirical understanding of how the ability to endogenously determine the information structure affects the behavior of agents in the presence of coordination motives and incomplete information. This lack of empirical guidance has led theoretical efforts to focus on the role of information acquisition as a tool to reduce fundamental uncertainty and, by increasing the correlation of private signals, strategic uncertainty. However, information choices might also be driven by behavioral forces not captured in the standard models. In particular, the experimental literature on coordination games with complete information has shown that different mechanisms that precede the coordination stage can allow subjects to select in terms of how they play the game, endogenously improving coordination (see Van Huyck et al. (1993), Crawford and Broseta (1998), Cachon and Camerer (1996), and Cooper et al. (2018)). It is an open question whether a similar mechanism can arise when subjects have the possibility of choosing the precision of the information they observe and if so, how it affects coordination.

In this paper we study experimentally how subjects choose and use information in a coordination game with incomplete information. We investigate the role of costly information acquisition as a way to reduce uncertainty and as a behavioral tool for subjects to select in terms of their behavior in the coordination stage. To do so, we implement a two-player, two-stage global game where subjects first choose privately the precision of their private signal (information acquisition stage) and then, based on their observed signals, choose between a safe action and a risky action that is profitable only if both players coordinate on it (coordination stage).² Information acquisition is private in the sense that players do not observe the precision choice of their opponent before choosing an action in the game. Consistent with the experimental literature on global games, we find that the majority of our subjects use threshold strategies in the coordination stage, for their preferred precision. We also observe that, while individual precision choices are stable from the beginning of the experiment, there is a clear heterogeneity in the precision to which subjects converge. We show that this

¹Examples of coordination settings with incomplete and asymmetric information include price-setting decisions in monopolistically competitive settings (Hellwig and Veldkamp (2009)), investment choices in the presence of positive demand spillovers (Angeletos and Pavan (2004)), financing and rollover decisions (Morris and Shin (2004)), or political revolts (Edmond (2013)).

²We choose global games as our theoretical framework because of their widespread use in the theoretical literature that studies coordination problems with incomplete information (see Morris and Shin (2003), Angeletos and Lian (2016), and references therein).

heterogeneity in precision choices, in turn, affects the level and quality of thresholds that subjects use in the coordination stage.

To identify to what extent this heterogeneity is driven by subjects using information choices as a selection device, we compare our results to the findings of Szkup and Trevino (2020), who study how subjects respond to exogenous changes in the signal structure in an identical experimental setup, but without the initial stage of costly information acquisition. We find that in our setup, the heterogeneity in precision choices translates to heterogeneity in thresholds in the coordination game beyond what we observe when precision levels are exogenously determined. First, the relationship between thresholds and precisions is steeper under endogenous information since subjects who choose a high precision set thresholds that are closer to the efficient level than when a high precision is exogenously determined. Likewise, the thresholds of subjects who choose a low precision show a very low desire to coordinate on the risky action, even lower than what is observed when given an exogenous low precision. These results imply a reversal in comparative statics with respect to the theoretical predictions of our model.³

Furthermore, we identify a novel effect that is unique to our setup and manifests in the quality of the thresholds associated with different levels of precision. We show that, regardless of the level of the thresholds, different precision choices lead to differences in the dispersion or predictability of threshold strategies, rooted in differences in the extent to which subjects use their signals when choosing an action. We also find that the individual stability of thresholds across rounds and the convergence of thresholds within pairs is positively related to the precision at which subjects converge. These results are indicative of subjects using precision choices as a vehicle for selection in the way they intend to behave in the coordination stage.

Following Cooper et al. (2018), we can think of two main mechanisms of selection that could be behind our results. The first is non-strategic and corresponds to differences due to unobserved characteristics (preferences) that lead to heterogeneity in precision choices and actions. We refer to this simply as selection, with the understanding that it is not driven by strategic motives. The second channel is driven by strategic anticipation and relies on the forces of forward induction. That is, subjects try to anticipate the action of their opponent in the coordination game based on the beliefs about the opponent's precision choice. We refer to this as strategic anticipation or strategic selection. In order to understand which mechanism could give rise to our results, we study the dynamics of precision choices in the first 10 rounds of the experiment (50 rounds in total). These initial rounds are crucial to understand the process that drives people to eventually settle on a given precision level. To try to disentangle the two channels of selection, we investigate if strategic forces (i.e., the desire to coordinate) are behind the observed behavior of our subjects. Since our game is characterized by strategic complementarities in both precision and actions, we first investigate

³Szkup and Trevino (2020) document that thresholds do not respond to exogenous changes in precision as predicted by the theory of global games. Under exogenous information, estimated thresholds are non-increasing in precision. We find that under endogenous information thresholds are strictly increasing in precision.

whether the desire to coordinate in precision in the first stage drives precision choices and then we study the differential responsiveness of actions to signals corresponding to different precisions.

To investigate coordination in the first stage of the game, we focus on the dynamics of individual precision choices. We find little experimentation with precision choices for all subjects, regardless of what precision level they eventually converge to. That is, individual precision choices are surprisingly stable from the very beginning of the experiment. To understand whether individual precision choices are affected by the other player’s past precision choices, we offered subjects the possibility to observe the history of past precision choices made by their opponent by clicking on a button in the feedback screen at the end of each round. We find that subjects choose to observe the precision choice of their opponent in the feedback screen infrequently, only about 30% of the times in the first 10 rounds. Moreover, even when they choose to observe it, these observations have a low predictive power for subsequent precision choices. Instead, subjects’ precision choices are mostly driven by their own past decisions. These results suggest that the relation between actions and precision choices that we establish later in the experiment is not a consequence of individually experiencing different precision choices and their effect on actions, or of learning the precision choices of others. In other words, the process of establishing a stable precision choice does not seem to be driven by strategic motives in the first stage of the game.

To understand how precision choices affect the predictability of actions in the coordination stage, we compare the responsiveness of actions to private signals across different precision levels and to the case where information is exogenously determined. Unlike what we observe under exogenous precisions, the extent to which subjects’ actions respond to their signals significantly depends on the precision they choose. Subjects who choose a high precision are significantly more responsive to their signals than those who choose medium or low precisions and than subjects who are exogenously endowed with a high precision. The opposite is true for subjects who choose a low precision. Since the two experiments are identical except for the nature of information (exogenous versus endogenous) and since we do not find support for strategic considerations driving precision choices, we interpret the differences in actions across both experiments as a manifestation of selection that becomes possible when information is endogenized. In other words, our results suggest that information acquisition acts as a selection mechanism that changes the way subjects behave in the coordination game. Moreover, our analysis suggests that the driver of this selection is not strategic, but instead might reflect heterogeneity in preferences from the very beginning of the experiment.

Having found little empirical support for strategic anticipation as the driver of the selection we observe in our data, we turn our attention to a theoretical mechanism that relies on strategic anticipation to see if, at least in theory, it can explain the effects of selection on the observed precision choices and their associated thresholds in the coordination game. We explore the model of sentiments in the perception of strategic uncertainty of Szkup and Trevino (2020) that can rationalize the empirical observations in the setup with exogenous

information. In the presence of costly information acquisition, sentiments, or subjective perceptions of the probability distribution over others' actions, can be interpreted as a channel for selection driven by strategic anticipation. This is because sentiments capture the association between information choices and expectations about behavior in the coordination stage. While this model can potentially explain medium and low precision choices in our setup, it requires an extremely steep profile of sentiments (i.e., extreme subjective probabilities) to explain the choice of a high precision. This implies that strategic anticipation via sentiments is unlikely to be the mechanism behind our results.

Overall, our paper provides evidence that selection via information acquisition arises in coordination games with important consequences on outcomes and payoffs. This channel is not captured by standard theories of coordination games with costly information acquisition that have been widely used in applications such as investment decisions, credit provision, or bank runs. For example, in the context of bank runs, our results suggest that the presence of information that can be costly acquired would lead to heterogeneity in the strategies used by depositors beyond what can be attributed to differences in the quality of information. Depending on the underlying fundamentals (such as the strength of the bank's balance sheet) and the composition of depositors (with depositors being heterogeneous in their preferences for the choice and use of information), this might increase or decrease the likelihood of a bank run occurring. This effect is missing from the global games models that have been used to study banking regulation and crisis prevention (see, for example, Rochet and Vives (2004), Bebchuk and Goldstein (2012), or Eisenbach (2017)). Our results call for extending existing models to take into account the behavioral aspects documented in this paper.

Related Literature — Our paper contributes to the broader literature that studies experimentally coordination games with complete information and documents persistent coordination failure (see Van Huyck et al. (1990, 1991) or Cooper et al. (1990, 1992)). A strand of the literature proposes mechanisms that lead to selection as a way to endogenously enhance coordination in games of complete information. Van Huyck et al. (1993) introduce a pre-play English auction as a way to improve coordination in the median effort game of Van Huyck et al. (1991). In this game, forward induction leads subjects to stay in the auction at a given price if they expect to earn more than it by choosing a median level that is larger than the price paid in the auction. Crawford and Broseta (1998) provide a model of the efficiency-enhancing effects of this pre-play auction that draws on the power of forward induction. Cachon and Camerer (1996) show that giving subjects the option to pay a fixed price for participation leads to more efficient coordination by eliminating equilibria with payoffs lower than it. This simple mechanism allows subjects to select into a group that is willing to pay this price and, thus, coordinate.

Cooper et al. (2018) compare performance in a coordination game when subjects can choose endogenously the type of incentives they face and when they are exogenously assigned to them. Different from Van Huyck et al. (1993) and Cachon and Camerer (1996), subjects who select into the high performance contract do not explicitly pay to play the game, instead,

this cost is incorporated into the contract by an auction mechanism. Cooper et al. (2018) find that subjects who select into high performance contracts coordinate significantly more than those who are assigned to them exogenously, providing evidence for selection as a mechanism to enhance coordination.

Our setup differs from these papers in two main ways. First, we study a coordination game of incomplete information so the uncertainty faced by players in our setup is both strategic and fundamental. Second, selection in our paper occurs through costly information acquisition, which allows subjects to choose among different levels of precision in order to reduce fundamental uncertainty. In contrast to the mechanism in Cachon and Camerer (1996), information acquisition does not directly reduce strategic uncertainty by reducing the set of actions rationalizable by forward induction in the coordination stage. Similarly, the auction mechanism of Cooper et al. (2018) is built so that selection via the participation in the auction leads to an incentive scheme that favors efficiency, which makes the benefits in terms of efficiency of selecting into a high-performance contract very clear for subjects. In our setting, selection via the choice of a high precision does not change the incentive scheme of subjects. Instead, the efficient outcomes associated to high precision choices are due solely to the more efficient thresholds chosen by these subjects in the coordination game. Despite these differences, we find similar qualitative results to the environments with complete information since subjects who are willing to pay a higher cost for a high signal precision also choose strategies that lead to significantly more efficient outcomes than (i) subjects who observe signals of exogenously high precision and (ii) subjects who choose lower precisions.

