Optimization incentive and relative riskiness in experimental coordination games

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Optimization incentive and relative riskiness in experimental coordination games

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Abstract

We compare the experimental results of three stag-hunt games. In contrast to Battalio et al. (2001), our design keeps the riskiness ratio of the payoff-dominant and the risk-dominant strategies at a constant level as the optimisation premium is increased. We define the riskiness ratio as the relative payoff range of the two strategies. We find that decreasing the riskiness ratio while keeping the optimization premium constant increases sharply the frequency of the risk-dominant strategy. On the other hand an increase of the optimization premium with a constant riskiness ratio has no effect on the choice frequencies. Finally, we confirm the dynamic properties found by Battalio et al. that increasing the optimization premium favours best-response and sensitivity to the history of play.

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Keywords: Coordination game; Game theory; Experimental economics.

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1 Introduction

Harsanyi & Selten (1988) stated that players should trust each other in order to reach a Pareto-superior equilibrium, whenever coordination on "risky" is required. However, experimental findings suggest that subjects do not trust enough their partners to be able to coordinate on a Pareto-superior equilibrium. For instance most experiments on coordination games with Pareto-ranked equilibria showed that subjects coordinate more frequently on Pareto-dominated equilibria (Cooper, Dejong, Forsythe & Ross 1992, Straub 1995, Battalio, Beil & Van Huyck 1990). Subjects choices seem to be more sensitive to the risk-characteristics than to the payoff characteristics of the available strategies. For example, Schmidt, Shupp, Walker & Ostrom (2003) found that subjects are more responsive to changes in the risk-dominance characteristics than in changes in the payoff-dominance level, both in one-shot and repeated games. They show that an increase in the efficiency loss of playing the Pareto-inferior (risk-dominant) strategy, does not affect the choice-frequency of the risk-dominant strategy. In contrast, increasing the riskiness of the payoff-dominant strategy favours risk-dominance play. Battalio, Samuelson & Van Huyck (2001), BSVH thereafter, showed that when the incentive to best-respond becomes stronger the risk-dominant strategy is more frequently chosen. They measure the incentive to best-respond by the *optimization premium*, defined as the expected payoff difference between the risk-dominant and the payoff dominant strategies.

Figure 1: Stag hunt games are defined by: a>c, a>d, d>b and (d-b)>(a-c)

	X	Y
X	a, a	b, c
Y	c, b	d, d

Consider the stag-hunt game illustrated in figure 1. Given the parametric restrictions defining stag-hunt games, this game admits 3 Nash equilibria : the payoff-dominant equilibrium (XX), the risk-dominant equilibrium (YY), and a mixed equilibrium where each player chooses X with probability $q^* = \frac{d-b}{a-c+d-b}$. The optimization premium (OP) is defined by (1.1).

$$OP = \pi(X, q) - \pi(Y, q) = \delta(q - q^*) \tag{1.1}$$

where $\pi(X, q)$ is the expected payoff of a player who chooses X and who expects her opponent to choose strategy X with probability q (a similar definition applies to $\pi(Y, q)$). Note that the optimization premium differs from zero only if players do not mix properly. For a given deviation from q^*, the optimization premium is increasing in δ, the optimization premium parameter. The experimental findings of BSVH can be summarized as follows: an increase of δ leads to more best-reply choices, a higher sensitiveness to past realized gains, and a higher choice frequency of the risk-dominant strategy (Y). BSVH's conjecture is strongly supported by their data, and by their estimates of the quantal response equilibrium model. The value of δ is equal to 50 in their game $2R$, 25 in their game R and 15 in their game $0.6R$.

Increasing the OP parameter from 15 to 25 increased the choice frequency of Y from 49.42% in game $0.6R$ to 60.80% in game R, and increasing the OP parameter from 25 to 50 increased the choice frequency of Y from 60.80% in game R to 89.50% in game $2R$.

In their experimental design, BSVH avoided possible confounds, by keeping constant the best response correspondence across games, i.e. the risk-dominant strategy had exactly the same basin of attraction in each of their three games. However, the change in the OP parameter affected the "relative riskiness" of the two strategies. As can be seen from the payoff tables of figure 2, a subject who takes into account the variability of the strategies' payoffs, is more likely to choose the risk-dominant strategy as the OP parameter is increased.

