# A First Experimental Test of Multilevel Game Theory: The PD Case

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**Abstract**

The prisoner's dilemma is played by two players in each of two groups. The two groups compete for an external prize whose allocation is determined by the degree of within-group coordination. The experimental evidence supports the predictions of multilevel game theory well.

## 1. Introduction

Many real-life interactive situations involve simultaneous interaction at several levels of organization. Interaction between groups affects interaction within groups.

Outside economics, multilevel conceptions are present within political science, international relations, mathematical sociology (micro-macro debate), network analysis, complexity research, social psychology,[1] evolutionary biology (group selection), philosophy (aggregativity). Within economics, the impact of interaction between groups on the interaction within groups has been predominantly analyzed for the impact of product-market competition on managerial slack, the impact of between-group competition on within-group behavior with no external rent, and within the collective rent seeking literature which conceptualizes agents within groups as simultaneously striving for payoffs and public goods at two organizational levels.[2]

Hausken and Cressman (2004) have developed a multilevel game theory, allowing for arbitrarily many levels, and arbitrarily many actors at each level. Strategy sets and payoffs are translated between levels, and multilevel Nash equilibria are determined. This article is the start of a program that tests multilevel game theory experimentally.

## 2. Design

We investigated within-group interaction in the prisoner's dilemma in the parameterization shown in Table 1, for two players in each of two groups:

Table 1. Within-group PD game.

| | | Column player | |
|---|---|---|---|
| | | One | Two |
| Row player | One | 3,3 | 1,4 |
| | Two | 4,1 | 2,2 |

We investigated the impact of interaction between groups on the interaction within groups by letting the two groups compete for an external prize, or rent, P. Multilevel game theory predicts a switch from defection to cooperation as prize P increases from below to above 4 (Hausken 1995:474).

[1] Bornstein and Rapoport (1988) have also performed experimental research, accounting e.g. for social psychological phenomena such as preplay communication, and showing e.g. that intergroup competition may enhance cooperation.

[2] See Hausken and Cressman (2004) for references.

The between-group payoff is determined by the degree of cooperation (One) in each group. If the sum of the payoffs earned by the two members of the first group is a) larger, b) equal to, or c) smaller, than the sum of the payoffs earned by the two members of the other group, then the two members of the first group share equally a) the entire external prize P, b) 50% of prize P, or c) 0% of prize P, respectively.[3]

We varied the prize from 0 to 24. Specifically, we ran participants through 14 rounds with an external prize sequence P = 0, 24, 2, 12, 0, 8, 4 which we repeated once. Subjects did not receive feedback on the outcomes of their choices until after the last round. This set-up is generally considered a reasonable approximation of one-shot games. The repetition of the prize sequence was motivated by recent evidence that simple repetition does affect choices (Weber 2004) and indeed we find this in our experiment, too.

In each round, we paired each participant with three other participants (one in her or his group and two in the "competing" group) who were randomly drawn from the participants in the experimental session. Matching scheme and parameterization were common knowledge.

## 3. Implementation

Because of laboratory constraints, the experiment was conducted in two sessions. Each of the sessions had twelve participants for a total of twenty-four participants. Participants were recruited at the Center for Economic Research and Graduate Education (CERGE) and the Institute of Economics Studies (IES), both graduate programs of economics at Charles University in Prague, Czech Republic. Participants were promised that on average they would earn between 300 and 400 Czech Koruns[4]; they were also told that their actual payoff would depend on their decisions, and the decisions of other participants, during the experiment. About half of the students had previously encountered game theory.

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[3] Two cooperators in one group share the entire prize when there is one cooperator in the other group. With allocation proportional to the number of cooperators in each group, indifference between cooperation and defection occurs when P=12 (Hausken 1995:476).

[4] According to the official conversion rate 100 koruns are about $4. In terms of real purchasing power it is about twice as much. E.g., a large glass of beer is less than $1 in a neighborhood pub. Thus, our subjects faced an interactive choice task with relevant pecuniary consequences.

The experiment was conducted on the Bank Austria Portable Experimental Laboratory (seehttp://home.cerge-ei.cz/ortmann/BA-PEL.html for technical specifications). One session was conducted at CERGE, the other at IES. In both sessions, subjects were seated randomly and then read the instructions (see http://home.cerge-ei.cz/ortmann/instructions.html) which explained the within-group PD game as well as the interaction with the other group, and the matching scheme.

To make their options as clear as possible to our subjects, we presented them – as part of the instructions -- with a table which listed the 16 combinations of actions caused by four players choosing between two actions, and the associated payoff. We also specified the between-group payoff as a function determined by the degree of cooperation (One) in each group. The subjects were not informed that the Nash equilibrium was to choose One (cooperation) when P=4, and to choose Two (Defect) when 0=P=4.

The instructions (which were in English) were read aloud and distributed on paper which subjects were allowed to refer to as the experiment unfolded on the screen. All monetary units were in Experimental Currency Units (ECU), converted to CZK at the end of the experiment, at a conversion rate of 1 ECU = 5 CZK ˜ 1/6 Euro ˜ $1/5. The average total payoff per subject was 297 CZK, min payoff 225 CZK, max payoff 347.5 CZK. Students were also paid a show-up fee of 50 CZK.