Our paper builds on previous experiments on coordination games with incomplete information. Heinemann et al. (2004) were the first to test predictions of global games experimentally. Other work in this literature includes Cabrales et al. (2007), Duffy and Ochs (2012), Darai et al. (2017), Avoyan (2019), Trevino (2020), and Frydman and Nunnari (2023). Our paper is also related to the experimental literature on beauty contest models with incomplete information that studies how changes in the information structure affect welfare (see, e.g., Cornand and Heinemann (2014, 2015), or Baeriswyl and Cornand (2014)). Baeriswyl and Cornand (2021) and Szkup and Trevino (2024) study information acquisition in this setting focusing on attention allocation across information sources. The closest paper to ours is Szkup and Trevino (2020) who analyze how exogenous changes in information precision affect behavior in global games. The results of Szkup and Trevino (2020) can be viewed as a natural control treatment for this paper. None of these papers consider selection as a possible driver of coordination.

2 Theoretical framework and experimental implementation

In this section, we briefly describe the model and provide the equilibrium predictions for the parameters used in the experiment. The general model and proofs can be found in the Online Appendix. Note that the purpose of our experiment is not to test the predictions of

this model. Instead, we use this theoretical framework to give structure to our experimental investigation of the ways in which the choice and use of information affect the way people play coordination games, beyond the channels proposed by this standard model.

We consider a two-stage, two-player game. Payoffs are determined by an unknown state of fundamentals, $\theta \sim N(50, 50)$. In the first stage (information acquisition stage) players choose the precision of the private signal about θ that they receive at the beginning of the second stage (coordination stage).⁴ In the coordination stage, players can choose between a safe action (action B), which always pays 0, and a risky action (action A), whose payoff depends on whether action A is successful or not. Whether action A is successful or not is determined by the value of θ and the actions of players. As a guiding example, we could think that players have to choose whether to invest in a project (action A) or not (action B). Investment is risky and costly, so if a player chooses to invest they have to pay a cost of 18 and they get payoff θ only if the investment is successful. This is illustrated below:

	Success	Failure
Invest (action A)	$\theta - 18$	-18
Not invest (action B)	0	0

Table 1: Payoffs in the game

Investment is successful if either $\theta \geq 0$ and both players invest, or if $\theta \geq 100$, regardless of the actions of the other player. Otherwise, investment fails and a player who chooses to invest earns no return. The payoff from not investing is normalized to 0. That is, for all $\theta \in [0, 100)$ players would have a desire to coordinate on investing.

Players do not observe θ . Instead, at the beginning of the coordination stage, each player i observes a noisy private signal x_i about the realization of θ given by

$$x_i = \theta + \sigma_i \varepsilon_i, \quad (1)$$

where $\sigma_i > 0$ and $\varepsilon_i \sim N(0, 1)$ is an idiosyncratic noise, *i.i.d.* across investors, and independent of the realization of θ . The precision of the private signal, determined by σ_i , is chosen privately by each player in the information acquisition stage and its cost depends on its informativeness.⁵ Table 2 presents the menu of precision levels, standard deviations, and associated costs available to subjects in the experiment.⁶ We refer to information choices as precision choices to be consistent with the language used in the experiment. We use the term precision as a qualitative measure of informativeness of the signals, i.e., we compare levels of

⁴See Carlsson and van Damme (1993), Morris and Shin (2003), or Szkup and Trevino (2020) for a review of standard global games, which have been used to study a variety of economic phenomena, such as speculative currency attacks (Morris and Shin (1998)), political revolts (Edmond (2013)), debt roll over decisions (Morris and Shin (2004)), or technology adoption (Frankel and Pauzner (2000)).

⁵Recall that the precision of a normally distributed random variable is defined as the inverse of its variance.

⁶In the general model we assume that individual precisions are chosen from a continuous interval. See the Online Appendix for details.

precision, and not magnitudes of standard deviations.⁷

Precision level	Standard deviation	Cost
1	1	6
2	3	5
3	6	4
4	10	2
5	16	1.5
6	20	1

Table 2: Precision choices

Once players have chosen the informativeness of their signal, σ_i , they privately observe their signal realizations x_i , choose an action and then payoffs are realized according to Table 1. Notice that in this game precision choices are covert, i.e., players do not observe the other person's precision choice before choosing their own action.

We solve the game by backward induction and show that, for any vector of precision choices $\boldsymbol{\sigma} = \{\sigma_1, \sigma_2\}$, there is a unique dominance solvable equilibrium in threshold strategies $\{x_1^*(\boldsymbol{\sigma}), x_2^*(\boldsymbol{\sigma})\}$ in the coordination stage where optimal actions follow the rule:

$$a_i(x_i; \boldsymbol{\sigma}) = \begin{cases} A \text{ (invest)} & \text{iff } x_i \geq x_i^*(\boldsymbol{\sigma}) \\ B \text{ (not invest)} & \text{iff } x_i < x_i^*(\boldsymbol{\sigma}) \end{cases}$$

That is, player i chooses the risky action A if and only if their observed signal is greater than a threshold x_i^* . The equilibrium threshold x_i^* , which depends on precision choices, is the value of the signal for which a player is indifferent between taking the risky and the safe action. We show that as the noise in private signals converges to zero and the game approximates the complete information game, the equilibrium threshold converges to the risk-dominant equilibrium of the complete information game, which in this case corresponds to a threshold of 36 (see the Online Appendix for details). Previous experimental evidence shows that subjects coordinate on this limiting threshold when playing a global game without information acquisition (see Heinemann et al. (2004)).⁸

We move on to the first stage of the game where players choose optimal precision choices, given the equilibrium threshold strategies in the coordination stage. In our experiment this translates to a unique Bayesian Nash Equilibrium where players choose symmetrically precision level 4 and set an optimal threshold in the coordination stage of 28.31.⁹ That is, the

⁷We decided not to have a default precision chosen for subjects in order to avoid status quo biases. The reason to introduce a discrete choice set for precisions was to simplify the choice for subjects and the data analysis. We believe six is a reasonable number of options to observe dynamics in the level of informativeness that subjects choose, without losing statistical power.

⁸Note that in our case with two players the risk dominant equilibrium coincides with the prediction of global games in the limit, as the noise vanishes. Cabrales et al. (2000) show that the risk dominant equilibrium is often selected in 2×2 coordination games.

⁹Notice that in equilibrium, since precision choices are symmetric, thresholds are also symmetric and we can drop any subscripts when writing down equilibrium objects, i.e., $\sigma_1^* = \sigma_2^* = \sigma^*$ and $x_1^* = x_2^* = x^*$.

unique equilibrium predictions for our experiment are for both players to choose:

$$\{\sigma^*, x^*\} = \{6, 28.31\}$$

It is important to notice that, even if subjects deviate from choosing the equilibrium precision at the information stage, we can compute equilibrium thresholds in the coordination stage for any combination of precision choices. For non-equilibrium precision choices, the model predicts that thresholds are increasing in individual precisions.¹⁰ We have chosen parameters such that the mean of the prior is high with respect to the cost of investing to ensure that the effect of precisions on thresholds does not depend on the precision of the prior (see Szkup and Trevino (2015)).¹¹

Notice that in this standard model there is no scope for selection via information choices. We choose a model without selection to give theoretical structure to our experiment in order to explore the emergence of selection in the data without assuming a priori a specific mechanism. Instead, our objective is to study if and how selection arises in our setup, to characterize it, and to analyze its effects in terms of outcomes and payoffs.

2.1 Experimental design

The experiment was conducted at the Center for Experimental Social Science at New York University and the EconLab at the University of California, San Diego using the usual computerized recruiting procedures. Each session lasted 90 minutes and subjects earned on average \$25. All subjects were undergraduate students from New York University and University of California, San Diego.¹²

Our experimental design follows closely the design and parametrization of Szkup and Trevino (2020) (ST20 henceforth). In their treatments, subjects play only the second stage of the game described above with a symmetric and exogenous precision for their private signals. Therefore their treatments are natural control treatments for our experiment. In ST20, depending on the treatment, subjects observe signals with either precision level 1, 4, or 6 from Table 2. By comparing behavior in the coordination game of subjects that actively choose a precision level to the behavior of subjects that are exogenously endowed with precision will allow us to understand the effects of selection via information acquisition. Our experimental design is also related to the work of Heinemann et al. (2004), who test

¹⁰To understand why the theory predicts that thresholds are increasing in precision, note that when the mean of the prior distribution of θ is high relative to the cost of taking the risky action (50 and 18 in our case, respectively), players set low thresholds as the risky action is likely to succeed in expectation due to the high mean of θ and the cost of failure is relatively low. As precision increases, however, players pay less attention to the information contained in the prior. This makes players less optimistic about the success of the risky action. A lower weight assigned to the prior also makes it harder for the players to predict their opponent's action since their opponent now relies more on their private signal and less on the common information provided by the prior. Both of these effects discourage taking risky action, and thus thresholds are increasing in precision.

¹¹Implicit in this prediction is that precision choices are strategic complements, which leads players to coordinate on both precisions and actions.

¹²Instructions for all treatments can be found at http://econweb.ucsd.edu/~itrevino/pdfs/instructions_st_endogenous.pdf.

the predictions of the global games model of Morris and Shin (1998) in the laboratory and find that, on average, 92% of the strategies observed are consistent with the use of threshold strategies that lie between the theoretical prediction and the risk dominant equilibrium.

Each session consisted of 50 independent rounds. We implement a between subjects design with two main treatments. In the first treatment subjects played the coordination game with costly information acquisition as in Section 2, where subjects privately chose from a set of precisions with no default option, as described in Table 2, then receive a signal, and choose an action. We refer to this as the treatment with Direct Action choice (DA), for which we have 114 subjects. Consistent with previous literature (e.g., Heinemann et al. (2004) and ST20) we find widespread use of threshold strategies in our DA treatment. Motivated by this observation, we design the Strategy Method (SM) treatment with the purpose of studying the evolution of reported thresholds across rounds. This treatment is identical to the DA treatment except that we use the strategy method to elicit thresholds in the coordination game. That is, before observing their signal, subjects have to choose a cutoff value such that they would take the risky action if their signal is higher than this cutoff and the safe action otherwise. Hence, this treatment allows us to observe thresholds directly, rather than infer them as in the DA treatment.¹³ We had 44 subjects for the SM treatment, for a total of 158 subjects. The experiment was programmed and conducted with the software z-Tree (Fischbacher (2007)).

