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and Asymmetric Prisoner's
Dilemma Games**

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Cooperation in Symmetric and Asymmetric Prisoner's Dilemma Games*

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Abstract

We experimentally study the effect of asymmetry on cooperation in a 40 period prisoner's dilemma game in fixed partner design. We distinguish between a high and low payoff symmetric prisoner's dilemma and an asymmetric game combined out of both symmetric ones. Asymmetry significantly decreases cooperation, as low-type players are significantly more likely to defect after mutual cooperation and high-type players tolerate defection significantly more often than the former. Asymmetry also has a significant negative effect on the stability of cooperation rendering long sequences of mutual cooperation extremely rare. In addition, we also find that lower payoff differences enhance the stability of cooperation in the symmetric game.

JEL-Classifications: C81, D70, C91.

Keywords: Symmetry, Asymmetry, Payoff Differences, Prisoner's Dilemma, Experiments.

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1 Introduction

The prisoner's dilemma (PD) has been an important model of conflict in economics, psychology, political science, sociology and biology as well as other disciplines for over five decades. Previous experiments on the PD have shown that in contrast to theoretical predictions, cooperation rates have generally been very high in the symmetric payoff variant of the game. The present paper studies cooperation in the PD in a more realistic scenario by systematically analyzing the effects of asymmetric payoffs.

Almost all studies investigating the PD are designed in such a way that payoffs are identical for both players.¹ Asymmetry is, however, an important property of many economic and non-economic problems. Most real world interactions entail different outcomes for each player, even if all players choose cooperatively.² The same obviously applies if all decide non-cooperatively. The present research focuses on this much broader type of conflict. We modified the symmetric payoff matrix in such a way that both the cooperative and the defection payoff for player i is either larger or equal to that of player j . We therefore depart from the standard approach to study social interactions characterized by conditions of symmetry and equality. A systematic analysis of the asymmetric PD is not only a valuable addition to the existing (mostly symmetric) PD literature but it is also of particular relevance for understanding reciprocity, equity and fairness especially in light of recent theoretical developments based exclusively on symmetric experimental games (see for instance Fehr and Schmidt (1999) who base their theory of inequity aversion on findings of symmetric games; see also Fehr and Schmidt (2003)).³

¹See Flood (1958) for the first experimental analysis of the game that at the same time is also an exception to this rule.

²Asymmetry plays an important role in various areas spanning from, for instance, competition policy questions surrounding collective dominance or a cartel stability issues (see Friederiszick and Maier-Rigaud (2006)) to governance questions surrounding collective action problems and the management of common-pool resources (see Ostrom (1990)).

³As Murnighan et al. (1990, p.181) note: "research has been inexplicably absent on the

Referring to the classic strategy tournaments by Axelrod (1984), Murnighan (1991, p. 464) writes:

“Axelrod (1984) found that certain strategies (tit-for-tat) effectively train an opponent to choose cooperatively. As a result, both parties do well and the likelihood that they will fall into mutual non-cooperation is minimized. Axelrod posits that similar results as found in the two-person, symmetric, iterated games would follow from games that satisfy PD’s requirements even if the players’ payoffs differ. Findings on asymmetric PD’s question the generality of Axelrod’s claim.”

According to Murnighan, asymmetric dilemmas require much more complicated negotiations than typical PD games. The dilemma no longer consists of a relatively simple choice between the risks of mutual cooperation and the regrets of mutual defection. The complexity of the game adds more dynamic considerations. Pairs who can implement schemes of alternations do much better in increasing their payoffs while simultaneously reducing the temptation to defect. As a result, the main hypothesis of this paper is that asymmetry reduces cooperation rates. Asymmetry increases the complexity of the game by adding to the problem of cooperation the problem of reaching a mutual understanding of what a desirable outcome is.

Asymmetry is not a well-defined concept, though. There is not only an infinite number of combinatorial possibilities but asymmetry can also be introduced in some cells only or in a design where no player has consistently higher payoffs than the other in each cell (c.f. Murnighan et al. (1990), and Murnighan and King (1992)). Finally, including negative payoffs adds an additional dimension.⁴ As the review of the literature on asymmetric PD games in Section 3 will show,

effects of asymmetry”. See also Hennig-Schmidt (2002) and de Jasay et al. (2004) for a critique of the “symmetry” approach.

⁴According to Kahnemann and Tversky (1979) and Tversky and Kahnemann (1981), negative payoffs can have a substantial impact.

cooperation rates are not easily comparable: not only do the payoff parameters vary across studies but also the number of repetitions, the matching protocol, the remuneration and the justification for the asymmetry presented to participants render the experiments difficult to compare. As Lave (1965) and others have shown, these factors can have an important influence on cooperation rates.

Given the problems of comparability, we chose a comprehensive experimental design to systematically compare behavior in symmetric and asymmetric situations (SYM, ASYM respectively) .

We analyze two symmetric and one asymmetric PD game played repeatedly with a fixed opponent over 40 periods under perfect information. In SYM, we consider two symmetric treatments with HIGH and LOW payoffs for both players where $LOW = \frac{2}{3}$ of HIGH. ASYM is an asymmetric combination of both symmetric games where player i gets the high payoff and player j the low payoff of the SYM treatments.

We observed 70.00% cooperation in LOW, 59.17% in HIGH and 38.75% in ASYM, a substantial and significant difference between treatments. Cooperation patterns are unstable roughly until period 10. Cooperation then stabilizes at a rather high level of about 80% in LOW, and 65% in HIGH. In ASYM, cooperation gradually rises from 15% to about 55% until period 33. In all treatments, there is a strong time effect and we observe an end effect starting in period 37. The general finding that cooperation is increasing over time is in line with other studies (Rapoport and Chammah (1965), Lave (1965), Murnighan and King (1992), Brenner and Hennig-Schmidt (2006)).

As hypothesized, asymmetry indeed substantially decreases cooperation rates, pointing towards the higher complexity of the game, whereas symmetry has a positive effect on mutual cooperation. We also find that high-type players tolerate defection more often than low-type players. Defection by low-type players, possibly motivated by the aim to equalize payoffs, is less often answered or more readily tolerated by high-type players. With respect to the stability of coopera-

tion, we find that asymmetry has a negative impact rendering long sequences of mutual cooperation extremely rare. Low-type players are more likely to defect after mutual cooperation than high-type players.

In addition to the hypothesized effect of asymmetry on cooperation, we also find lower payoff differences in LOW to enhance the stability of mutual cooperation once it has been reached, i.e. CC is followed by CC more often in LOW than in HIGH or ASYM.

The remainder of the paper is organized as follows. Section 2 presents the games studied. Section 3 reviews the relevant experimental literature on symmetric PDs and the limited experimental literature on asymmetric PDs. Section 4 gives a detailed description of the experimental design and the experimental protocol. Section 5 presents the results and section 6 concludes with a discussion of the main findings.

