

Cooperation in Prisoner's Dilemma Game: Influence of Players' Social Roles

Evgenia Hristova (ehristova@cogs.nbu.bg)

Maurice Grinberg (mgrinberg@nbu.bg)

Iskra Georgieva (issgeorgieva@gmail.com)

Milena Borisova (borisova_milena@abv.bg)

Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street, Sofia 1618, Bulgaria

Abstract

The paper aims to extend the findings of a previous study (Grinberg et al., 2012) exploring the impact of social relations on the cooperation in the Prisoner's dilemma game. Relations between players are manipulated by assigning different roles. The roles embodied the four basic types of human relations in line with Fiske's relational models theory (Fiske, 1991): *communal sharing, authority ranking, equality matching, and market pricing* (players are assigned roles of *team mates, chief and subordinate, partners, and opponents*, respectively). Cooperation rates, mutual cooperation, mutual defection, and payoffs gained were subsequently analyzed and compared for a series of forty games. As a result we identified that the *market-pricing* condition is characterized by considerably lower individual and mutual cooperation, higher mutual defection and lower payoff in comparison to the conditions impersonating the remaining three relational types.

Keywords: Prisoner's Dilemma, decision-making, cooperation, social interaction, relational models

Introduction

Prisoner's Dilemma Game

Games are formal tools to study social interactions. The Prisoner's dilemma (PD) game is one of the most extensively studied social dilemmas as it is considered to model interactions in many social situations and problems such as overpopulation, pollution, energy savings, participation in a battle, etc. (Dawes, 1980). It is used to study cooperation and conflict in interactions between individuals, groups, and societies (Rapoport & Chammah, 1965).

In the PD game the players simultaneously choose their moves – to cooperate (C) or to defect (D) – without knowing the choice of the other player. The payoff table for the two-person PD game is presented in Figure 1. The payoffs of the Prisoner's dilemma game (see Figure 1) satisfy the inequalities $T > R > P > S$ and $2R > T+S$. Because of this game structure a dilemma appears, as there is no obvious best move. On one hand, the D choice is dominant for both players – each player gets a larger payoff by choosing D (defection) than by choosing C (cooperation) 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 (payoff R for each player).

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

		Player II	
		C	D
Player I	C	3, 3	1, 4
	D	4, 1	2, 2

Figure 1: Payoff tables for the PD game with standard notation for the payoffs and an example with specific payoff values. In each cell the comma separated payoffs are the Player I's and Player II's payoffs, respectively.

As the PD game is used as a model for describing social dilemmas and studying the phenomenon of cooperation, there is a great interest in the conditions that could promote or diminish cooperation. In formal game theory players are supposed to try to maximize their payoffs in a completely selfish manner (Colman, 2003). From this point of view the dominant strategy in the game is defection (in one-shot or in repeated PD games with a fixed and known number of games). This prediction is in contrast with the behavior of the players observed in laboratory settings or in real life situations.

In human societies, people cooperate all the time and often cooperation is seen as one of the foundations of human civilization (see e.g. Gärdenfors, 2003). Sally (1995) provides a meta-review of the experiments involving PD games published between 1958 and 1995 and shows that in its iterated version (the game is played many times), cooperation choices are made in 20-50 % of the games (mean 47.4 %) and even in one-shot games many players cooperate, although much less than in the iterated version.

Several studies have shown how cooperation can emerge from expected utility or anticipatory reinforcement models without any specific relations between the players (see e.g. Grinberg, Hristova, & Lalev, 2010; and the references there in).

Other theories explain the cooperative behavior in PD games in terms of socially established values and stress the importance of social interaction and relationships. *Reputation building theory* (Kreps et al., 1982; Andreoni & Miller, 1993) assumes that the player is building himself a reputation of a cooperative player to build herself the image of trust and thus to provoke cooperation by the other player. Trivers (1972) puts accent on *reciprocity* as a widespread norm and basis of societies: people reciprocate cooperation

with cooperation. Another influential theory about cooperation in PD game is based on the concept of *altruism*. It assumes that some players are not strictly self-interested and from an altruistic perspective, cooperation can yield higher payoffs than defection (Cooper et al., 1996).

