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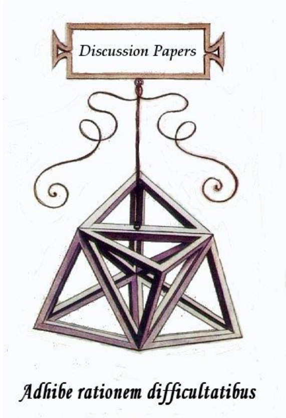

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An experiment on coordination in a modified stag hunt game

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Keywords: stag hunt, coordination, risk-dominance, risk framing

JEL: C91, C72, D8

An experiment on coordination in a modified stag hunt game

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Abstract

The paper experimentally investigates whether adding a dominated strategy changes subjects' decisions in a stag hunt decision context. Specifically, we run two two-periods treatments where respectively 1) the decision makers firstly face the standard stag-hunt matrix and then the modified three-options matrix and 2) the decision makers firstly face the modified three-options matrix and then the standard two-options stag-hunt matrix. Given the circumstance that the added strategy is dominated, standard rationality assumption would predict no changes in participants decisions across periods and treatments. On the contrary, our results show that the exposure to one or the other treatment frames the decision-situation in a different way. Decision makers become less propense to take the risk of "hunting stags" in the modified three-options matrix, after they are firstly exposed to the two-options standard stag-hunt matrix. *Vice versa*, they appear more propense to change their decision towards the payoff dominant equilibrium, when they are firstly exposed to the modified three-options matrix and then to the two-options standard stag-hunt matrix.

1. Introduction

The stag hunt game is a well-known coordination game where two players may coordinate on an outcome that ensure both players a higher payoff but necessarily requires cooperation (i.e. hunting a stag) or on an another outcome that provide them a lower payoff but independently on the cooperation of the other (i.e. hunting hares) (for an overview see Skyrms, 2004). Accordingly, the game possesses two Nash equilibria, namely a *payoff dominant* equilibrium and a *risk dominant* equilibrium. According to the definitions firstly proposed by Harsanyi and Selten (1988, 80–90, 355–359), a Nash equilibrium is payoff dominant if it is Pareto-superior to all the other Nash equilibria. On the other hand, a Nash equilibrium is risk dominant when it is the less risky for both players given the uncertainty concerning the other player's decision. In other words, in a symmetric 2x2 game, when the two players assign equal probability to the circumstances that the other player will choose one option or the other, and one of the two options results as strictly preferred for both, the strategy profile that they both opt for is the risk-dominant equilibrium. Crucially, in such coordination game the decision of the player depends on the expectations on the other's decisions.

Since Jean-Jacques Rousseau – who firstly proposed the game to analyse the social contract (Rousseau, 1754) – the stag hunt has been extensively used to model social coordination on conventions (Young, 1993, 1996; Lewis 2008). The experimental literature analysed different applications and specifications of the game to investigate whether they affect the coordination on one or the other equilibria (Battalio et al., 2001; Devetag and Ortman, 2007; Schmidt et al., 2003). This piece of research aims at contributing to this literature by investigating whether adding a dominated strategy changes subjects' decisions on which equilibria to seek for coordination. Confronting the standard stag hunt strategies with an additional irrelevant one provides the theoretical advantage of discovering potential bias on how the decision-maker frame the coordination problem and build the expectations on others' decision. This in turn could provide further insights on how the stag hunt game is played in daily life social interactions and conventions where often the decision maker faces more that two options – being these relevant or not.

The paper is organised as follows. Section 2 presents the experimental design. Section 3 shows some preliminary results. Section 4 discusses them and concludes.

2. Experimental Design

In this experiment we compare the participants' decisions in a) a standard two-options stag hunt game and b) a three-options game where a dominated strategy is added to the two options of the standard stag hunt. Rationality assumptions would predict that participants should not change decision when facing one or the other of the two matrix. Accordingly, they should not expect others to change their decision. However, we make the hypothesis that the two games induce a different framing of the decision situation. This framing potentially affects the decision-maker perception of the risky feature of the game at stake. In particular, we expect that when facing the three-options game the decision maker could perceive that coordinating on the payoff dominant equilibrium would be relatively less likely than coordinating on it in the two-options game because of the presence of the third strategy and the potential larger variability of the opponents' decision. Accordingly, the decision-maker would opt for defending him/herself from the perceived higher risk by opting for the safer strategy and expecting the others do the same. However, this would count as a bias, since the probability of coordinating on the payoff dominant strategy is not affected by the introduction of the dominated third option.