2 The Prisoner's Dilemma Game

Table 1 presents a typical 2-player matrix game in normal form. This game is a PD if and only if the following conditions are met for both player i 's and j 's payoffs:

$$a > b > c > d \tag{1}$$

and

$$2b > a + d > 2c \tag{2}$$

The first part of the second condition goes back to Rapoport and Chammah

Table 1: General 2×2 prisoner's dilemma game in normal form (PD)⁶

	Cooperate	Defect
Cooperate	(b_i, b_j)	(d_i, a_j)
Defect	(a_i, d_j)	(c_i, c_j)

(1965) who proposed it in the context of iterated (symmetric) PD's in order to eliminate the possibility of simple alternation between DC and CD providing higher payoffs than mutual cooperation thus removing the dilemma.⁵

The formal presentation in table 1 is more general than the presentations usually found because it also accounts for asymmetric payoffs. In symmetric games, the indexed payoffs are equivalent to each other such that e.g. $a_i = a_j = a \forall i \neq j$.

It is well known that both players defecting is the unique Nash equilibrium of the one-shot PD game. Applying the logic of backward induction, Luce and Raiffa (1957) showed that the unique Nash-equilibrium outcome in the finitely repeated PD game under perfect information is again the one in which both players defect in every single period. In fact, the unique subgame-perfect equilibrium is both players defecting in all periods (see, e.g., Binmore (1992)).⁷

The general formulation of the PD makes no restriction as to symmetry or asymmetry of players' payoffs. The asymmetric PD can be operationalized in many ways as long as at least one of the payoffs a_i to d_i differs from a_j to d_j in table 1. Our present study assumes $a_i > a_j$, $b_i > b_j$, $c_i > c_j$, $d_i = d_j$, that is, the payoffs of player j are 2/3 of the payoffs of player i . The parameters are given in

⁵There exist several experimental studies with iterated PD games that violate this assumption and thereby no longer allow a separation of effects due to asymmetry or payoff maximization through simple alternations. In the experiment by Lave (1965) and by McKeown et al. (1967) the condition is violated for one of the players. Murnighan et al. (1990) and Murnighan and King (1992) implement so-called asymmetric dilemmas knowing that a subset of the games discussed violates the condition either for one or for both players.

⁶Note that the first element of the payoff vectors refer to the row player.

⁷For an overview of the theoretical literature see e.g. Binmore (1992) and Osborne and Rubinstein (1994).

table 2.

Table 2: Experimental parameters

	HIGH	
	Cooperate	Defect
Cooperate	(12,12)	(0,18)
Defect	(18,0)	(6,6)
	LOW	
	Cooperate	Defect
Cooperate	(8,8)	(0,12)
Defect	(12,0)	(4,4)
	ASYM	
	Cooperate	Defect
Cooperate	(12,8)	(0,12)
Defect	(18,0)	(6,4)

3 Experimental Research on Symmetric and Asymmetric PDs

Almost all studies investigating the PD analyze symmetric situations. A few studies are devoted to asymmetric settings though. In the following subsection, we first refer to some relevant experimental papers on symmetric PDs. In subsection 3.2, we will give an overview of the experimental literature on asymmetric PD games.

3.1 Experimental Research on Symmetric PDs

Rapoport and Chammah (1965) conducted a series of laboratory experiments in which participants played a PD game repeated over 300 periods. Depending on the parameters of the game, overall cooperation rates varied between 26.8 and

77.4%. The authors found mutual cooperation in 53% of all dyads and more than 23% in the last 25 periods. Mutual defection took place in 17% of the dyads. Cooperation in the first period varied between 45 and 70% decreasing in the second period to 35 - 65%. Inquiring into the dynamics of the decision process, Rapoport and Chammah found cooperation waning in the first half of the experiment. Thereafter, cooperation increased to roughly the level at the beginning of the experiment with mutual cooperation rising steadily. The authors attribute this phenomenon to the fact that “Learning goes both ways in Prisoner’s Dilemma. First the subjects learn not to trust each other; then they learn to trust each other” (p. 201).

Studies on the PD with a much lower number of periods and restart effects show that average cooperation levels start relatively high between 40%-60%; and then gradually decline over time.

Selten and Stoecker (1986) investigated behavior in a repeated prisoner’s dilemma game with $a_i = a_j = 145$, $b_i = b_j = 60$, $c_i = c_j = 10$, $d_i = d_j = -50$. 35 participants played a ten-period PD in stranger design repeated 25 times. The most common pattern of behavior was initial periods of mutual cooperation followed by an initial defection that was then followed by non-cooperation in the remaining periods. The authors also find players exhibiting end effect play. The end effect is defined as at least four consecutive periods of mutual cooperation with no further cooperation following the first defection thereafter. A very striking result is the emergence of the first defection. Players start to defect earlier and earlier in subsequent supergames so that cooperation unravels from the end.⁸

Andreoni and Miller (1993) analyze a 10-period PD in partner design repeated 20 times with changing the co-player each repetition. They also study how people behave if they have a 50/50 chance to meet a computer player playing a tit-for-tat strategy. Parameters are $a_i = a_j = 12$, $b_i = b_j = 7$, $c_i = c_j = 4$, $d_i = d_j = 0$.

⁸For an extensive discussion of the paper see Roth (1995).

Average cooperation rates start relatively high at around 60% and subsequently decrease until period 6 (8) where a sharp end effect is observed. Looking at the first period of defection over the 20 supergames there is a clear tendency for cooperation to last until later periods.

Maier-Rigaud and Apesteguia (2006) analyze a 20-period PD in partner design. Parameters are $a_i = a_j = 400$, $b_i = b_j = 300$, $c_i = c_j = 100$, $d_i = d_j = 0$. Average cooperation started at almost 70% and declined to below 30% in the first three periods. It rose to approximately 60% and then declined more or less steadily throughout the game to approximately 20% in the last period. Overall cooperation was 33%.

For surveys of the experimental literature on symmetric PD games, see Lave (1965), Rapoport and Chammah (1965), Oskamp (1971), Roth and Murnighan (1978), Roth (1995) and Ledyard (1995).

3.2 Experimental Research on Asymmetric PDs

There is only a small literature on asymmetric PD games exhibiting a substantial variation in experimental conditions.⁹

Schellenberg (1964) ran symmetric and asymmetric experiments with $a_i = a_j = 5$, $b_i = b_j = 3$, $c_i = c_j = 1$, $d_i = d_j = 0$ in the symmetric treatment. Asymmetry was obtained by multiplying the payoffs of one of the players by two, i.e. $a_i = 10$, $a_j = 5$, $b_i = 6$, $b_j = 3$, $c_i = 2$, $c_j = 1$, $d_i = d_j = 0$. Two series of experiments of 20 periods each were conducted where participants were rewarded by course credit.

In the first series of experiments, participants played against “stooges” that either followed an initially cooperative and increasingly non-cooperative strategy or an initially non-cooperative and increasingly cooperative strategy. The main

⁹The first PD experiment by Flood and Dresher (c.f. Flood (1958)) assumed asymmetry in the diagonal and in d , i.e. $b_i \neq b_j$, $c_i \neq c_j$, $d_i \neq d_j$, but $a_i = a_j$, i.e. $a_i = a_j = -1$, $b_i = 0.5$, $b_j = 1$, $c_i = 0$, $c_j = 0.5$, $d_i = 1$, $d_j = 2$.

finding based on the first series of experiments is that participants are more cooperative in the high-type player role and less cooperative in the low-type player role in the asymmetric game, the symmetric baseline game yielding cooperation rates in-between. In the series of experiments where no “stooges” were used Schellenberg did not find higher cooperation rates for high-type players. Schellenberg explains this interaction effect by the low cooperation of low-type players. The second series of experiments did not yield statistically significant differences between symmetric and asymmetric games.