Figure 2: The three stag hunt games experienced by Battalio & al. (2001).

	X	Y			X	Y			X	Y
X	45, 45	0, 35		X	45, 45	0, 40		X	45, 45	0, 42
Y	35, 0	40, 40		Y	40, 0	20, 20		Y	42, 0	12, 12

Games 2R	Game R	Game 0,6R
$\delta = 50$	$\delta = 25$	$\delta = 15$

To see this, let us take the point of view of player A in the games illustrated in figure 2. Since player B can choose strategy X with any probability $q \in [0, 1]$, the expected range of possible outcomes ($a - b$ in figure 1) if player A chooses strategy X is the same for the three games (equal to 45). In contrast, the expected range of possible outcomes if he chooses Y ($|c - d|$ in figure 1) is 30 in game $0.6R$, 20 in game R and 5 in game $2R$. We conjecture that this difference in perceived payoff ranges, might have attracted subjects towards the risk-dominant strategy in the BSVH experiment.

Let us define the relative riskiness (RR) of the two strategies by the ratio of the expected payoff ranges of the two strategies, $RR = \frac{|c-d|}{(a-b)}$, assuming that $c \neq d$. Note that our definition of RR also corresponds to the ratio of the standard deviations of the two strategies, $\frac{\sigma_Y}{\sigma_X} = \frac{\sqrt{(c-d)^2 p(1-p)}}{\sqrt{(a-b)^2 p(1-p)}}$. If RR is close to 1, the two strategies involve similar risk. As it approaches zero, the risk-dominant strategy becomes relatively safer than the payoff-dominant strategy. [1] In BSVH's experimental design RR is equal to $1/9$ for game $2R$, $4/9$ for game R and $6/9$ for game $0.6R$. Our conjecture is that decreasing RR, all other things equal, favours the choice of the risk-dominant strategy.

In order to isolate the effect of the optimization premium, we design a new experiment in which the relative riskiness of the strategies (RR) is kept constant while the optimization premium is increased. We find that, keeping RR constant and increasing OP does not affect the choice of the risk-dominant strategy, for our choice of parameters. Furthermore, increasing RR while keeping OP constant, increases

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[1]In our experiment we exclude the case where $RR = 0$, i.e. $c = d$. A more general measure of relative riskiness should allow for the case where $c = d$ as compared to $(a–b)$.

the frequency of choice of the risk-dominant strategy. Finally, our data shows that the dynamic properties of increasing OP, are unaffected by RR: increasing OP leads to more best-reply choices and to a higher sensitiveness to past realized gains, independently of RR. The latter result, might be explained by the fact that RR is a constant which only depends on the structure of the game, while OP depends both on a constant (δ) and the expected deviation with respect to q^*.

The remainder of the paper is organized as follows. In section 2 we describe our experimental design that allows us to control for the optimization premium and the relative riskiness ratio. Section 3 presents our experimental findings and section 4 concludes.

2   Experimental design

Our experiment, which follows Battalio et al.'s (2001) design, involves the three stag hunt games described in figure 3.

Figure 3: The three stag hunt games of our experiment.

	X	Y
X	45, 45	0, 42
Y	42, 0	12, 12

Game 1

	X	Y
X	40, 40	20, 37
Y	37, 20	32, 32

Game 2

	X	Y
X	44, 44	4, 38
Y	38, 4	28, 28

Game 3

Game 1 is a replication of BSVH's game $0.6R$, which corresponds to our baseline treatment. Game 2 has the same OP parameter as game 1 (equal to 15), but as a lower RR than game 1 : $RR_2 = 1/4 < RR_1 = 2/3$. Game 3 has the same RR than game 2 ($RR_3 = 1/4$) but has an OP parameter twice as large as in game 2 ($OP_3 = 30$). The three games have two pure-strategy Nash equilibria, the risk-dominant equilibrium (YY) and the payoff-dominant (XX), and one mixed-strategy equilibrium where X is selected with probability 0.8. The three games have an identical best response correspondence and the same expected payoff (36) at the mixed equilibrium, as in BSVH. [2] Since games 1 and 2 have the same OP, following BSVH, the selection frequency of the risk-dominant strategy should not differ significantly between the two games. However, if subjects' behaviour is affected by RR, they might choose more frequently the risk-dominant strategy in game 2. This is stated as conjecture 1.

