Disjunction Effect in Prisoners Dilemma: Evidences from an Eye-tracking Study

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Abstract

The paper presents an eye-tracking study of the decision making processes leading to the disjunction effect in Prisoners Dilemma games. The experimental results suggest a different information acquisition pattern between the situations in which the move of the opponent is known and not known, respectively. The result is consistent with a complexity based explanation of the problem.

Keywords: disjunction effect, eye-tracking, Prisoners Dilemma, decision making

Introduction

Prisoner's dilemma

The Prisoner's dilemma (PD) game is one of the most extensively studied social dilemmas. PD is a two-person game. The payoff table for this game is presented in Figure 1. In the PD game the players simultaneously choose their moves – C (cooperate) or D (defect), without knowing their opponent's choice.

In order to be a Prisoner's dilemma game, the payoffs should satisfy the inequalities T > R > P > S and 2R > T+S. Because of this game structure a dilemma appears – there is no obvious best move. On one hand, the D choice is dominant for both players – each player gets larger payoff by choosing D than by choosing C no matter what the other player chooses. On the other hand, the payoff for mutual defection (P) is lower than the payoff if both players choose their dominated C strategies (R for each player).

As PD game is used as a model for describing social dilemmas and studying the phenomena of cooperation, there is a great interest in the conditions that could promote or diminish cooperation. Many such factors were found to influence the choices of the participants playing the PD game.

		Player II	
		C	*D*
Player I	C	R, *R*	S, *T*
	D	T, *S*	P, *P*

Figure 1: Payoff table for the PD game. In each cell the comma separated payoffs are the Player I's and Player II's payoffs, respectively.

One such factor is related to the payoffs in the game matrix. The *cooperation index* (CI), computed as CI = (R–P)/(T–S) (see Rapoport and Chammah, 1965 for details) is assumed to indicate the degree to which a player can be motivated to cooperate with the other player (to choose the C move).

Disjunction effect

The disjunction effect in Prisoners Dilemma (PD) was introduced by Shafir & Tversky (1992) and has been studied in a number of recent studies (e.g. see Li & Taplin, 2002; Busemeyer et al. 2006; Li et al., 2007). In these experiments, participants are told they would play a two-person prisoners' dilemma against an opponent – human participant or computer. In two of the experimental conditions they know what their opponent move will be – C or D – and in another condition the move of the opponent is unknown as in a usual PD game. In all experiments, the common result is that players mostly defect when they know the move of the opponent (no matter if it is C or D) and cooperate more when they don't know what the opponent's move is. The logical expectation is that if people choose defection for the two possible moves of the opponent, they should make a similar choice – defection – even if they don't know what the opponent's move is because their move is the same in both cases. However, people don't do this and cooperate more in the latter situation and this was called the disjunction effect (Shafir & Tversky, 1992). The explanation given by Shafir and Tversky states that people make always reason-based choices or, in other words, they need a reason in order to make a choice. Thus, when they know that their opponent will play C, they defect to get the higher payoff and if they know that she will play D they defect in order to avoid the lowest payoff and punish the opponent (see Figure 1). A second possible account of the disjunction effect has been related to complexity (e.g. see Croson, 1999). When a player knows the other player's move she needs to acquire only part of the information (e.g. concentrate on one column in the matrix of the game with only the payoffs determined by the known choice of the opponent). On the other hand, when the opponent's move is uncertain all the available information has to be attended to in order to make a move and the complexity of this task increases leading to the observed disjunction effect. Although the results in one of the experiments presented in Croson (1990) seem to exclude the latter possibility, no complete understanding exists so far of the phenomenon as seen from the recent attempts to give alternative explanations some of which based even on quantum computation models (see Busemeyer et al., 2006).

Information acquisition

Information acquisition studies investigate what information is sought, how long the information is examined, the sequence of acquisition, and the amount of information acquired (Einhorn & Hogarth, 1981; Lohse & Johnson, 1996). These data are important in studying the decision processes because patterns of information acquisition suggest certain possible strategies for information processing and information evaluation (Payne, Bettman, & Johnson, 1997). There is evidence that patterns of information acquisition influence the cognitive processes and in particular, change the decision making strategies (see e.g. Johnson, Payne, & Bettman, 1988; Bettman & Kakkar, 1977).