Subjects were randomly matched in pairs at the beginning of the session and played with the same partner in all rounds. We chose fixed pairs because we are interested in comparing the estimated thresholds to the equilibrium predictions, and in equilibrium players' beliefs about information choices are correct. Fixing pairs, as opposed to randomizing pairs each round, helps subjects' to form correct beliefs about their partner's play. This is particularly important given the complexity of our environment. In addition, fixed pairs allows us to compare our results against ST20 who also used fixed pairings.¹⁴ The game that subjects played in each round (stage game) has a unique equilibrium for the parameters chosen in the experiment. Since there were finitely many rounds and the stage game was identical across rounds, a standard backward induction argument implies that the finitely repeated game has a unique subgame perfect equilibrium where players play the unique stage-game equilibrium in every round. Therefore, the theoretical predictions of the one shot game are still valid in our experimental setup.¹⁵

To avoid framing effects, the experiment and instructions used a neutral terminology. Subjects were told to choose between two actions, A or B , avoiding terms such as “risky” or

¹³This feature of our treatment is related to the study of Duffy and Ochs (2011) who use the strategy method to elicit thresholds in coordination games. See Brandts and Charness (2011) for a survey comparing the strategy method and direct action choices in experiments.

¹⁴For robustness ST20 ran an additional session of the game with random matching and found no evidence that the matching protocol affected their results.

¹⁵We do not observe endgame effects or any evidence of conditional cooperation, likely due to the complex nature of our two-stage game and the incomplete information structure, which makes it difficult for subjects to effectively detect or punish deviations.

“safe” action. To avoid bankruptcies, subjects entered each round with an endowment of 24 tokens from which they subtracted their precision cost. From Table 2 we can see that even if subjects chose the most precise information, the lowest payoff they could get in a round was zero (in case of an unsuccessful coordination attempt).

Before starting the first paying round, subjects faced a practice screen for up to 5 minutes where they could generate signals for the different available precisions and they were given an explanation of the payoffs associated with each possible action, given their signal and the underlying state θ .

Each round of the experiment consisted of two decision stages:

1. Subjects chose privately from a menu of precisions and associated costs (see Table 2).
2. Subjects observed a signal $x_i \sim N(\theta, \sigma_i^2)$ and simultaneously decided whether to choose the risky action (A) or the safe action (B).

As stated above, in treatment SM subjects chose an action in the second step by stating a cutoff value for their signal before observing the actual signal realization.

After each round, subjects received feedback about their own choice of precision, their own private signal, their choice of action, the realization of θ , how many people in their pair chose A , whether A was successful or not, and their individual payoff for the round. In addition, by pressing separate buttons, each subject could observe the history of their own precision choices and the precision choices of their pair member. At the end of the experiment, the computer randomly selected five of the rounds played and subjects were paid the average of the payoffs obtained in those rounds, using the exchange rate of 3 tokens per 1 US dollar.

3 Experimental results

We are interested in understanding how information choices affect subjects’ actions. To this end, we begin by presenting aggregate data on precision choices and the corresponding actions. These results establish how subjects play the game. To study the effects of selection via information acquisition we then proceed in two steps. First, we compare both the level and quality of thresholds of the subjects that converge endogenously to a specific precision level to the thresholds estimated by ST20 where precision is exogenously allocated to subjects. Second, we study the dynamics of precision choices in initial rounds.

3.1 Aggregate results

Table 3 shows the frequencies of individual precision choices for the last 25 rounds of the experiment, once behavior has stabilized.¹⁶ In order to better understand the evolution

¹⁶This includes choices in treatments DA and SM. We aggregate the data because the distributions of precision choices are not statistically different between these two treatments. This was expected since the treatment effect, if present, would be in the second stage of the game.

of precision choices, we also show frequencies in the first 5 and the last 5 rounds of the experiment. As we can see, the most popular precision choice is level 4, the equilibrium precision, which seems to be the result of choices shifting from other precisions as subjects gained more experience in the experiment. However, we also see significant heterogeneity in information choices that prevails until the end of the experiment.

Precision level	Standard deviation	Cost	Precision choices in rounds:		
			26-50	1-5	45-50
1	1	6	12.2%	15.57%	11.27%
2	3	5	8.56%	12.03%	8.23%
3	6	4	16.18%	20.25%	16.96%
4	10	2	36.33%	25.19%	34.68%
5	16	1.5	5.32%	6.96%	6.33%
6	20	1	21.42%	20%	22.53%

Table 3: Frequencies of individual precision choices, DA and SM treatments

Selection via information acquisition requires not only heterogeneity of precision choices, but also stability of individual precision choices (i.e., subjects select by choosing a precision level and sticking to it). We find that, on average, in the last 25 rounds of the experiment, an individual subject chooses the same precision level for 22 out of 25 rounds. To illustrate this pattern, Figure A.1 in the Appendix contains the transition matrix of individual precision choices in the last 25 rounds, showing strong stability (low probabilities of switching between precision levels from one round to the next). Given this stability result, we characterize subjects by their preferred precision choice defined as the most frequently chosen precision in the last 25 rounds. Table A.1 in the Appendix reports the frequency of preferred precision choices, demonstrating that the heterogeneity of aggregate precision choices reported in Table 3 is driven by between-subject heterogeneity. We revisit this heterogeneity in Section 3.2, where we study how these different groups of subjects play the coordination game.

Turning our attention to actions, for the DA treatment Figure 1 plots the cumulative distribution function (CDF) of the decision to take the risky action for each signal realization, by individual precision choice. The value of the signal for which subjects take the risky action with probability one-half corresponds to the indifference point beyond which subjects would switch to take the risky action. We highlight two observations. First, looking at the intersection of the curves corresponding to the different precision levels with the 0.5 line, we see that cutoff points tend to be larger for lower precisions, suggesting that a higher precision leads to a higher likelihood of taking the risky action.¹⁷ While at odds with the theoretical predictions, this is in line with existing experimental evidence on global games with exogenously set precisions (see ST20). We explore this observation further in Section

¹⁷We find further evidence of this relationship in the aggregate data by running two regressions (one for the DA and one for the SM treatment) to determine the statistical effect that each level of precision has on individual actions (for DA) and on reported thresholds (for SM). This analysis is reported in Tables A.2 and A.3 in the Appendix.

3.2 when we study individual strategies.

Second, as we move towards lower precision levels the slopes of the CDFs decrease, indicating that the dispersion of actions is higher for people who choose lower precisions. In particular, when subjects choose the lowest precision their choices exhibit a large dispersion, indicating lower predictability of actions based on observed signals compared to subjects who choose higher precisions. This is a first sign that the way in which subjects play the coordination game (in terms of cutoff level and predictability) is related to the precision they choose. Subjects who choose higher precisions, seem to be more “invested” in the game and tend to have a more predictable action pattern (lower dispersion) than those who choose lower precisions. Importantly, this relationship between predictability of actions and precision of information is not present when precision is exogenously set (see Figure A.2 in Appendix A), which reinforces our interpretation of selection via information choices.

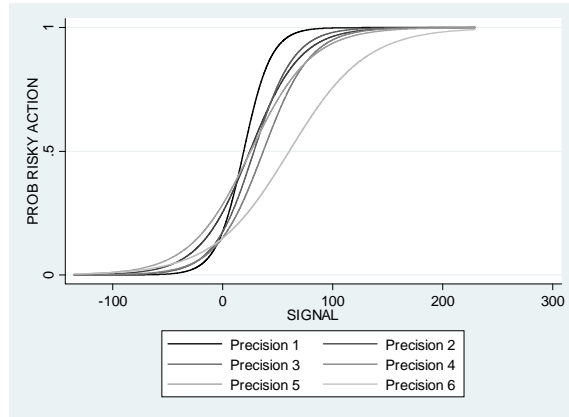


Figure 1: Probability of taking the risky action by precision choices, DA treatment

3.2 Estimated thresholds and convergence in precision

To understand how precision choices affect the way subjects play the coordination game, we turn our attention to the estimation of threshold strategies for the DA treatment and the analysis of reported thresholds in the SM treatment. Since thresholds depend on precisions, we focus on those subjects who exhibit stability in their individual precision choices in the last 25 rounds of the experiment (72.79% of our subjects).¹⁸ We define individual convergence in precision as the case where a subject chooses the same precision level for the last 25 rounds, with at most five deviations. We also establish a notion of convergence in precision choices within a pair. Our categorization is illustrated in Figure A.3 in the Appendix. We say that a pair exhibits non-stable behavior if at least one of its members does not converge individually in their precision choice (panel (a) of Figure A.3). A pair exhibits stability but not convergence when both members converge individually in their own precision choices,

¹⁸If individual precision choices were changing a lot over the last 25 periods, it would be difficult to estimate thresholds by conditioning on a precision choice, since it would be constantly changing.

but the levels at which they converge are more than one level apart (panel (b) of Figure A.3). We say a pair exhibits weak convergence when both members converge individually to a precision and these two precision levels are at most one level away from each other (panel (c) of Figure A.3). We say that a pair exhibits full convergence if both members converge individually to the same level of precision (panel (d) of Figure A.3).

For the estimation of thresholds we use the notion of weak convergence and restrict our attention to pairs that converge to high precision (levels 1 and 2), medium precision (levels 3 and 4), and low precision (levels 5 and 6). Note that weak convergence includes full convergence. Table 4 summarizes the combinations of precision choices across pairs in our experiment according to weak convergence. Approximately two thirds of the pairs in our experiment exhibit weak convergence in precision choices. Among these pairs, the highest proportion converges to medium precisions, which corresponds to the theoretical prediction.

	High	Medium	Low
High	10.53%	19.30%	5.26%
Medium		35.09%	14.04%
Low			15.79%

Table 4: Weak convergence of precision choices, DA and SM treatments

3.2.1 Threshold estimation: DA treatment

We identify three types of action rules in the coordination game: thresholds, degenerate strategies, and random choice. Thresholds can be either perfect or almost perfect. We say that a subject uses a perfect threshold if they take the safe action for low values of the signal and the risky action for high values of the signal, with exactly one switching point (i.e., the intersection of the sets of signals for which a subject chooses either action is null). For almost perfect thresholds we allow these two sets to overlap for at most three observations. This means that subjects take the safe action for low signal values and the risky action for high signal values, but these two sets can intersect for at most three observations. A subject uses a degenerate strategy if their choice of action is constant and does not depend on the signal (i.e., always taking the risky or safe action). A subject exhibits random behavior when they do not follow a pattern based on the observed signals.