Conjecture 1 *For a given optimization premium, a lower riskiness ratio increases the choice frequency of the risk-dominant strategy.*

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[2]Note that in the three games of Battalio et al. (2001) and in games 2 and 3 of our design the risk measure of Schmidt et al. (2003) is equal to 1.386. Therefore, their measure cannot discriminate between these games.

Since OP_3 is larger than OP_2, according to BSVH the frequency of the risk-dominant strategy should be larger in game 3 than in game 2. However, if the riskiness ratio has a stronger impact on subject's strategy selection than OP, we expect that a change in OP that keeps RR constant will have a negligible impact on the choice frequency of the risk-dominant strategy. This is stated as conjecture 2.

Conjecture 2 *For a given riskiness ratio, an increase of the optimization premium does not affect the frequency of choice of the risk-dominant strategy.*

While RR might affect subjects' strategy choices, there is no reason to believe that it affects also the dynamic properties of the repeated game. Indeed, in contrast to OP which takes into account players expectations, RR does not depend on players beliefs, since it is only a measure defined by the payoff-structure of the game. We therefore conjecture, as in BSVH, that an increase in the OP parameter increases the sensitivity to the history of play. Again, since RR depends only on the payoff-structure, there is no reason to believe that increasing RR affects the sensitivity to the history of play.

Conjecture 3 *The sensitivity to the history of play is independent of RR but increases with OP.*

To get a deeper insight about the effect of OP, we analyze our data with respect to a strong measure of "coordination success". We define an outcome as one of "strong coordination", if all subjects belonging at a given group coordinate on the same strategy, either X or Y. We take the number of periods in which "strong coordination" is observed as an indicator of coordination success. While "strong coordination" might be considered as a too stringent measure of coordination success, it has the advantage to discard fortuitous coordination. Fortuitous coordination arises because of the random matching protocol within groups which allows some player pairs to coordinate by chance. [3] By relying on a strong criterion success, we are less likely to conclude erroneously that coordination was achieved. This is stated as conjecture 4.

Conjecture 4 *The frequency of "strong coordination" is independent of RR but increases with OP.*

192 subjects, selected randomly from a pool of about 1200 volunteers, participated in a computerized experiment that was run at LEES. [4] Participants were students from various universities and business schools. Each of the three treatments involved 64 participants divided into 8 groups of 8 subjects. After each subject had

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[3] In a given period, each independent group can reach between zero and four pure strategy Nash equilibria (8 subjects paired by two).

[4] Laboratoire d'Economie Expérimentale de Strasbourg, BETA (Bureau d'Economie Théorique et Appliquée).

read his instructions [5], they were read again aloud by the experimenter to induce common knowledge of the game.

At the beginning of the experiment, each participant was randomly assigned to a group of eight subjects for the 75 rounds of the game. [6] Subjects were told that in each period they would be randomly paired with one of the members of their group for playing one of the games illustrated in figure 3. In each round, subjects had access to a history screen, displaying for each past period t : i) their decision for period t, ii) the decision of the player with whom they were randomly matched in period t, their payoff for period t and their cumulative payoff for each past period up to the current period. Payoffs were measured in points, with a known conversion rate : 1 point = 0.006 euros. [7]