Eye movement recordings provide objective and quantitative evidence on what is being processed at the moment (Just & Carpenter, 1976; Duchowski, 2002). Eye-tracking data are used in a large number of studies of cognitive processes (for a review see Rayner, 1998). The pattern of eye movements reveals what information is being looked at, for how long and how often. Position, duration and sequence of fixations can be used to study different tasks keeping in mind the important assumption that the information subjects are look at is closely related to the information they are processing. So, data about looking patterns could be used to gain knowledge about the thinking patterns.

Goals of the present study

The main goal of the present paper is to present additional information about the cognitive processes involved in decision making under conditions leading to the appearance of the disjunction effect by studying scan paths in all conditions – when the move of the opponent is known and when it is not. In previous eye-tracking studies of PD game (Hristova & Grinberg, 2005; Grinberg et al., 2005) it is demonstrated that different eye-movement patterns are related to different playing strategies. So, the expectation is that eye-tracking data can shed additional light on the disjunction effect by giving information on the zones attended and the differences in attendance in the two conditions.

In previous experiments (see Shafir & Tversky, 1992; Croson, 1999) the players were led to believe they are playing a series of one-shot PD game against human partners. The first goal of the experiment was to explore the presence or absence of the disjunction effect when the players are not playing with other humans but with a computer as a second player and as done in Busemeyer et al (2006) but with eye-tracking recording. If the disjunction effect is due to the complexity of the game (the cooperative choices could be regarded as mistakes or inability to take into account all the available information), then the effect should be observed also when human players are paired with a computer partner. As this has been established in Busemeyer et al. (2006) the complexity explanation of the disjunction effect should be seriously considered and scan paths can give unique information in this respect.

Therefore, the second goal of the present experiment is to explore the information acquisition patterns in the conditions that are used to study the disjunction effect – when the opponent's move is not known, when the opponent has cooperation; and when the opponent has chosen defection.

Experiment

Participants

20 subjects with normal or corrected to normal vision took part in study. They were paid for their participation on the basis of the points earned during the experiment. Due to technical difficulties with the recordings, the eye-tracking records of 4 subjects were discarded. So, choices of all 20 subjects were analyzed, but the eye-tracking data of 16 subjects were analyzed.

Payoff Matrices

A set of 9 Prisoner's dilemma games was used in the experiment. Each of the 9 PD matrices was presented 3 times during the game playing: the computer move in not known yet, the computer move is known to be move 'C' (cooperation), the computer move is known to be move 'D' (defection). These 27 payoff matrices that are later used in the analysis were intermixed with 73 other games resulting in a total of 100 games. Portion of these additional games were PD games, portion of them had different payoff structure than the PD games, but all of them were 2-players symmetric games. The 27 PD games were pseudo-randomly distributed between the 12th and the 96th game. Playing games with different strategic structure was used to introduce the PD games as one-shot games and prevent subjects for using strategies applicable in the repeated play of PD.

Although the payoffs were different, the cooperation index of all PD games was equal to 0.5. The differences between pairs of payoffs were also kept constant. The average payoff per trial is also an important predictor of cooperation (Oskamp and Perlman, 1965). Taking this into account, the payoffs' magnitudes were kept within certain limits. T was between 51 and 85 points (mean 71), R was between 43 and 76 points (mean 62), P was between 23 and 56 points (mean 42), S was between 12 and 45 points (mean 31). As it could be seen, all the payoffs were 2-digit numbers and in such a way the attention was not attracted by very distinctive numbers (e.g. 3-digit number among 2-digit numbers).

Eye Movements Recordings

Eye movements were recorded using the Tobii 1750 remote binocular eye-tracker with 50 Hz sampling rate. The eye-tracker was calibrated using a 9-point grid. The accuracy of the gaze position record is about 0.5 degrees visual angle.

The game was presented on the Tobii monitor (17”, 1280x1204 pixels). Each box containing payoffs or moves occupied about 1 degree visual angle on the screen. The distance between two adjacent boxes was at least 1 degree visual angle to ensure stable distinction between eye-fixations belonging to respective zones. The schematic game interface is presented in Figure 2.