Sheposh and Gallo (1973) ran symmetric and asymmetric experiments with $a_i = a_j = 5$, $b_i = b_j = 4$, $c_i = c_j = 1(-2)$, $d_i = d_j = 0(-3)$ in the symmetric treatments. Asymmetry was obtained by multiplying the payoffs of one of the players by three, i.e. $a_i = 5$, $a_j = 15$, $b_i = 4$, $b_j = 12$, $c_i = 1(-2)$, $c_j = 3(-6)$, $d_i = 0(-3)$, $d_j = 0(-9)$.

Participants played for real money. The authors hypothesized cooperation in the asymmetric treatment to be less than in the symmetric treatment. In particular, low levels of cooperation were expected from participants with lower payoffs. If their orientation is to minimize disparity of payoffs their only recourse would be minimal cooperative play.

80 participants played the game in pairs for 50 periods with feedback information on payoffs in each period. The dependent measure was the number of cooperative choices. The statistical method used for analyzing the results was ANOVA.¹⁰ The asymmetric game produced significantly less cooperative behavior than the symmetric game (31.1% vs. 39.2%). Low-type players cooperated significantly less than high-type players (25.1% vs. 37.1%).

The authors then conducted a data analysis in terms of the conditional probabilities of one player’s response in a given period as a function of the other player’s choice in the preceding period. Were participants concerned with relative out-

¹⁰See section 5 and Appendix A for a discussion of this method and its pitfalls for analysing categorical data.

comes and did they try to avoid being surpassed by the other player? The smaller amount of cooperation in the asymmetric treatment was attributable to the significantly lower proportion of cooperative moves by participants in the low-type position. Sheposh and Gallo’s tentative interpretation is that participants’ concern centered on the relative payoff rather than absolute personal gain. Low-type players consequently avoided cooperative play in order to reduce other’s actual payoffs. Participants were less concerned with the notion of increasing their own payoffs than with redressing the imbalance caused by the asymmetrical structure of the game.¹¹

Talley (1974) conducted several experiments with 168 participants each under various combinations of asymmetry and information. Asymmetry was created as in Sheposh and Gallo (1973) by multiplying the payoffs of one of the players by three. Treatments varied also with respect to information concerning others’ payoffs, i.e. symmetry or asymmetry was not always known. Results indicated full information to enhance cooperation in the symmetric games, while it reduced cooperation in the asymmetric games. In particular, lower overall cooperation in the asymmetric game was attributable to lower amounts of cooperation by low-type players.

Croson (1999) compared behavior in a symmetric and an asymmetric PD game. 80 participants were divided into 4 treatments, two of them involving a regular symmetric PD game ($a_i = a_j = 85$, $b_i = b_j = 75$, $c_i = c_j = 30$, $d_i = d_j = 25$) and two an asymmetric one. Participants played 5 games each, 2 of them being the above mentioned PD games in a stranger design. Croson (1999) considers asymmetry in all cells, i.e. $a_i > a_j$, $b_i > b_j$, $c_i > c_j$, $d_i > d_j$ the parameters being $a_i = 95$, $a_j = 75$, $b_i = 85$, $b_j = 65$, $c_i = 40$, $c_j = 20$, $d_i = 35$,

¹¹This is our reading of the paper because the claim that “subjects were concerned less with the notion of winning more money than their opponent than with the notion of preventing their opponent from surpassing them” (p. 332) is unclear. It is not clear how low types could avoid being surpassed by high-type players without defecting. Not being surpassed is a first step for low types on the way to higher relative profits and the two motives can therefore not be distinguished.

$d_j = 15$. Participants were informed about their payoffs at the end of each period and were paid at the end of the session. Cooperation in the symmetric treatment was rather high with 77.5%. Cooperation in the asymmetric treatment was significantly lower amounting to 62.5%. There was, however, no significant difference between high-type and low-type players.

The next papers focus on asymmetry without comparison to symmetric situations.

Murnighan et al. (1990)¹² conducted a series of asymmetric dilemma experiments only a few of which were asymmetric PD's. All asymmetric PD games involved identical off-diagonal cells with $a_i = a_j = 40$ and $d_i = d_j = 0$. One game implements $b_i > b_j$, with $b_i = 32$ and $b_j = 21$ but $c_i < c_j$, with $c_i = 2$, $c_j = 19$ and the other three $b_i > b_j$ and $c_i > c_j$ with $b_i, c_i = 30, 24$; $24, 22$; $28, 24$ and $b_j, c_j = 28, 20$; $22, 4$; $24, 4$ respectively.¹³

Participants in the experiment were students whose course credit depended on their performance in the game. No monetary payments were involved. Participants in three studies played in three-person groups, subsequently they played as individuals. They were allowed to exchange anonymous messages after the second period. The groups played the game between 8 and 20 periods, not knowing beforehand when the game would be terminated.¹⁴ Based on our calculations, overall cooperation was 54%. Excluding the game where player type could not be consistently defined over all cells, low-type groups defected 45% and high-type groups 55% of the time.

In Murnighan and King (1992), nine different asymmetric dilemmas are considered only three of which fulfill the iterated PD condition and consequently are asymmetric PD games. All three games (called HIGH/HIGH in the paper)

¹²The experiment and the results are also reported in King and Murnighan (1988) and in Murnighan (1991).

¹³The respective games are Game 2 and 3 from the second experiment and Game 8 from the third. The game where player type could not be consistently defined over all cells is Game 4 of the second experiment.

¹⁴Note that the probabilistic nature of the game also affects the game theoretic prediction.

involved identical off-diagonal cells with $a_i = a_j = 40$ and $d_i = d_j = 0$. One game implements $b_i > b_j$, with $b_i = 36$ and $b_j = 24$ but $c_i < c_j$, with $c_i = 18$, $c_j = 20$ and the other two $b_i > b_j$ and $c_i > c_j$ with $b_i, c_i = 36, 4$; $36, 32$ respectively and $b_j, c_j = 24, 20$ each time. Participants had full information on all outcomes and communication was allowed. Based on our calculations, and aggregated over all three asymmetric PDs, cooperation rates were 64% over the first 8 periods (84% if the first two periods are excluded).

The next papers analyze asymmetric dilemma games that violate the iteration condition. Although technically not PD games, a brief discussion of the main findings is relevant to the present study given the alternation patterns observed.

Lave (1965) ran a symmetric and an asymmetric experiment where asymmetry was obtained by multiplying the payoffs of one of the players by 2.5 in case of mutual cooperation, the parameters being $a_i = a_j = 10$, $b_i = 2$, $b_j = 5$, $c_i = c_j = -3$, $d_i = d_j = -5$. Participants played for 50 consecutive periods and no communication was allowed. Even though computer players were used in some of the treatments, in the asymmetric sessions participants were paired with each other. Lave found a decline of cooperation from 57.5% to 50% when comparing the symmetric with the asymmetric treatment.