Although these social theories of cooperation have been proposed to explain cooperative behavior unexpected by normative game theory, it is interesting to consider more general social theories that are more closely related to the game theoretic analysis of social relations. In our opinion such a theory is the relational models theory proposed by Alan Fiske (Fiske, 1991) which is trying to decompose any social interaction to four basic relations and thus seems amenable to game theoretic representation.

Moreover, as the PD game is central in the modeling of social interactions it can be used to explore the existence and limits of the relational social types as posited by relational social models (see e.g. Haslam, 2004). Exploring the potential of games like the PD game as modeling relational types is one of the goals of this paper which is a continuation of a first analysis presented in Grinberg, Hristova, & Borisova (2012).

Relational Models Theory

Relational models theory (Fiske, 1992; Fiske & Haslam, 1996; Rai & Fiske, 2011) states that there are four basic schemas that are used to build, organize and maintain relationships and interactions among individuals in a society. These models are supposed to be universal and all relations could be described by these models or by combination of them. The four types of relations generate four modes for every aspect of the interactions between people – resource allocation, moral judgments, decision-making, etc. These four relation models are the following (Fiske, 1992):

- **Communal Sharing** – relations in an undifferentiated group of people with equivalent status. Everyone in a community - which could consist of two members or could be very large – has some rights and some duties. The focus is on commonalities and not on distinctions;
- **Authority Ranking** – implies an ordinal ranking in society and this ranking scheme determines one's relative status. For instance, military hierarchy can be considered a prototype of such relations;
- **Equality Matching** – relations are based on a model of one-to-one correspondence as in turn-taking, tit-for-tat strategies, etc. The social prototype would be friendship networks, in which reciprocity is a norm which rules the distribution of wealth;
- **Market Pricing** – based on a model of proportionality in social relations in which people reduce their interaction to some ratios of utility measures. Examples of relations of this type are the ones governed by prices, rational calculations, expected utilities, etc.

Social Interactions and Cooperation

In formal game theory payoffs, strategies and choices are analyzed independently from any context or meaning. Most experiments for studying PD game employ neutral presentation of the game. In order to be able to control for extraneous variables, game is presented in neutral formulation, choices are labeled as 'A' and 'B', or as '1' and '2', etc. Participants in the game are usually called 'players', or 'you' and 'the other' and usually are unfamiliar with one another, in most cases also a visual contact between them is avoided. This is done in order to isolate cognitive processing of information and to capture influence of other factors.

However, we think that deeper understanding of decisions in games should consider social relations involved in the interactions. People behave differently in social interactions described as formal games with similar strategies and payoffs, depending on whom they interact with, what is the situation, what are the possible choices.

Sally (2001) states that social interaction is essential and the social dilemmas like PD need to be investigated from such a perspective. In the paper the importance of closeness between players in game strategy building is discussed. According to this account, players change their choices if they perceive the other player as a friend or a stranger.

Other studies focused on the influence of game description, game title, etc. As such labels and description give different context of the interaction, it is expected that they change the behavior of the players.

Some studies explored the influence of the title given to the game. Ellingsen et al. (2012) found more cooperation when the game is labeled 'Community Game' vs. 'Stock Market Game'. Liberman et al. (2004) found a similar effect in the first round cooperation comparing the game titles 'Community Game' and 'Wall Street Game'.

Another study explored the influence of the general interpretation context (Eiser & Bhavnani, 1974). Participants cooperate more when they are told that the experiments studies 'international negotiation' or 'interpersonal interaction' compared to 'economic bargaining' or neutral description.

Zhong et al. (2007) manipulated several factors – game label, choices labels, outcome labels and found that giving interpretative labels promotes cooperation and this is especially the case when 'trust' and 'cooperation' are used as labels.

