Ambiguous Information and Market Entry: An Experimental Study

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14 August 2010

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August 12, 2010

Abstract

We study experimentally how entry into a market with uncertain capacity is affected by the type of information potential entrants have available. Our focus is on behavior in a two-market entry game. In the risky information market there are two possible market capacities, both known to occur with probability 1/2. In the ambiguous information market the two possible market capacities effectively occur with probability 1/2 but participants are only told that there is uncertainty about capacities. We find that average entry is higher under ambiguous information than under risky information. To control for comparison effects and the effects of strategic interaction in the two-market environment we also study a two-lottery individual decision problem and one-market entry games with ambiguous and risky information. For these two cases the experimental results show no difference between information conditions. Our results are consistent with the notion that complex strategic interaction leads to higher market entry under ambiguous information.

JEL Classification: C72, C92, D81, M2, L1.

Keywords: Market entry games; Experiment; Risk; Ambiguity.

*We gratefully acknowledge the help from Bram Cadsby, Ninghua Du, Jason Shachat, Robin Hogarth, Rosemarie Nagel, Pedro Rey- Biel, Fei Song, Peter Wakker. All the errors are our own responsibility.

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1 Introduction

We study experimentally how entry into markets with uncertain capacity is affected by the type of information potential entrants have available. Our focus is on behavior in an entry game with two markets. In both markets capacity is uncertain and can take two possible levels. In one of the markets the information about the uncertain capacity is precise, in the sense that the probabilities of the two capacity levels are known. In the other market the information is ambiguous, the probabilities are not known.

Our general motivation is to contribute to the understanding of strategic behavior in an entrepreneurial context. What we do is related to three lines of research. Two of these lines are experimental and the third relates to broader issues. The first is the study of behavior under different kinds of uncertainty. Knight (1921) was the first to distinguish between what he called situations of risk where relevant probabilities are known and what he called situations of uncertainty, where probabilities are unknown or imperfectly known. Later Ellsberg (1961) suggested - in a number of thought experiments - that the presence of imprecise or ambiguous information about probabilities can affect decision making in ways that lead to inconsistencies with standard models of behavior under uncertainty. Following the Ellsberg paradox numerous individual decision making experiments were carried out and new theoretical models of decision-making under uncertainty were developed.

The issue we focus on is a simpler one, namely how people's behavior varies in a strategic context between situations of risk and situations of ambiguity. There are some other experimental studies that study ambiguity in various strategic contexts, different from the one we analyze. Sarin and Weber (1993) study ambiguity in an experimental asset market using auctions and find that the market price for the unambiguous bet is considerably larger than the market price of the ambiguous bet. Chen et al. (2006) study ambiguity in the first and second sealed bid auctions and find that in first price auctions, bids are lower with the presence of ambiguity, which can be explained as ambiguity loving. Drouvelis et al. (2009) compare behavior with and without common priors as a means for understanding adjustment behavior in signaling games. Kocher and Trautmann (2010) study selection either into an auction for risky project or into one with ambiguous prospects and find that most subjects select into the risky market. Jamison and Karlan (2009) report that in an experimental auction game for which both players should theoretically prefer that private valuations not be common knowledge, players do earn higher profits without the information, but many of them choose to have the information anyway. This preference is attributed to ambiguity aversion. [1]

The second line of research our work is related to is the experimental analysis of market entry games. A market entry game with the basic features of business entry situations was first studied in the experiments by Daniel Kahneman (1988), and was then explored more thoroughly by Amnon Rapoport and his colleagues (Rapoport et al. 1998; Rapoport et al. 2002a; Rapoport et al. 2002b). Rapoport et al. (2000) is the first study that analyzes entry in a two-market entry game.

Pogrebna and Schade (2009) go one step further and study a two-market entry game in which markets are heterogeneous with respect to capacity, entry costs and potential payoffs. One common characteristic of all the market entry experiments above is that the entry decision is made under a given market capacity. In our design market capacity is uncertain,

[1] For a synthetic overview of uncertainty issues see Wakker (2008).

a feature that we consider to be characteristic of many, particularly new markets. We believe that our combination of two markets with the presence of exogenous uncertainty yields a useful simplified representation on entrepreneurial entry environments.

The third related research line relates to broader business and economic issues. "Excess entry" into markets and high rates of business failure are important economic phenomena. Dunne et al. (1988) estimate that 61.5 percent of all entrants exited within five years and 79.6 percent exited within ten years in the four-digit U.S. manufacturing industries. Most of these exits were failures. (see also Shapiro and Khemani, 1987; Dunne et al., 1989a, b; Geroski, 1991; Baldwin, 1995; Wu and Knott, 2006).

Some possible explanations of overentry have been developed. A long history of entrepreneurship literature has asserted that it is entrepreneurs' risk bearing characteristics and ambition that lead to excess entry. More recently, in two different experimental studies, Camerer and Lovallo (1999) find that overentry results from entrepreneurs' overconfidence when making decisions, while Grieco et al. (2007) suggest that it is related to their self-assessed competence and emphasize the effects of feelings of competence in economic activity. All these studies focus on the importance of entrepreneurial personality in understanding overentry. Entrepreneurial personality is one way to understand overentry into markets. However, more common human tendencies may also be a factor. It is also possible that the presence of imprecise information about relevant market parameters may play a role in inducing over-entry in a context like the entry game we study here.

We present data from three different treatments. Our focus is on behavior in a two-market entry game. In this game, each player has three options. One is not entering any of the markets and obtaining a payoff with certainty. The other two choices are entering into one of two markets with uncertain capacities in which payoffs will depend both on the capacity realization and on the number of entrants. In the risky information market there are two possible market capacities, both known to occur with probability 1/2. In the ambiguous information market the two possible market capacities effectively also occur with probability 1/2 but participants are only told that there is uncertainty about capacities.

The data exhibit over-entry in both the risky and the ambiguous market. We also find that average entry is higher under ambiguous information than under risky information. What drives the ambiguity-seeking behavior we find? One possibility is that it is the fact that risk and ambiguity are jointly present in the two-market entry game. Indeed, Fox and Tversky (1995) and Chow and Sarin (2001) report that differences in behavior between a situation of ambiguity and one with known probabilities disappear when behavior is measured in a non-comparative environment. Although in those studies the comparative environment led to ambiguity aversion, while in our two-market game we observe that subjects are comparatively attracted by ambiguity, it may still be a relevant factor in our case. Another possibility is that it is the joint presence of exogenous and strategic uncertainty that causes the behavior we observe.

We use two treatments to test separately for these two factors. In one treatment, we remove the strategic interaction but still let players face a risky and an ambiguous situation simultaneously. Specifically, subjects can choose to participate in a lottery with risky information and another one with ambiguous information. We refer to this treatment as the individual choice situation. In the other treatment, we remove the comparative effects of risk and ambiguity but keep the strategic game setting. Here we compare the behavior of subjects that can choose to enter a market with stochastic market capacity and risky information and another one with the same distribution of stochastic capacity but ambiguous information about it. In other words, strategic interaction under risky and ambiguous information takes place separately (between subjects) and is compared later. We refer to this treatment as the one-market entry game. The results from the individual choice situation and from the one-market entry game show no difference in the attitude towards risk and towards ambiguity. Taken together these results are not compatible either with a comparative ignorance explanation or with one based on the joint presence of exogenous and strategic uncertainty.[2]

Our results can be summarized as follows. In relation to the excess-entry literature discussed above we can say that the combination of the presence of two markets and of uncertainty does induce excess-entry and more so if the information about market capacities is ambiguous. The higher entry under ambiguous information can no be explained either by the joint presence of exogenous and strategic uncertainty or by a comparative ignorance type argument. Perhaps it is the higher complexity of the situation that triggers less thoughtful and more impulsive decisions leading to over-entry exacerbated under ambiguous information.[3]In the final section of the paper we come back to this. Given that natural environments are invariably complex our two-market entry game may be a useful instrument for analyzing entry issues.

The paper is organized as follows. The next section introduces our treatments and the

[2]Note that if we had only run one of the two treatments, we could have incorrectly concluded that one of the two explanations discussed above was the correct one. See Abbink and Brandts (2008) for another market experiment in which two treatments yields results that are contradictory with each and Abbink and Brandts (forthcoming) for a discussion of what one can learn from complex market environments like ours.

[3]In a very different line of research, psychologists have used the concept of ambiguity tolerance (Furnham and Ribchester 1995) to refer to the way an individual perceives and processes information about ambiguous situations when confronted by an array of unfamiliar and complex clues. Complexity in strategic environments may arouse the tolerance for ambiguity in some people.

theoretical benchmarks. the market entry game and characterizes its equilibria. Section 3 presents the results. Section 4 contains the conclusions.

2 Experimental Treatments and Theoretical Benchmarks

In this section we first present the three treatment in detail, then move to our parameter choices and the theoretical benchmarks and end with description of our experimental procedures and participants.

Treatments

Our design is composed of three treatments. Treatment 1 is a two-market entry game with uncertain capacities in both markets. Treatment 2 is an individual choice situation, where individuals face two lotteries without any strategic interaction. Treatment 3 is a one-market game with uncertain capacity. Treatment 1 - involving two markets - is our central treatment. Being the most complex treatment, one can consider it to be the one closest to the natural environments we are interested in. Treatments 2 and 3 control for the two sources of complexity present in the two-market game.

Treatment 1: A two-market entry game.

