CONTEXT DEPENDENCE OF COOPERATION INDEX JUDGMENT SCALES IN PRISONER'S DILEMMA

Maurice Grinberg, Evgeniya Hristova

***Abstract**: Context effects in the iterated Prisoners' Dilemma (PD) games are investigated with special focus on dynamical effects, i.e. effects due to interactions between the players in the course of the game. Cooperation index is computed as a ratio of the payoffs and is used to characterize how cooperative a given PD game is. The context is set by a first stage of the experiment in which games with low (0.1 and 0.3), high (0.7 and 0.9) and full (0.1–0.9) range of the games' cooperation index are played by different groups of players. In a subsequent stage, differences between the groups are found in the evaluation of how people would play in games with the full range of cooperation indexes. In the three groups, correlations between the previous game outcome and the following move are established showing a peak in the cooperative moves after a game in which both players have been cooperative. Possible relations of the results obtained with similar psychophysical findings are discussed.*

***Keywords**: cooperation, context effects, social interactions, experimental game theory*

Introduction

In recent years, more and more attention has been paid to the difficulties encountered by rational choice theory when applied to social phenomena involving interactive decision making e.g. [Colman, 2003]. These difficulties are related to the fact that in complex decisions the lack of information about other people's choices, time and resource limitations make the outcome unpredictable by any pure rational theory.

In game theory, based on the expected utility theory, the basic assumption is that each prospect (game) is considered separately and the resulting choice should be based only on the attributes (respectively, utility) of the particular prospect or game.

In experiments, however, people behave more 'irrationally' and receive higher payoffs than rationality theory would predict. It is widely accepted now that a strict theory of rationality is evidently insufficient for explaining human interaction [Colman, 1995]. The problems that this theory encounters when trying to describe or predict the outcomes of experiments are due mainly to the non-accounting of context effects. There are many experiments that demonstrate the influence of context in judgments and decision making and theories accounting for these effects (e.g. the range-frequency theory [Parducci, 1974], its extension to multi-attribute judgments [Cooke & Mellers, 1998], the expectation driven assimilation and contrast model [Manis, Biernat & Nelson, 1991].

Although most of these theories deal with perceptual stimuli or involve a choice among a set of alternatives, it can be expected that they can be applied to choices of moves during playing as well. This could be possible especially in the case when the games can be distributed in a range defined by some quantity derived from the payoffs. In PD games, we are dealing with in this paper, such a quantity is the Cooperation Index (CI) [Rapport & Chammah, 1965].

In order to check this assumption, several experiments with PD games have been performed [Vlaev & Chater, 2007]. They demonstrate the existence of context effects – effects of assimilation and contrast – due to the different range distribution and different combinations of games with respect to CI. In these studies, the basic assumption is that during decision making (choice of a move in a game) people employ the same judgments and comparison processes as during perceptual tasks, and hence the same principles and mechanisms are involved, which would lead to context effects that are similar to the ones observed in perceptual tasks (like magnitude estimation for example).

In the present paper, a somewhat different approach was chosen, based on the same assumptions. Firstly, we tried to explore the context effect due to a preliminary exposure to PD games with specific CI range on subsequent judgments about the likely choices made by the subjects for PD games taken from the whole CI range. Secondly, we wanted to determine to what extent the moves made by the subjects were influenced by the time-course of the game, by previous players' moves and game outcomes, which we call in the paper 'dynamic' context effects (see the discussion of similar effects in [Rapoport & Chammah, 1965]; and of sequential effects in [Parducci, 1974]).

The article is organized as follows. In Section 1, the goals of the article are stated and discussed as well as the hypotheses to be tested. In Section 2, an outline of the experimental design is presented. The results from the experiment are presented and discussed in Section 3. In Section 4 we give a general discussion of the experimental outcomes and draw some conclusions.

1. Goals and Hypotheses

Goals

In order to study the context and dynamic effects, considered above, we use the well-known PD game. We are interested in how the decisions subjects make are influenced by context (e.g. range of other games' CI in the sequence), by the dynamics of the playing and by the different payoffs in the game (reflected by CI in each PD game). On the other hand, we want to study how context, which in our case are the previously played games taken from the lower or higher CI range, affects the judgments of people's likely moves in games from the full CI range.

The Prisoner's Dilemma Game

The payoff table for this game is presented in Figure 1. The players simultaneously choose their move – *C* (cooperate) or *D* (defect), without knowing their opponent's choice.

		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 ones, respectively. The payoffs R, S, T, P satisfy $T > R > P > S$ and $2R > T + S$.