Analyzing individual behavior, Lave observed three cooperation strategy patterns. In the first one, participants stayed with the CC pattern and were not concerned about asymmetry. In the second pattern, participants alternated between CD and DC to get an expected value of 2.5 each. Finally, one pair settled on the optimal way of gaining equal payoffs: they played CC for five periods and DC in the sixth period achieving an expected value of $\frac{10}{3}$. In most cases, however, participants apparently failed to understand each others' signals and had great difficulties to settle on some stable cooperation strategy. Lave read participants' choices as being concerned about equal payoffs. They tried to achieve equality even though they had to pay a great deal of money to do so.¹⁵ With costly

¹⁵That participants in experiments may be willing to do so has also been shown by Güth

unilateral defection ($d < 0$), and asymmetry in the CC cell ($b_j > b_i$), alternating patterns became very salient for participants concerned about equal payoffs.

According to the global summary of results in Murnighan et al. (1990), in particular taking into account the 10 additional games not being PD's, participants rarely fell into a deficient series of non-cooperative outcomes. They instead used the off-diagonal payoffs to increase the outcome of the low player by simple or complex patterns of alternation. They implemented what Pruitt (1981) termed "integrative solutions". The low-type player j chose cooperatively most of the time, yet defecting regularly. This was tolerated by the high-type player i who chose cooperatively in every period. Thus, they jointly gained more than they would otherwise have been able to had they decided competitively. Murnighan (1991) states that arriving at complex alternation patterns requires a series of cognitive discoveries. Players that do not lose much if both players defect must first discover their "power" and realize how to use it to increase their payoffs. If they succeed to establish such a pattern of complex alternation they also establish less temptation for either player to defect because they both would lose. Implementing complex integrative solutions was certainly facilitated by allowing players to communicate. This was further corroborated by Murnighan and King (1992), who found that cooperation was rare when communication was not allowed. Providing bargainers with information on possible strategies was clearly important for evoking alternations. Discovering complex alternation schemes was difficult. Once discovered and implemented, complex alternation was stable. Defections were rare compared to mutual cooperation.

McKeown et al. (1967) conducted an experiment operationalizing asymmetry in all but the CC cell, with $a_i > a_j$, $b_i = b_j$, $c_i > c_j$, $d_i > d_j$, i.e. $a_i = 110$, $a_j = 200$, $b_i = b_j = 100$, $c_i = -150$, $c_j = 50$, $d_i = -200$, $d_j = 20$.¹⁶ Participants

et al. (2003).

¹⁶Note that for consistency, we reversed the labels of player i and j . In McKeown et al. (1967) the i player was the low-type player.

received feedback on the scores of every single period but did not get a cumulative score. Participation in the experiment fulfilled course requirement, thus no monetary payments were involved. Participants first played in the low-type position and then in the high-type position against a dummy over 100 trials. It was stressed in the instructions that they were playing in the weaker/stronger position. An analysis of variance for repeated measures showed that when participants are in the role of the low-type player, they are significantly more cooperative than in the role of the high-type player. Given that payoffs in the *CC* cell remain the same, such a result could also be explained by the fact that *DD* results in higher relative payoffs for the high-type player. In addition, the low- and high-type position was switched during the game, rendering complex patterns unnecessary to recalibrate outcomes.

4 Experimental Design

To pursue our research goals, we devised a 3×1 design by running two symmetric (SYM) payoff treatments (HIGH) and (LOW) and one asymmetric treatment (ASYM). See table 2 for the payoffs chosen in our design.¹⁷ HIGH is the normal form game already studied by Pruitt (1967) and Pruitt (1970) with $a_i = a_j = 18$, $b_i = b_j = 12$, $c_i = c_j = 6$, and $d_i = d_j = 0$. LOW is characterized by generally lower payoffs with $a_i = a_j = 12$, $b_i = b_j = 8$, $c_i = c_j = 4$, and $d_i = d_j = 0$.

In both treatments, $b = 2c$, and $a = 3c$. Moreover, $\frac{a_{HIGH}}{a_{LOW}} = \frac{b_{HIGH}}{b_{LOW}} = \frac{c_{HIGH}}{c_{LOW}} = \frac{3}{2}$. ASYM is the asymmetric game where player i (player j) has the same payoffs as both players have in HIGH (LOW). In that sense, ASYM is a composition of both symmetric games.

The experiment was conducted at BonnEconLab, the Experimental Economics Laboratory at the University of Bonn. It was programmed in z-Tree

¹⁷In all the experimental games we used the neutral labels A and B, instead of cooperate and defect and the requirements for iterated PD's were satisfied (equation 2 above).

(Fischbacher (1999)) using a modified version of the program by Maier-Rigaud and Apesteguia (2006). At the beginning of each session, participants were randomly assigned to one of the 18 computer terminals. Before the session started, participants first had to read the instructions (see Appendix C), and then had to answer test questions to check if they understood the game they were about to participate in (see Appendix D). The experiment was started only once all participants had correctly answered all test questions. At the end of the experiment, participants were asked to fill out a questionnaire where they had to give reasons for their decisions (see Appendix E).

In all treatments, it was common knowledge that participants played the same game against the same opponent for 40 periods. In each treatment, we had nine independent observations. We chose 40 periods in partner design to enable the development of cooperation over time. In particular, we wanted to study whether asymmetry continues to be relevant in later periods of the game or whether it can be viewed as an initial complication losing importance over time.

A total of $2 \times 9 \times 3 = 54$ students mainly majoring in law or economics participated in the experiment. The experiment took 40 minutes on average. Taler (the experimental currency) were transformed into Euro at the exchange rate of 1 Taler = €0.04.¹⁸ The average payoff over all treatments was €12.39.

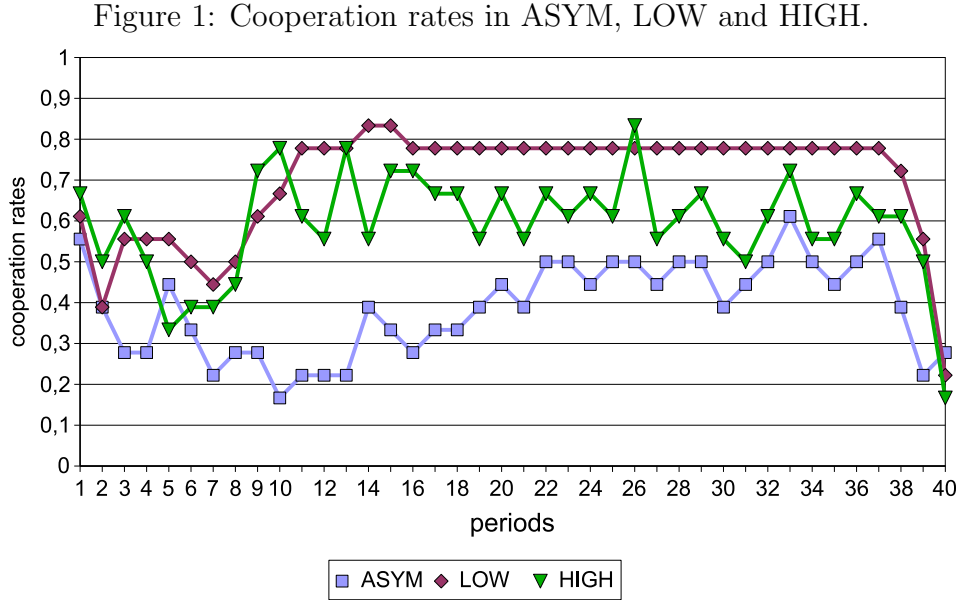
5 Results

5.1 Cooperation Rates over Time

Over all periods, we observe 70.00% cooperation in LOW, 59.17% in HIGH and 38.75% in ASYM. We found unstable patterns of cooperation and defection until roughly period 10. Cooperation then stabilizes at a rather high level of about

¹⁸At the time the experiment was run €1 roughly corresponded with \$1. Purchasing power was, however, higher.