This entry game is played by a group of 7 players facing two independent markets. Each player i has to choose - simultaneously with and independently from the other players - whether to stay out ($S^i = X$) for a fixed payoff 12 or enter one of the markets ($S^i = Y$) or ($S^i = Z$). Payoffs are linear in the number of entrants and are computed from the following formula, which is common knowledge:

$$\pi_i(\partial) = \begin{cases} 12, & \text{if } S^i = X \\ 12 + 2(c_Y - m_Y), & \text{if } S^i = Y \\ 12 + 2(c_Z - m_Z), & \text{if } S^i = Z, \end{cases}$$

where c_j $(j = Y, Z)$ is the market capacity in market j and m_Y and m_Z are the numbers of actual entrants, (including subject i), into the two markets, with $0 \leq m_Y + m_Z \leq 7$.

In both markets capacity was uncertain and could independently take a low value $\underline{c}$ or a high value $\overline{c}$. Participants knew that, if they entered either of the markets, they would face an uncertain capacity. The way of operationalizing the uncertainty about market capacities is one of the important design choices.

For both markets the probability for the two capacity levels was $p = \frac{1}{2}$, drawn independently for each period. However, the information about p was different for the two markets, being precise in one market and ambiguous in the other market. In the market with precise information, market Y, subjects were explicitly told that capacity c_j was from one of the two values $\underline{c}$ and $\overline{c}$ each occurring with probability $\frac{1}{2}$. We will refer to this situation of an uncertain capacity with known probability as one involving risk.

In the market with ambiguous information about market capacities, market Z, subjects only knew that capacity c_j was from one of the two values $\underline{c}$ and $\overline{c}$ and that the probability of the two capacity levels was constant across all periods. We will refer to this situation of an uncertain capacity with unknown probability as one involving ambiguity.

The probability we used for the market with ambiguous information - the true probability - was $p = \frac{1}{2}$, just as in the market with precise information. In making this choice we were guided by the simple idea that if a prior is not known, it is reasonable to assume that subjects will start with a uniform prior.[4] This idea, often called the principle of indifference or the principle of insufficient reason, has a long tradition, going back to Jacob Bernouilli and Laplace. We feel that $p = \frac{1}{2}$ is a good starting point for the kind of comparison we are interested in. In our context, it has to be related to the fact that subjects make decisions repeatedly; more on this below.

In both markets the low and high capacity levels were 1.1 and 3.1, respetively. [5] The realizations of $\underline{c}$ and $\overline{c}$ for the two markets over the 50 periods were generated by the computer. Two observations are important here. First, we used two realizations in the different sessions of treatment 1, as well as in treatments 2 and 3. In half of the sessions of treatment 1, we used realization 1 for market Y and realization 2 for market Z. In the other half of the sessions, we switched the two realizations for the two markets, so that now realization 2 was used for market Y and realization 1 for market Z. This controls for sampling error and, hence, facilitates the comparison between behavior in the two markets.

Second, we generated realizations of the sequence of capacities before the experiments took place and chose two realizations in which two values appears quite evenly around 25 periods out of 50 periods. We wanted to avoid results distorted by extreme sequences of values of $\overline{c}$ and $\underline{c}$. Below we will explain how the two realizations were used in treatments 2 and 3.

Treatment 2: An individual choice situation.

In this treatment players choose between a safe choice and two lotteries, which are constructed using the payoff functions of treatment 1, discussed above. Similarly to treatment

[4] Drouvelis et al. (2009) also use this assumption.

[5] By choosing these non-integer values we avoid multiple equilibria in the game; more on this below.

1, c_Y and c_Z are random variables that take values 1.1 and 3.1 with probability $p = \frac{1}{2}$. The variables m_Y and m_Z in treatment 1 have been set equal to 2.1, so as to make a risk-neutral decision-maker indifferent between choosing the safe choice X or either of the safe lotteries Y and Z. As for treatment 2, information about the random variable was precise for lottery Y and ambiguous for lottery Z.[6]

The payoff function for this treatment was the following:

$$\pi_i(\partial) = \begin{cases} 12, & \text{if } S^i = X \\ 12 + 2(c_Y - 2.1), & \text{if } S^i = Y \\ 12 + 2(c_Z - 2.1), & \text{if } S^i = Z \end{cases}$$

Without interaction there are no equilibria to consider. The issue here will be a simple comparison between the frequency of choice Y and that of Z.

Treatment 3: A one-market entry game

This treatment consists of two subtreatments: a one-market entry game with uncertain capacity and precise information about capacities and an analogous game with ambiguous information about capacities. A one-market entry game is played by a group of 5 players who must decide simultaneously and independently whether to enter a market ($S^i = Y$) or to stay out ($S^i = X$). The payoff to player i's is computed from the following formula, which is common knowledge:

$$\pi_i(\partial) = \begin{cases} 6, & \text{if } S^i = X \\ 6 + 2(c - m), & \text{if } S^i = Y \end{cases}$$

Where choice Y denotes a market with risky or ambiguous capacities. $0 \leq m \leq 5$ is the number of subjects (including subject i) choosing Y. c is the actual market capacity

[6] The value 2.1 is quite close to the pure strategy equilibrium number of entrants in the strategic game in Treatment 1.

occurring in a certain period.

2.1 Theoretical Benchmarks and Parameter Choices

For the two treatments with interaction, the equilibria of the one-shot game yield theoretical benchmarks to which the data can be compared. In what follows we describe the equilibria based on the assumption that players evaluate ambiguous information about uncertainty in the same way as precise information. For the two-market game of treatment 1 there are $N!/m_Y^*!m_Z^*!(N-m_Y^*-m_Z^*)!$ pure strategy equilibria with $m_j^* = |c_j|$ $(j = Y, Z)$, where $|c_j|$ is the largest integer smaller than the expected value of capacities in market j, c_j.

Additionally, there is a symmetric mixed Nash equilibrium with entry probability of firm i in market j given by $E_j^i = \frac{\left(p\bar{c}_j+(1-p)\underline{c}_j\right)-1}{N-1}$. Note that the expected number of entrants in the symmetric mixed equilibrium is $N * E_j^i$, which is different from but can be very close to the pure strategy equilibria value m_j^*.

Given that there were 7 players and the capacities in both markets where $\underline{c} = 1.1$ and $\bar{c} = 3.1$ with $p = \frac{1}{2}$, the pure strategy Nash equilibria have 2 players entering each of the two markets (and three staying out), while the symmetric mixed strategy Nash equilibrium predicts an individual entry probability 0.183 and the expected number of entrants in each of the markets being 1.281.

As shown above, for the one-market games of treatment 3 we chose different parameters. There were now five players and $\underline{c} = 2.1$ and $\bar{c} = 4.1$ with $p = \frac{1}{2}$. Pure strategy Nash equilibria have 3 players entering and 2 players staying out. Symmetric mixed strategy Nash equilibria predict an entry probability 0.525 and the expected number of entrants 2.625.

What is the rationale behind the parameter choices for the two entry games? First, we choose $\underline{c}$ and $\overline{c}$ to be non-integers so that there exists only one pure equilibrium number of entrants [7]. At the same time, the values are close to an integer so that in equilibrium the payoff difference to those entering one market and those staying out remains quite small.

Second, the outside option, the capacity and the number of of players in a group all differed between the two and the one-market treatments, wtih values of 12, 1.1/3.1 and 7 in treatment 1 and of 6, 2.1/4.1 and 5 in treatment 2. We chose these values to keep the equilibrium choices more comparable. For the pure strategy equilibria, the two-market entry game In treatment 1 has 3 players always choosing Out and 4 players always choosing Entry (2 in each market), so that the ratio of Out to Entry choices is 3/4. While the one market entry game has 2 players always choosing Out and 3 players always choosing Entry. The ratio of Out to Entry is her 2/3, which we judged to be close to 3/4.

For the mixed strategy equilibria of the two-market game of treatment 1 the expected number of entrants is $2.562 = 1.281 + 1.281$, while the expected number of entrants in the one-market game is 2.625, a number rather close to 2.562.

In most of the literature on repeated play of market entry games in fixed matching, individuals' coordination on the behavior of others lead to an asymmetric pure equilibrium even though such play may take a long time to emerge. In the present experiments, under coexistence of uncertain capacity and multimarket settings, coordination among players becomes very hard. Given the assumption of identical incentives among players, one might think that the mixed symmetric equilibrium is particularly salient.

In treatment 2, the lottery treatment, payoffs of each individual are independent of other

[7] If $\underline{c}_j$ and $\overline{c}_j$ are integers, there exists two pure equilibria entrant numbers.

players. In the payoff formula we set a fixed value 2.1 in the place of the number of entrants m_j. This number is close to the pure strategy equilibrium entrant number 2 in treatment 1.

2.2 Procedures

The experimental procedures for all three treatments follow the same steps. At the beginning of a session subjects received the instructions on paper. The instructions were worded in neutral terms, without any reference to markets. After the instructions had been read aloud by one of the experimenters, subjects completed a set of review questions on the computer terminals to test their understanding of the instructions. They could not finish this part until they had answered all the questions correctly. In the instructions subjects were told that they would have to make one choice between two options (treatment 3) or between three options (treatments 1 and 3) in each of the periods of the session, and that they would play the same game repeatedly in 50 consecutive periods. In treatments 1 and 3 - involving strategic interaction - subject were told that they would play the 50 periods with the same group with fixed partners.

In order to ensure that subjects clearly understood the payoffs resulting from choosing to enter a market, the instructions also included payoff tables showing all possible payoff values from choosing entry. Such payoff tables were shown to subjects in each period. In each period all subjects made decisions simultaneously without communication among them. For the case of ambiguous information fixed matching raises the possibility that subjects choose the option with ambiguous information to learn more about the true underlying distribution of capacities. In the results section we take this possibility into account.

We use fixed matching based on the following considerations. First, it makes it easier to obtain many statistically independent observations. Second, it facilitates comparability with previous studies of market entry games most if which also use fixed matching.