In an isolated game, the *D* strategies are strongly dominant for both players because each player receives a higher payoff by choosing *D* rather than *C* whatever the other player might do. The dilemma is that if both players adopt *D* strategy, the payoffs (P, P) are lower for both of them than if they both had chosen dominated *C* strategies. In the latter case however, they have to trust their opponent and take the risk of getting the lowest payoff – S (taken to be 0 in the present experiment).

Rapoport and Chammah [Rapoport & Chammah, 1965] have proposed the so-called Cooperation Index (CI) with $CI = (R–P)/(T–S)$, as a predictor of the probability of C choices, monotonously increasing with CI. In Figure 2 two examples of PD games with CI equal to 0.1 and 0.9, respectively are presented.

Player II

Player I		*C*	*D*
	C	56, 56	0, 60
	D	60, 0	2, 2

CI=0.1

Player II

Player I		*C*	*D*
	C	56, 56	0, 60
	D	60, 0	50, 50

CI=0.9

Figure 2: Examples of PD games with different CI.

Further in the paper, we assumed that CI defines a scale (a cooperativeness scale), along which the PD games can be distributed. By treating cooperativeness as a cognitive dimension measured by CI, we can borrow concepts from psychophysics and investigate for the existence of context phenomena in judgment and decision making similar to those found in psychophysics (see [Vlaev & Chater, 2007]).

Hypotheses

In the light of the goals presented above the following hypotheses are tested:

- When primed with *low*- or *high range CI* games sessions, we expect a change in the whole subject's judgment scale similar to the one observed in psychophysical experiments. The subjects who participated in the *low range CI* condition will underestimate the cooperativeness of the games and those who participated in the *high range CI* condition will overestimate the cooperativeness of the games over the full range of CI's.
- Players move choices depend not only on the game at hand or the combination of games in a session, but also on the previous moves of the player and his opponent, and on the previous game outcomes in the session.

2. Method

Experimental design

The experiment had three parts. In the first part, subjects played a sequence of PD games against a computer. There were three experimental conditions that differed in the CI range of the games.

In the second part, the subjects were asked to judge what people would play in a set of full CI range games, using a 7-point scale. In this stage, we expected to find some differences between the three groups, corresponding to different experimental conditions from the first part.

In the third part of the experiment, we wanted to explore the way subjects perceive games without playing them. In this part, we test if subjects distinguish PD games according to their CI. This would justify the consideration of the latter as an analogue to a psychophysical quantity.

Part 1. Play Against the Computer. Each subject played 50 PD games against the computer. On the interface, the moves were labeled ‘1’ and ‘2’. Further in the paper, we will use for convenience *cooperation* (C) instead of move ‘1’ and *defection* (D) instead of move ‘2’.

The computer uses a modified version of the tit-for-tat strategy that takes into account the 2 previous moves of the player. This allowed the subject to choose her own strategy. The payoffs were presented as points, which were transformed into real money at the end of the experiment. The subjects were asked to play in a way to maximize their score. No emphasis on cooperation and defection has been made. After each game, the subjects got feedback about their and the computer’s choice and could monitor permanently the total number of points they have won and its money equivalent. The subjects received information about the computer’s payoff only for the current game and had no information about the computer’s total number of points. This was made in order to prevent a possible shift of the subject’s goal – from trying to maximize the number of points to trying to compete with the computer by just earning more points than it, as observed in the pretests. Thus, the subjects were supposed to pay more attention to the payoffs and their relative magnitude and indirectly to CI.

The games were randomly generated for each subject with maximal payoff T between 22 and 78 points in order to avoid possible effects due to large differences between the values of the payoffs in different games. Games were presented in a random order with respect to CI.

There were three experimental conditions that differed in the CI ranges of the games played.

- *Control* condition – each subject played 50 games covering the whole range of CI, including 10 games for each CI equal to 0.1, 0.3, 0.5, 0.7, and 0.9, respectively.

- *Low-range-CI* condition – each subject played 50 games, including an equal number of games with CI equal to 0.1 and 0.3.
- *High-range-CI* condition – each subject played 50 PD games with high-range CI, including an equal number of games with CI equal to 0.7 and 0.9.

Part 2. Game ratings. Subjects were asked to make judgments for different games, covering the whole CI range, about their cooperativeness. 35 PD games (equal number of PD games with CI = 0.1, 0.3, 0.5, 0.7, and 0.9) were presented on the computer screen one at a time. The subjects had to respond to the question 'What do you think people would play in this game?' using a 7 point scale – from 'definitely 1 (*C*)' to 'definitely 2 (*D*)'. Subjects did not receive feedback after each game if their rating was right or wrong. But at the end of this part of the experiment they received additional points (money) for their ratings. In this stage, we expected to find some differences between the three groups due to the different experimental conditions in the first part.