In total, 93.39% of the subjects in the DA treatment use threshold strategies for their preferred precision choice, a result in line with earlier findings in the experimental global games literature (see, for example, Heinemann et al. (2004) and ST20), thus supporting the theoretical prediction of threshold use. However, the frequency of threshold use depends on precision choices. We find that 100% of subjects whose preferred precision is level 1, 2, or 3 use threshold strategies. For precision level 4, 97.37% of subjects use thresholds, the one subject who does not use a threshold uses the degenerate strategy of always taking the risky action. There are only 2 subjects choosing precision level 5, one uses a threshold and

one behaves randomly. For precision level 6, 78.94% of the subjects use threshold strategies and the rest use the degenerate strategy of always choosing the safe action. These results are consistent with the observation from Figure 1 that shows a large dispersion of actions for subjects who choose lower precisions and the opposite for subjects who choose high precisions, which is not observed when information is exogenously given (see ST20). These observations are also consistent with the interpretation that subjects use precision choices as a selection mechanism that relates to their approach when playing the game, with subjects who choose a higher precision being more likely to have monotonic, signal-dependent strategies than subjects who choose a lower precision who are more likely to set degenerate strategies.

In Table 5 we present the estimated threshold for subjects in pairs that converge to high, medium, and low precision levels and contrast them with the equilibrium predictions. For the DA treatment we present two different estimations, one using a random effects logit and one called the Mean Estimated Threshold (MET).¹⁹ For the SM treatment we compute the Mean Reported Thresholds (MRT) that subjects report in the strategy method. Recall that we define weak convergence to high precision as pairs that converge to precision levels 1 or 2, medium precision as pairs that converge to precision levels 3 or 4, and low precision as pairs that converge to precision levels 5 or 6. Therefore, for each precision level (high, medium, low) we report equilibrium thresholds corresponding to both precision levels. We also include the risk dominant threshold of the underlying complete information game since the theory predicts that this is what thresholds should converge to as the signal noise vanishes. Standard deviations are reported in parenthesis.

	High precision		Medium precision		Low precision	
Logit (RE) (DA)	18.74 (4.94)		42.71 (12.25)		60.24 (26.54)	
MET (DA)	17.27 (11.12)		39.72 (24.94)		63.58 (32.65)	
MRT (SM)	20.32 (3.56)		34.34 (16.39)		31.27 (21.4)	
Theoretical prediction x^*	Info 1	Info 2	Info 3	Info 4	Info 5	Info 6
	35.31	33.88	31.61	28.31	22.82	18.73
Risk dominant threshold	36		36		36	

Table 5: Estimated thresholds and equilibrium predictions, DA and SM treatments

Table 5 shows that the estimated thresholds for high precision in both the DA and SM

¹⁹We use two different methods to estimate thresholds. First, for each precision level, we pool the data of all the subjects who use thresholds in each treatment and fit a logistic function with random effects to determine the probability of taking the risky action as a function of the observed signal. We estimate the mean threshold of the group by finding the value of the signal for which subjects are indifferent between taking both actions, i.e., for which the logistic function gives a value of $\frac{1}{2}$. For the second method we take the average, individual by individual, between the highest value of the signal for which a subject chooses the safe action and the lowest value of the signal for which he chooses the risky action. This number approximates the switching point for the subject. We then take the mean and standard deviation of the thresholds in the group and refer to this estimate as the Mean Estimated Threshold (MET).

treatments are significantly lower than the threshold predicted by the theory and significantly lower than the estimates for medium and low precisions. Moreover, the thresholds estimated in the DA treatment are not significantly different from 18, which corresponds to the efficient threshold in the game. In contrast, in both the DA and SM treatments, the estimated thresholds for medium precision are not statistically different from the equilibrium predictions for precision 3 or for the risk dominant threshold, but they are larger than the equilibrium prediction for precision 4 at the 5% level of significance. Finally, in the DA treatment the estimated thresholds for low precision are statistically larger than the equilibrium predictions. The estimated thresholds for low precision in the SM treatment are also larger than equilibrium but the difference is not statistically significant.²⁰ Overall, these results indicate two departures from the theory. First, we see a reversal in comparative statics because the estimated thresholds tend to be decreasing rather than increasing in precision choices. Second, subjects who choose a high precision set lower thresholds than equilibrium, while the opposite is true for subjects who choose a low precision. In what follows we refer to these empirically observed departures from the theory as the *threshold-level effect* of increasing precision.

The threshold-level effect has also been documented under exogenous information (see ST20), which allows us to rule out costly information acquisition as a source of this deviation. Note that we can think of the data of ST20 as a control treatment for our study since their experimental procedures and parameters are identical to the ones we implement. Therefore, by comparing the level and quality of estimated thresholds with the thresholds under exogenous information we can establish differences that captures the effects of selection that is present only when precision choices are endogenous. Table A.4 in the Appendix reports the estimated thresholds with exogenous precision of ST20, which are non-increasing in precision with medium and low precision thresholds not statistically different from one another. In contrast, when the information structure is endogenous, thresholds are strictly decreasing in precision choices and are statistically different from each other. Therefore, while the threshold-level effect is also present when information is exogenous, it is amplified when subjects choose the precision of their signals.²¹ In what follows, we focus on our DA treatment to make comparisons with the results of ST20 who only use direct action choice in their experiment.

Figure 2 plots the estimated thresholds in the DA treatments under exogenous and en-

²⁰Note that the strategy method might affect the way subjects play the game by imposing the use of thresholds, thus putting more structure on their thinking. This might explain the differences between the DA and SM treatments.

²¹ST20 propose a mechanism based on sentiments about the perception of strategic uncertainty to explain the threshold-level effect, where players' subjective beliefs about the probability that the other player takes the risky action are affected by the fundamental uncertainty in the environment. In their data, subjects in environments with high precision perceive lower strategic uncertainty than subjects in environments with low precision. They also argue that popular models such as QRE, Level-k, or Cursed Equilibrium cannot explain this result. In Section 5 we explore whether a similar phenomenon could be at play in our environment.

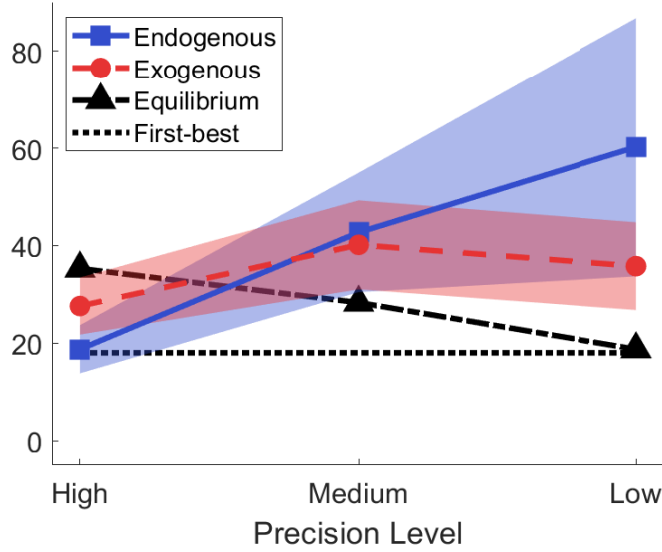


Figure 2: Equilibrium, first-best, and estimated thresholds, DA treatment

dogenous information, together with shaded standard deviation intervals, as well as the corresponding equilibrium and first-best thresholds. The threshold-level effect is notably amplified under endogenous information. This is evident from the larger divergence between the equilibrium predictions and the estimates under endogenous information, relative to the corresponding divergence under exogenous information. These results suggest that when information is endogenized, subjects use precision choices as a way to select according to the way they intend to behave in the coordination game. In particular, subjects who choose a higher precision for their signal are more inclined to take the risky action than others. The high precision that they choose minimizes the probability of taking the risky action when it would be unsuccessful by allowing subjects to better coordinate with their opponent (due to an increase in the correlation between their signals). We can think of these subjects as being more “invested” in the game (in the sense that they pay a high price to get a better signal in the information stage) and trying to extract as much payoff as possible in the coordination stage. In contrast, subjects who choose the lowest precision observe noisier signals and tend to “play it safe” during the coordination stage by either setting a high threshold (take the risky action infrequently) or by using the degenerate strategy of always choosing the safe action. We can interpret these subjects as being less “invested” in the coordination game.

It is not surprising that endogenizing precision choices leads to a more pronounced threshold-level effect. Subjects who intend to play safe, independent of their signal, might not find it worthwhile to pay for a precise signal, while subjects who want to condition their action on their signal and choose the risky action if the expected state is sufficiently high, are more likely to prefer a precise signal. As a result, the selection that occurs in the game with endogenous precision might lead to having subjects who are more tolerant to strategic

risk choosing a high than a low precision. This translates to a lower (higher) threshold, conditional on choosing a high (low) signal precision, than in the game where the high (low) signal precision is exogenous.

Figure 2 also illustrates another important effect of the selection that occurs through precision choices. Focusing this time on the standard deviation of threshold (as depicted by the shaded areas in Figure 2), we see that the dispersion of thresholds is stable under exogenous information as we move across precisions. However, when information is endogenous, we see a clear increase in dispersion of thresholds for subjects who select a low precision. This suggests that, regardless of the actions taken in the game (threshold level), different choices of precision give rise to different levels of dispersion or predictability of thresholds within a precision group. In particular, the behavior of subjects who choose high precision is very predictable, while the opposite is true for subjects who choose low precisions. We refer to this as the *threshold-quality effect*. This effect was first hinted at in Figure 1 when we observed an increase in dispersion of individual actions as subjects chose lower precisions.

3.2.2 Dynamics of reported thresholds: SM treatment

To further study the threshold-quality effect we turn our attention to the SM treatment where, instead of observing signals and choosing actions in every round, subjects reported the cutoff value for their signal above which they would take the risky action. This treatment allows us to study the stability of individual thresholds and the convergence of thresholds within pairs over time.

We first analyze the evolution of individual reported thresholds in all 50 periods of the experiment for subjects in pairs that coordinate on high, medium, and low precision in our SM treatment. For each subject we calculate the difference in absolute value between the threshold reported in one period with respect to the threshold reported in the previous period. Then we compute the average of these differences across all subjects from pairs that coordinate on a given precision level. This is portrayed in Figure 3. The vertical bar at period t illustrates how much, on average, subjects changed the value of their own threshold in period t with respect to the threshold reported in period $t - 1$.