80% in LOW, and 65% in HIGH. In ASYM, cooperation gradually rises from 15% to about 55% until period 33. In all treatments, we see an end effect starting in period 38 (see figure 1).



Aggregated over all treatments (54 observations), cooperation amounts to 61.11% in period 1, declining to 42.59% in period 2. After period 8, cooperation recovers and varies around 60% until period 38. In the last two periods, we observe the well-known end-game effect.

Appendix B gives a detailed account of all dyads in all three treatments. Stability of cooperation is higher in the symmetric treatments (HIGH and LOW) than in ASYM. Long-lasting cooperating dyads are characterized by long ranges on the CC-line, i.e. on the x-axis. Long sequences of mutual cooperation (i.e. more than 20 periods) are extremely rare in ASYM.¹⁹

¹⁹The idea that mutual cooperation is less desirable in ASYM also shows up in the answers given in the final questionnaire. As a reason for the choices made, one player for instance states: “Alternating between A and B was the most effective decision for both players.” Another participant states the goal “to maximize profits under the condition that both players receive equal payoffs”.

5.2 Effects of Treatments and Time on Cooperation

In this subsection, we analyze how the treatment variable and how time influence cooperation rates. Note that the dependent variable “cooperation” is categorical in that there are only two possible choices, namely cooperation and defection. In many statistical analyses, defection or cooperation rates are analyzed by an ANOVA design (see for instance Sheposh and Gallo (1973)). Both ANOVA and regression analysis are parametric tests and even the non-parametric versions presume ordinary scales with a sufficient range of ranks because ties cause problems. Cooperation and defection are two categories, however, and therefore are measured on a nominal scale. Analyzing such data with ANOVA and regression analysis is problematic because these methods confound expected value and variance. In other words, cooperation rates close to 0 or 1 result in low and cooperation rates near 0.5 result in high error variance.

Therefore, another statistical method has to be applied accounting for this problem. Configuration Frequency Analysis (CFA) (c.f. Bortz et al. (2000), Von Eye (2002)) is an adequate statistical tool to analyze dichotomous data. CFA is a χ^2 - technique, approximating a multinomial distribution by a χ^2 - distribution (for details on this method see Appendix A). Such an approximation can only be applied if the expected frequencies in the respective cells are sufficiently large. When employing CFA on our data set we have to account for this requirement. For that reason, we do not investigate each period separately, but divide the 40 periods into four quarters of 10 periods each in order to analyze the evolution of cooperation over time.

To apply CFA, we construct a $3 \text{ (treatment: HIGH, LOW, ASYM)} \times 4 \text{ (time: Q1, Q2, Q3, Q4)} \times 2 \text{ (choice: cooperation, defection)}$ -table. Treatment and time are the independent variables, choice is the dependent variable. The dependent variable is recorded in both of its realizations (C, D) for both players. We thus obtain 720 choices over all 40 periods and 180 choices for each quarter (c.f. table

Table 3: Evolution of Cooperation and Defection over time in treatments HIGH, LOW, and ASYM.

	HIGH				LOW				ASYM			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Cooperate	96	117	114	99	97	142	140	125	58	57	84	80
Defect	84	63	66	81	83	38	40	55	122	123	96	100
	180	180	180	180	180	180	180	180	180	180	180	180

Table 4: Frequency of Cooperation and Defection in treatments

	HIGH	LOW	ASYM	total
Cooperate	426	504	279	1209
Defect	294	216	441	951
	720	720	720	2160

3).

The calculated χ^2 -value that, in terms of interpretation, corresponds to the SS_{tot} -value (total sum of squares) in a two-factorial ANOVA is 197.3 (df = 11).

RESULT 1: There is a strong treatment effect.

SUPPORT: To analyze the two main effects of treatment and time, we decompose table 3 into two sub-tables 4 and 5 with table 4 comprising the treatment effect and table 5 analyzing the choices over time.

The treatment effect is highly significant ($\chi^2 = 147,13$; df = 2; p 0,000).

RESULT 2: There is a strong time effect.

SUPPORT: The effect of time is highly significant ($\chi^2 = 30,79$; df = 3; p 0,000).

The observed frequencies of cooperation (c.f. table 5) in the first quarter are much lower and in the third quarter are much higher than the calculated expected values.

RESULT 3: There is a strong interaction effect between treatment and time.

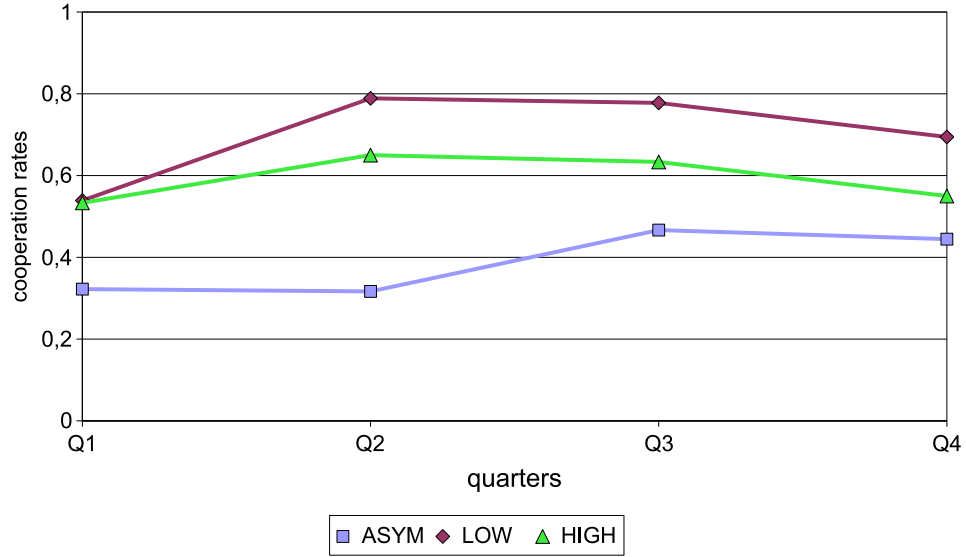
SUPPORT: Subtracting the χ^2 -values of the two main effects from the χ^2 -total-value gives the statistic test-value for the interaction between the time and the

Table 5: Frequency of Cooperation and Defection over time

	Q1	Q2	Q3	Q4	total
Cooperate	251	316	338	304	1209
Defect	289	224	202	236	951
	540	540	540	540	2160

treatment variable. This interaction-effect is also highly significant ($\chi^2 = 19,61$; $df = 6$; $p = 0,003$). It is documented by the non-parallel lines of cooperation rates in HIGH, LOW, and ASYM over time (figure 2). Note that the strength of the interaction effect is weak compared to the main effects.

Figure 2: Cooperation rates over time



There is also a strong difference between cooperation rates in ASYM and the aggregated symmetric treatments as our detailed analysis in the following subsection shows.