3   Results

Figure 4: Evolution of the X strategy selection in each game
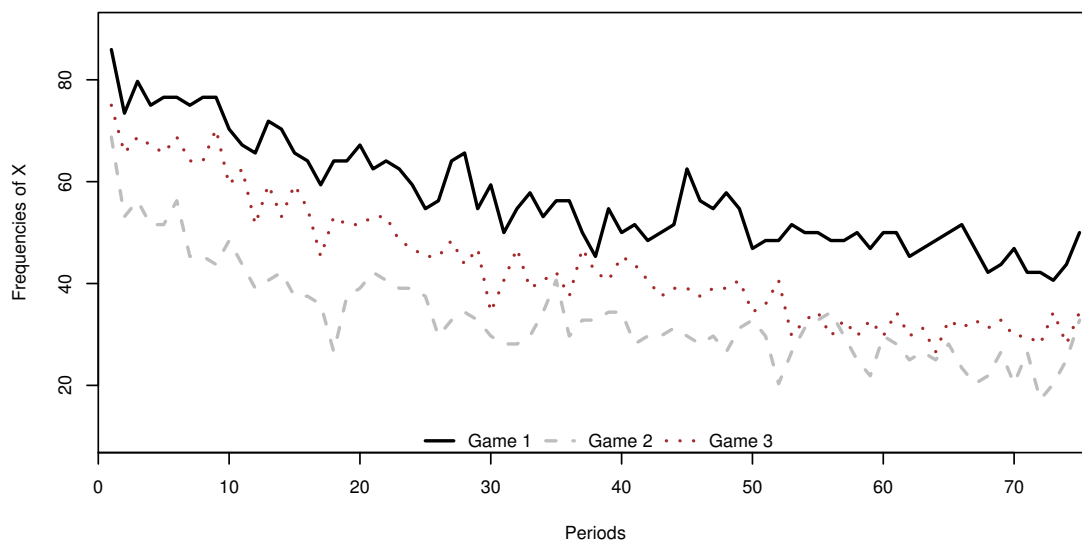
Result 1 *Our baseline treatment replicates BSVH findings.*

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[5]Instructions for game 1 are given in appendix A. For games 2 and 3 only the payoff matrix were changed.

[6]Either game 1, 2 or 3 depending on the session.

[7]Repeated play of the payoff-dominant equilibrium for seventy-five periods results in a subject earning €20.25

Support: The comparison of the selection frequency of the X strategy in our game 1 and in game $0.6R$ of BSVH does not reveal any significant difference (Mann Whitney two-sided p-value = 0.753). Our observations thus replicate those of BSVH. We therefore take the data of our game 1 as a baseline for further tests.

Figure 4 reports the evolution of the frequency of the payoff-dominant strategy (X) over time for the three games. Figure 4 reveals a larger and persistent choice frequency of the payoff-dominant strategy for game 1 compared to games 2 and 3. Comparing games 2 and 3, the choice frequency of X appears to be larger in game 3 than in game 2 for the first 50 periods, but the two games have more or less equal frequencies of X choices for the remaining 25 periods.

Result 2 *A lower RR for given OP increases the choice frequency of the risk-dominant strategy.*

Table 1: Frequencies of strategy X selection in games 1-3: first period, average over 75 periods and average over the five last periods.

Game	First period	Average	Last five periods
1	85.94	56.98	43.75
2	68.75	33.71	24.38
3	75.00	43.79	30.94

Support: Table 1 reports the choice frequencies of the X strategy for the first period, the average of all periods and the average of the 5 last periods. The first period frequency and the average frequency are significantly larger in game 1 than in game 2 (Mann Whitney one-sided [8] p-value = 0.026 and p-value = 0.033). Average frequencies over the five last rounds also differ significantly (MW p-value = 0.057).

Result 3 *A higher OP for given RR does not affect the choice frequency of the risk-dominant strategy.*

Support: The average frequency of strategy X selection (see table 1) is not significantly different between games 2 and 3 (MW p-value = 0.186). There are also no significant differences in the first period and in the last five periods of play (MW, p-value = 0.223 and p-value = 0.684 respectively).

Result 4 *The sensitivity to the history of play is stronger for larger OP but is unaffected by RR.*

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[8]MW thereafter.

Support: For testing conjecture 3 about the sensitivity to the history of play we rely, as BSVH, on the Quantal Response Equilibrium (McKelvey & Palfrey 1995) given in expression (3.1), where q_{it} is player i's belief that his opponent chooses X at time t, q_0 is the initial probability, $I=1$ if i's opponent plays X at time τ and $I=0$ otherwise, and d is a discount factor: $d=1$ if subject i's beliefs are of the fictitious play type (Brown 1951) and $d=0$ if his beliefs are of the Cournot (1960) type.

$$q_{it} = \frac{q_0 d^{t-1} + I_{i1}d^{t-2} + \ldots + I_{it-2}d + I_{it-1}}{d^{t-1} + d^{t-2} + \ldots + 1} \tag{3.1}$$

Subject i selects the payoff-dominant strategy (X) in period t with probability P_{it}, which depends on his propensity to choose a best response to his estimated probability that his opponent selects strategy X in period t. As in BSVH we rely on the logistic response-function P_{it}, defined by (3.2).

$$P_{it} = \frac{\exp\left(\alpha + \beta(q_{it} - q^*)\right)}{1 + \exp\left(\alpha + \beta(q_{it} - q^*)\right)} \tag{3.2}$$

In expression (3.2) α captures the tendency to move away from the low payoffs. $\beta_j = \lambda\delta_j$ where δ_j is the OP parameter corresponding to game j and λ is the precision parameter of the logit error model. Assuming that players best-respond according to the quantal-response equilibrium model, λ corresponds to the common noise parameter. Table 2 reports the estimates.