Part 3. Free game grouping. Subjects were asked to group 20 games (4 for each CI equal to 0.1, 0.3, 0.5, 0.7 and 0.9, respectively) and specify the criteria applied. The results were transformed in a similarity matrix and used in a multidimensional scaling (MDS) procedure. Here, we wanted to explore the way subjects perceive PD games without playing them (thus discarding direct dynamical effects).

Participants

There were in total 90 participants divided into groups of 30 subjects per condition (42 males and 48 females). All were university students with an average age of 23 years (ranging from 18 to 35 years).

Procedure

Each subject was randomly assigned to one of the three experimental conditions and after being instructed played 9 training games. All subjects participated in all three parts of the experiment and were paid according to the number of points they have got during the experiment.

Dependent variables

Cooperation is measured as the fraction of games in which subjects chose move *C* in the first part of the experiment. It is assumed that cooperation will be influenced by CI of the games, the context (CI range), and the dynamics of the playing.

Cooperation ratings (CR) are judgments subjects made in the second part of the experiment. These ratings were related to the likely move for a given game. In the analysis, these ratings are transformed in cooperativeness ratings. The lower is the scale value on the 7-point scale the higher is the perceived cooperativeness of the game and the higher is the CR. CR are expected to depend on games' CI and on context – the range of the CI of the games played in the first part of the experiment.

The research presented in this article was guided by the broad goal of studying deeper cognitive effects on how people make decisions in iterated PD game. More specifically, we wanted to check to what degree a CI judgment scale exists, how and when it is used by the participants and to what extent it is influenced by relevant context.

By 'context' in the present experiment we understand the specific CI range of the games in a given game sequence played by subjects (e.g. CI = 0.1, 0.3 and CI = 0.7, 0.9 are called low-range-CI and high-range-CI contexts). We expected to observe a change in the judgment scales about appropriate game moves due to this type of context. It was anticipated that subjects who played PD games in a low-range-CI context will underestimate the cooperativeness of the PD games and vice versa, subjects who played PD games in the high-range-CI will overestimate the cooperativeness of the PD games. Moreover, when priming with low- or high-range-CI game sessions, we expected a change in the whole subject's CI scale, including the full range of possible CI values.

PD games used in experiment

The payoff matrices were randomly generated in order to avoid memory effects or big differences in the payoffs for games with the same CI that could favor different strategies (e.g. subjects could pay more attention to games with higher payoffs than to games with the same CI but with much smaller payoffs). Oskamp and Perlman [Oskamp and Perlman, 1965] claimed that the average payoff per trial ((T+R+P+S)/4, see Figure 1) is a very important factor with significant effect on the level of cooperation. Taking this into account, we generated the games so that T is between 22 and 78 points (mean 50), R was between 11 and 76 points (mean 41), P was between 1 and 66 points (mean 16). For simplicity we set S = 0. The mean average payoff per trial was 27 points (SD = 9 points). In order to make the subjects concentrate exclusively on the payoff table when making their choice, they were instructed to try to maximize their payoffs and not for instance to compete with the computer.

The game was presented to them in a formal and a neutral formulation to avoid as much as possible other factors and possible contexts. No cooperation or defection was mentioned in the instructions. Subjects were not informed about the existence of CI.

3. Results and Discussion

Subjects with different strategies with respect to CI

In the first part of the experiment, we defined the context with respect to game sets with different CI range. However, CI is not a PD game characteristic obvious to the subjects. Although it is intuitive (it is reasonable to cooperate more when R is high and P and T are relatively low), there is no guarantee that all of the subjects were able to take advantage of it in their move choices.

As the data from the present experiment show, confirming well known previous results (see e.g. [Rapoport & Chammah, 1965]), there is a significant influence of CI on the cooperation rate in all three context conditions – subjects cooperate more in PD games with higher CI. However, if we look more closely at the data, not all of the subjects in each condition follow this trend. As a factor analysis showed, two groups of strategies can be singled out. For the first strategy (called further CI-based strategy) the dependence of cooperation with CI is a monotonously increasing function while for the second strategy (non-CI-based strategy) no such dependence is seen (see Figure 3). In the full-range-CI (control), low-range-CI and high-range-CI groups there were 12, 13 and 14 subjects, respectively, whose play was consistent with the CI-based strategy. The remaining subjects did not base their strategy on CI.

The mean cooperation, however, was not significantly different for the CI-based and non-CI-based strategies – 36% and 25% ($F(1, 28) = 3.8$, $p = 0.061$) for the full-range-CI group, 24% and 21% ($F(1, 28) = 0.18$, $p = 0.675$) for the low-range-CI group, and 43% and 42% ($F(1, 28) = 0.005$, $p = 0.944$) for the high-range-CI group, respectively.