At the end of one period, the only information they received is their own payoffs and their payoff history. This kind of information feedback tries to simulate the situation in the field, where entrepreneurs face both competitors and variable market conditions. They are only able to know the final result of their decisions, such as their payoffs, but not how their payoffs result from the interaction of the two factors.

In addition, this information feedback makes it hard for subjects to learn the probabilities about capacities and others' strategies for the case of ambiguous information.[8]

2.3 Participants

184 students from the Universitat Autónoma de Barcelona of Spain participated in our experiments. They were recruited through e-mail invitations on an experimental recruiting website using the ORSEE system[9]. Each subject was only allowed to participate in a single session that lasted around 45 minutes. 84 students participated in Treatment 1 in 12 groups of seven, and we ran four sessions[10] with 21 subjects seated in each session. 25 students participated in Treatment 2, and we ran two sessions[11] with 12 subjects and 13 subjects in

[8]Some seminar participants have asked why our design did not include the elicitation of beliefs about others' behavior. The answer is that given in our interest in connecting our work to some field-issues we thought it more natural to avoid belief elicitation at this point.

[9]Greiner, B., (2004). An Online Recruitment System ORSEE.

[10]As mentioned above, for the realizations of capacities $\underline{c}$ and $\overline{c}$, in two sessions we use realization 1 for the risky market and realization 2 for the ambiguous market; in the other two sessions, we switch the two realizations between the two markets.

[11]Here in one session we use realization 1 for the risky market and realization 2 for the ambiguous market; in the other session, we switch the two realizations between the two markets.

each session. 75 students participated in treatment 3 in 8 groups of five and 7 groups of five separately, and we ran two separate sessions for the one-market game with risk and with the one-market game with ambiguity.[12]

3 Experimental Results

Our experimental results are separated in two parts. We first present the results pertaining to the two-market entry games. In the second part, we report the experimental results of the one-market entry game and the individual choice game. We will relate the data in the two parts to explain why and how people deal with uncertain information of risk and ambiguity in strategic games.

3.1 Results of the two-market entry game

In this section, we analyze entry behavior moving from the aggregate level to the group level and finally to the individual level. We first look at the aggregate number of entrants of all subjects in risky and ambiguous markets over 50 periods, then do the same by group and, finally, we examine individual decision processes. We summarize our findings in three results. We first state each result and then present the evidence that supports it. Our first result pertains to the direct comparison of entry into the two markets.

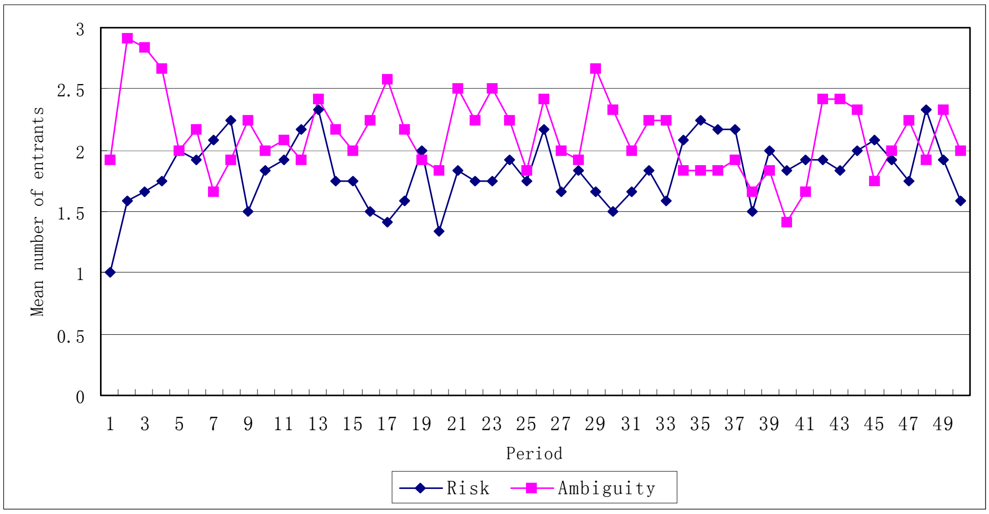
Result 1: The number of entrants into the ambiguous market is higher than that into the risky market. This difference diminishes over time but does not disappear.

[12] Here in the one-market game with risky information, we use realization 1 in one session and realization 2 in the other session. We do the same in the one-market game with ambiguous information.

We get into the heart of the matter by comparing the numbers of entrants over time in the risky information and ambiguous information markets. The two panels of Figure 1 show the number of entrants into the two markets, averaged over all groups, by period and averaged over every 5 periods respectively. In the upper panel, one can see that in the first four periods there is a large difference in the number of entrants in the ambiguous market (with the highest value around 3) and the risky market (with the lowest value around 1). From then on the number of entrants in both markets fluctuates between 1.5 and 2.5. The impression is that the number in the ambiguous market is higher than the number in the risky market in most periods, but the difference is not very clear in the final periods.

The lower panel of Figure 1 shows the average number of entrants averaged over every 5 periods. One can see that the number of entrants in the risky market is always slightly below the pure strategy equilibrium value 2 and is always above the mixed strategy equilibrium value 1.281. Comparatively, the number in the ambiguous market is always above 2, except for the value pertaining to periods 36-40. Figure 1 suggests that there is a preference for entering into the ambiguous market rather than into the risky market. The difference in mean entrants in the two markets becomes smaller and both values get closer to the pure strategy equilibrium value 2 in the final periods.

Table 1 gives a complementary view of the data shown in Figure 1. It shows the distribution of the number of entrants ($N = 0, 1, 2, 3, 4, 5, 6, 7$) into each of the two markets in the first 25, the last 25 and all 50 periods, respectively. The numbers listed in the table denote the number of times the two markets had the eight possible numbers of entrants. Observe two important features of the data shown in the table. First, $N = 2$ is the mode both for ambiguity and for risk. Second, for each of the numbers of entrants $N \leq 2$ (i.e.,



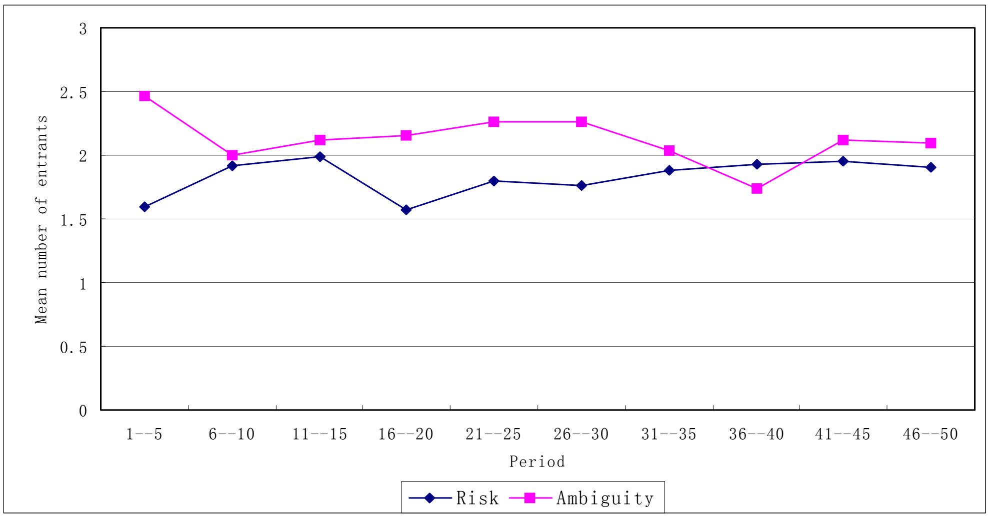


Figure 1: Mean number of entrants by period (top) and by every five periods (bottom) in Treatment 1

including no entry), the numbers of entrants into the risky markets are higher than those of entrants into the ambiguous markets. Comparatively, for $7 > N > 2$, the numbers of entrants into the ambiguous markets are higher than those of the entrants of risky markets. The numbers shown in Table 1 confirm the impression that, on average, there is more entry into the ambiguous information market.

Table 1. Distribution of the number of entrants in Treatment 1

	Periods1-25		Periods 26-50		Periods1-50	
Entrants	Risk	Ambiguity	Risk	Ambiguity	Risk	Ambiguity
0	34	13	23	10	57	23
1	95	75	93	82	188	157
2	99	99	99	121	198	220
3	51	76	67	62	118	138
4	19	29	16	20	35	49
5	2	5	2	5	4	10
6	0	3	0	0	0	3
7	0	0	0	0	0	0

We now move to looking at more disaggregated data. Table 2 reports the mean number of entry into the two markets for each of the twelve groups; standard deviations appear in parentheses, both for the first and the last 25 of the total 50 periods. In periods 1-25, the mean for ambiguity is higher than that for risk for all 12 groups. In periods 26-50, the same holds except for group 1 and group 2.

Table 2. Observed mean number of entrants by group in Treatment 1

	Periods 1-25		Periods 26-50	
	Risk	Ambiguity	Risk	Ambiguity
Gr.1	1.8	2.52	2.24	1.92
	(1.135)	(1.174)	(1.145)	(1.132)
Gr.2	1.96	2.48	2.44	2.24
	(1.219)	(1.174)	(1.239)	(0.909)
Gr.3	1.56	2.6	1.8	2.08
	(1.102)	(0.851)	(0.983)	(0.893)
Gr.4	1.84	2.16	2	2.28
	(1.010)	(1.049)	(0.695)	(0.920)
Gr.5	1.76	2.36	1.96	2.36
	(1.179)	(1.057)	(0.826)	(1.130)
Gr.6	1.8	2.2	1.72	2.6
	(1.023)	(1.061)	(0.920)	(1.135)
Gr.7	1.8	2.48	1.76	1.92
	(1.061)	(0.902)	(1.072)	(0.629)
Gr.8	1.6	1.76	1.28	1.32
	(0.983)	(1.369)	(0.920)	(0.971)
Gr.9	2.12	2.12	2.12	1.8
	(1.073)	(1.180)	(1.180)	(0.983)
Gr.10	1.72	1.72	1.48	1.64
	(1.253)	(0.963)	(1.103)	(0.845)
Gr.11	1.44	1.68	1.56	1.88
	(0.806)	(0.884)	(0.755)	(0.713)
Gr.12	1.88	2.32	2.28	2.56
	(1.110)	(1.520)	(0.963)	(0.986)
Average	1.773	2.2	1.887	2.05
	(1.097)	(1.155)	(1.049)	(1.014)
Num $(Risk \geq Ambiguity)$	0		2	
Pro. $(Risk \geq Ambiguity)$	0.00		0.019	

The next to the last row reports the p-values from a binomial test of the difference in the entrants, based on a null hypothesis that the number of entrants is the same for ambiguity and risk (as is true in equilibrium). The results of the text show that we can easily reject the null hypothesis of equal entry into the two markets.