2.1 Main treatments

In each session, we run two treatments, named *Treatment 2* (Tr.2, henceforth) and *Treatment 3* (Tr.3, henceforth). Each treatment consists of two rounds each containing either a) a standard two-options stag hunt game (SH2, henceforth) or b) a three-options game containing the two options of the stag hunt and an additional dominated strategy (SH3, henceforth). The payoffs matrices of the two games are shown in figure 1.a and 1.b. The two treatments differ with respect to the order the SH2 and SH3 are played. In Tr2, participants played the SH2 in the first round and the SH3 in the second round. In Tr3, participants played the SH2 in the first round and the SH3 in the second round.

	Wheel		*Ball*	
Wheel	4	4	4	1
Ball	1	4	7	7

Figure 1.a: 2x2 payoffs matrix of SH2

	Orange		*Wheel*		*Ball*	
Wheel	8	2	4	4	4	1
Orange	0	0	2	8	0	1
Ball	1	0	1	4	7	7

Figure 1.b: 3x3 payoffs matrix of SH3

2.2 Rewards

We have varied the types of rewards in order to control for possible effects due to differences in incentive schemes. In particular, we have converted the sum of the payoffs obtained by each participant in the two rounds both in monetary payments (sessions A_2 and A_3) and in scores that have been added to the individual final mark of the course (sessions B_2 and B_3). Moreover, we run two sessions with no reward (sessions C_2 and C_3). Table 1 below summarizes the number of sessions we run for each treatment.

	Monetary reward	**Mark reward**	**No reward**
Tr2	*2 sessions A_2*	*2 sessions B_2*	*1 sessions C_2*
Tr3	*2 sessions A_3*	*1 sessions B_3*	*1 sessions C_3*

Table 1: summary of sessions.

We run the sessions in classes of different courses in order to obtain a heterogeneous sample with respect to exposure to math and to game theory courses (control questions in the final questionnaire). Specifically, A) the “monetary reward” has been applied in one statistics and one economics class,

B) the “mark reward” has been applied in two economics classes; C) the “no reward” has been applied in one economics class[1]. In a final questionnaire we collected information about gender, age, exposure to math and game theory courses, risk aversion. The text of the questionnaire together with the transcript of the instructions for Tr2 is reported in Appendix A.

2.3 Implementation

We have conducted the experiment sessions in the form of in-class experiment at the University of Pisa, Italy. The sessions involved 388 students of the Department of Economics and Management. Professors of the respective courses were asked for permission to do the experiment in their classroom time. None of the subjects took the experiment twice, since students attend different courses depending on the letters of their surname. Students in each session were randomly attributed to one half of the room. One sit was left empty between each student in order to ensure no communication and anonymity[2]. Participation in the survey was not compulsory. If anyone did not want to participate, they could opt out. Two members of the research team were present during each session to explain the instructions, to deliver paper copies of the experimental procedure, to answer personally to any questions and to collect the papers with the subjects’ decisions. It took about 20 minutes to complete each session.

3. Preliminary results

3.1 Between- and within-treatments comparisons

In the following tables 2.1 and 2.2, we compare Tr.2 with Tr.3 results, respectively in Period 1 and in Period 2.

	Tr.2	**Tr.3**
Ball	77	71
Wheel	129	91

Table 2.1: Period 1, between-treatments comparison.

	Tr.2	**Tr.3**
Ball	39	88
Wheel	167	74

Table 2.2: Period 2, between-treatments comparison.

[1] We implemented the two treatments, Tr2 and Tr3 in simultaneous sessions run in the same class. The only exception is the mark reward incentive for which we run an additional Tr2 spare session.

[2] The experiment was performed in large classes, with 220 seats.