The analysis of the non-CI-based strategies did not reveal any single simple strategy based on previous moves, game outcome or interaction with the computer. It is also possible that some of the subjects from the non-CI-based group paid attention to the general structure of the payoff matrix and not to the relative magnitudes of the payoffs thus eliminating the CI dependence from their moves.

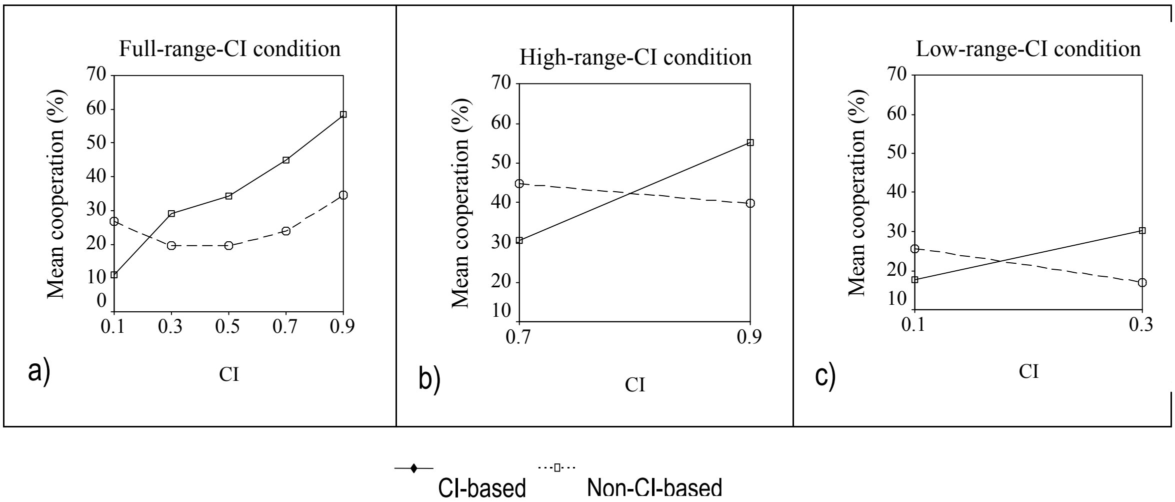

Figure 3: Mean cooperation (% of C choices), in part one of the experiment, for PD games with different CI for subjects with different strategies. a) Full-range-CI condition; b) High-range-CI condition; c) Low-range-CI condition

Whatever the strategy used, the question arises whether the subjects from this second group are sensitive at all to CI. The second part of the experiment shed some light to the answer of this question.

Context effects on cooperation ratings

As stated earlier, our main goal in this paper is to check if the judgments about the cooperation ratings of PD games are influenced by the previously played games. We expected context (defined by the CI range of the games played by each subject group in the first part of the experiment) to influence cooperation rating in the second part of the experiment.

In order to perform this analysis, we computed mean cooperation ratings for the games with the same CI. These average cooperation ratings were analyzed in a repeated-measures analysis of variance with CI as a within-subjects factor and the experimental condition (full-range-CI (control) vs. low-range-CI vs. high-range-CI) as a between-subjects factor. The sphericity assumptions were not met, so the Hyunh-Feldt correction to the degrees of freedom was applied.