However, in all of these studies the influence of the players' roles is not explored. In all of them the players are labeled neutrally as 'You' and 'Other person' (Ellingsen et al., 2012; Eiser & Bhavnani, 1974; Zhong et al., 2007) or as 'Player 1' and 'Player 2' (Liberman et al., 2004). As players' labels and roles could also serve to denote social relations, it is worth exploring their influence on cooperative behavior.

Relational models and PD game

In a previous study (Grinberg et al., 2012), we made a first attempt to apply the Fiske's relational models theory (Fiske, 1991) to playing in PD games. In the experiment (see for details Grinberg et al., 2012), the relational models between players (communal sharing, authority ranking, equality matching, and market pricing) were operationalized by using various ways of distributing the total payoff gained by a dyad of players in a series of Prisoner's dilemma games: each player receives the total payoff (*communal sharing*), one of the players receives more than the other (*authority ranking*), each player receives half of the total payoff (*equality matching*), each player receives a portion of the total payoff proportional to his/hers individual payoffs (*market pricing*). For these four conditions, the cooperation rates, the mutual cooperation, the mutual defection, and the payoffs gained were analyzed and compared for a series of forty games. The results of Grinberg et al. (2012) showed that the market pricing distribution scheme leads to less cooperation, less mutual cooperation, more mutual defection and less total payoff than in the other three distribution schemes.

This is an interesting result taking into account the fact that in formal game theory, in many experiments, and in many real life situations, the players are perceived as individualistic beings. It is also evidence that the topic deserves further exploration and has motivated the present study.

Goals of the Study

The goal of the present study is to explore the mapping of the Fiske's relational models theory to Prisoner's dilemma game focusing on the **players' roles** corresponding to the four relational models (Fiske, 1992) as follows:

- **communal sharing** – group of people with strong bonds, wherein everyone is equivalent to the other and all resources are common;
- **authority ranking** – people are ordered hierarchically and the resources are distributed according to the person's rank;
- **equality matching** – a balanced relationship based on turn-taking, tit-for-tat strategies and equal distribution of the resources;
- **market pricing** – relations based on proportionality and comparison – it is important 'how the person stands in proportion to others'

We aim to explore what is the influence of the role assigned to the player on a set of game outcomes that characterize the playing of a PD game – cooperation, mutual cooperation, and mutual defection. It is also important to check the influence of the assigned role on the overall payoffs that are received – e.g. what type of model is more beneficial in terms of payoff earned in interactions shaped by the strategic structure of the PD game.

Based on the results obtained in Grinberg et al. (2012), the cooperation rate is expected to be the highest if the players are acting in a communal sharing relation and the

lowest when the players' roles are defined according to the market pricing model. In the latter scenario, we expect a more individualistic behaviour of the players.

Method

Stimuli and Procedure

A sequence of 40 Prisoner's dilemma games is used in the current experiment. All of the games had the payoff matrix given in Figure 2.

		Player II	
		C	D
Player I	C	40, 40	10, 50
	D	50, 10	15, 15

Figure 2: Payoff table for the PD game used in the experiment.

Participants were tested in pairs. After receiving the appropriate instructions for the corresponding experimental condition, each dyad played 5 training games (whose results were not included in the analysis) followed by 40 games that were further analyzed. On the computer game interface, the cooperation move was labeled '1' and the defection move was labeled '2'. Matlab 7.6.0 (R2008a) was used for presenting the game and recording the choices of the players. After each game the subjects got feedback about their own and the other player's choice and payoffs in the current game. They could also constantly monitor their own total payoff; the total payoff of the other player; and the monetary equivalent of their own total payoff.

The instructions for the experiment explained in detail the rules of the game and included several test questions to ensure that participants understood them correctly. There were five instructions that varied only in the description of the players' roles and the corresponding relations between the players in the game.

The experimenters secured that the participants had not visual, verbal and any kind of other contact between them before and during the experiment. Therefore, no player knew who the other player was before the end of the experiment. Subjects were paid real money accordingly to the final payoff in the game. Each session lasted about 20 minutes.