Procedure

20 subjects with normal or corrected to normal vision took part in the eye-tracking experiment. Each subject played 100 games against the computer. The game was presented in a formal and a neutral formulation. On the interface, the moves were labeled ‘1’ and ‘2’. Cooperation or defection were not mentioned on the interface or in the instructions. Further in the paper, for convenience, we will continue to use cooperation instead of move ‘1’ and defection instead of move ‘2’. Subjects were instructed to try to maximize their payoffs and not to try to ‘beat’ the computer. After each game the subjects got feedback about their and the computer’s choice and payoff in the current game. This information was visible for 5 seconds and then the next game automatically appeared. Subjects could also permanently monitor the money they have won so far.

The computer played randomly generated moves. The subjects were not aware of that. They were told that the computer also tries to get as much points as possible.

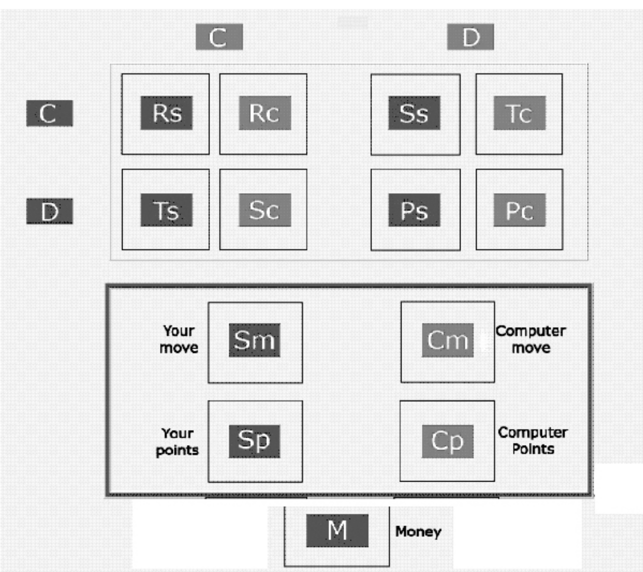

Figure 2. Schematic representation of the game interface. In the figure notations that are used in the analysis are represented. During playing, the actual payoffs and moves are presented.

Results and Discussion

Playing

The number of cooperative choices for PD games was used as a dependent variable characterizing the participants’ playing and choices. Results are presented in Figure 3. The expected pattern for a disjunction effect appeared in the data. When the computer’s move was not known, the players cooperated in 12 % of the games. When the computer’s move was known and the computer chose move ‘C’ (cooperation), the subjects cooperated in 7 % of the games. Finally, when the computer’s move was known and the computer chose move ‘D’ (defection), the subjects cooperated in 3 % of the games.

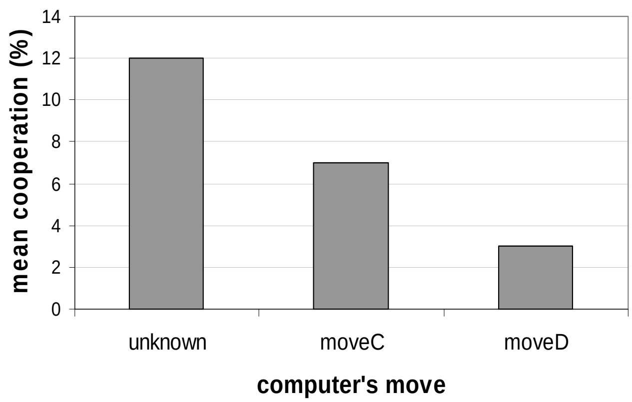

Figure 3. Mean cooperation (%) in the three different experimental conditions: the computer’s move is not known (*unknown*); the computer’s move is known and it is move – cooperation (*moveC*); the computer’s move is known and it is defection (*moveD*).

The number of cooperative choices was compared using t-test for proportions. In the total of 180 PD games for all 20 subjects in which the computer’s move was not known (*unknown* condition), 21 cooperative choices were made. These choices were compared to the 13 cooperative choices when the computer’s move was known to be cooperation (*moveC* condition) and to the 7 cooperative choices when the computer’s move was known to be defection (*moveD* condition). The test yielded $p = 0.001$ for difference between *unknown* and *moveD* condition and $p=0.053$ one-sided for the difference between the *unknown* and *moveC* conditions. The difference between the *unknown* condition and both conditions in which the computer’s move is known is statistically significant ($p = 0.006$).