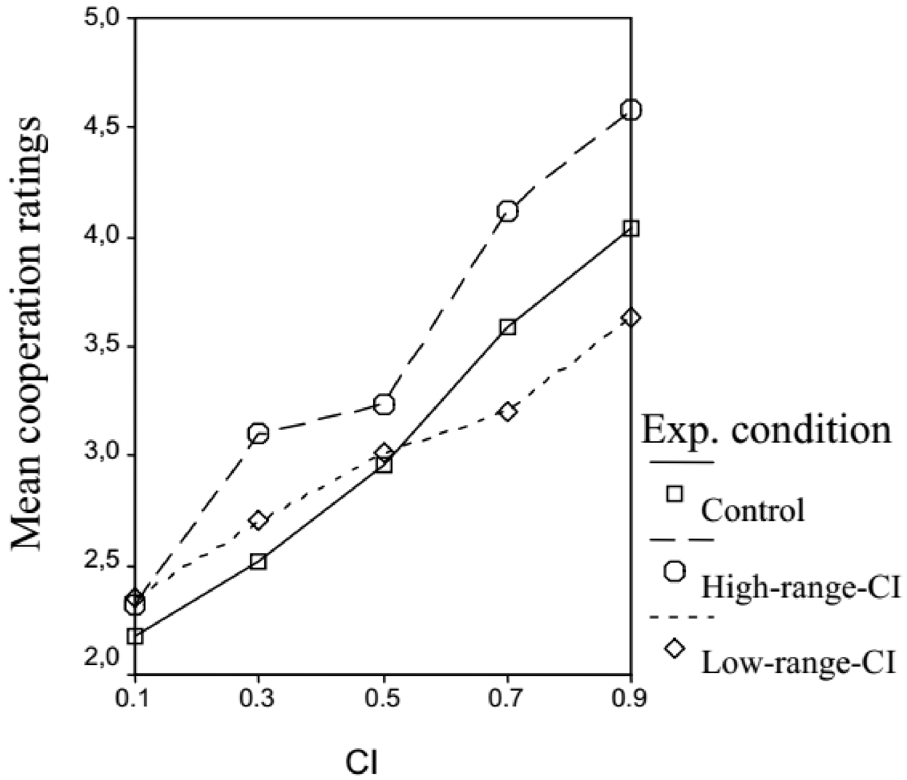

Figure 4: Comparison of the estimated mean cooperation ratings as a function of CI between the three experimental groups.

The interaction between CI and the experimental condition was found to be statistically significant – F(5, 227) = 2.59, p = 0.025 (see Figure 4). In order to compare the experimental groups for each level of CI, a post-hoc test was used. We found a significant difference in the cooperation ratings between the high-range-CI and the low-range-CI experimental conditions for CI = 0.7 (F(2, 87) = 4.98, p = 0.09) and CI = 0.9 (F(2, 87) = 4.1, p = 0.02).

These results confirm our main hypothesis about the influence of context on cooperation ratings.

Further, it is interesting to analyze what are the contribution to this effect coming from the two strategies delineated in each experimental condition – the CI-based and the non-CI-based strategies. To see this, we carried on the same analysis as for the whole experimental groups separately for each strategy subgroup (see Figure 5).

CI-based strategy group. The main effect of CI is significant ($F (3, 109) = 44.85$, $p < 0.001$). Subjects gave higher cooperation ratings with increasing CI (see Figure 5a). Although the main effect of the experimental group is not significant ($F (2, 36) = 2.247$, $p = 0.12$), there is a statistically significant interaction between CI and the experimental group ($F (6, 109) = 2.196$, $p = 0.048$). We found also a significant difference in the cooperation ratings between the high-range-CI and the low-range-CI conditions for CI = 0.7 ($F(2, 38) = 4.62$, $p = 0.016$) and CI = 0.9 ($F(2, 38) = 3.66$, $p = 0.036$). The subjects in the high-range-CI group gave higher overall cooperation ratings compared to the subjects in the low-range-CI group. This result is in accordance with our preliminary hypotheses. This effect is stronger for higher CI (0.7 and 0.9) and indiscernible for CI = 0.1. One possible explanation for the latter is that the strategy D is the dominant strategy for one-shot PD games and remains prevalent for iterated PD as well. The number of moves C is relatively small and is about 20% for low CI. This can lead to very small differences in cooperation for the different context conditions, which are beyond the sensitivity of the present experiment.

Non-CI-based strategy group. Surprisingly, in the non-CI-based strategy group, the main effect of CI was also significant ($F(3, 137) = 33.12$, $p < 0.001$). Subjects gave higher cooperation ratings with increasing CI as in the CI-based strategy group (see Figure 5b). However, neither the main effect of the experimental group ($F (2, 48) = 1.625$, $p = 0.208$) nor the interaction between CI and the experimental group ($F (6, 137) = 1.039$, $p = 0.402$) were significant. Thus, no context effect was observed for the non-CI-based group despite the fact that they took into account CI in their judgments.

This result can be explained by assuming that only the CI-based strategy group from part one of the experiment was influenced by the manipulation of the context (playing different sets of games with respect to CI). The non-CI-based group although sensitive to CI, as evinced by the judgment task in the second part of the experiment, didn't pay or paid less attention to the payoff's relative magnitudes and thus remained uninfluenced by the context.

In this way, it seems that the context effect observed in the experiment came mainly from subjects with the CI-based strategy in part one (see Figure 5a). The non-CI-based group was not influenced noticeably by the context. The latter, however, showed the same qualitative dependence of cooperation on CI and demonstrated that all subjects were sensitive to CI. In order to understand better this relation we analyze for each experimental group the difference between the two strategies in cooperativeness ratings.