We performed the Pearson's χ-squared test for both the periods and we got χ-squared = 1.3117, df = 1, p-value = 0.2521 for Period 1 and χ-squared = 48.697, df = 1, p-value = 2.987e-12 for the second period. Accordingly, in the case of between-treatments comparison of Period 1, we cannot reject the null hypothesis of independence between the first choice and the treatment. In other words, our treatments do not account for the difference in the choices in the first period. On the other hand, in the case of between-treatment comparison of Period 2, we do reject the null hypothesis of independence between the second choice and the treatment. Hence, treatments affect decisions made in the second period. This means that passing from SH2 to SH3, rather than from SH3 to SH2, explains the difference in the results of the second period (see within-treatment results below). In particular, we observe that subjects opted for "Ball" much more in the second period of Tr.3 than in the second period of Tr.2 (and *vice versa*, that subjects opted for "Wheel" more in the second period of Tr.2 than in the second period of Tr.3).

In the following tables 3.1 and 3.2, we compare, for each treatment, participants' choices made in the first period with those made in the second period. In particular, rows indicate the choices made in the first period, while columns those made in the second period. Accordingly, each cell reports how many participants that opted for one or the other option in the first period (in rows), opted for one or the other option in the second period (in columns)[3].

Period 1 | Period 2	**Ball**	**Wheel**
Ball	34	43
Wheel	5	124

Table 3.1: Tr. 2, within-treatment comparison

Period 1 | Period 2	**Ball**	**Wheel**
Ball	58	13
Wheel	30	61

Table 3.2: Tr. 3, within-treatment comparison

We performed the Pearson's χ-squared test for both treatments and we get, χ-squared = 48.383, df = 1, p-value = 3.507e-12 for Tr.2 and χ-squared = 36.218, df = 1, p-value = 1.764e-09 for Tr.3. Therefore, we reject the null hypothesis of independence between the choice in the first and in the second period in both treatments. Thus, there is evidence of the effect of both Tr.2 and Tr.3 on the participants' decision between the first and the second period. In particular, we observe that, in Tr. 2, 43 participants changed his/her decision from "Ball to "Wheel", while only 5 from "Wheel" to "Ball". On the other hand, in Tr. 3, 30 participants changed his/her decision from "Wheel" to "Ball", while

[3] For example, the cell (Ball, Ball) in Table 2.1 indicates that in treatment 2, 34 participants chose "Ball" both in the first and the second period. Accordingly, in the same treatment, 43 participants chose "Ball" in the first period and "Wheel" in the second.

13 from “Ball” to “Wheel”. Thus, we can preliminary conclude that a) the exposure of participants firstly to SH2 and than to SH3 mainly changed participants’ decision from “Ball” to “Wheel” and b) the exposure of participants firstly to SH3 and than to SH2 mainly changed participants’ decision from “Ball” to “Wheel” in the second period. This evidence is further investigated in the following section by performing a logit regression.

3.2 Logit regression

We estimate two specifications of a glm link logit model in order to study whether our treatments affect the probability of switching from “Wheel” to “Ball” and from “Ball” to “Wheel” between the two periods. To this purpose, we take into consideration the following variables:

- **Session:** students belonging to sessions B_2, B_3 (base); students belonging to sessions A_2, A_3, C_2, C_3 (see table 1 above).
- **Treatment:** Tr.2 (base), Tr.3
- **Sex:** Female (base), Male.
- **Years_Univ:** First year (base), Second year, Others.

The first specification of the logit model takes into consideration as the response variable the decision to change from “Wheel” in the first period to “Ball” in the second, i.e. the binary variable Y=1 if subjects switched from “Wheel” to “Ball” and Y=0 otherwise. Accordingly, the model is specified by the following equation: P(Y=1) = β_0 + β_1Treatment + β_2Sex + β_3Session. Table 4 below shows the estimates of the regression coefficients[4] and the odds ratio (OR).