Table 6: Frequency of Cooperation and Defection in SYM and ASYM.

	ASYM	SYM	total
Cooperate	279	930	1209
Defect	441	510	951
	720	1440	2160

5.3 Comparison of Cooperation Rates between SYM and ASYM

In this subsection, we are interested in how asymmetry affects cooperation. It has been pointed out in the literature that players might try to even out the asymmetric payoff structure and aim for equal payoffs (Lave (1965), Murnighan et al. (1990) and Murnighan and King (1992), de Herdt (2003)). If this were indeed the case for both players then a complicated alternation strategy of full cooperation for the high-type player (i) and defection of the low-type player (j) on every fourth move should be observed. But even if such a complicated pattern is not observed players might (try to) alternate between cooperation and defection to get more equal payoffs than by mere cooperation and higher payoffs than by mutual defection. Such behavioral patterns would lead to lower cooperation rates in ASYM. We therefore hypothesize that asymmetry leads to lower cooperation rates.

RESULT 4: Asymmetry leads to lower cooperation rates.

SUPPORT: In table 6, we pool the data of the symmetric conditions LOW and HIGH of table 4 and compare them to ASYM. We find that cooperation rates in ASYM are highly significantly lower ($\chi^2 = 129,99$; $df = 1$; $p = 0,000$).

Based on Pruitt’s considerations on integrative solutions and the experimental results by Schellenberg (1964), Sheposh and Gallo (1973) and Talley (1974), occasional defection of low-type players in ASYM might be tolerated to a greater extent than defection in the SYM treatments. We therefore investigate whether we find a difference in defection rates of high-type players compared to low-type

Table 7: Frequency of defections by player type and SYM/ASYM-treatment.

	low-type player	high-type player	total
SYM	216	294	510
ASYM	227	214	441
	443	508	951

players.

RESULT 5: High-type players in ASYM tolerate defection more often than in SYM.

SUPPORT: Table 7 depicts the frequency of defections (out of 2160 observations) by player type and treatment. We test for statistical independence of player type and SYM/ASYM-treatment with respect to the number of defections in a χ^2 -test. The difference is highly significant ($\chi^2 = 15.82$; $df = 1$; $p = 0.001$). This finding is due to the high defection rates of high-type players in SYM. It points to the fact that defection by low-type players in ASYM is less often answered or more readily tolerated by high-type players in ASYM than defection in SYM.

5.4 Analysis of Dyads

Our descriptive analysis in subsection 5.1 has shown stability of cooperation to be higher in the symmetric treatments than in ASYM. Cooperative dyads are characterized by *CC* moves.

RESULT 6: Asymmetry reduces the stability of cooperation in dyads.

SUPPORT: Long sequences of mutual cooperation (i.e. more than 20 periods) are extremely rare in ASYM (1 out of 9 dyads), whereas such long sequences are found 4 times in HIGH and 7 times in LOW. This difference is highly significant ($p \leq .0165$, Fisher exact). There is, however, no difference between the symmetric treatments ($p \leq .180$, Fisher exact). These findings clearly indicate that symmetry matters for the stability of cooperation.

RESULT 7: Lower payoff differences in LOW as compared to HIGH and ASYM

Table 8: Strategic interactions in ASYM (frequencies).²⁰

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	67	9	2	0	2	80
CD	3	11	25	26	1	66
DC	7	16	13	17	0	53
DD	2	26	9	118	6	161
Sum	79	62	49	161	9	360

enhance the stability of cooperation once it has been reached.

Strategic interactions in our three treatments are summarized in tables 8 - 10. Column 1 shows the four possible choice combinations of both players. The first letter characterizes the high-type player's choice, e.g. *DC* reads that the high-type player defected (*D*) and the low-type player cooperated (*C*). Columns 2 - 5 display how players responded to the move in the previous period aggregated over the first 39 periods. Column 6 shows choices in the last period separately because no move followed. Note that choices in each treatment sum up to 360 observations only because the two moves of both players in one period (*CC*, *CD*, *DC*, *DD*) are aggregated into one observation, e.g. we have $40 \times 9 = 360$ aggregated choices.

Table 8 presents strategic reactions in ASYM while tables 9 and 10 deal with LOW and HIGH respectively.

SUPPORT: *CC* is followed by *CC* in ASYM with a probability of 0.859 (67/78²¹), in LOW with a probability of 0.957 (224/234) and in HIGH with a probability of 0.849 (146/172). Thus, the stability of cooperation once reached is about the same in ASYM and HIGH but significantly higher in LOW. The four-cell χ^2 -Test comparing HIGH and LOW yields ($\chi^2 = 28.85, df = 1, p \leq .000$). The same test

²⁰Note that in ASYM, the *i* player is the high-type and the *j* player is the low-type player, so that for instance *CD* implies cooperation of the high-type and defection of the low-type player. For LOW and HIGH, there is no distinction between *CD* and *DC*.

²¹Column 7 minus column 6, e.g. *CC* : $80 - 2 = 78$.

Table 9: Strategic interactions in LOW (frequencies).

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	224	7	2	1	1	235
CD	1	6	1	14	1	23
DC	5	4	0	1	1	11
DD	2	2	7	74	6	91
Sum	232	19	10	90	9	360

Table 10: Strategic interactions in HIGH (frequencies).

dyad	followed by				40th period	Sum
	CC	CD	DC	DD		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
CC	146	7	15	4	1	173
CD	8	3	14	11	0	36
DC	6	12	8	17	1	44
DD	9	12	5	74	7	107
Sum	169	34	42	106	9	360

comparing ASYM and LOW yields ($\chi^2 = 12.06, df = 1, p \leq .001$).

We further test whether symmetry affects mutual cooperation being aware that the choices over the 40 periods are not independent.

RESULT 8: Symmetry has a positive effect on mutual cooperation.

SUPPORT: For this test, we sum over all choices following a previous *CC*-dyad (first cell in column 7 in tables 8 to 10). The null hypothesis is that $p(CC | SYM) = p(CC | ASYM)$. As tables 8-10 show, in ASYM, 80 out of 360 dyads choose CC whereas in the aggregated LOW and HIGH treatments, *CC* dyads sum up to 408(235 + 173) out of 720(360 + 360) aggregated choices. The four-cell χ^2 -Test ($\chi^2 = 114.96, df = 1, p \leq .000$) yields a significant difference in that the frequency of cooperative dyads is significantly higher in SYM than in ASYM.

We next test whether the different payoff structures in the symmetric treatments HIGH and LOW influence mutual cooperation.

RESULT 9: Lower payoff differences in LOW have a positive effect on mutual cooperation.

SUPPORT: The null hypothesis is that $p(CC \mid HIGH) = p(CC \mid LOW)$. We find 235 CC-dyads out of 360 choices in LOW, and 173 CC-dyads out of 360 choices in HIGH (tables 9 and 10). The four-cell χ^2 -Test ($\chi^2 = 21.74, df = 1, p \leq .000$) yields a significant difference in that the frequency of cooperative dyads is significantly higher in LOW than in HIGH.

Does the player type have an impact on the cooperation pattern in ASYM? In other words, are low-type players more likely to shift from mutual cooperation to one-sided defection than high-type players?

RESULT 10: Low-type players are more likely to defect after mutual cooperation than high-type players.