Next we compare observed behavior to the theoretical benchmark behavior presented in section 2.

Result 2: Both symmetric mixed strategy and pure strategy equilibrium strategies fail to explain individual behavior, both under risky and ambiguous information markets. Subjects mix their entry decisions but in a way very heterogeneous.

Recall that in the pure strategy equilibrium the number of entrants into each of the markets is 2, while in the mixed strategy equilibrium it is 1.281. Observed average entry rates are 1.83 for the risky market and 2.125 for the ambiguous market. These figures are quite far from the mixed equilibrium figure and somewhat closer to the figure for the pure equilibrium, We now look at individual behavior more closely to see to what extent it is in line with equilibrium behavior. We start by plotting individuals' proportions of entry into each market of the two markets. The two panels of Figure 2 show individual entry frequencies in periods 1-25 and periods 26-50 respectively. Both graphs plot the observed proportion of an individual's entry in the risky information market, shown on the X axis, against his proportion of entry in the ambiguous information market, shown on the Y axis. Each data point is based on 25 observations for each individual. For example, the points on the diagonal line OB describe individuals whose entry frequencies in the two markets are the same, while points on the diagonal line AC describe individuals whose sum of entry frequencies in the two markets equals 1, in other words, those who never choose Out. In another example, the points on the line OA represent individuals who never enter the risky information market. In both panels, one can see the benchmark point indicating the mixed-strategy equilibrium[13].

[13] The mixed strategy equilibrium value in the risky information market is 0.183. Such a prediction is based on the assumption of risk neutrality. Symetrically, we posit the equilbrium value in the ambiguous information market to also be 0.183 under the assumption of a neutral attitude towards risk and the application of

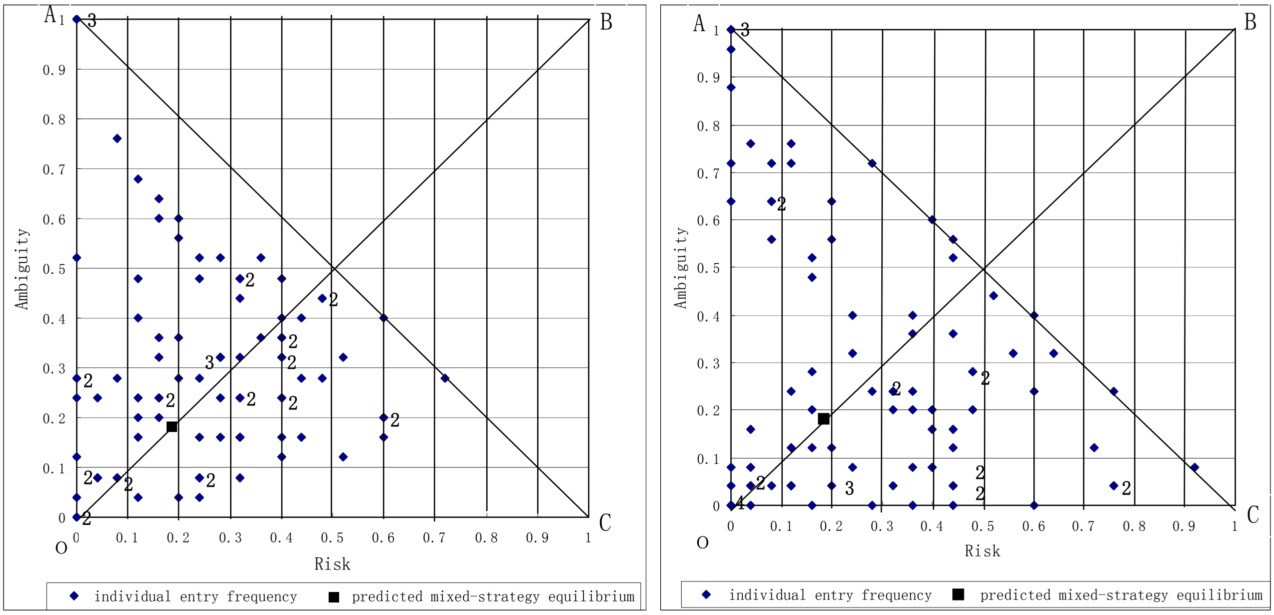


Figure 2: Observed entry frequency in periods 1-25 (left) and in periods 26-50 (right) of Treatment 1

One can see that in both panels the points representing individual entry frequencies are scattered without any clear concentration in any particular area. Individuals clearly mix between entry into one and the other market, but in ways which are hard to account for by the symmetric mixed-strategy equilibrium. It seems that the points are more loosely distributed in the right graph compared with the left one and such changes may be helpful in explaining the diminishing difference in entry into the two markets. In particular, many points move to the edge of the graph (X axis, Y axis and the diagonal line AC).

Summarizing, subjects mix their choices but in a heterogeneous way. The observed mixed entry behavior is far from the symmetric mixed strategy equilibrium prediction. Mixed strategies in repeated games was studied in market entry games by Rapoport, Seale and

the principle of insufficient reasoning, i. e. probability $\frac{1}{2}$, for the case of unknown probability.

Winter (2000) and Zwick and Rapoport (2002). The common characteristic in these studies is that there are significant departures from mixed strategy equilibrium play at the individual level, where there are many subjects who either enter too frequently or too infrequently, and most importantly there may exist sequential dependencies that constitute adaptation and repetition bias. This raises the question whether, in our experiment, do individuals' decisions follow a certain form of adaptation, such as coordination, and does individual entry behavior converge to the pure strategy equilibrium prediction?

Figure 3 shows the number of entrants into the two markets in each group over 50 periods. We can see clearly that the numbers fluctuate even in the final periods and that no coordination at the pure strategy equilibrium is achieved.

The results we have reported until now show that entry into the ambiguous market is larger than into the risky market and that observed behavior is far from both the pure and the mixed equilibrium outcomes. Our third result pertains to a more detailed analysis of individual behavior over time. The motivation for looking at this feature of our data is twofold. First, given that we chose an environment with repeated play it's important to look deeper into whether behavior changes over time. Second, the analysis of behavior over time may yield some insights into the reasoning process behind observed behavior.

Result 3: There is more persistence when in the ambiguous market than when in the risky market: for any payoff-level staying in ambiguity is more frequent than staying in risk.

A simple way of studying strategies in repeated situations is to observe how subjects switch between choices. Here we are interested in studying the choices in period t based on the case of having entered into the risky market and the ambiguous market in period $t-1$.

Figure 3: Number of entrants by period by group in Treatment

Subjects may react quite differently to payoff information from a previous risky choice or a previous ambiguous choice.

We will look at this issue by relating choices in period t to choices and the consequences of choices in period $t-1$ based on the aggregate observations across all subjects over 50 periods. Table 3 reports the observed proportions of choices Out, Risk and Ambiguity in period t in response to the payoffs 2.2, 4.2, 6.2, 8.2, 10.2, 12, 12.2, 14.2 and 16.2 in period $t-1$, where we separate the observations into three blocks depending on the sources (Out/Risk/Ambiguity) of the payoffs.

The upper block in the table presents proportions in every choice in response to various payoffs received in period $t-1$ in choosing Risk. The middle block presents proportions in every choice in response to various payoffs received in period $t-1$ in choosing Ambiguity.

Table 3. Aggregate proportions of entry choices in period t in response to choice and payoffs in period $t-1$

	Period $t-1$								
	Payoffs (Obs.) in Risk market								
Period t	2.2	4.2	6.2	8.2	10.2	12.2	14.2	16.2	All payoffs
		(5)	(72)	(195)	(264)	(258)	(186)	(99)	(1079)
Out		0.6	0.472	0.405	0.307	0.244	0.258	0.222	0.306
Risk		0.2	0.361	0.354	0.443	0.484	0.538	0.434	0.446
Ambiguity		0.2	0.167	0.241	0.25	0.271	0.204	0.343	0.248
$\frac{Ambiguity}{Out+Ambiguity}$		0.25	0.261	0.373	0.449	0.526	0.442	0.607	0.448
	Payoffs (Obs.) in Ambiguity market								
	2.2	4.2	6.2	8.2	10.2	12.2	14.2	16.2	All payoffs
	(12)	(25)	(126)	(226)	(274)	(283)	(228)	(77)	(1251)
Out	0.583	0.64	0.397	0.345	0.270	0.184	0.149	0.182	0.260
Risk	0	0.16	0.214	0.181	0.226	0.180	0.202	0.104	0.191
Ambiguity	0.417	0.2	0.389	0.473	0.504	0.636	0.649	0.714	0.549
$\frac{Risk}{Out+Risk}$	0	0.2	0.350	0.344	0.456	0.495	0.575	0.364	0.424

	Payoffs (Obs.) in Out
	12
	(1786)
Out	0.629
Risk	0.205
Ambiguity	0.166
$\frac{Risk}{Risk+Ambiguity}$	0.553

We look at the data in two different ways. First, we compare the proportions of staying in Risk in the first block with the proportions of staying in Ambiguity in the second block in response to the same payoffs. It describes how people stick to the same choice. In the upper block, we observe that the proportions of staying in Risk are quite similar for various payoffs in Risk in period $t-1$, while in the middle block, the proportions of staying in Ambiguity increase as the payoffs in Ambiguity in period $t-1$ increase. In comparison the proportions of people sticking to Risk is always equal or lower than those of sticking to Ambiguity in response to the same payoff level, and the difference becomes larger for high payoff levels. How can these differences be explained? Taking the payoff information of 14.2 and 16.2 as an example, this payoff information implies that the capacity is high and there are 2 and 1 entrants in the market, respectively, in the period. However, it seems that people react to it differently depending on whether such information stems from a risky or an ambiguous market. For a payoff of 16.2 the frequency of sticking to the risky market is 0.434 and 0.714 in the ambiguous market, for a payoff of 14.2 the frequency of sticking to the risky market is 0.538 and 0.649 in the ambiguous market and the same direction of the inequality holds for all other payoff levels except 4.2, where the two relevant frequencies are equal. People tend to stick more to their previous choice if they had chosen to enter an ambiguous market.