Table 2: Estimation of the individual behavior in the three games.

Game	# Observations	Log Likelihood	α	β	d	q_0
1	4800	-2141.531	1.432	5.066	0.851	0.827
			(0.049)	(0.14)	(0.017)	(0.06)
2	4800	-2274.360	1.090	4.768	0.896	0.690
			(0.07)	(0.15)	(0.01)	(0.05)
3	4800	-1959.049	1.460	5.563	0.885	0.706
			(0.051)	(0.16)	(0.017)	(0.05)

The estimated initial frequencies (q_0) are very close to the observed initial frequencies (85.94% in game 1, 68.75% in game 2 and 75.00% in game 3). α is larger in game 1 than in game 3, and in game 3 than in game 2, meaning that in case of a coordination failure subjects have moved away from the lowest outcome of the payoff-dominant strategy in games 1 and 3 (equal to 0 and 4 respectively, see figure 3). The value of the discount factor is between 0.8 and 0.9 meaning that subjects take into account almost the complete history of the game (fictitious play). β in game 2 is slightly lower than in game 1 but the difference is not significant (Wald test, p-value = 0.150), supporting the first part of conjecture 3. Finally β is equal to 5.56 in game 3, a significantly higher value compared to game 2 (Wald text p-value < 0.001). Subjects are more sensitive to the history of play in game 3, supporting

the second part of conjecture 3.

Result 5 *The frequency of "strong coordination increases with OP, but is unaffected by RR.*

Support: As explained in section 2, the selection frequency of strategy X does not correctly account for coordination success because of the random matching protocol within groups. We therefore rely on our criterion of "strong coordination", i.e. the number of periods where all members of a group choose the same strategy (either X or Y). The corresponding data is reported in table 3. "Strong coordination" on the payoff-dominant strategy occurred 146 times in game 1 and 22 times in game 2, whereas "Strong coordination" on the risk-dominant strategy occurend 36 times in game 1 and 150 times in game 2. Both differences are significant at the 10% level (MW p-value = 0.074 and p-value = 0.069 respectively), supporting conjecture 1. The total number of periods where the eight subjects in a group have chosen the same strategy, without distinguishing X and Y, is equal to 182 for game 1 and to 172 for game 2, a non-significant difference (χ^2 p-value = 0.595) supporting the first part of conjecture 4.

Table 3: Number of periods where the eight subjects in the group have choosen the same strategy.

Game	Payoff-dominant strategy (X)	Risk-dominant strategy (Y)	Total
1	146	36	182
2	22	150	172
3	143	102	245

In game 3 the eight subjects have chosen the payoff-dominant strategy in 143 periods, and the risk-dominant strategy in 102 periods. Thus, the number of periods where all (eight) subjects selected the risk-dominant strategy is not significantly different between games 2 and 3 (MW p-value = 0.333), supporting conjecture 2. Moreover we observe a total of 245 periods where the eight group members have chosen the same strategy, either X or Y, against 172 in game 2, the difference is significant (χ^2 p-value < 0.001), supporting the second part of conjecture 4. Hence we confirm that an increases in the optimization premium, all things equal, increases the likelihood of "strong coordination", in accordance with BSVH.