**4. Results and Discussion**

The aggregate results of the two sessions are shown in Figure 1 below.

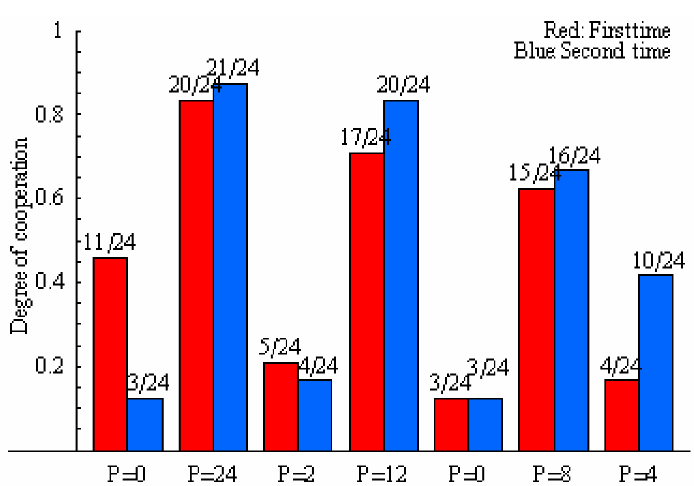

Fig. 1. Experimental results.

Proceeding from left to right, the seven red columns present the degree of cooperation (measured as frequency of choices of One) in the first seven rounds, while the seven blue columns present the degree of cooperation in rounds 8-14 in which we repeated the prize sequence from the first seven rounds.

The first round P=0 result with 11 subjects out of 24 cooperating is typical for PD games that are played the first time, or once (e.g., Ortmann & Tichy 1999; see also Camerer 2003). In contrast, the 8$^{th}$ round P=0 result reveals 3 participants that cooperate, which is also the degree of cooperation in rounds 5 and 12. This reduction is significant, but not to zero. A few subjects cooperate for reasons that might have to do with bounded rationality or outright subject confusion (e.g., Simon 1955; Andreoni 1995), altruism (Andreoni & Miller 2002), or false expectations of what other players might do. The remarkable fact is that in rounds 5, 8, and 12 only 3 out of 24 participants cooperate, a percentage much lower than what one finds typically in the literature (e.g., Ortmann & Tichy 1999, see also Camerer 2003).

Increasing the prize to P=24 induces 20 and 21 participants to cooperate, in rounds 2 and 9, respectively. The degree of cooperation when P=24 is as close to one as the degree of defection when P=0. Decreasing the prize to P=2 in rounds 5 and 10 induces only 5 and 4 participants to cooperate, respectively, a result roughly in line with the prediction of multi-level game theory.

Increasing the prize to P=12 in rounds 4 and 11 induces 17 and 20 participants to cooperate, respectively, while P = 8 in rounds 8 and 12 yields 15 and 16 cooperators, respectively. This latter result is still above 50%, but subjects appear to realize that the prize, when allocated to two or four subjects, is not significantly larger than the within-group payoffs.

Nash equilibrium theory predicts indifference between cooperation and defection for P = 4 and that is indeed what we approximately see in round 14, up from only 4 cooperators in corresponding round 7.

Although Nash equilibrium theory predicts an abrupt switch from defection to cooperation as prize P increases from below to above 4, Fig. 1 reveals a smoother transition. Attempting to explain anomalous behavior in one-shot games, Goeree and Holt (2001:1416-1418) model players' introspective thought processes and propose a logit specification for which the choice probabilities of actions are proportional to exponential functions of the associated expected payoffs, and the error parameter determines how sensitive choice probabilities are to payoff differences. The monotonicity of behavior in our experiment that is revealed in Fig. 1 seems to suggest such an explanation.

Interestingly, especially in light of Weber (2003), Fig. 1 also shows that learning occurs through the 14 rounds, even without feedback on actions until after the last round. For P=0, a substantial number of subjects, 8, correctly learn to defect rather than cooperate from round 1 to round 5. For P=2, one subject correctly learns to defect rather than cooperate from round 3 to round 10. For P=24,12,8, from one to three subjects correctly learn to cooperate rather than defect from rounds 2,4,6 to rounds 9,11,13. For P=4, if we interpret indifference to theoretically imply 12 cooperators out of 24 subjects, we may tentatively say that six subjects correctly learn to cooperate rather than defect from round 7 to round 14. Hence consistently for all prizes subjects adjust their behavior correctly, toward either cooperation or defection, from the first time (rounds 1-7) to the second time (rounds 8-14) of any given prize. Such overwhelmingly correct learning moves nicely into the direction of the theory.

## 5. Conclusion

Our first experimental test of multilevel game theory, applying the prisoner's dilemma, suggests that the theory is well supported by the empirics. In our subsequent research we shall test the BoS/Chicken games. Since these games have multiple equilibria, a different experimental design will be used.

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