The second way of looking at the data of table 3 is to study switches in decisions. On the one hand, we make a comparison of switches from one market to the other market. The proportions of switches from an ambiguous market to a risky market in response to most payoff levels are slightly lower than from a risky to an ambiguous market. On the other hand, we study how they make decisions between the other two choices once they deviate from the one choice. The expression in the last row, $\frac{Ambiguity}{Out+Ambiguity}$, in the upper block and the expression, $\frac{Risk}{Out+Risk}$, in the middle block describe the percentages of entering ambiguity or risk proportions when switching out of risky or ambiguous choices of period $t-1$. The value $\frac{Ambiguity}{Out+Ambiguity}$ increases as the amount of payoffs increases, while the value$\frac{Risk}{Out+Risk}$ reacts little to different payoffs. It seems that when people switch out of a risky market, they prefer ambiguous market to staying out, while when they switch out of an ambiguous market, they may be not very interested in entering in risk. To conclude our description of the data of Table 3, individuals prefer to stay in Ambiguity and are more likely to switch from Risk to Ambiguity than from Ambiguity to Risk.

We can also look at switches in decisions at the group level, aggregated over 50 periods. Table 4 reports the observed proportions of choices Out, Risk and Ambiguity in each group in period t in response to choices Out, Risk and Ambiguity in period $t-1$ respectively. The proportions of sticking to the same choice are, except for group 4 and group 5, higher for Ambiguity are higher than for Risk. The proportions of switching to Ambiguity are higher than those of switching to Risk in all the 12 groups. All the observations in Table 3 and 4 suggest that there exists more persistence in the Ambiguous information market.

Table 4. Proportions by group of entry choices in period t in response to choice and payoffs in period $t-1$

		Period $t-1$		
		Risk	Ambiguity	Out
Risk (Period t)	Gr.1	0.485	0.236	0.179
	Gr.2	0.430	0.256	0.277
	Gr.3	0.354	0.113	0.274
	Gr.4	0.479	0.309	0.122
	Gr.5	0.626	0.164	0.125
	Gr.6	0.437	0.129	0.243
	Gr.7	0.517	0.234	0.116
	Gr.8	0.338	0.132	0.194
	Gr.9	0.311	0.240	0.348
	Gr.10	0.375	0.160	0.198
	Gr.11	0.438	0.149	0.164
	Gr.12	0.53	0.15	0.252
Ambiguity (Period t)	Gr.1	0.253	0.582	0.149
	Gr.2	0.262	0.479	0.261
	Gr.3	0.244	0.670	0.123
	Gr.4	0.372	0.473	0.158
	Gr.5	0.187	0.612	0.199
	Gr.6	0.253	0.603	0.193
	Gr.7	0.303	0.617	0.095
	Gr.8	0.169	0.421	0.163
	Gr.9	0.311	0.417	0.163
	Gr.10	0.2	0.580	0.109
	Gr.11	0.219	0.552	0.126
	Gr.12	0.17	0.533	0.325
Out (Period t)	Gr.1	0.263	0.182	0.672
	Gr.2	0.308	0.265	0.462
	Gr.3	0.402	0.217	0.603
	Gr.4	0.149	0.218	0.719
	Gr.5	0.187	0.224	0.676
	Gr.6	0.310	0.267	0.564
	Gr.7	0.180	0.150	0.789
	Gr.8	0.493	0.447	0.643
	Gr.9	0.377	0.343	0.489
	Gr.10	0.425	0.259	0.692
	Gr.11	0.342	0.299	0.710
	Gr.12	0.3	0.317	0.423

Table 5 shows the results of a multinomial logit regression analysis to test the findings above. In the regression, the dependent variable is the action chosen by one subject in period t, $S \in \{0, 1, 2\}$, where 0, 1 and 2 denote staying out, entering in risk and in ambiguity respectively. The logit regression is of the form:

$prob(S = i) = \frac{\exp(b_0 + b_{profit}P + b_r R + b_a A + b_g G)}{1 + \sum_{i=0}^{2} \exp(b_0 + b_{profit}P + b_r R + b_a A + b_g G)}$

Here, P is an individual's payoff, R is a dummy variable indicating one's choice of entering risky market ($R = 1$), A is a dummy variable indicating one's choice of entering ambiguous market ($A = 1$) and G is a dummy variable indicating the female ($G = 1$) in period $t - 1$. Our goal is to associate the entry choices in period t with profits and entry choices in period $t - 1$. Since there are multiple entry choices, we choose the first choice ($S = 0$) the base choice as the comparison group. The output above has two parts, labeled with the outcome variable $Entry(t)$. They correspond to two equations:

$log(\frac{P(S=1)}{P(S=0)}) = b_0 + b_{profit}P + b_r R + b_a A + b_g G$

$log(\frac{P(S=2)}{P(S=0)}) = b_0 + b_{profit}P + b_r R + b_a A + b_g G$

with bs being the raw coefficients listed in Table 5.

For example, we can say that for dummy variable ambiguity=1 (compared with ambiguity=0), $log(\frac{P(S=1)}{P(S=0)})$ will be increased by 1.024, and $log(\frac{P(S=2)}{P(S=0)})$ will be increased by 2.327. Similarly, for dummy variable risk=1 (compared with ambiguity=0), $log(\frac{P(S=1)}{P(S=0)})$ will be increased by 1.623, and $log(\frac{P(S=2)}{P(S=0)})$ will be increased by 1.262. All the coefficients are significant at level 1% when clustered by group.

Therefore, we can say that, in general, both a choice of ambiguity and a choice of risk in period $t-1$ will increase one's preference to entering in risk ($S=1$) or ambiguity ($S=2$) compared with the outside choice of a fixed payoff.

From another angle, $log(\frac{P(S=2)}{P(S=1)})$ will be increased by 1.306 ($=2.314-1.008$) when facing $S=2$ in period $t-1$. $log(\frac{P(S=1)}{P(S=2)})$ will increase by 0.355 ($=1.598-1.243$) when facing $S=1$ in period $t-1$. We observe persistence (of positive values) in both markets and stronger effects ($log(\frac{P(S=2)}{P(S=1)}) > log(\frac{P(S=1)}{P(S=2)})$) in ambiguous markets.

Table 5. Multilogit regression model of entry decision in period t in response to choice and payoffs in period $t-1$

	Entry(t) (compared with Out)	
	Risk	Ambituity
	$\ln \frac{P(S=1)}{P(S=0)}$	$\ln \frac{P(S=2)}{P(S=0)}$
Profit(t-1)	0.125 *	0.166 *
	(0.019)	(0.018)
Dummy (risk=1 at t-1)	1.623 *	1.262 *
	(0.096)	(0.107)
Dummy (ambiguity=1 at t-1)	1.024 *	2.327 *
	(0.110)	(0.100)
constant	−2.622 *	−3.321 *
	(0.238)	(0.228)
Pro>chi2	0.0000	
Wald chi2(6)	885.50	
Num. of Obs.	4116	
Pseudo R2	0.1000	

*significant at the 1% level, clustered by group.

This higher persistence in the market with ambiguous information is not easy to interpret. It is compatible with the notion that, under risk, participants have more self-control over their behavior and stick more to a pattern of switching between markets intended to make their behavior unpredictable. In contrast, the higher persistence under ambiguity can be interpreted as the result of a more unreflective tendency to simply stick to a decision which has yielded a positive payoff. Note that the differences in the frequencies of staying in the same market tends to be higher for the higher payoff levels 14.2 and 16.2 than for the lower ones 4.2 and 6.2. This suggests that, without precise information about the exogenous probability, subjects lose some control over their decisions and this effect is stronger when they receive high payoffs.

3.2 Results of the individual choice game and the one-market entry game

The previous section raises two questions about how to explain the results. Does ambiguity seeking result from players interacting in strategic environments? Does it result from the information type itself or from the comparative effects between information types? In this section we provide answers to these questions. As before, we first state a result and then discuss the support we have for it,

Result 4: There is no difference in the number of entrants between the risky information lottery and the ambiguous information lottery in Treatment 2.