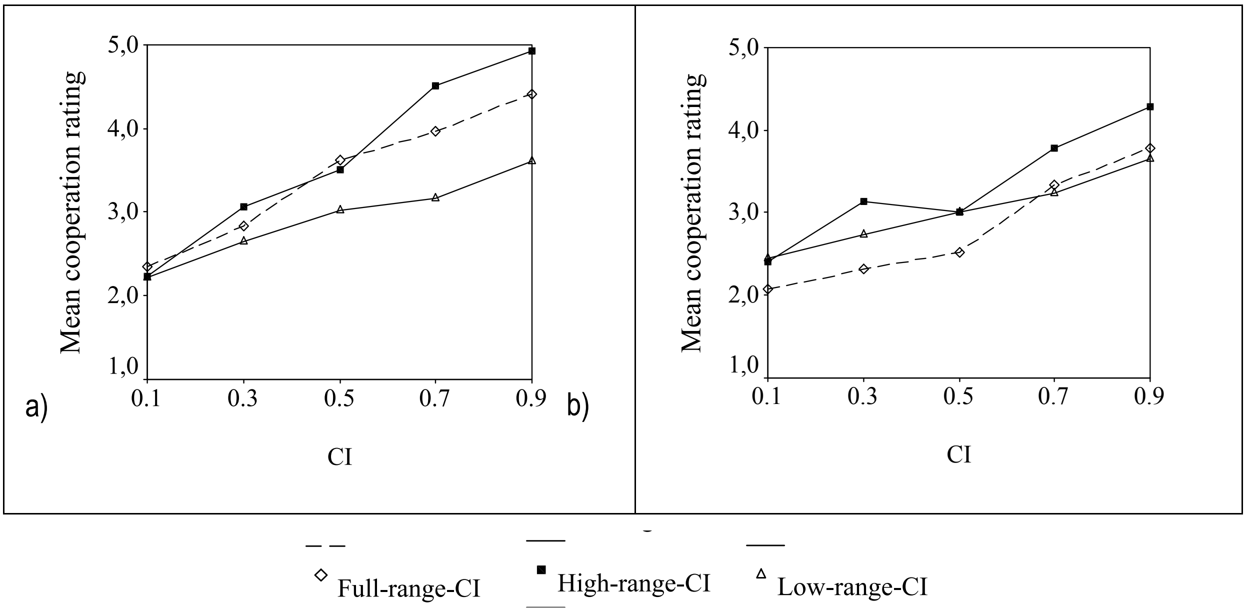

Figure 5: Mean cooperation ratings for PD games with different CI for each experimental condition: a) CI-based strategy subjects; b) non-CI-based subjects.

In Figure 6, the same data as the one plotted in Figure 5 is presented, but for each experimental condition.

In the full-range-CI condition, the CI-group gave more cooperative ratings than the non-CI-group ($F(1,28)=6.35$, $p = 0.018$). On the other hand, both groups of subjects show CI sensitivity in their judgments – they give higher ratings for games with higher CI. The effect of CI is significant ($F(3, 66) = 32.76$, $p < 0.001$) and the interaction between the CI and the strategy is not significant.

a)

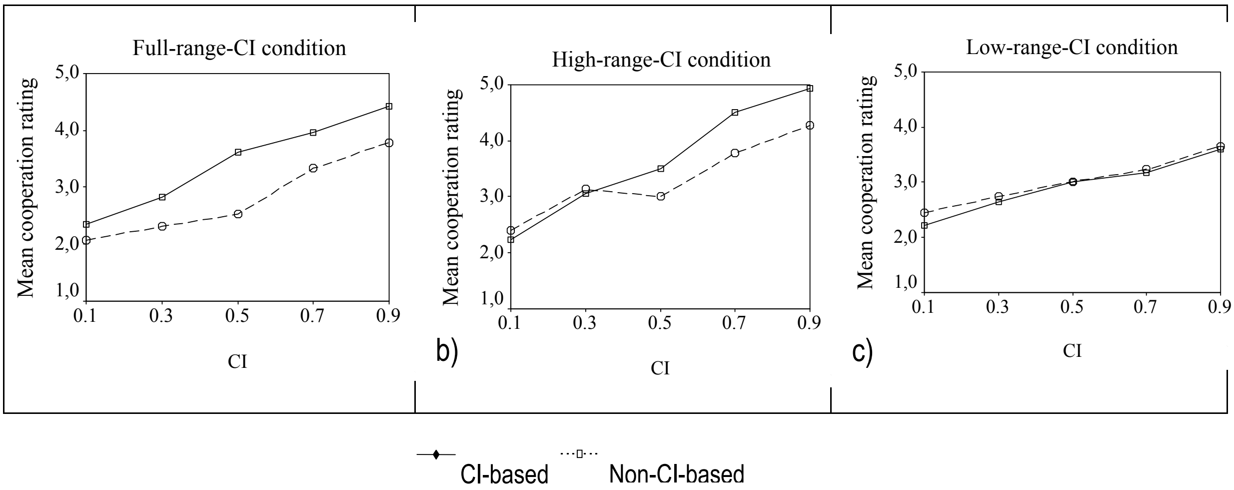

Figure 6: Mean cooperation ratings in part two of the experiment for PD games with different CI for subjects with different strategies. a) Full-range-CI condition; b) High-range-CI condition; c) Low-range-CI-Condition.