4   Conclusion

In stag-hunt games, subjects choices are both attracted by the risk-dominant equilibrium and the Pareto-dominant equilibrium. Which of the two underlying strategies is more likely to be chosen by subjects depends on many factors related to the

payoff-structure of the game. BSVH showed that the optimization premium plays a crucial role : subjects are more likely to choose the risk-dominant strategy when the optimization premium is increased, and their behaviour becomes more sensitive to past outcomes of the game. In this paper we showed that the relative riskiness of the two strategies has a considerable influence on subjects' choice of strategies. For a given value of the optimization premium parameter, subjects choose more frequently the risk-dominant strategy as it becomes relatively less risky compared to the payoff-dominant strategy. Furthermore, when the relative riskiness of the two strategies is unaffected by an increase in the optimization premium, the choice frequency of the risk-dominant strategy remains unchanged. In BSVH's experiment, the change in the OP parameter affected simultaneously the relative riskiness of the strategies, making it impossible to sort out the effects of these two properties of the payoff structures. For our set of parameters, it seems that the relative riskiness has a stronger effect than the optimization premium parameter, although it is difficult to compare the magnitude of the changes for the two parameters. However, we confirm that an increase in the OP parameter has a significant impact on the dynamics of play, as in BSVH, whether or not the relative riskiness of the strategies is affected simultaneously.

A   Instructions (translated from french)

General context of the experiment

The experiment consists of a succession of periods, in each of which you will be asked to choose one of two options called X and Y. You will be named "player A" during the experiment. At the beginning of each period, in each group (composed of 8 participants), the computer system will form 4 pairs of subjects. For instance, at the beginning of each period, you will be assigned to another participant randomly chosen in your group : this person will be called "player B". Like you, player B will have to make a choice between options X and Y. Your decisions will lead to a gain at the end of each period. This gain depends on your own choice and the choice of player B for the current period. Gains will be measured in points during the experiment, and points will be converted into Euros at the end of the experiment (the conversion procedure of points into Euros is explained at the end of the instructions). The remainder of the instructions details the gains associated to options X and Y and the way you will interact with player B within a period.

In the experiment you will be named player A and the participant with whom you are matched in a given period will be called player B. This terminology has been chosen to facilitate both the understanding of the instructions and the reading of the information on your computer screen. Player A and player B face exactly the same situation : they both have the same choice options and the same associated gains.

Course of the game

The experiment involves 75 periods. In each period, you can choose between two options : X or Y. In any given period your choice will be matched with the choice of player B. If you choose option X and player B chooses X, you will earn 45 points and player B will earn 45 points. If you choose option X and player B chooses Y, you will earn 0 point and player B will earn 42 points. If you choose option Y and player B chooses Y, you will earn 12 points and player B will earn 12 points. Finally, if you choose option Y and player B chooses X, you will earn 42 points and player B will earn 0 point. Table 4 summarizes your possible earnings for a period. Table 5 summarizes the possible earnings for player B with whom you are matched for the period.

At the time you make your choice you do not know the choice of player B. Similarly, player B does not know your choice, when making his own choice. At the end of each period you will be informed about the choice of player B and your earning for the period.

Table 4: Player A's earnings

		Player B chooses	
		Option X	Option Y
You choose	Option X	A earns 45 points	A earns 42 points
(Player A chooses)	Option Y	A earns 0 point	A gagne 12 points

Table 5: Player B's earnings

		Player B chooses	
		Option X	Option Y
You choose	Option X	B earns 45 points	B earns 0 point
(Player A chooses)	Option Y	B earns 42 points	B earns 12 points

At the beginning of the next period, you will be randomly matched by the computer system to another player B chosen among the 7 other members of your group. Once you are assigned to a new player B, the next period starts. In the upper right corner of your computer screen, the number of the period and the cumulated earnings from period 1 to the current period will be displayed. By clicking the "History" button a table recording previous periods data will appear : the table contains for each past period, the number of the period, your choice for that period, player B's choice for the period, and your earning for the period.

Each period follows the same procedure. At the beginning of a period, a random matching procedure determines to which player B (chosen among the 7 other members of your group) you will be assigned for that period. After that, each player chooses either option X or option Y. At the end of each period, the data of the period will be displayed.

At the end of period 75, your total earning for the 75 periods will be converted into Euros according to the following rule : 1000 points equal 6 Euros. For example if your total number of accumulated points is equal to 2500, you will earn 15 Euros.

Before the experiment will start, you will be asked to answer a short questionnaire to check your correct understanding of the instructions. At the end of the experiment, you will be paid individually by the experimenter. During the eventual waiting time, you can make written comments.

You are requested to not communicate with any other participant during the experiment. If you have any question, please raise your hand, an assistant will come to you to answer individually.

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