In summary, subjects cooperated more when the opponent’s move was not known compared to both situations in which the opponent’s move was known (no matter if it was cooperation or defection). It is a demonstration of the disjunction effect in settings in which subjects are aware that they are playing against a computer. It is interesting to note also the fact that subjects are cooperating more when they know that the computer has cooperated (*moveC* condition) than when they know that the computer has defected (*moveD* condition) (p=0.04 one-sided).

Information acquisition

We define several areas on the screen that are interesting in studying information acquisition during PD game playing. Each Area of Interest (AOI) contains the box in which the information is presented and a small region around it. Here we present the analysis of the eye-tracking data for the four AOIs containing the subject's possible payoffs These AOIs are referred to as T_S, R_S, P_S, and S_S (see Figure 2).

Number of fixations in each AOI reflects the relative importance of the information presented in the AOI (Jacob & Karn, 2003). Another measure that is commonly used in eye-tracking studies is the duration of fixations in a given AOI. However, it reflects the difficulty of information extraction rather than importance (Jacob & Karn, 2003). What's more, in the present experiment the information in each AOI was similar (and the duration of fixations was almost the same). Taking this into account we chose to use the number of fixations in each AOI as a measure of attention devoted to it and as a dependent variable.

The average number of fixations in each AOI containing the subject's possible payoffs are presented in Figure 4. Mean number of fixation in each AOI is analyzed in a repeated-measures analysis of variance with experimental condition (*unknown*, *moveC*, *moveD*) as a within-subjects factor. Post-hoc analysis was used to compare each two experimental condition.

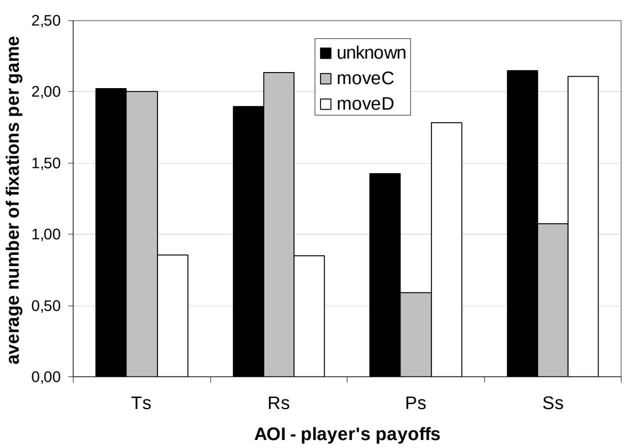

Figure 4. Mean number of fixations in AOIs containing subject's possible payoffs (T_S, R_S, P_S, and S_S) in the three different experimental conditions: the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*moveC*); the computer's move is known and it is defection (*moveD*).

When subjects knew that the computer's move was defection they attended less to the AOIs denoted as Ts and Rs compared to the other two experimental conditions (all p < 0.001) (see the left two stacks in Figure 4). When the computer's move is defection, the subject's possible payoffs are S or P. The subjects paid more attention to these two payoffs and less attention to their other two possible payoffs T and R (see Figure 5 rightmost). The difference in mean number of fixations between the column (Rs+Ts) and (Ss+Ts) when the computer move is known to be defection is statistically significant (t (15)=-4.3, p=0.001).

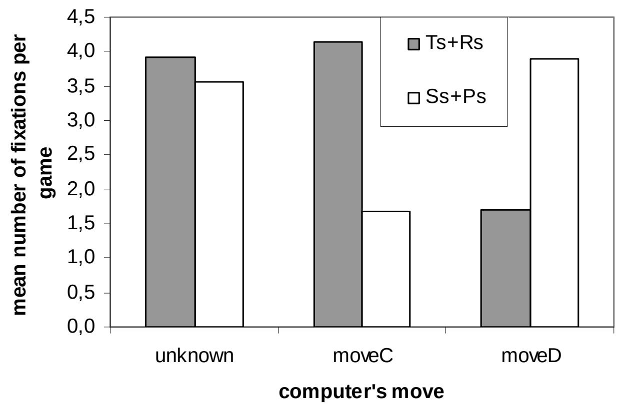

Figure 5. Mean number of fixations in AOIs containing subject's possible payoffs aggregated in columns belonging to opponent's move 'cooperation' (Ts+Rs) and move 'defection' (Ss+Ps) in the three different experimental conditions: the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*moveC*); the computer's move is known and it is defection (*moveD*).