In high-range-CI and in the low-range-CI condition there is no significant difference in the cooperation ratings between the two strategy groups of subjects. Both groups of subjects show CI sensitivity in their judgments – they give higher ratings for games with higher CI. The effect of CI is significant ($F(3,79) = 37.85$, $p < 0.001$ and $F(3,68) = 11.6$, $p < 0.001$, respectively). The interaction between CI and the strategy is not significant.

Therefore, all subjects gave higher cooperation ratings with increasing CI. In this part of the experiment, they were not engaged in playing and the main basis for cooperation ratings was the payoff matrix.

It is interesting to note that in Figure 6, full CI scales can be seen even for the low-range-CI group and for the high-range-CI group, which have not seen the full CI range of games. Recently, the question of the existence of absolute scales has been discussed (see e.g. [Stewart et al., 2003]) and the case made that subjects do not have absolute scales.

Multi-dimensional scaling

In the third part of the experiment subjects had to divide 20 games into similarity groups with respect to the magnitude and structure of the payoffs. No context effect has been found in the grouping in the three experimental conditions. The similarity tables were strongly correlated ($r > 0.85$, $p < 0.001$) and the data have been analyzed together. The MDS revealed that at least three dimensions are needed to explain the grouping done by the subjects.

In Figure 7, a two-dimensional solution is presented, corresponding to the two most important dimensions. It shows clearly separated groups of games with the same CI. This result confirms that subjects effectively distinguish games with respect to their CI.

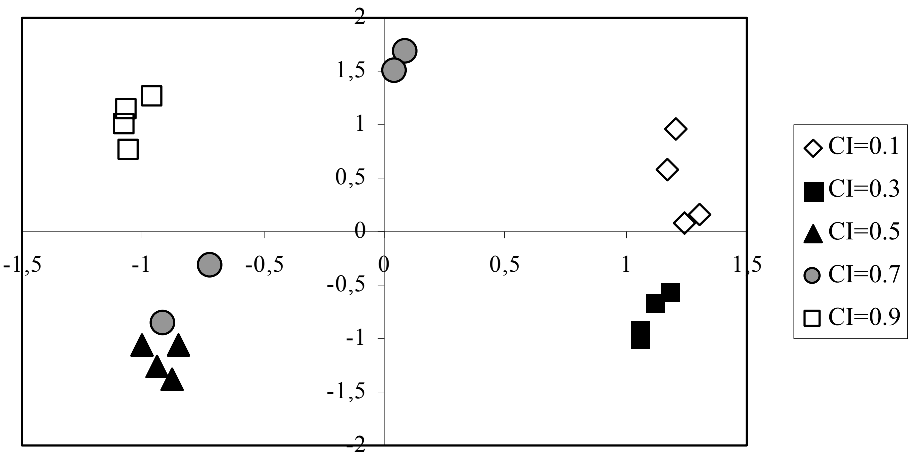

Figure 7: MDS results for games with different CI.

Effect of CI on Cooperation

It is largely accepted that when the CI increases the relative number of C choices also increase.

For each experimental condition, cooperation (the fraction of cooperative choices in %) was analyzed in a repeated-measures analysis of variance with CI as a within-subjects factor. The main effect of CI on cooperation was significant for the control condition, $F(4,116) = 11.43$, $p < 0.001$ and for the high-range-CI condition, $F(1,29) = 7.192$, $p = 0.012$. It was not significant for the low-range-CI condition.

In the control condition, although the main effect of CI was significant, planned contrasts showed that the cooperation increased only for PD games with CI = 0.9. In the low-range-CI condition, there was no significant difference in cooperation for games with CI = 0.1 and CI = 0.3. In the high-range-CI condition, the cooperation for games with CI = 0.9 was significantly higher than the one for games with CI = 0.7. It seems that the effect of CI is observed only for higher CI (0.9). When CI is between 0.1 and 0.7, there is no significant difference in cooperation.

There are several possible explanations of these results. One possibility may be that subjects cannot distinguish between CI lower or equal to 0.7. It seems that this is not the case as indicated by the results of MDS and by the fact that there was very strong effect of CI on CR subjects made. Another possibility is that cooperation is influenced in greater extend by other factors, such as the game dynamics and context.