The two graphs in Figure 4 report the aggregate proportions of entry into each of the markets by period and by every 5 periods respectively. The two lines in each graph describe the entry proportions of all individuals into each market and the changes over 50 periods. The two lines are at approximately the same level. The number in both markets decreases

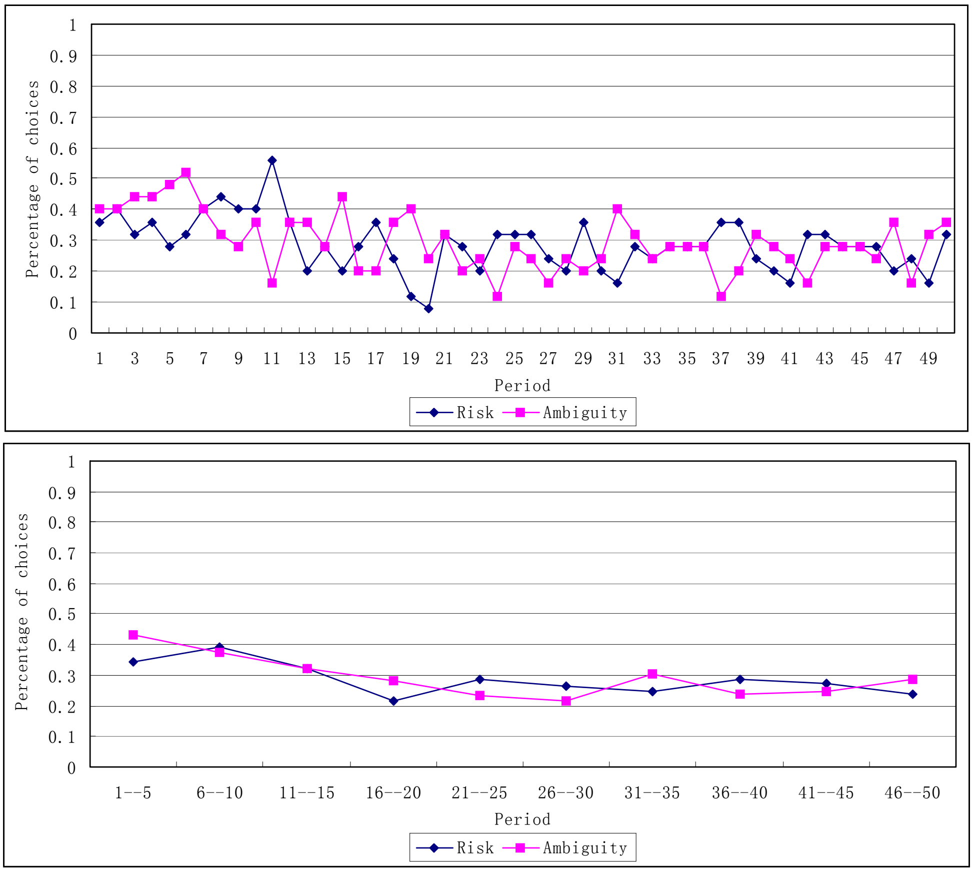


Figure 4: Percentage of choices by period (top) and by every 5 periods (bottom) in Treatment 2

from the interval $[0.3, 0.5]$ to the interval $[0.2, 0.3]$ in period 11, and the value keeps very stable till the final periods. The results of the individual choice game in Treatment 2 report no difference between choice of risk and ambiguity.

We can also look at individual data to compare entry frequencies in both markets. Table 6 (analogous to table 4 for Treatment 1) reports the proportions of entry into the two markets in the first 25 and the last 25 periods respectively by individual in the game, for all 25 subjects. The last three rows in the table show the statistics on the number of subjects who enter more in Risk, those who enter in Risk and Ambiguity with equal frequencies, and those who enter more in Ambiguity, which are 12, 3 and 10 respectively in periods 1-25 and are 10, 7 and 8 respectively in periods 26-50. Subjects behave heterogeneously and there are no clear indications for a preference for either market, either in the first or in the last 25 periods. Both Table 6 and Figure 4 show no clear tendency of entering more into either market.

Table 6. Observed proportions of entry by individual in Treatment 2

	Periods 1-25		Periods 26-50	
Subject	Risk	Ambiguity	Risk	Ambiguity
1	0.52	0.44	0.64	0.36
2	0.36	0.36	0.04	0.56
3	0.2	0	0	0
4	0.4	0.28	0.12	0
5	0.16	0.84	0.68	0.24
6	0.32	0.6	0	0.8
7	0.16	0.08	0.16	0
8	0.48	0.04	0.2	0.68
9	0.44	0.08	0.76	0
10	0.68	0.16	0.56	0.04
11	0.68	0.2	0.2	0.24
12	0	0	0	0
13	0.44	0.4	0.36	0.52
14	0	0.48	0	0
15	0.28	0.36	0.64	0.16
16	0.4	0.44	0.6	0.28
17	0.2	0.56	0.44	0.44
18	0.16	0.56	0	0.52
19	0.28	0.36	0.16	0.4
20	0.04	0.08	0	0
21	0.4	0.36	0.4	0.44
22	0.16	0.08	0.04	0.04
23	0.6	0.24	0.28	0.2
24	0.44	0.44	0.28	0.56
25	0	0.76	0	0
Average	0.312	0.328	0.262	0.259
Num. $(Risk > Ambiguity)$	12		10	
Num. $(Risk = Ambiguity)$	3		7	
Num. $(Risk < Ambiguity)$	10		8	

Result 4 clarifies two facts. First, it is not simply that repeated play of the game leads to more choices of ambiguity in an attempt of sampling the distribution and finding out the true probability. We observe a slight overentry into the ambiguous information market only in the first 5 periods, but this is not long enough to figure out the probability information of the ambiguous information market. Second, without strategic interaction, individuals are indifferent between the two markets, so that the result for the two-market case is not simply due to a comparison effect of the type reported in Fox and Tversky (1995). We now move to our final result.

Result 5: There is no difference in the number of entrants when players face risky or ambiguous information in a one-market entry game in Treatment 3.

The two panels of Figure 5 show number of entrants into the two markets, averaged over all groups, by period and averaged over every 5 periods respectively. Recall that here the data from two separate market games played between subjects. As in Figure 4, we find that the two lines indicating risky information and ambiguous information overlap over all 50 periods. At the beginning, the mean numbers of entrants in both types of information are higher than both the mixed strategy equilibrium number 2.625 and the pure strategy equilibrium number 3, and they are around the pure strategy equilibrium level 3 in the middle periods of the game, but increase again somewhat in the final periods to the original level. Hence we can conclude that the result in our two-market game is not due to the existence of strategic interaction.

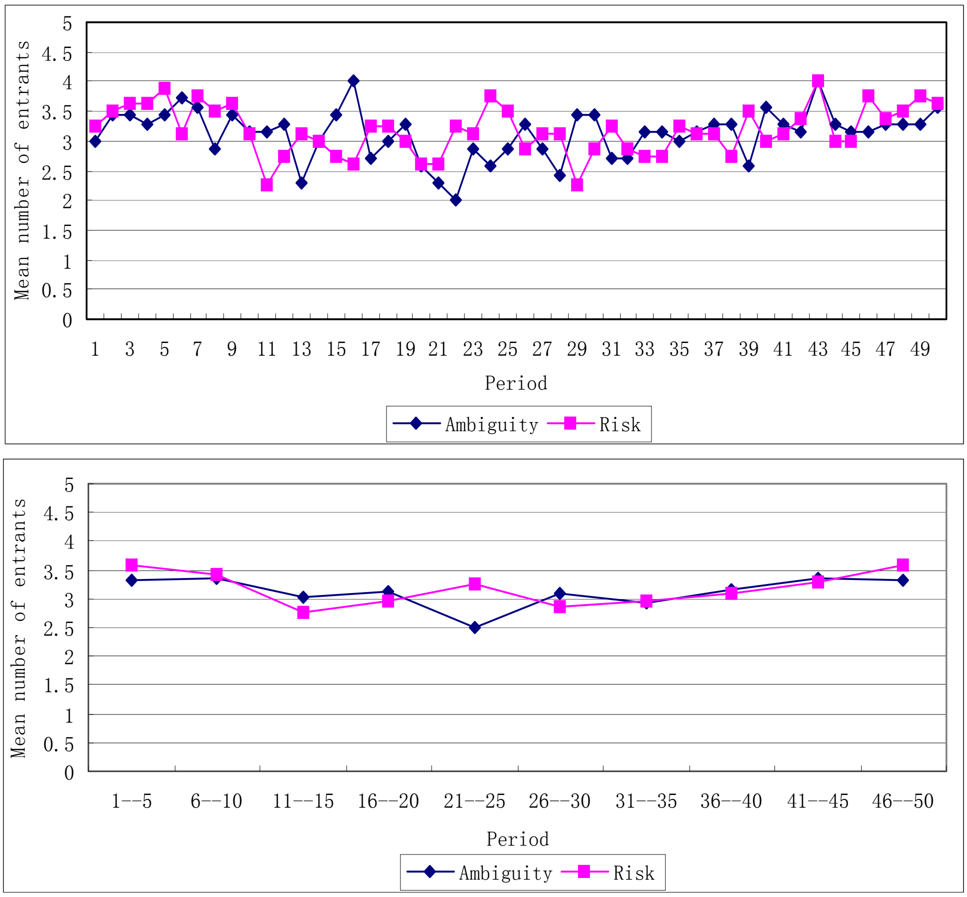


Figure 5: Mean number of entrants by period (top) and by every 5 periods (bottom) in Treatment 3

4 Summary and Conclusions

Our experiments find ambiguity seeking in a strategic two-market entry game, but no ambiguity effects in either an individual choice problem or a one-market entry game. The ambiguity-seeking behavior we find is striking since most previous studies on ambiguity find that people prefer to avoid situations with ambiguous information. A tight explanation of our results is hard to formulate. However, we conjecture that in strategic games ambiguity effects may depend on the strategic complexity of the games. The aversion to ambiguity has been widely documented mostly in individual decision-making environments. In contrast, strategic complexity together with ambiguous information may make people feel competent and overconfident vis-à-vis the competition. In a complex environment the competition may trigger over-entry and this tendence is strengthened when the probabilities about the state of the market are unknown. The idea of overconfidence and competence in economic decisions goes back at least as far as Adam Smith (1776) in the *The Wealth of Nations*. There Smith argues that people systematically overestimate their chances of success in any venture.