Coefficients:					
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.9358	0.6113	-6.439	1.20e-10	***
Treatment3	2.1106	0.5037	4.190	2.79e-05	***
SexMale	-0.7250	0.3841	-1.887	0.0591	.
SessionAC	0.8458	0.5150	1.642	0.1005	
OR:					
(Intercept)	Treatment3	Sex	SessionAC		
0.01952927	8.25282798	0.48432751	2.32991050		

Table 4: Glm link logit regression on the probability of switching from “Wheel” to “Ball”

From these results we infer that the probability of changing from “Wheel” to “Ball” between the first and the second round (Y = 1) increase from Tr.2 to Tr.3. The OR is 8.3 (high OR), so confirming

[4] Significance codes are as follows: 0 '***' ; 0.001 '**' ; 0.01 '*' ; 0.05 '.' ; 0.1 ' ' 1.

the positive impact of Tr.3 on the change in the direction of the payoff-dominant equilibrium[5]. According to the ratio between the residual sum of square and the residual degrees of freedom, that is 0.97 (this ratio is taken to be 1 in the estimation of the coefficients), we confirm the absence of overdispersion (which should affect the estimates of regressions coefficients, if present). The AUROC (Area Under the ROC curve) is 79%, using an optimized cut-off equal to 0.16. The AUROC indicates a very good prediction power of the model. Sensitivity is 51% and specificity is 87%. Other covariates surveyed in the experiment has been tested in the model, but they are not significant. We also test the effect of the treatment using generalized linear mixed models. Anyway, the effect of the treatment always results in an OR of about 8. Therefore, we choose the simplest model.

The second specification of the logit model takes into consideration as the response variable the decision to change from "Ball" in the first period to "Wheel" in the second, i.e. the binary variable Y=1 if subjects switched from "Ball" to "Wheel" and Y=0 otherwise. Accordingly, the model is specified by the following equation: P(Y=0) = β_0 + β_1Treatment + β_2Session + β_3Years_Univ(2nd) + β_4Years_Univ(Oth.). Table 5 below shows the estimates regression coefficients and the Odds Ratios (OR).

Coefficients:					
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.1194	0.2453	-4.563	5.04e-06	***
Treatment3	-1.0228	0.3452	-2.963	0.00305	**
SessionAC	-0.6324	0.3078	-2.055	0.03991	*
Years_Univ_II	0.3038	0.5323	0.571	0.56811	
Years_Univ_Oth.	0.8756	0.4551	1.924	0.05437	.

OR:				
(Intercept)	Treatment3	SessionAC	Years_Univ_II	Years_Univ_Oth.
0.3264759	0.3595796	0.5313281	1.3550350	2.4004263

Table 5: Glm link logit regression on the probability of switching from "Ball" to "Wheel".

Therefore, the probability of changing from "Ball" to "Wheel" between the first and the second round (Y = 1) decreases from treatment 2 to treatment 3. The OR is 0.36, so confirming the negative impact of Tr.3 on the change in the direction of the risk-dominant equilibrium[6]. Overdispersion is not present

[5] OR={P(Y=1|Treat=3)/P(Y=0|Treat=3)}/{P(Y=1|Treat=2)/P(Y=0|Treat=2)}=8.3 or equivalently, the Odds of P(Y=1) given Treat = 3 is 8.3 times bigger than the Odds of P(Y=1) given Treat = 2.

[6] {P(Y=1|Treat=3)/P(Y=0|Treat=3)}/{P(Y=1|Treat=2)/P(Y=0|Treat=2)}=0.36 or equivalently, the Odds of P(Y=1) given Treat = 3 is 1/3 of the Odds of P(Y=1) given Treat = 2.

according to the ratio between the residual sum of square and the residual degrees of freedom, which is 0.98. The AUROC is 69%, using an optimized cut-off equal 0.31. The AUROC indicates a limited prediction power of the model. Sensitivity is 3% (very low capability to predict true positive) and specificity is 97% (high number of true negative correctly predicted). Other covariates surveyed in the experiment has been tested in the model, but they are not significant. As done for the above model, we also tested the effect of the treatment using generalized linear mixed models. Anyway, the effect of the treatment always results in an OR of about 0.3. Therefore, also in this case we choose the simplest model.

4. Conclusion

The experimental results confirm the hypothesis that the presence of an irrelevant (dominated) strategy affects coordination in the stag hunt game. This is at odd with standard rationality assumptions. In particular, we observe that when participants were exposed first to the SH2 matrix and then to the SH3 matrix they tended to move towards the risk-dominant equilibrium. On the contrary, when participants were exposed first to the SH3 matrix and then to the SH2 they tended to move towards the payoff dominant equilibrium. This change in decisions is reflected by the results of the second period of the two treatments where participants deciding to "hunt stags" in the Tr.3 outnumbered those in Tr.2. The logit regression confirmed the evidence that Tr.3 affect positively the probability of individual switching from hare to stag and negatively the reverse switching from stag to hare (and vice versa for Tr.2).