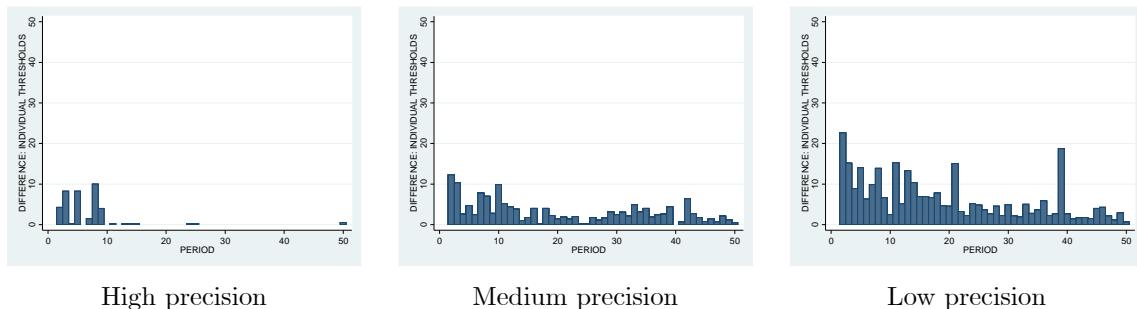


Figure 3: Convergence of individual thresholds, SM treatment

Figure 3 shows a lot of stability in individual thresholds for subjects in pairs that co-

ordinate on high precision levels. We observe some experimentation in the initial periods (as expected), but thresholds quickly stabilize after 10 rounds and in the last 25 rounds the mean difference is consistently zero, except for the last round. For medium precision levels the mean difference of individual thresholds is less than 7 after the first 10 rounds. For low precision levels it takes a longer time for individual thresholds to stabilize and in the last 25 rounds the mean difference is less than 7 in all but one period. Therefore, we see that subjects who choose a high precision tend to choose the same threshold period after period and that this individual stability seems to decrease as subjects choose lower precisions. This is in line with Figure 1 and illustrates the threshold-quality effect, which is consistent with selection since the stability and predictability of individual thresholds over time depends on precision choices.

Stronger evidence for selection and the threshold-quality effect comes from studying convergence of thresholds within pairs. To analyze this we compute the average difference in absolute value between the reported thresholds of pair members, for each period and each precision level. Recall that subjects do not receive feedback about the threshold reported by their pair member, but only observe whether the action A (risky action) was successful or not. Thus, it is not trivial for subjects to converge in their thresholds within pairs. We plot our results in Figure 4.

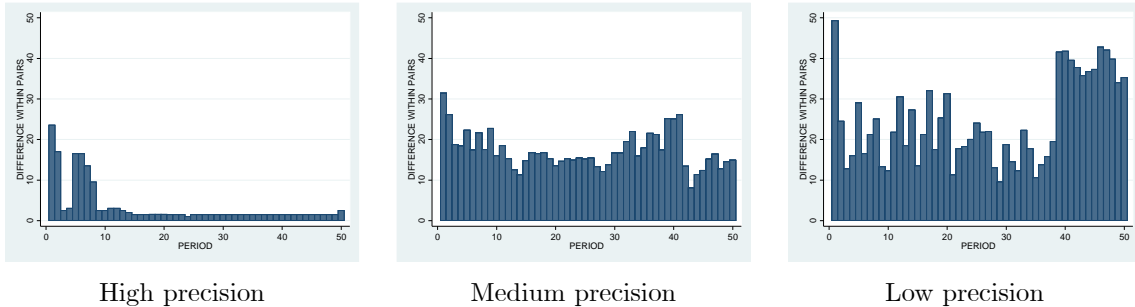


Figure 4: Convergence of thresholds within a pair, SM treatment

We see from Figure 4 that subjects from pairs that converge to high precision levels coordinate extremely well on their thresholds and that this is not the case for people who choose lower precisions. This further illustrates the threshold-quality effect that results from selection: the greater stability of individual actions of subjects in pairs that converge to a high precision, illustrated in Figure 3, naturally allows them to better coordinate their actions. However, when subjects choose lower precisions individual strategies become less predictable, therefore, it is harder to coordinate actions within a pair, leading to large disparities of thresholds and less successful coordination for low precision levels. Thus, Figure 4 suggests that selection, via the threshold-quality effect, has non-trivial implications for the extent of coordination that subjects achieve.

We think of the threshold-quality effect as the mechanism behind the observed disparities in terms of stability and convergence of thresholds across precision levels. Unlike the

threshold-level effect, which was also present in the case of exogenous information, the threshold-quality effect is unique to the game with endogenous information. This is because adding an initial stage of information acquisition opens the door to selection. As a consequence, we see that regardless of the level of thresholds, the quality of individual play improves with precision choices, as illustrated in Figures 3 and 4 (and suggested by Figures 1 and 2 and by Figure A.2 in the Appendix). Selection reflects how some subjects are more likely to choose the highest precision and set a “cleaner” strategy, we might think of them as subjects who are more “invested” in the game, while those who are not very “invested” in the game (or who are unsure about how to play the game) might opt for the cheapest precision and choose actions in a less predictable way (even not signal-dependent) in the coordination stage.²²

4 Understanding selection: Analysis of early rounds

In this section we focus on behavior in the initial rounds of the experiment to understand the mechanisms behind our results. These initial rounds are crucial to understand the process that drives people to eventually settle on a precision level. We follow Cooper et al. (2018) and think of two main channels of selection that can arise in our experiment. The first is non-strategic and corresponds to differences due to unobserved characteristics (preferences) that lead to heterogeneity in precision choices and actions. We refer to this simply as selection, with the understanding that it is not driven by strategic motives. The second channel is driven by strategic anticipation and relies on the forces of forward induction. That is, subjects are able to anticipate the action of their opponent in the coordination game based on the opponent’s precision choice. We refer to this as strategic anticipation or strategic selection.

To try to disentangle the two channels of selection, we investigate if strategic forces (the desire to coordinate) are behind the observed behavior of our subjects in order to assess if strategic anticipation is the driver of our results. Since our game is characterized by strategic complementarities in both precision and actions, we proceed in two steps. First, we investigate whether the desire to coordinate in precision in the first stage drives precision choices. We argue that it is unlikely that subjects’ precision choices are driven by learning from others or from strategic considerations in the information stage. Instead, we show that subjects’ precision choices are stable even in the very first rounds of the experiment, when we typically would expect to see more variation. This is important in order to establish the effects of selection in the second stage because it implies that the relation between subjects’ actions and precision choices that we have documented for the last 25 rounds of the experiment is

²²While we discuss the threshold level and quality effects separately, it is likely that these effects are related to each other. For example, when subjects converge to a high precision, being able to better predict the other’s behavior might encourage both subjects to set a lower threshold. It is important to note, however, that such an argument goes against the theoretical mechanism of global games where an increase in the precision of signals increases strategic uncertainty for signals close to the threshold, which is the reason why equilibrium thresholds are increasing in precision (see Morris and Shin (2003)). This theoretical notion has been challenged by ST20.

not a consequence of individual experimentation or learning how others play the game under different precisions. In other words, the process of establishing a stable precision choice does not seem to be driven by strategic motives in the first stage of the game.

Second, to understand how precision choices affect the predictability of actions in the coordination stage, we compare the responsiveness of actions to private signals across different precision levels and to the case where information is exogenously determined. To do this, we study behavior in the first 10 rounds separating subjects according to the precision they eventually converge to in the last 25 rounds to see the initial behavior of people that eventually converge to high, medium, or low precision levels. This illustrates the differential responses to precision that arise from selection.

4.1 Strategic motives in the information acquisition stage

To study if subjects' information choices are driven by strategic considerations we focus on their behavior in first ten rounds of the experiment and on the subjects' that converged individually in their precision choices in the last 25 rounds, unless specified explicitly otherwise.

We first establish that individual precision choices are persistent (stable) from the very beginning of the experiment. Figure 5 plots the histogram of the number of times subjects chose their initial preferred precision level (the most frequent individual precision level in the first ten rounds.)

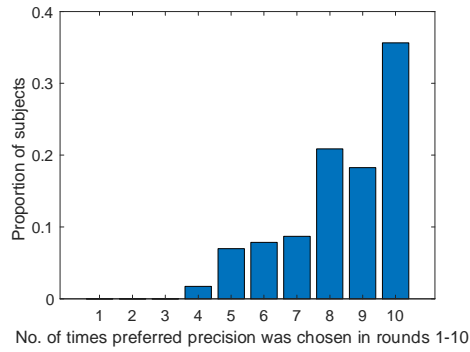


Figure 5: Histogram of initial preferred precision choices in rounds 1-10, DA and SM treatments.

Figure 5 shows that about 75% of subjects chose the same precision level (high, medium, or low) at least 8 out of 10 times, with 36% of subjects never switching. This indicates little experimentation with information choices from the very beginning of the experiment. Figure A.4 in the Appendix shows the same data, disaggregated according to the precision to which subjects converge in the last 25 rounds. We can see that subjects who converge to a high precision are more likely to choose the same precision in all ten initial rounds and subjects who converge to a low precision show less stability in their precision choices. Figure A.5

in the Appendix shows that subjects’ preferred precision in the first ten rounds coincides with the precision to which subjects converge to in the last 25 rounds in 82% of cases. Taken together, these results establish persistence of individual precision choices from the beginning of the experiment.

To establish whether this stability in individual precision choices in the first ten rounds is due to a desire to coordinate in precision with the other player (i.e., if it is driven by strategic motives in information acquisition), we analyze how many times, in the first ten rounds, subjects choose to observe their partner’s precision choice in the feedback screen and how they react to this information.²³ First, we find that, on average, subjects clicked on the button to check their partner’s precision choice in the first ten rounds only 31% of the time.²⁴ Next, we show that, even when subjects checked their partner’s precision choice, this had little impact on their subsequent precision choices. To do this, we run a multinomial probit that regresses the probability of a subject choosing a high, medium, or low precision in the first ten rounds as a function of their own precision choice in the previous period and the precision choice of their opponent in the previous period, conditional on the subject choosing to observe this information. We report two types of analysis of predictive margins to understand the persistence of individual precision choices in Tables 6 and 7.

Table 6 reports the probability that a subject chooses the same precision level (high, medium, or low) in two consecutive periods, depending on their observation about the precision choice of their opponent. Column 2 in Table 6 corresponds to the cases where subjects did not choose to observe their opponents’ precision choices in the previous period, while columns 3, 4, and 5 correspond to the cases where subjects chose to observe their opponents’ precision choices, which were high, medium, or low, respectively. We report in parenthesis the frequency of these occurrences. The rows correspond to the probability with which a subject chose a precision (high, medium, low) in period t , given that they chose the same precision in period $t - 1$ and given the observation of their opponent’s precision, denoted by X and determined by the relevant column.

From Table 6 notice first that in most instances subjects chose not to check the precision choice of their opponent (between 63% and 72% of the times, across precision choices). Moreover, in these instances the probability that subjects chose the same precision in two consecutive periods was 0.81 to 0.86, depending on the precision level. This shows substantial stability in individual precision choices even in the first ten rounds of the experiment when we typically expect to see more variation. This is consistent with the results from Figure 5 and suggests that the individual decision to choose the same precision across rounds is

²³Recall that, at the end of each round, subjects could access information about their opponent’s precision choices by clicking a button. Therefore, we know in which instances subjects observed the precision choices of others.