SUPPORT: Mutual cooperation is maintained in 67 cases. Never does mutual cooperation directly lead to mutual defection in the succeeding period. One-sided defection after mutual cooperation is observed 9 times for low-type players (CD) and only 2 times for high-type players (DC). We tested the null-hypothesis that the probability of DC after mutual cooperation equals the probability of CD after mutual cooperation, i.e. $p(DC \mid (DC \cup CD)) = p(CD \mid (DC \cup CD)) = .5$.²² The binomial test shows low-type players to be significantly more likely to defect after mutual cooperation than high-type players ($p \leq 0.006$).

5.5 Analysis of Alternating Strategies

Instead of playing the subgame-perfect equilibrium of DD minimizing the payoff difference²³ or the cooperative solution of CC maximizing joint payoff²⁴ in all 40 periods, players may pursue different goals in asymmetric games. Players

²²We believe this test to be the more adequate one. Testing for a statistical difference between 2 out of 78 and 11 out of 78 (resulting in $p \leq 0.081$), the relative difference between 2 and 11 is lost in the “noise” of the high frequency of cooperation with 78 observations.

²³ $(40 \times 6) + (40 \times 4) = 400$, payoff difference 80.

²⁴ $(40 \times 12) + (40 \times 8) = 800$, payoff difference 160.

may try to even out the asymmetric payoff structure and aim for equal payoffs (c.f. de Herdt (2003)).²⁵ In our setting, equal payoffs are attainable by a rather complicated alternation pattern: if the high-type player cooperates all the time, and the low-type player defects in every fourth period both players get an average per-period payoff of 9.²⁶

We found only one dyad (number 7) that succeeded in establishing an alternation sequence yet providing a Pareto inferior solution (see appendix B). The strategy of alternating between *DC* and *CD* in each period, thus yielding an average per-period payoff of 6 to the low-type player and of 9 to the high-type player was much simpler and the pattern lasted for the final 20 periods.²⁷

6 Conclusion

The basic hypothesis analyzed in this paper concerns the frequency of cooperative play in asymmetric (ASYM) versus symmetric (HIGH and LOW) PD games. As conjectured we find asymmetry to reduce cooperation rates by up to 41 percentage points. In addition, we find a treatment effect between HIGH and LOW symmetric games, in that cooperation rates are significantly higher in LOW than in HIGH for the last three quarters. LOW induces the highest cooperation rates in all quarters followed by HIGH lying below LOW in the last three quarters and finally ASYM with significantly lower cooperation rates for all four quarters. Moreover, cooperation rates in ASYM do not increase from the first to the second quarter as in the other treatments.

In addition to the generally positive effect of symmetry on cooperation, lower payoff differences in LOW as opposed to HIGH have a positive effect on the

²⁵See also the literature on inequity aversion, for instance Fehr and Schmidt (1999) or Bolton and Ockenfels (2000).

²⁶Playing *CC* for three periods gives 36 to the high-type player and 24 to the low-type player. Playing *CD* in the fourth period adds another 12 to the low-type's account.

²⁷There exist a few failed attempts of other groups that could be interpreted as trying to establish an alternation pattern.

frequency of mutual cooperation and enhance the stability of cooperation once it has been reached.²⁸

From the evidence gathered it seems that in symmetric games individual players' ranking of outcomes is likely to be the same for both players. In asymmetric games, however, this seems not to be the case because for the low-type player the *CC*-outcome in all periods may not be as attractive thereby rendering coordination on a mutually compatible outcome more difficult.²⁹ In particular, player's perception of what constitutes a fair outcome is likely to diverge.³⁰ In the asymmetric PD, low-type and high-type players appear to have a different initial understanding of what constitutes a mutually acceptable outcome (or series of outcomes, for example in an alternation strategy) reducing cooperation rates. It appears that equality arguments are important and depend on the relative position of the player. As a low-type player, occasional defection may be a salient choice, "justified" by the idea that this redresses the unmotivated asymmetry in payoffs. This is in line with the finding by Roth and Malouf (1979) and Roth and Murnighan (1982) from bargaining experiments. They found that bargaining strategies depend on the counterpart's payoffs. In particular the low-type position is used to argue for special advantages.³¹ High-type players may in contrast initially focus on mutual cooperation as the salient choice rejecting responsibility for the assignment of types that low-types try to redress. Such a

²⁸In contrast, Ahn et al. (2001) manipulated only off-equilibrium and off-Pareto optimal payoffs in their symmetric PD experiment (i.e. cells *CD* and *DC* with a and d) without finding any effect on cooperation rates.

²⁹This also holds for the player(s) for whom $2b > a + d$ is violated.

³⁰This is further accentuated by the fact that in our design asymmetry is imposed without being specifically motivated. This may allow low-types to insist on occasional defection not being counted as such (entailing no retaliation by high-types) because the assignment of the high- or low-type position may be perceived as arbitrary. If asymmetry is motivated and motivation is treated as an experimental design variable this line of argument could further be tested. An experimental study designed along these lines may allow the manipulation of fairness norms.

³¹As found in Talley (1974), information about other player's payoffs has a positive effect on cooperation in symmetric games while decreasing cooperation of low-types in asymmetric games.

self-serving bias resulting from the lack of a mutually acceptable salient outcome reduces cooperation.³²

Although cooperation rates in ASYM eventually increase in the third quarter, indicating some coordination of strategies, they do not approach the levels found in symmetric games. Essentially, asymmetry reduces the frequency of cooperation and the stability of cooperation in dyads. Low-type players are more likely to defect after mutual cooperation than high-types, and high-types tolerate such defections more often than in symmetric games. From this perspective, there seems to be at least a tendency to accommodate lower payoffs by low-types.

³²See Babcock et al. (1995) and Babcock and Loewenstein (1997) for a discussion of the negative effects of self-serving biases in bargaining.

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APPENDIX A: Configuration Frequency Analysis (CFA)

The design used in this experiment is similar to an ANOVA-like 3×3 design (Frame \times Payoff-Structure).³³ However, the dependent variable is dichotomous. Participants can either cooperate or defect. The number of cooperative and defective moves adds up to the number of decisions. The adequate procedure for the analysis of such data is a chi-square-technique that takes the difference of dependent and independent variables into account. Such procedures have been developed in the context of configuration frequency analyses (CFA) and are known as interaction structure CFA (c.f. Von Eye (2001)). Thus, as in an ANOVA, two main effects and an interaction-effect can be analyzed (c.f. Bortz et al. (2000, p. 364ff.)). Configurational Frequency Analysis (CFA) is a multivariate method for typological research that involves categorical variables. It allows to identify those cells in a cross-classification that contain more (or fewer) cases than expected based on some chance model, such as the expectation that two categories are stochastically independent from each other. Similar to χ^2 -tests CFA involves the estimation of expected cell frequencies. The expectations are compared to the observations.

In addition, if independent and dependent variables can be distinguished and the dependent variable is dichotomous as in our case (defection or cooperation), the CFA can be applied in an ANOVA-like manner. The categories of the contingency tables of the independent variables can be understood as “fixed factors”, the frequency of cooperation (if cooperation is coded with 1 and defection is coded with 0) is the dependent measure to be analyzed in its dependency on main- and interaction-effects.