Experimental Conditions

The **players' roles** are varied in accordance with the four relational models described above in a between-subjects design. We also added a control condition, exposed to the most common neutral presentation of the PD game. So, there are 5 experimental conditions as a total differing in how players are labeled in the instructions and on the game interface and how the sequence of games is presented (a sentence in the instruction defines the relations between players)

- **Team condition** – the players are labeled as 'teammates'; instruction: 'You will play a sequence of

games based on team-work between players with your team-mate' (*communal sharing relational model*);

- **Hierarchy condition** – the players are labeled as ‘chief’ and ‘subordinate’, correspondingly; instruction: ‘You will play a sequence of games based on hierarchy between players with your chief/subordinate’ (*authority ranking relational model*).
- **Partners condition** – the players are labeled as ‘partners’; instruction: ‘You will play a sequence of games based on equality (parity) between players with your partner’ (*equality matching relational model*);
- **Opponents condition** – the players are labeled as ‘opponents’; instruction: ‘You will play a sequence of games based on competition between players with your opponent’ (*market pricing relational model*).
- **Players condition** – the players are labeled as ‘players’; instruction: ‘You will play a sequence of games with the other player’ (*control condition*).

The names for players’ roles in each experimental condition are used consistently throughout the experimental session – in the instructions and on the game interface.

Participants

Forty pairs (80 participants) took part in the experiment – 8 pairs in each experimental condition. Participants were randomly assigned to their experimental condition. In the *hierarchy condition*, it was randomly determined which player will be in the *subordinate role* and which player in the *chief role*.

Data of one dyad was removed because one of the players reported after the game end that he has participated in a similar experiment. Thus, we ended with 7 pairs in the *hierarchy condition* and data of 78 participants was analyzed (46 female, 32 male, mean age 24 years). For this condition, although the players were asymmetrically labeled (*chief* and *subordinate*) the results are not significantly different, so they are analyzed together.

Results

To explore the influence of the players’ roles on choices and cooperation in the PD games, the following dependent variables are analyzed: number of **cooperative choices for each player**; number of games with **mutual cooperation in a pair**; number of games with **mutual defection in a pair**. For clarity, in the figures, the results are presented in percentages. However, the analysis is performed using the specified dependent variables.

The average **payoff per game (in points)** is considered a measure to assess which players’ roles led to higher profits.

Each dependent variable is analyzed in ANOVA with *players’ roles* as between-subject factor with 5 levels (*team vs. hierarchy vs. partners vs. opponents vs. players*).

Cooperation

The cooperative choices (%) are presented in Figure 3. The analysis shows a significant influence of the players’

roles on the number of cooperative moves ($F(4, 73) = 3.44$, $p = 0.012$).

Post-hoc LSD test shows that the cooperation rate in the *opponents condition* is significantly lower than the cooperation rate in the *team condition* ($p = 0.003$), in the *hierarchy condition* ($p = 0.003$), and in the *partners condition* ($p = 0.025$). All other differences are non-significant.

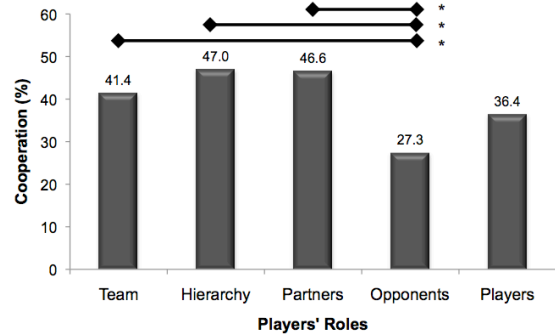


Figure 3: Average percentage of cooperative choices for different players’ roles. (* means $p < 0.05$).

This analysis shows that the labels for the players’ roles influence the cooperation rate and lead as expected to lower cooperation for players labeled as ‘opponents’. In the terminology of Fiske’s theory, the market pricing relational model leads to diminished cooperation in comparison to the other three relational models. While this does not seem strange for the *team* and *partner conditions*, it is to some extent for the *hierarchy condition*. For the latter, however, detailed analysis showed that one pair of players cooperated 100 % of games which led to this strange results which is at odds with the results of Grinberg et al. (2012) for the corresponding condition.