²⁴If we consider the first 25 rounds, the overall frequency drops to 24%. Subjects who eventually converge to high, medium, and low precision levels check this information 25.83%, 28%, and 20.67% of the time, respectively. The propensity to look at this information is similar across precision types, suggesting that the interest in others’ past precision choices is not related to the precision level selected by subjects.

p_{t-1}^j	Not observed	High	Medium	Low
$\Pr(p_t^i p_{t-1}^i, p_{t-1}^j)$				
$\Pr(H H, X)$	0.85 (72%)	0.92* (10%)	0.69* (13%)	0.66* (5%)
$\Pr(M M, X)$	0.86 (71%)	0.83 (8%)	0.91** (14%)	0.76* (6%)
$\Pr(L L, X)$	0.81 (63%)	0.73 (4%)	0.81 (14%)	0.95*** (19%)

Note: p_t^i corresponds to subject i 's own precision choice in round t ; p_t^j corresponds to subject i 's opponent's precision choice in round t . Statistical significance at the 1% (***), 5% (**), and 10% (*) within rows with respect to not observing the opponent's precision choice.

Table 6: Predictive margins of observing other's precision choices on the probability of choosing the same precision in consecutive periods, DA treatment

not necessarily influenced by the precision choice of others, which reinforces that strategic motives are not the main driving force of individual precision choices.

When subjects choose to observe the precision choice of their opponent they are responsive to their observations in the expected direction, with the more significant effects when both pair members choose the same precision. Notice, however, that even when subjects observe that their opponent chose a different precision, they still choose their same individual precision with at least 0.66 probability.

Table 7, on the other hand, reports the estimated probability that a subject chooses precisions high, medium, or low (variation between rows), given that they observed their opponent choosing that same precision in the previous period, depending on their own precision choice in the previous period (variation within columns). Just as in Table 6, we report in parenthesis, below the probabilities, the frequency of these occurrences. Table 7 indicates that the probability of choosing the same precision level as their opponent in a subsequent period (following the opponent's choice) is very low unless the opponent's precision choice coincided with the subject's own precision choice in the previous period, for all precision levels. As illustrated by the large probabilities on the main diagonal, the main driver of precision choices for subjects seems to be their own past precision choice and the same precision choices by their opponent reinforce such choices.

When including coordination success and failure in the previous period as explanatory variables in this multinomial probit specification we find insignificant coefficients on those variables, suggesting that outcomes in the game in the previous period do not affect subsequent precision choices.

Overall, these results suggest that precision choices are not driven by a desire to coordinate with others in the information acquisition stage, that is, by strategic anticipation of others' precision choices.

p_{t-1}^i	High	Medium	Low
$\Pr(p_t^i p_{t-1}^i, p_{t-1}^j)$			
$\Pr(H X, H)$	0.92 (70.6%)	0.12*** (14.7%)	0.13*** (14.7%)
$\Pr(M X, M)$	0.25** (17.3%)	0.91 (76.0%)	0.17** (6.7%)
$\Pr(L X, L)$	0.16*** (7.4%)	0.22*** (16.7%)	0.95 (75.9%)

Note: p_t^i corresponds to subject i 's own precision choice in round t ; p_t^j corresponds to subject i 's opponent's precision choice in round t . Statistical significance at the 1% (***), 5% (**), and 10% (*) within rows with respect to entries on the main diagonal.

Table 7: Predictive margins of variations in own past precision choices on the probability to choose the same precision as the other's past choice, conditional on observing it, DA treatment

4.2 Effects of selection in the coordination game

We now explore how selection via precision choices affects the way that subjects play the coordination game by studying how action rules respond to observed signals across precision levels (variations in signal responsiveness across subjects who select into different precisions) and with respect to the case where we shut down the possibility of selection (when precision is exogenous). Using the same specifications to estimate thresholds as in Section 3.2.1, each column of Table 8 presents the coefficients of a random effects logistic regression that explains action choices (safe vs risky action) as a function of observed signals for the first 25 rounds of the experiment.²⁵ Columns (A), (B), and (C) correspond to control treatments (from ST20) where selection is not possible, i.e., when subjects observe a high, medium, or low precision exogenously. Columns (D), (E), and (F) correspond to subjects in our experiment from pairs that endogenously converge to (select into) high, medium, and low precisions, respectively.

	Exogenous			Endogenous		
	A - High	B - Med	C - Low	D - High	E - Med	F - Low
Signal	0.058*** (0.005)	0.067*** (0.005)	0.063*** (0.005)	0.095*** (0.019)	0.045*** (0.004)	0.032*** (0.007)
Constant	-1.141*** (0.259)	-2.393*** (0.285)	-2.139*** (0.333)	-1.073 (0.694)	-1.544*** (0.362)	-3.37*** (1.038)

Clustered (by subject) standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 8: Risky choices in the game as a function of observed signals, by precision type, DA treatment and ST20 data

²⁵These specifications control for location effects, which are not significant, so they are not presented in the table, for ease of exposition.

Notice that the reliance on signals when precision is exogenously determined (columns (A)-(C)) is independent of the actual precision level (the coefficients for signal, while statistically different from zero, are not statistically different from each other at the 1% level of significance). This implies that, in the absence of a selection mechanism, subjects' reliance on their signals does not depend on the signal's precision.²⁶ However, when subjects have the opportunity to choose the precision of their signals we see a very different pattern. First, notice that subjects who choose a high precision (column D) are significantly more responsive to their signal than subjects who choose a medium precision (column E) and those who choose a medium precision rely on their signal significantly more than subjects who choose a low precision (column F). These observations suggest that choosing the precision of signals gives subjects the possibility to select in terms of how they play the coordination game. These findings also establish that the predictability of actions in the coordination game (first hinted in Figure 1) is directly linked to the decision to invest in more precise information, illustrating the threshold-quality effect discussed above. Since this difference in responsiveness to signals is not observed when precision is exogenously set, we interpret this behavior as a result of selection via information acquisition.

The effects of selection go beyond the differential reliance on signals when subjects endogenously choose their precision. Selection is also established by comparing the responsiveness of signals within a precision level when precision is either given to subjects or endogenously chosen (columns (A) vs (D), (B) vs (E), and (C) vs (F)). We can think of the precision-invariant reliance on signals under exogenous information structures as the baseline effect of signals on actions. Subjects who choose high precision (column D) rely significantly more on their signal than the baseline level (column A, $p\text{-value} < 0.01$). On the other hand, subjects who choose a low precision rely on their signal significantly less than those who are exogenously endowed with a low precision (column C vs F), $p\text{-value} < 0.01$).

Taken together, these results suggest that the heterogeneity in behavior that we observe in the experiment is a result of an underlying heterogeneity of preferences for information that manifests itself from the very beginning of the experiment. This heterogeneity gives rise to selection in the quality of information that subjects seek, which ultimately determines not only how aggressively subjects seek to coordinate with others (threshold-level effect), but also how cleanly or predictably they do so (threshold-quality effect).

4.3 Welfare effects of selection

To investigate the payoff consequences that result from selection via information choices, we compare realized payoffs to the payoffs of ST20 when information is exogenously determined.

²⁶Recall that thresholds correspond to the value of the signal for which subjects are indifferent between actions, that is, for which the probability of taking the risky action is $\frac{1}{2}$, which, for a logistic regression, corresponds to the ratio of the negative of the coefficient of the constant divided by the coefficient of the signal. Therefore, the observed differences in estimated thresholds under exogenous information correspond to differences in the intercept term (truly a threshold-level effect) because subjects' reliance on their signals does not vary across precision levels.

We focus only on our DA treatment since this is the same treatment that ST20 have. To make payoffs comparable across different sessions, treatments, and experiments, we normalize all the payoffs with respect to the first-best payoffs that correspond to the recommendation of a social planner that faces no informational constraints (i.e., choosing the risky action whenever it is profitable, $\theta \geq T$).²⁷ We refer to this ratio as the payoff-efficiency index as it captures payoff losses with respect to efficient play. In Table 9 we compare the payoff-efficiency index for subjects in pairs that converged to high, medium, or low precisions to the payoff-efficiency index under exogenous precisions, computed using data from ST20. We focus only on payoffs in the coordination stage to make these indices comparable across treatments. Standard deviations are reported in parenthesis.

Precision	High	Medium	Low
Endogenous Information			
Realized	0.96 (0.05)	0.79 (0.17)	0.32 (0.35)
Exogenous Information			
Realized	0.93 (0.16)	0.80 (0.25)	0.74 (0.20)

Table 9: Payoff-efficiency index for observed payoffs in endogenous and exogenous DA treatments.

As we can see in Table 9, the payoff-efficiency index is increasing in precision for both endogenous and exogenous information structures with all differences being statistically significant at the 5% level. This reflects the threshold-level effect. However, two important differences between these two treatments emerge. First, notice that this effect is more prominent in the endogenous treatment: we see a dramatic decrease in the payoff-efficiency index for subjects who choose a low precision compared to the case when a low precision is exogenously set (from 0.74 to 0.32, significant at the 1% level). Second, we see that the dispersion of payoffs is decreasing in precision in the treatment with endogenous information that is consistent with the threshold-quality effect, which emerges as a consequence of selection. In particular, there is less variation in payoffs of subjects who choose a high precision than those who face an exogenous high signal precision (to the 5% level of significance). Conversely, the payoff-efficiency index of subjects who choose a low precision is significantly more disperse than under exogenous low precision (to the 5% level of significance). Therefore, we identify clear payoff effects from selection.

Finally, in Table 10 we analyze payoffs in the two-stage game, taking into account the cost of precision when computing realized payoffs. Despite the increasing cost of precision, subjects

²⁷First-best payoffs have the advantage of being computed directly using the observed realizations of θ and do not depend on precision choices. In contrast, equilibrium payoffs and constrained efficiency payoffs in the coordination game depend on precision choices.

in pairs that converge to a high precision experience the lowest loss in terms of efficiency, though the difference in the payoff-efficiency index between high and medium precision is not statistically significant. On the other hand, the differences in the payoff-efficiency index for high and medium precision to the one for low precision are statistically significant to the 1% level. This implies that the “savings” in terms of precision cost that subjects who chose the low precision made were not enough to offset their poor performance in the coordination stage.

Precision	High	Medium	Low
Payoff-efficiency index	0.76 (0.05)	0.70 (0.16)	0.29 (0.36)

Table 10: Payoff-efficiency index in the two-stage game, DA treatment

5 Sentiments as a theoretical mechanism of selection

Our results provide little empirical support for strategic anticipation as the driver of the selection via precision choices that we see in our data. In this section, we turn our attention to a theoretical mechanism that relies on strategic anticipation as a last attempt to see if, at least in theory, it can explain the effects of selection via precision choices on their associated thresholds in the coordination game.