When subjects knew that the computer's move was cooperation they attended less to the AOIs denoted as Ss and Ps compared to the other two experimental conditions (all p < 0.03) (see the right two stacks in Figure 4). When the computer's move is cooperation, the subject's possible payoffs are R or T. The subjects paid more attention to these two payoffs and less attention to their other two possible payoffs S and P (see Figure 5 rightmost). The difference in mean number of fixations between the column (Rs+Ts) and (Ss+Ts) when the computer move is known to be cooperation is statistically significant (t (15)=9.53, p<0.001).

In summary, the eye-tracking data show that when the opponent's move is known, the eye-movement patterns are changed. Subjects start paying attention predominantly to the payoffs that correspond to the opponent's move. By considering only 2 of their possible payoffs it probably becomes easier for them to choose their dominant strategy (defection). That reasoning is in accordance with the complexity explanation of the disjunction effect that states that larger number of payoffs that should be considered when the computer's move is not known represents a challenge to the cognitive capacities of the players. Because of this sometimes subjects are not able to discover their dominant strategy in the one-shot PD games (to defect).

However, when the computer's move is known, the cognitive load is less (because only 2 payoffs have to be considered) and players are capable of finding the more profitable strategy.

Another analysis that is worth considering is the one that examines the total number of the AOIs containing the subject's possible payoffs. It is seen from Figure 6 that the number of fixation per game on the possible subjects' payoffs is similar in the three conditions. Combined with the previous findings (that in the *unknown* condition subjects pay attention to all four of their payoffs, while in the *moveC* and *moveD* conditions subjects' attention is concentrated to only two of the payoffs), this means that in the *unknown* condition more payoffs have been looked at less frequently than in *moveC* and *moveD* conditions. That supports the complexity explanation of the disjunction effect.

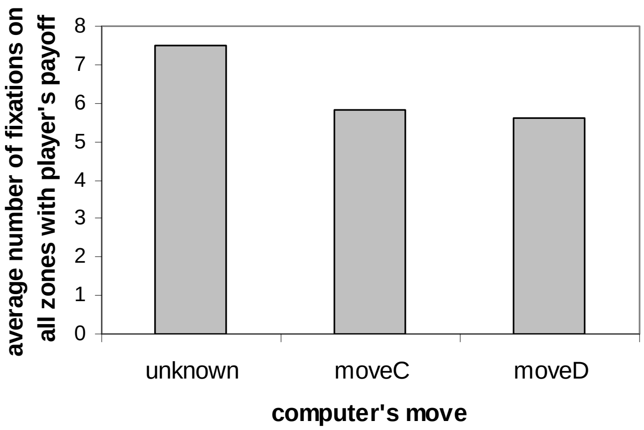

Figure 6. Total number of fixations in AOIs containing subject's possible payoffs in the three different experimental conditions: the computer's move is not known (*unknown*); the computer's move is known and it is cooperation (*moveC*); the computer's move is known and it is defection (*moveD*).

Conclusion

In the present paper, we have investigated information acquisition patterns in PD games related to the appearance of the disjunction effect. The results confirm the results of Busemeyer et. (2006) that disjunction effect can be obtained also when subjects are playing against a computer and know about it. The eye-tracking results, obtained for the first time for PD game related disjunction effect, confirm the hypothesis that when the move of the computer is known participant attend mostly to information related to the possible game outcomes with respect to the known move of the opponent. This specificity of scan paths confirms that participants can and do concentrate on less information when they know their opponent's move. In the opposite case when information about the opponent's move is not available, they look at all of the payoffs. Effectively this may mean that more pieces of information are processed for shorter times which could be the reason for the disjunction effect. Thus we consider that this study supports the complexity explanation of this effect.

Theoretical efforts are in progress to propose a model account of the data presented here.

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