Mutual Cooperation

Average percentage of games in which there is mutual cooperation (both players have chosen to cooperate) is presented in Figure 4.

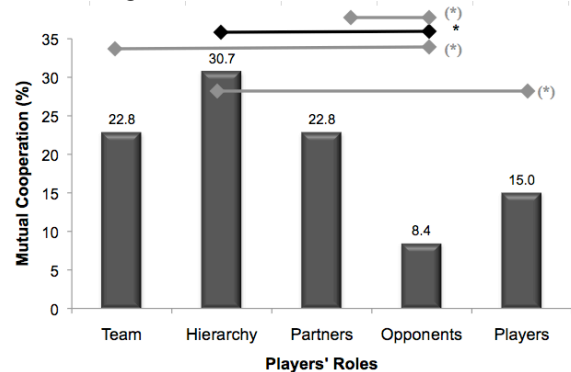


Figure 4: Average percentage of mutual cooperation in a pair in each distribution condition (* means $p < 0.05$; (*) – marginally significant difference).

The ANOVA does not identify a statistically significant influence of the players' roles on the number of mutual cooperative game outcomes ($F(4, 34) = 2.03, p = 0.112$). However, the Post-hoc LSD test shows that a difference exists between the opponents and hierarchy condition ($p = 0.013$). Marginally significant differences are observed between the opponents and partners condition ($p = 0.09$), between the opponents and team condition ($p = 0.09$), and between control (players) and hierarchy condition ($p = 0.074$).

It turns out that mutual cooperation is the lowest (~8 %) in the opponents condition. This result is consistent with the assumption that the competition, distinctive for the money pricing relational model, will induce an individualistic participants' behavior.

Mutual cooperation is also relatively low in the control condition – the condition with neutral description of the players' roles. The interesting result is again in the hierarchy condition for which the high mutual cooperation is obtained (~31 %) but as discussed earlier it is partially due to one pair of players which cooperated throughout the whole series of games.

Mutual Defection

The average percentage of games with mutual defection (both players have chosen to defect) is presented in Figure 5. ANOVA does not identify a statistically significant influence of the players' roles on the number of games with mutual defection ($F(4, 34) = 2.07, p = 0.106$). However, a further conducted Post-hoc LSD test identifies significant difference between the opponents condition and partners condition ($p = 0.009$), and marginally significant difference between opponents condition and hierarchy condition ($p = 0.066$).

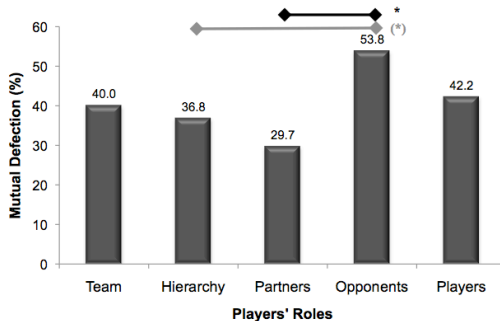


Figure 5: Average percentage of mutual defection in a pair in each distribution condition (* means $p < 0.05$; (**) – marginally significant difference).

Therefore, it can be concluded that when the players are labeled as opponents, mutual defection is a much more typical choice. It should be noted that mutual defection leads to the lowest possible payoff for the pair. Although defection is the dominant strategy for players in one-shot PD games, here the players play 40 games and mutual defection leads to the worst collective payoff – thus the dilemma structure of the game arises as the opposition between individual and collective

rationality. However, it is interesting to note the high mutual defection in the team condition.

Average Payoff

The payoff analysis was conducted on the basis of the average payoff per game (in points) (see Figure 6). ANOVA shows a significant influence of the distribution type on the payoff ($F(4, 73) = 2.50, p = 0.049$).