ST20 propose a mechanism based on sentiments to explain the threshold-level effect when precision is exogenous. Sentiments in ST20 refer to subjective beliefs about the probability of the other player taking the risky action and depend on the fundamental uncertainty in the environment. Their model with sentiments can rationalize their findings, where subjects believe that others are more likely to take the risky action than in the standard model in environments with high precision, and the opposite is true in environments with low precision. In the presence of costly information acquisition, this type of sentiments could be interpreted as a vehicle for selection driven by strategic anticipation because these subjective beliefs relate information choices and expectations about behavior in the coordination stage. In other words, sentiments could capture the idea that players choose a high precision expecting coordination on the risky action for a wide range of signal realizations, and the opposite when choosing a low precision.

To evaluate whether this type of sentiments can be driving the observations in our data, we follow ST20 and extend our baseline model to feature sentiments that vary with precision choices. We then use this model to investigate whether heterogeneity in the slope of the sentiments’ profiles (how much sentiments change as precision increases) can rationalize the amplification of the threshold-level effect and the emergence of the threshold-quality effect in the presence of costly information acquisition. More precisely, the setup we consider is

the same as in Section 2, but, following ST20, we assume that players have subjective beliefs about the likelihood that the other player takes the risky action.²⁸ In particular, we assume that for $i \in \{1, 2\}$, conditional on observing signal x_i , player i believes that his opponent, player j , takes the risky action with probability

$$\Pr_i(x_j \geq x_j^* | x_i) = \int_{\theta=-\infty}^{\infty} \left[1 - \Phi\left(\frac{x_j^* - \theta}{\sigma_j} - \alpha_i(\sigma_i)\right) \right] \phi(\theta | x_i) dx_i,$$

where x_j^* is the threshold used by player j , σ_j is player j 's precision choice, and $\alpha_i(\sigma_i) \in \mathbb{R}$ is player i 's sentiment about the likelihood that his opponent takes the risky action when player i chooses precision σ_i . Thus, if $\alpha_i > 0$ then player i believes that the likelihood that player j takes the risky action is larger than the Bayesian belief. In this case we say that player i exhibits positive sentiments. The opposite is true if $\alpha_i < 0$. Figure A.6 in the Appendix plots the sentiments that rationalize the estimated thresholds with endogenous and exogenous information.

Intuitively, this model captures the possibility that players with steep profiles of sentiments (i.e., players who exhibit large positive sentiments under high precision but exhibit large negative sentiments under low precision) select a high precision while those with flat sentiment profiles choose a low precision. To evaluate whether this model, based on strategic anticipation, can rationalize our findings, we ask which sentiment profiles can support high precision, medium precision, and low precision as equilibrium choices in the extended model. In particular, we compute the sentiment level implied by the observed behavior for subjects that converged to a particular precision level and ask what sentiments these subjects would have to exhibit if they were to choose either of the other two precision levels in order to rationalize their precision choice.²⁹

In Figure A.7 in the Appendix we report the optimal precision choices of players as a function of the sentiments associated with the other two precision levels. That is, each panel of Figure A.7 depicts the optimal precision choice of a player whose opponent chooses one of the three precisions (high, medium, or low) and expects the player to also choose that

²⁸We also assume that players can choose only among the six precision levels used in the experiment. We consider a model with a discrete number of precision choices to limit the complexity of the problem and to make it easy to map directly the model to the data.

²⁹To compute these profiles, we do the following. Suppose selection was driven by heterogeneity in sentiment profiles. We can estimate the sentiments associated with a high precision for subjects in pairs that converged to high precision directly from the data by computing the level of sentiments needed to rationalize the estimated threshold for these subjects. This allows us to compute the expected utility associated with choosing a high precision. We then compute the utility of a player who unilaterally deviates from choosing a high precision when his opponent chooses high precision and expects the player to choose high precision. We do so for a range of different sentiment levels and possible deviations to medium and low precisions. If, for a given pair of sentiments associated with medium and low precision, the player finds it optimal to deviate to either of these levels, then we say that this profile of sentiments cannot support a high precision choice. If, on the other hand, the player finds it optimal not to deviate from a high precision choice, then we say that this sentiment profile can rationalize a high precision choice. For simplicity, we report results that refer to precision level 1 (high) and we focus on deviations to precision levels 4 (medium) and 6 (low) since these are the most common precision choices in the experiment. We follow an analogous approach for medium and low precision.

precision, as this player’s sentiments associated with the other two precisions vary. We see that in the case of high precision, the player would choose high precision (black area in left panel) if and only if the sentiments associated with medium and low precision were extremely negative and far below the values implied by our experimental data (see Figure A.6 in the Appendix). On the other hand, we see that a medium precision choice is indeed easily supported by the sentiment profile implied by our experimental data.³⁰ We also see that, at the values of sentiments estimated using our data, subjects whose opponents expect them to choose low precision would find it optimal to deviate to high precision. However, for flatter sentiments profiles (where high and medium precisions are associated with smaller values of sentiments), the choice of low precision can be rationalized by a model with sentiments that vary with precision choices.

We conclude that while the story of sentiments as a vehicle of selection based on strategic anticipation is intuitive and also consistent with the experimental findings under exogenous information structures, our numerical simulations suggest that for sentiments, and thus strategic anticipation, to be the main driver of selection, subjects who choose a high precision would need to exhibit an extremely steep sentiment profile with implausible sentiments for medium and low precision. Moreover, notice that the nature of the sentiments that we have discussed does not capture the differential responsiveness to private signals documented in Section 4. We interpret this as evidence that sentiments are unlikely to be the main driver of selection.

6 Conclusion

We have studied the dual role of costly information acquisition in coordination games as a way to reduce uncertainty and as a vehicle for subjects to select in terms of their behavior in the coordination stage. We find clear evidence of selection that manifests in the form of a threshold-level and a threshold-quality effect in the coordination game. While the threshold-level effect is consistent with the observations under exogenous precisions (see ST20), we show that when precision is endogenized, this effect becomes more pronounced and leads to a reversal of comparative statics with respect to the theoretical predictions. The threshold-quality effect, which is responsible for the differences in predictability and stability of strategies, is novel and is specific to our environment with selection. This effect illustrates the selection mechanism because it suggests that subjects who are more invested in the game will select into acquiring the best available information and set clean, clear strategies in the game, while subjects who are not too invested in the game will not purchase better, more expensive information, and their behavior in the game will be more erratic.

³⁰ Given the estimated sentiments associated with a medium precision, there does not exist a level of sentiments associated with high precision that would make a player deviate from medium to high precision. This is because the estimated sentiments from subjects in pairs that converge to high precision are close to zero and for that level switching to high precision is associated with a lower utility, even if the player believed that once he deviated the other player would always take the risky action.

Our analysis of subjects’ behavior suggests that the selection in our experiment is a result of an underlying heterogeneity of preferences for information and not of strategic anticipation. This heterogeneity gives rise to selection in the quality of information that subjects seek, which ultimately determines not only how aggressively subjects seek to coordinate with others (threshold-level effect), but also how cleanly or predictably they do so (threshold-quality effect). We document significant differences in payoffs that depend on the way subjects select, with the highest gains being associated with high precision choices (despite the high cost for such precision) and the highest losses with low precision choices (despite saving money on precision).

An interesting avenue for future research is to understand the nature of the selection process. We can think of several reasons why some subjects might choose the lowest possible precision and not engage in setting clean or surplus-extracting strategies in the game. One possibility is that they find the cognitive effort of setting such strategies to be too high. This could explain the larger incidence of degenerate strategies that are not signal-contingent for low precision subjects. Similarly, a high cognitive cost to find an optimal strategy could drive these subjects to engage in trial and error type of behavior, which leads to noisier strategies. There are, of course, other possible explanations, such as subjects choosing not to actively engage in the game and signaling this intent by spending as little money as possible on information. Whatever the explanation, our results suggest that the initial stage of costly information choice can help researchers understand subjects’ intentions in games through the signaling mechanism that arises due to selection.

There exists a large and active literature in macroeconomics and finance that studies the impact of information acquisition in settings with coordination motives and incomplete information (see Angeletos and Lian (2016) for a survey). This work focuses on the effect of information choices on fundamental and strategic uncertainty, assuming rationality and abstracting from any selection notions. Our results call for exploring the behavioral aspects documented in this paper in these models.

Conflict of interest: Not applicable.

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Appendix

A Additional Results

Aggregate results

We find that, on average, in the last 25 rounds of the experiment an individual subject chooses the same level of precision for 22 out of the last 25 periods and that the most popular precision choice is the equilibrium level 4. To illustrate this result, Figure A.1 contains the transition matrix of precision choices in the last 25 rounds. The entry a_{ij} of the matrix shows the probability of choosing precision level j in round $t+1$, given that a subject chose precision level i in round t , for $i, j \in [1, 6]$ and $t > 25$.

	Prec 1	Prec 2	Prec 3	Prec 4	Prec 5	Prec 6
Prec 1	0.91	0.04	0.01	0.006	0.004	0.03
Prec 2	0.06	0.78	0.06	0.05	0.02	0.03
Prec 3	0.01	0.03	0.83	0.08	0.02	0.03
Prec 4	0.003	0.01	0.033	0.9	0.033	0.021
Prec 5	0.005	0.055	0.09	0.16	0.51	0.18
Prec 6	0.02	0.01	0.02	0.04	0.04	0.87

Figure A.1: Transition matrix of precision choices in the last 25 rounds, DA and SM treatments

By looking at the diagonal entries of the transition matrix, we can see that most precision levels seem to be absorbent states, i.e., if a subject chooses a precision in one period, it is very likely he will make the same choice in the next period.³¹ This effectively means that individual precision choices are stable over the last 25 rounds. Given this stability result, we characterize subjects by their preferred precision choice.

Table A.1 shows the frequency of subjects that choose each precision level as their preferred precision, confirming a substantial heterogeneity of subjects' preferences for information. Notice that the frequency of individual preferred precisions is similar to the frequency of precision choices in the last 25 rounds, implying that the heterogeneity of choices reported in Table 3 is driven by the between-subject heterogeneity reported in Table A.1.

For the DA treatment, we present in Table A.2 the results of a random effects logit where the dependent variable is the decision to take the risky (1) or the safe (0) action and the independent variables are dummies for the six precision levels, interacted with the signal realizations, and we include location controls.³² All the coefficients for the interacted variables are positive and significant to the 1% level and the magnitudes of the coefficients decrease for lower precisions. Positive coefficients imply that subjects are more likely to take

³¹Precision level 5 is the least absorbent state. However, this is the least popular precision choice.

³²We interact precisions and signals because the decision in the game is determined by the value of the signal, and the information choice affects how precise the signal is.