Effect of previous game on cooperation. Performing this analysis, we wanted to test whether a particular player's move depends only on the game at hand (payoffs, structure etc.) or also on the previous moves and game outcome.

In Figure 8, the relationship between game outcome and next move is shown. When the previous game outcome was DD, CD or DC the cooperation was between 26 and 28%. However, in the case of a CC outcome the cooperation increased to 56 %, $\chi^2 = 208.3$, $p < 0.001$.

The increase in the cooperation when the previous game outcome was CC was more prominent in high-range-CI condition – from 32–38% (for all other game outcomes) to 68%. The increase in cooperation was also significant for the control condition (from 26–29% to 41%) and for the low-range-CI condition (from 20–21% to 44%).

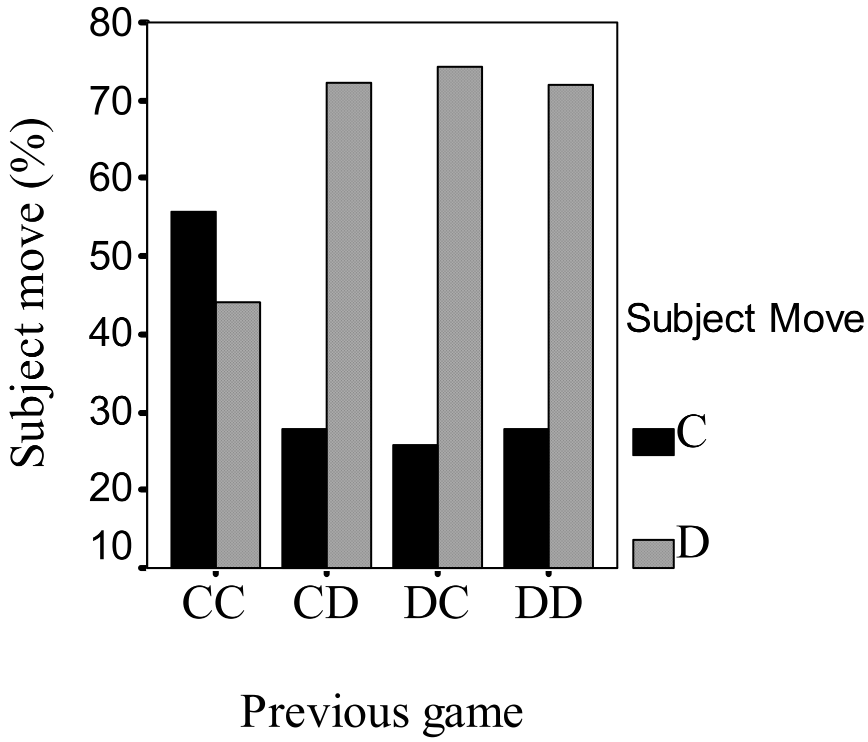

Figure 8: Effect of the previous game outcome on subjects' moves.

4. Conclusion

In this paper, we presented an experiment designed to investigate dynamical and context effects in iterated PD games. The initial hypotheses were confirmed largely. Context effects were observed both in subjects' choices in the first part of the experiment and in their cooperation ratings in the second.

In the second part of the experiment, significant differences between experimental conditions have been observed. Subjects participating in the low-range-CI condition gave lower cooperation ratings for PD games with CI equal to 0.7 or 0.9 than subjects participating in the high-range-CI condition. On the other hand, for the other values of CI no significant difference could be found. One possible reason is the fact that move D is the most probable (more than 70% of the cases) and we could not reach statistical significance although differences may have been present. A future experiment must shed light on this problem.

Probably these results mean that in the iterated play of PD games, there are strong dynamical context factors that influenced the subjects' decisions apart from CI of the current game. The most important of them was found to be the previous game outcome. Subjects made more choices that are cooperative after a game where both players have cooperated, compared to cases with different outcomes. Additionally, a tendency was observed in the first part of the experiment, that in the course of the game the cooperative choices decreased. This effect was most pronounced for the high-range-CI condition and shows an initial cooperative attitude, although the subjects played against a computer.

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The obtained results demonstrate the complexity of the cognitive processes involved in PD game playing and cooperativeness judgment. They support the conclusions that subjects are influenced by previous experience (context) in their judgment of the cooperativeness of PD games. Interestingly, subjects who did not take CI into account in their actual strategy choices were also influence by CI in their cooperation ratings. The finding that participants are sensitive to CI no matter how they play is supported by the MDS analysis. The fact that this sensitivity to the payoff structure is not seen in actual play is attributed to the dynamic of the play related to the moves of the opponent and the respective game outcomes which was evidenced by the found dependency on the previous game outcome.

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