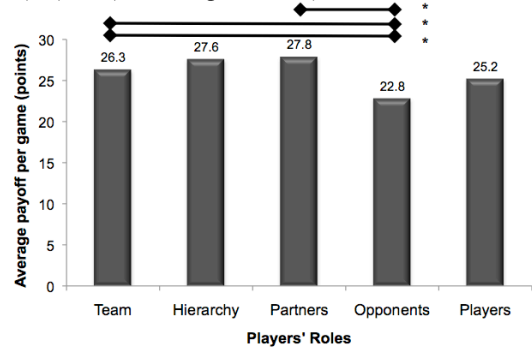


Figure 6: Average payoff per sequence of 40 games for a pair in each distribution condition (* means $p < 0.05$).

Significant differences were established through post-hoc LSD test between the opponents and team condition ($p = 0.006$), between the opponents and hierarchy condition ($p = 0.001$), between the opponents and partners condition ($p = 0.001$).

The payoff for the participants is lowest when the players are opponents (compared to the other three relational models). This is an interesting result especially since the roles of opponents presumably represent the market pricing relational model, which is related to individualistic attitude and profit orientation. However, taking into account that the highest number of games with mutual defection are found in the opponents condition, the result could be explained by the lower payoff that the players get when they both defect.

Conclusions and Discussion

The presented study aims at further examining the presumable influence of social relations over cooperative and non-cooperative behavioral patterns in the Prisoner's dilemma game. Within our experiment subject were assigned different roles that corresponded to the four basic relations, defined by the Relational models theory: communal sharing, authority ranking, equality matching, and market pricing.

The results outline a clear tendency towards lower individual and mutual cooperation, higher mutual defection and lower total payoff when players are directly labeled as 'opponents' (a role model typical for the market pricing relation) in comparison to all other role sets. Simply put whenever participants are led to perceive 1) the other player as their enemy in the game; and 2) the game as a game of open competition, they cooperate less and earn lower payoff both individually and as a pair. This result, though logical and intuitive in nature, questions the actual success potential of a profit-oriented behavioral model within the Prisoner's dilemma game and real life situations reflecting this game.

As it can be concluded competitiveness may not be the best approach towards goal accomplishment whenever a mutual dependency on participants' choices is present regardless of whether we are facing a person who we deem our opponent.

Strikingly similar results were observed in a previous study (Grinberg et al., 2012) examining the effect of the payoff distribution over the cooperation levels in Prisoner's dilemma game. Lower individual and mutual cooperation, higher mutual defection and lower total payoff were observed when the joint profit was divided among players according to their individual contribution – the experimental condition impersonating the *market pricing* relation. In comparison, in both experiments the conditions reflecting the remaining three relational models are characterized with higher levels of individual and mutual cooperation and payoff plus lower defection rate. What can be concluded as a summary of both studies is that in line with our expectations, the relational model of *market pricing*, no matter how framed, “awakens” individualistic, egoistic and concurrent behavioral tendencies among subjects resulting in lower level of cooperation within the Prisoner's dilemma game. Moreover, the influence of these tendencies over individuals seems irrespective of the influence of rationality itself. This in its nature supports the idea that human relations may affect our choice of behaviors in a decisive manner irrelevant of our rational awareness.

An interesting area for exploration remains the condition comprising the *authority ranking* relation. As it can be seen in both studies this relation could lead to high cooperation despite the different roles of the players or the inequality in the payoffs received. Cooperation levels within the condition are more or less the same as the ones observed in the two “cooperative in nature” conditions – *communal sharing* and *equal matching*. It can be thus speculated that inequality does not trigger competition to the extent individualism and “self-sufficiency” do. Therefore such a relation of inequality may not be an obstacle for subjects to perceive the game as a game of an in-team dependency and choose a cooperative behavioral pattern.

The studies conducted produce results with broader implication potential. The research on the effect of human relations on the behavior in social dilemmas is fundamental for the understanding of complex phenomena within the field of both decision making in games and real-life situation in economy, politics, military field etc.

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