Precision level	Standard deviation	Cost	Preferred precision
1	1	6	11.39%
2	3	5	7.59%
3	6	4	15.19%
4	10	2	38.61%
5	16	1.5	6.33%
6	20	1	20.89%

Table A.1: Preferred individual precision choices in the last 25 rounds, DA and SM treatments

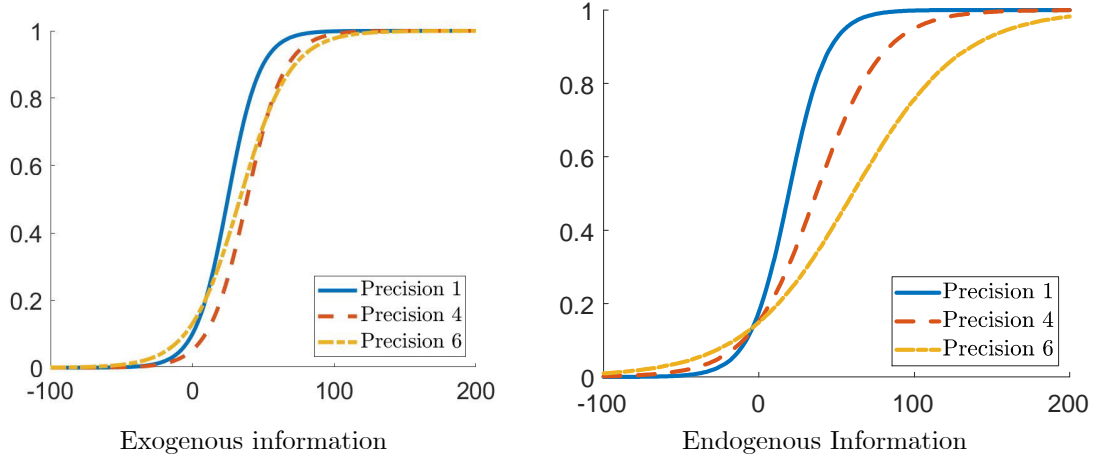


Figure A.2: Probability of taking the risky action by precision choices under exogenous information (ST20 data) and with endogenous information in DA treatment.

the risky action for higher signal realizations, for all precision levels, consistent with the monotonicity implied by threshold strategies. The decrease in magnitude of the coefficients for lower precision implies that this effect is stronger when subjects choose very precise signals than when they observe noisier signals. We find similar evidence in the SM treatment. Table A.3 reports the results of a random effects OLS regression where the dependent variable is the threshold reported by subjects and the independent variables are dummies for each level of precision, setting precision 1 as the baseline. Each of these dummies takes the value of 1 if the subject chooses this precision level and 0 otherwise. We find that the reported thresholds depend positively and significantly on the level of precision chosen. The magnitudes of the coefficients for each precision level increase as we move towards less precise information, suggesting that less precise information gives rise to higher thresholds, corroborating the findings of Table A.2 for the DA treatment.

Variable	Choice of risky action {0,1}
Precision 1*signal	0.148*** (0.021)
Precision 2*signal	0.135*** (0.018)
Precision 3*signal	0.103*** (0.011)
Precision 4*signal	0.087*** (0.007)
Precision 5*signal	0.041*** (0.013)
Precision 6*signal	0.056*** (0.006)
Location	0.387 (0.515)
Prec 1*signal*loc	-0.037 (0.029)
Prec 2*signal*loc	-0.077*** (0.02)
Prec 3*signal*loc	-0.016 (0.015)
Prec 4*signal*loc	-0.022** (0.008)
Prec 5*signal*loc	0.015 (0.015)
Prec 6*signal*loc	-0.015** (0.007)
Constant	-2.837*** (0.367)
N	2850

Clustered (by subject) standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table A.2: Choice of the risky action as a function of precision, DA treatment

Variable	Reported threshold
Precision 2	6.25 (4.00)
Precision 3	10.65*** (3.48)
Precision 4	10.78*** (3.39)
Precision 5	12.87*** (3.66)
Precision 6	12.54*** (3.23)
Constant	20.66*** (5.14)
N	1100

Clustered (by subject) standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Table A.3: Reported threshold as a function of precision, SM treatment

Threshold estimation and convergence in precision

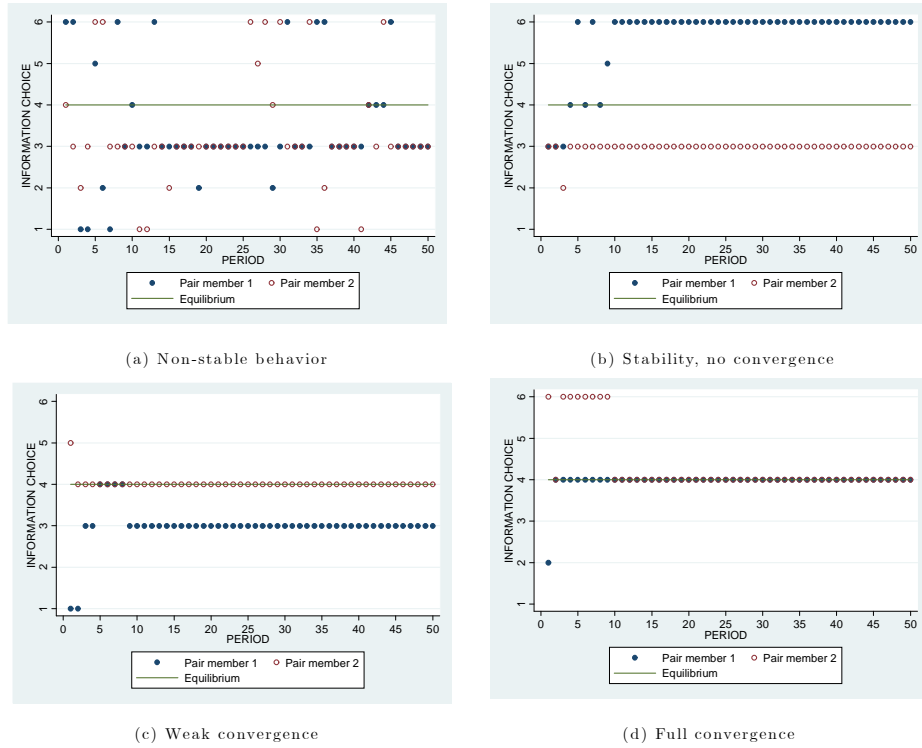


Figure A.3: Examples of types of convergence in precision within a pair

	High precision		Medium precision		Low precision	
<i>Exogenous Information</i>						
Logit (RE) (DA)	27.61 (5.86)		40.16 (9.13)		35.79 (9.00)	
MET (DA)	27.42 (19.16)		40.37 (18.77)		36.23 (23.36)	
Theoretical prediction x^*	Info 1	Info 2	Info 3	Info 4	Info 5	Info 6
	35.31	33.88	31.61	28.31	22.82	18.73
Risk dominant threshold	36		36		36	

Table A.4: Estimated thresholds and equilibrium predictions with exogenous information from ST20 data

Selection: Analysis of early rounds

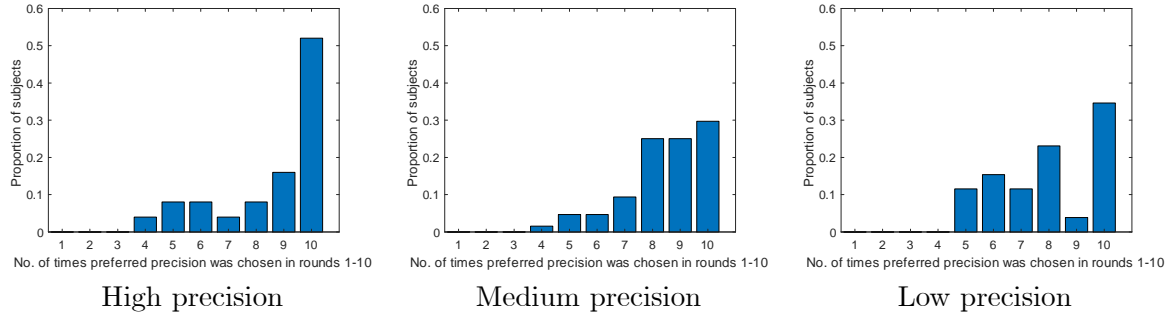


Figure A.4: Histogram of initial preferred precision choices in rounds 1-10, by precision level to which subjects converge, DA and SM treatments.

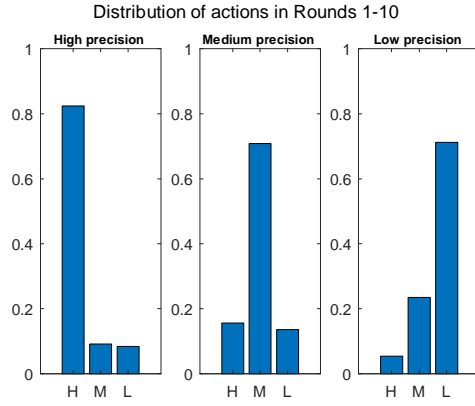


Figure A.5: Histogram precision level choices in rounds 1-10 by precision level to which subjects converge, DA and SM treatments.

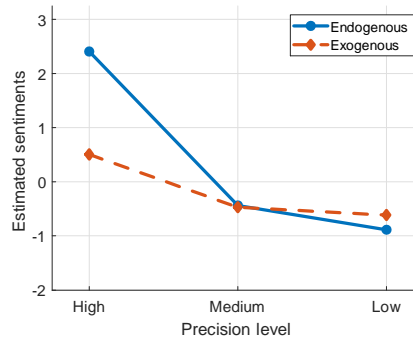


Figure A.6: Estimated sentiments consistent with thresholds, DA treatment and ST20 data.

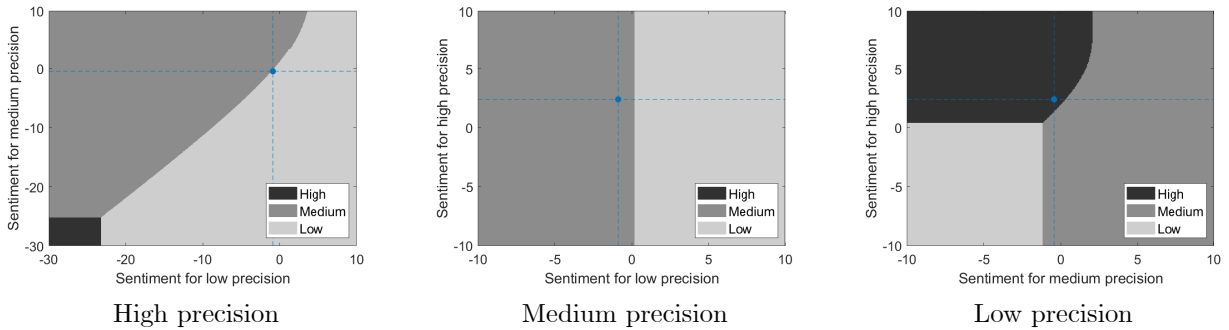


Figure A.7: Optimal precision choices of subjects whose opponents expect them to choose the given precision as a function of sentiments associated with the other two precision levels. The marker indicates estimated sentiments of the other two levels of precision