The CFA is carried out in several steps, similar to loglin model analyses. If for example a $(2 \times 2) \times 2$ table is to be analyzed, the numbers in brackets indicate that there are two independent variables with two respective values (similar to an ANOVA with two factors having two factor-levels each), and a dichotomous dependent variable (such as defection or cooperation), the first step consists in analyzing the pooled main- and interaction-effects between the two independent variables. In order to perform this analysis, the $2 \times 2 \times 2$ contingency table is transformed into a 4×2 contingency table (the frequencies of the two independent variables are handled as if they were one single category, thus transforming a 2×2 table into a row of four values for both the value 0 of the dependent variable and the value 1 of the dependent variable) that is analyzed with a chi-square-test and yielding a χ^2_{tot} -value. In the next step, this χ^2_{tot} -value is decomposed into its main-effects by constructing the 2×2 table for the first independent variable with the dependent variable and similarly constructing this contingency table for the second independent variable. The respective χ^2_A and χ^2_B values computed from these tables test the significance of the main effects. Subtracting the sum of the two χ^2 -values from the χ^2_{tot} -value gives the $\chi^2_{A \times B}$ -value.

In contrast to an ANOVA performed on cooperation rates, this approach avoids some statistical problems resulting from the application of a statistical test for cardinal data on dichotomous data. There, the variance of the observations (i.e. relative

³³Analysis of variance (ANOVA) is a statistical technique for analyzing data that tests for a difference between two or more means by comparing the variances within groups and variances between groups. The sources of variability between the groups may stem from one or more potential sources, sometimes referred to as “treatments” or “factors”.

frequency of co-operations) is not independent of the expected value (the mean). If the mean is near 0 or near 1 (in other words, if cooperation rates are very low or very high), the variance of the respective cells is lower than in cells where cooperation rates are near 0.5 (50%). Therefore, analyses of such data with ANOVA suffer from confounding variances and co-variances. This is why sometimes some transformations of the data are carried out. Depending on the kind of transformation that is done with the raw data (i.e. the cooperation rates) other problems may arise. We, therefore, prefer to use a Configuration Frequency analysis, knowing well that we depart from the analyses that are usually done in symmetric PD games and incorrectly in asymmetric PD games.

APPENDIX B: Choices in all Dyads

APPENDIX C: Instructions

[In All Treatments]

Note:

- You have 5 minutes to read the instructions. If after reading the instructions you have any questions, please contact one of the experimenters. Communication with other participants is not allowed during the experiment.
- After the 5 minutes you will be asked to fill out a test questionnaire about the experiment you will be part in. Once all participants have correctly answered all questions, the experiment will start.
- After completion of the experiment you will be asked to complete a computerized questionnaire
- Please do not leave your seat before you have filled out the questionnaire and your terminal number has been announced

The experiment:

The experiment consists of a decision situation in which you and another person will choose between A and B for 50 periods. Your position as well as the person you are interacting with is randomly assigned to you at the beginning of the experiment. The decision situation, as well as the person you interact with is identical in each period. You will see the decision made by the other person in each period after you made your own decision.

In each period, by deciding between a choice of A or B, you can decide the amount of Taler that you and the other person will receive. The following graph depicts the decision screen, you will see during the experiment.

In the left half you see the consequences of your own two decision options and below your decision buttons.

In the right half of the screen you see the decision options of the other person.

[In the LOW treatment only]

Periode 1 von 1

Verbleibende Zeit [sec]: 20

	A	B
A	8,8	0,12
B	12,0	4,4

	A	B
A	8, 8	0, 12
B	12, 0	4, 4

Ich wähle

Ich wähle

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you both receive 8.
- If you choose B and the other person as well, you both receive 4.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 12.
- If you choose B and the other person chooses A you receive 12 and the other person receives 0.

[In the HIGH treatment only]

Periode 1 von 1

Verbleibende Zeit (sec): 29

	A	B
A	12, 12	0, 18
B	18, 0	6, 6

	A	B
A	12, 12	0, 18
B	18, 0	6, 6

Ich wähle ☐ A

Ich wähle ☐ B

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you both receive 12.
- If you choose B and the other person as well, you both receive 6.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 18.
- If you choose B and the other person chooses A you receive 18 and the other person receives 0.

[In the ASYM treatment for the low-type player only]

The screenshot shows a game interface with a light gray background. At the top, there is a header bar with "Periode" on the left, "1 von 1" in the center, and "Verbleibende Zeit (sec): 20" on the right. Below the header, there are two payoff matrices. The left matrix is titled "meine Entscheidungssituation" and the right matrix is titled "Entscheidungssituation der anderen Person". Both matrices have a 2x2 grid of payoffs. Below the matrices, there are two red buttons labeled "A" and "B" with the text "Ich wähle" above them.

meine Entscheidungssituation		
	A	B
A	8, 12	0, 18
B	12, 0	4, 6

Entscheidungssituation der anderen Person		
	A	B
A	8, 12	0, 18
B	12, 0	4, 6

Ich wähle

Ich wähle

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you receive 8 and the other person receives 12.
- If you choose B and the other person as well, you receive 4 and the other person receives 6.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 18.
- If you choose B and the other person chooses A you receive 12 and the other person receives 0.

[In the ASYM treatment for the high-type player only]

Periode 1 von 1 Verbleibende Zeit [sec]: 20

	A	B
A	12,8	0,12
B	18,0	6,4

	A	B
A	12, 8	0, 12
B	18, 0	6, 4

Ich wähle

Ich wähle

The amount of Talers you earn in each period depends on your and the other persons decision:

- If you choose A and the other person as well, you receive 12 and the other person receives 8.
- If you choose B and the other person as well, you receive 6 and the other person receives 4.
- If you choose A and the other person chooses B, you receive 0 and the other person receives 12.
- If you choose B and the other person chooses A you receive 18 and the other person receives 0.

[In all treatments]

After each period you will be given information on: your last decision, the last decision of the other person, the number of Talers you earned in the last period, and the total number of Talers you have earned so far.

Payment:

The total number of Taler earned will be paid out anonymously to you at the end of the experiment 1 Taler corresponds to 0.04 Euro.

Thank you very much for your participation!

APPENDIX D: The Computerized Questionnaire

Question #	Question
1	Terminal number?
2	Major?
3	Job?
4	Semester?
5	Age?
6	Sex?
7	Did you ever take a microeconomics course?
8	Did you ever take a game theory class?
9	Please describe briefly the reasons for your choices
10	Did your decision behavior change during the experiment? If yes, how?
11	I believe that the main goal of this experiment was to maximize my own advantage [I fully agree, I strongly disagree]
12	I believe that the main goal of this experiment was to maximize the group advantage [I fully agree, I strongly disagree]
13	What daily life situation did this experimental situation remind you of the most?
14	You now have the opportunity to formulate any additional comments, suggestions or criticism you may have

APPENDIX E: The Test Questions

- How high is the profit of the other person, if she chooses A and you too?
- How high is your profit, if you choose B and the other person A?
- How high is the profit of the other person, if she chooses A and you B?
- How high is your profit, if you choose A and the other person too?
- How high is the profit of the other person, if she chooses B and you too?
- How high is your profit, if you choose B and the other person too?
- How high is the profit of the other person, if she chooses B and you choose A?
- How high is your profit, if you choose A and the other person chooses B?