Our results are in consonance with some previous studies on entry. Camerer and Lovallo (1999) is the only study of market entry games to explain over-entry in the field. They include a potentially potent psychological variable — relative skill perception—in market entry games. They create a paradigm in which entrants' payoffs depend on their skill to measure business entry decisions and personal overconfidence simultaneously. The results show that overconfidence about relative ability can trigger excess entry. Grieco et al. (2007) is the only other research which uses ambiguity to explain excess entry. However, instead of using strategic games with interaction among players, individuals receive their own private ambiguous information and make choices in isolation. The results suggest that entrepreneurial entry decisions can be explained by ambiguity seeking influenced by feelings of competence.

We believe that decision making in strategic environment with ambiguous information is a very common situation in the field, but is poorly understood. Hsu et al. (2005) study the neural basis of decisions under risk and ambiguity and find that there is a general neural circuit responding to different degrees of uncertainty, contrary to decision theory. There appears to be a long way to go in understanding behavior under ambiguity and more field experimental and brain studies will be needed to better understand this issue.

References

[1] Abbink, K., Brandts, J., (2008), "24. Pricing in Bertrand Competition with Increasing Marginal costs", Games and Economic Behavior, vol 63(1), 1-31.

[2] Abbink, K., Brandts, J., (forthcoming), "Drei Oligopolexperimente", in: The Selten School of Behavioral Economics. A Collection of Essays in Honor of Reinhard Selten. Ockenfels, Axel; Sadrieh, Abdolkarim (Eds.), Springer.

[3] Baldwin, J. R., (1995), The Dynamics of Industrial Competition, Cambridge: Cambridge University Press.

[4] Camerer, C. F., Ho, T-H, Chong, J-K, (2004), "A Cognitive Hierarchy Model of One-Shot Games", Quarterly Journal of Economics, 119(3), 861-898.

[5] Chen, Y., Katuscak, P., Ozdenoren, E., (2007), "Sealed Bid Auctions with Ambiguity: Theory and Experiments", Journal of Economic Theory, 136, 513-535.

[6] Camerer, C., Lovallo, D., (1999), "Overconfidence and Excess Entry: An Experimental Approach", American economic review 89(1), 306-318.

[7] Camerer, C., Weber, M., (1992), "Recent Developments in Modeling Preferences: Uncertainty and Ambiguity", Journal of Risk and Uncertainty 5, 325-37.

[8] Chow, C. C., Sarin, R. K., (2001), "Comparative Ignorance and the Ellsberg Paradox", The Journal of Risk and Uncertainty, 22(2), 129-139.

[9] Duffy, J., Hopkins, E., (2005), "Learning, Information, and Soring in Market Entry Games: Theory and Evidence.", Games and Economic behavior 51, 31-62.

[10] Dunne, T., Roberts, M. J., Samuelson, L., (1988), "Patterns of Firm Entry and Exit U.S. Manufacturing Industries", Rand Journal of Economics, 19(4), 495-515.

[11] Dunne, T., Roberts, M. J., Samuelson, L., (1989a), "Firm Entry and Postentry Performance in the U.S. Chemical Industries", Journal of Law and Economics, 32(2), 233-71.

[12] Dunne, T., Roberts, M. J., Samuelson, L., (1989b), "The Growth and Failure of U.S. Manufacturing Plants", Quarterly Journal of Economics, 104(4), 671-98.

[13] Drouvelis, M., Muller, W., Possajennikov, A. (2009), "Signaling Without Common Prior: An Experiment", Working paper.

[14] Ellsberg, D., (1961), "Risk, ambiguity and the Savage Axioms", Quarterly Journal of Economics, 75, 643-669.

[15] Einhorn, H. J., Hogarth, R. M., (1986), "Decision Making under Ambiguity", Journal of Business 59(4). 225-250.

[16] Erev I., Rapoport, A., (1998), "Coordination Magic and Reinforcement Learning in a Market Entry Game", Games and economic behavior 23, 146-175.

[17] Fischbacher, U., (2007), "z-Tree: Zurich Toolbox for Ready-made Economic Experiments", Experimental Economics, Experimental Economics 10(2), 171-178.

[18] Fox, C. R., Tversky, A., (1995), “Ambiguity Aversion and Comparative Ignorance”, The Quarterly Journal of Economics, 110, 585-603.

[19] Furnham, A., Tracy R., (1995), "Tolerance of Ambiguity: A Review of the Concept, Its Measurement and Applications", Current Psychology, vol 14(3), 179-199.

[20] Geroski, P. A., (1991), "Some Data-Driven Reflections on the Entry Process", in Paul A. Geroski and J. Schwalbach, eds., Entry and Market Contestability: An International Comparison. Oxford: Basil Blackwell, 282-296.

[21] Grieco, D., Hogarth, R. M., Karelaia, N., (2007), "Risk Taking and Excess Entry: The Roles of Confidence and Fallible Judgment", Working paper.

[22] Greiner, B., (2004), "The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics," Working paper.

[23] Hsu, M., Meghana B., Ralph A., Daniel T., Colin F. C., (2005), "Neural Systems Responding to Degrees of Uncertainty in Human Decision-Making", Science, vol 310, 1680-1683.

[24] Jamison, J. Karlan, D. S., (2009), "When Curiosity Kills the Profits: An Experimental Examination", Games and Economic Behavior, 66, 830–840.

[25] Kahneman, D., (1988), "Experimental Economics: A Psychological Perspective", in R. Tietz, Wulf Albers, and Reinhard Selten, eds., Bounded rational behavior in experimental games and markets. New york: Springerverlag.

[26] Knight, F. H., (1921), Risk, Uncertainty, and Profit. Hart, Schaffner, and Marx Prize Essays, no. 31. Boston and New York: Houghton Mifflin.

[27] Kocher, M. G., Trautmann, S. T., (2010), "Selection into Auctions for Risky and Ambiguous Prospects", Economic Inquiry, forthcoming.

[28] Normann, H-T, (1997), "Endogenous Stackelberg Equilibria with Incomplete Information", Journal of economics, 66(2), 1617-7134.??

[29] Pogrebna, G., Schade, C., (2009), "Innovation, Entry into Multiple Markets and Unobserved Heterogeneity", Working paper.

[30] Rapoport, A., Seale, D. A., Erev, I., Sundali, J. A., (1998), "Equilibrium Play in Large Market Entry Games", Management Science, 44, 119–141.

[31] Rapoport, A., Seale, D. A., Ordonez, L., (2002a), " Tacit Coordination in Choice Between Certain Outcomes in Endogenously Determined Lotteries", Journal of Risk and Uncertainty, 25, 21-45.

[32] Rapoport, A., Seale, D. A., Winter, E., (2000), "An Experimental Study of Coordination and Learning in Iterated Two Market Entry Games", Economic theory, 16, 661-687.

[33] Rapoport, A., Seale, D. A., Winter, E., (2002b), "Coordination and Learning Behavior in Large Groups with Asymmetric Players", Games and economic behavior, 39(1), 111-136.

[34] Shapiro, D., Khemani, R.S., (1987), "The Determinants of Entry and Exit Reconsidered", International Journal of Industrial Organization, 5(1), 15-26.

[35] Seale, D. A., Rapoport, A., (2000), "Elicitation of Strategy Profiles in Large Group Coordination Games", Experimental economics, 3, 153-179.

[36] Sarin, R., Weber, M., (1993), "Effects of ambiguity in market experiments", Management Science 39(5), 602-615.

[37] Wakker, P. (2008), "Uncertainty," In Lawrence Blume & Steven N. Durlauf (Eds.), The New Palgrave: A Dictionary of Economics 8, 428-439, The MacMillan Press, London.

[38] Wu, B., Knott, A. M., (2006), "Entrepreneurial Risk and Market Entry", Management Science, 52(9), 1315-1330.

[39] Zwick, R., Rapoport, A., (2002), "Tacit Coordination in a Decentralized Market Entry Game with Fixed Capacity", Experimental economics, 5, 253-272.

APPENDIX: Instruction of the two-market entry game

General Information

The purpose of this experiment is to study how people make decisions in a particular situation. From now on and till the end of the experiment any communication with other participants is not permitted. If you have a question, please raise your hand and one of us will come to your desk to answer it.

You will receive 4 euros for showing up on time for the experiment. In addition, you will make money during the experiment. Upon completion of the experiment the amount that you make will be paid to you in cash. Payments are confidential; no other participant will be told the amount you make.

Rounds and Groups:

This experiment will have 50 rounds. In each round you will be in a group with 6 other participants, totally 7 people. The members in your group will be fixed in all rounds. You will not be informed of the identity of people who you are playing with neither during the experiment nor in the end of the experiment.

Description of the Decision Task(s) in the Experiment:

In each round, you are asked to make a choice between one of three possible actions, action "X", action "Y." or action "Z". If you choose action X, you will receive a fixed amount of money. If you choose Y, your payoff will depend on the state of the world and the choice of other participants in your group. Given certain state of the world, the less the number of Y chosen by your group, the higher your payoffs is in choosing action Y. If you choose Z, your payoff will depend on the state of the world and the choice of other participants in your group. Given certain state of the world, the less the number of Z chosen by your group, the higher your payoffs is in choosing action Z.

The state of the world in action Y will be high or low. When you make your decision you do not know it is high or low. However, all of you know the probabilities of high or low.