These results are promising to the purposes of further theoretical discussion. At the present stage, we can preliminary envisage that the passage from the SH2 matrix to the SH3 entails a re-framing such that the risky feature of the decision situation becomes more salient and the decision-makers appears less propense to take the risk to seek for the payoff dominant equilibrium. On the other hand, the passage from the SH2 matrix to the SH3 entails a re-framing such that the opportunity to exploit the advantages of coordination becomes clear and the decision-maker appears more propense to take the risk to seek for the payoff dominant equilibrium. This reveal a bias in the decision of subjects, since the addiction (subtraction) of the irrelevant strategy should not have changed their expectation on others, but they act as if it did, by revealing the beliefs that the possibility that others could in principle opt for the dominated strategy actually reduces the probability of coordination on the payoff dominant equilibrium.

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Appendix A: Instructions

Part 1

Welcome! If you wish, you can take part in this experiment. The experiment consists of two parts. After the first one, we will ask you to open the sheet containing the instructions for the second part.

An ID number has been randomly assigned to each participant – the number that is on the top right. This number will always guarantee your anonymity, both with respect to the experimenters and to other participants.

At the end of the experiment, your choices will be randomly paired to those of another participant; depending on the choices of both, your payoff will be calculated. **The sum of your payoffs in the first and in the second part will be added to the exam score.**

All participants face the same options and possible outcomes as you.

In this first part you have to choose between the alternatives named "Ball" and "Wheel".

The following table summarizes the points that you and the participant paired with you will get for each combination of choices. The bold numbers in each cell indicates your points, the italics numbers the points of the other participant.

The Other

		Wheel		*Ball*	
YOU	Wheel	4	*4*	4	*1*
	Ball	1	*4*	7	*7*

In other words,

- If you choose "Wheel" you will get 4 if the participant coupled to you chooses "Wheel"
  4 if the participant coupled to you chooses "Ball"
- If you choose "Ball" you will get 1 if the participant coupled to you chooses "Wheel"
  7 if the participant coupled to you chooses "Ball"

For any question, please rise your hand and we will personally answer you.

Please, choose by checking one box:

Wheel ☐ Ball ☐

Part 2

In this second part you have to choose between the alternatives named “Ball”, “Wheel” and “Orange”.

The following table summarizes the points that you and the participant paired with you will get for each combination of choices. The bold numbers in each cell indicates your points, the italics numbers the points of the other participant.

the OTHER

		Orange		*Wheel*		*Ball*	
	Wheel	8	*2*	4	*4*	4	*1*
YOU	Orange	0	*0*	2	*8*	0	*1*
	Ball	1	*0*	1	*4*	7	*7*

In other words,

- If you choose “Wheel” you will get 8 if the participant coupled to you chooses “Orange”
4 if the participant coupled to you chooses “Wheel”
4 if the participant coupled to you chooses “Ball”
- If you choose “Orange” you will get 0 if the participant coupled to you chooses “Orange”
2 if the participant coupled to you chooses “Wheel”
0 if the participant coupled to you chooses “Ball”
- If you choose “Ball” you will get 1 if the participant coupled to you chooses “Orange”
1 if the participant coupled to you chooses “Wheel”
7 if the participant coupled to you chooses “Ball”

For any question, please rise your hand and we will personally answer you.

Please, choose by putting a cross in one box

Wheel ☐ Orange ☐ Ball ☐

Please, answer the following questions:

1. Have you passed the math exam? YES ☐ NO ☐
2. Did you attend game theory lessons? YES ☐ NO ☐
3. Are you Male ☐ Female ☐
4. Imagine you can roll a dice. You will win 4€ in case of an odd number and nothing otherwise. Which of the following is the maximum amount you'd be willing to pay to play?

less than 1€	1€	1,5€	2€	2,5€	3€	more than 3€

Thank you for your participation!