The state of the world in action Z will be high or low. When you make your decision you do not know it is high or low, and you also do NOT know the probabilities of high or low. However, you know that the probabilities of high and low are uniform in every round.

How payoffs are determined

Payoffs in every round of this game are determined as follows.

• If you choose action X, your payoff for the round is 12.

• If you choose action Y, your payoff for the round depends on the state of the world and the total number of players, including yourself, who choose action Y.

Suppose that n =1, 2, 3, 4, 5, 6 and 7 represent the number of players in your group who choose action Y. If you are one of these n players, your payoff for the round is given by:

Your points in one round $= 12 + 2(c - n)$

The value of c depends on the state of the world for choice Y. In every round it will be $c = 1.1$ with probability $\frac{1}{2}$ or $c = 3.1$ with probability $\frac{1}{2}$.

For example, if $c = 3.1$ and $n = 1$, that is, the state of world is high and you are the only player out of the group of 7 (1/7) who chooses action Y, then your payoff from choosing action Y would be $12 + 2(3.1 - 1) = 12 + 4.2 = 16.2$

For another example, if $c = 1.1$ and $n = 7$, that is, the state of the world happens and all five players (7/7) choose action Y, then each player's payoff from choosing action Y would be $12 + 2(1.1 - 7) = 12 - 11.80 = 0.2$

The complete set of possible payoffs you can earn from choosing action Y in each round are provided in the following table which you may refer to at any time during the experiment.

Payoffs in the low state of the world, $c = 1.1$

(with probability $\frac{1}{2}$)

Fraction of 7 players who choose action Y	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Payoff each earns from choosing action Y	12.2	10.2	8.2	6.2	4.2	2.2	0.2

Payoffs in the high state of the world, $c = 3.1$

(with probability $\frac{1}{2}$)

Fraction of 7 players who choose action Y	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Payoff each earns from choosing action Y	16.2	14.2	12.2	10.2	8.2	6.2	4.2

If you choose action Z, your payoff for the round depends on the state of the world and the total number of players, including yourself, who choose action Z.

Suppose that n =1, 2, 3, 4, 5, 6 and 7 represent the number of players in your group who choose action Z. If you are one of these n players, your payoff for the round is given by:

Your points in one round $= 12 + 2(c - n)$

The value of c depends on the state of the world for choice Y. In every round it will be $c = 1.1$ or $c = 3.1$ with unknown probability, but the probability keeps uniform in every round.

For example, if $c = 3.1$ and $n = 1$, that is, the state of world is high and you are the only player out of the group of 7 (1/7) who chooses action Z, then your payoff from choosing action Z would be $12 + 2(3.1 - 1) = 12 + 4.2 = 16.2$

For another example, if $c = 1.1$ and $n = 7$, that is, the state of the world happens and all five players (7/7) choose action Z, then each player's payoff from choosing action Z would be $12 + 2(1.1 - 7) = 12 - 11.80 = 0.2$

The complete set of possible payoffs you can earn from choosing action Z in each round are provided in the following table which you may refer to at any time during the experiment.

Payoffs in the low state of the world, $c = 1.1$

(with unknown probability, but uniform in every round)

Fraction of 7 players who choose action Z	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Payoff each earns from choosing action Z	12.2	10.2	8.2	6.2	4.2	2.2	0.2

Payoffs in the high state of the world, $c = 3.1$

(with unknown probability, but uniform in every round)

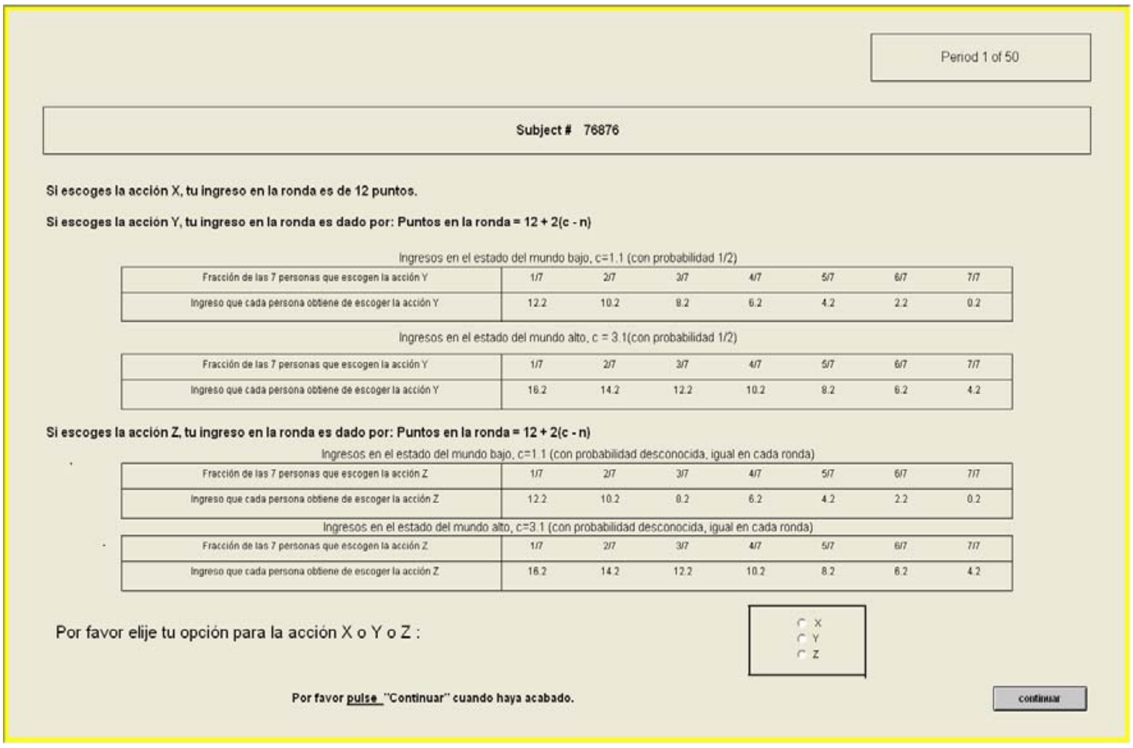
Fraction of 7 players who choose action Z	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Payoff each earns from choosing action Z	16.2	14.2	12.2	10.2	8.2	6.2	4.2

These payoff possibilities from playing action X, action Y or action Z will remain the same over all rounds. Are there any questions about how choices determine payoffs?

Playing a round:

Note that in each round, when you make your decision you will not know what the other participants in your group are doing in the round. You will also not know the state of the world.

First, you need to make your choice on action X, action Y or action Z. The computer will display a screen like the one shown below. Please press the button besides your choice. You may change your choices as often as you like, but once you click on "Enter" your choice is final.



Period 1 of 50

Subject # 76876

Si escoges la acción X, tu ingreso en la ronda es de 12 puntos.

Si escoges la acción Y, tu ingreso en la ronda es dado por: Puntos en la ronda = 12 + 2(c - n)

Ingresos en el estado del mundo bajo, c=1.1 (con probabilidad 1/2)

Fracción de las 7 personas que escogen la acción Y	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Ingreso que cada persona obtiene de escoger la acción Y	12.2	10.2	8.2	6.2	4.2	2.2	0.2

Ingresos en el estado del mundo alto, c = 3.1(con probabilidad 1/2)

Fracción de las 7 personas que escogen la acción Y	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Ingreso que cada persona obtiene de escoger la acción Y	16.2	14.2	12.2	10.2	8.2	6.2	4.2

Si escoges la acción Z, tu ingreso en la ronda es dado por: Puntos en la ronda = 12 + 2(c - n)

Ingresos en el estado del mundo bajo, c=1.1 (con probabilidad desconocida, igual en cada ronda)

Fracción de las 7 personas que escogen la acción Z	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Ingreso que cada persona obtiene de escoger la acción Z	12.2	10.2	8.2	6.2	4.2	2.2	0.2

Ingresos en el estado del mundo alto, c=3.1 (con probabilidad desconocida, igual en cada ronda)

Fracción de las 7 personas que escogen la acción Z	1/7	2/7	3/7	4/7	5/7	6/7	7/7
Ingreso que cada persona obtiene de escoger la acción Z	16.2	14.2	12.2	10.2	8.2	6.2	4.2

Por favor elije tu opción para la acción X o Y o Z :

X
Y
Z

Por favor pulse "Continuar" cuando haya acabado.

continuar

Meanwhile, the computer will "roll the die" to decide the state of the world of action Y, $c = 1.1$ or $c = 3.1$, and the state of the world of action Z, $c = 1.1$ or $c = 3.1$.

Then, the computer helps calculate the result, and you will be informed of your payoff in this round, your accumulated payoff in the past rounds, and the decision you have made.

Payoffs

At the end of the experiment you will be paid, in cash, the sum of the payoffs that you will have earned in the 50 rounds of the experiment plus show up fee 4 euros. The ratio between the experimental points and euros is 1 point = 0.02 euros. As noted previously, you will be paid privately and we will not disclose any information about your actions or your payoff to the other participants in the experiment.

Payoff quiz

Before we begin the experiment, please answer the following questions. The following questions aim at helping you understand how the payoffs are realized. We will go through the answers to a sample problem before you do the rest of the quiz. Please raise your hand if you are having trouble answering one of the questions.

Sample Question: If you made a choice of action X, and the state of the world $c = 1.1$ and the number of Y in your group is 1 and the number of Z in your group is 3, as a result, your payoff is ___6___.

Question 1: will the participants I am grouped with be the same in all rounds? _____

Question 2: Do you know the probability of high or low state of the world in action Y ?

____

Question 3: Do you know the probability of high or low state of the world in action Z ?

____

Question 3: If you made a choice of action Z, and the state of the world in action Z is $c = 3.1$ and the number of Z in your group is 2, as a result, your payoff is ______