Multiple prisoner's dilemma games with(out) an outside option: an experimental study*

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Abstract

Experiments in which subjects play simultaneously several finite prisoner's dilemma supergames with and without an outside option reveal that: (i) subjects use probabilistic start and endeffect behaviour, (ii) the freedom to choose whether to play the prisoner's dilemma game enhances cooperation, (iii) if the payoff for simultaneous defection is negative, subjects' tendency to avoid losses leads them to cooperate; while this tendency makes them stick to mutual defection if its payoff is positive.

Keywords: Prisoner's dilemma, cooperation, exit, experiments, loss aversion

JEL classification numbers: C14, C72, C78, C91

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1 Introduction

The Prisoner's dilemma game has been taken to the experimental laboratory well above 1000 times (see Sally (1995) for an overview). Its characteristic tension between the Pareto superiority of cooperation and the strict dominance of defection promises an interesting study of human behaviour. The game, indeed, deserves special attention since it formalizes many experiences of everyday life. Situations such as friendship formation, information sharing, joint research and selling and buying can all be modeled by this simple game.

The standard prediction that defection is the only rational outcome in the finite version of the game leaves a feeling of unease: it cannot be reconciled with observed cooperation levels. Controlled laboratory experiments have tried to nail down reasons for cooperation or the failure to cooperate. Many different explanations have been put forward, reaching from framing and presentation effects[1] to postulates on the intrinsic nature of human beings: how they reason and learn. E.g. persistent cooperation in one-shot experiments is often seen as evidence for the existence of intrinsically cooperative types. How well-founded are these explanations? Do existing experiments capture all aspects that might be important for cooperation?

The above examples of everyday prisoner's dilemmas reveal that human beings often play several such games simultaneously and that many of these games have a voluntary interaction structure. E.g. I can choose my friends or co-authors. Partner selection is a strategic choice and might therefore influence the outcome of the game.

In the last years, several theoretical papers have examined the influence of partner selection on cooperation levels[2]. Those papers confirm the strategic importance of partner selection and how it relates to cooperation; however, the extent to which cooperation is enhanced depends in a sensitive way on the model specifications and behavioural assumptions. The great majority of papers use deterministic finite automata to model behaviour within the prisoner's dilemma and some even use built-in stopping rules (e.g. if your game partner defects never interact with him again) to model partner selection. Thereby they implicitly assume the existence of deterministic player types who treat (identical) opponents with the same history of play in exactly the same way. Is it reasonable to assume that such types do indeed exist? To date, experimental evidence rests on shaky grounds, since there are no experiments which allow subjects to play the two-person prisoner's dilemma game simultaneously with several players. Even worse, some experimental studies impose deterministic types in the setup by requiring subjects to submit a deterministic

[1] E.g. the words chosen to instruct experimental subjects might encourage cooperation.

[2] These papers include among others Ashlock *et al.* (1996), Ghosh and Ray (1996), Hauk (1997), Morikawa *et al.* (1995) and (1996), Orbell and Dawes (1991), Peck (1993), Schluessler (1989), Smucker *et al.* (1994), Stanley *et al.* (1994), Tesfatsion (1995)

supergame strategy. Only if subjects choose the same strategy with identical opponents in a multiple game situation will the hypothesis of the existence of deterministic player types be well-founded.

The present paper examines whether the assumption of deterministic player types is justified and whether it is crucial for the increased level of cooperation in models where players can select or refuse game partners. In order to do so, partner selection is examined in an experimental environment without any ex-ante stopping rules or ex-ante player types. For this purpose three sets of experiments are conducted. In each setup every experimental subject plays 10 supergames of a 10-period finitely repeated two-person prisoner's dilemma with 6 other subjects simultaneously. I.e. in every period each subject plays 6 prisoner's dilemma games, choosing a strategy for each opponent. Subjects can choose a different strategy against each different opponent, if they wish to do so. Partner selection is modeled in its easiest form, namely as an outside option with zero payoff which results from the subjects' conscious decision not to enter (which is equivalent to exiting) a period of a game (i.e. to refuse a game partner). The experimental setups differ in whether exit is possible and in the relative payoff this exit option yields. In the basic setup there is no partner selection. In the second setup the payoff from exiting is better than the mutual defection payoff and in the third setup the payoff from exiting is worse. This implies that the strategic role of the outside option is very distinct in setup II and III. Moreover, setup III uses a different prisoner's dilemma payoff matrix.

The following paragraphs summarize the experimental results. The observations on individual behaviour in multiple game situations strongly reject the existence of deterministic player types: most subjects are not cooperatively or defectively inclined but use different types of behaviour against opponents with an identical history of play, i.e. they discriminate among equals. Discrimination is both common among subjects and persistent over time. This result seriously questions any deterministic type-dependent theoretical work. It is also bad news for experimental work in which subjects are required to commit to a deterministic supergame strategy.

Theoretical work on different forms on partner selection (most of it using deterministic types) has shown that voluntary interactions favour the Pareto superior (cooperative) outcome. The present experiment reveals that even without deterministic player types increased cooperation levels are achieved. In setup II, which uses the same payoff matrix as the baseline experiment, partner selection clearly enhances cooperation[3]. In this setup exiting (and defect in the unreached game) constitutes the subgame perfect equilibrium

[3]In the literature, the payoff structure of setup II has been examined for the *one-shot game*. Even in the one-shot game, experiments found that cooperation levels increased. (Orbell and Dawes (1993) for the 2-person case and Orbell, Schartz-Shea and Simmons (1984) for the n-person prisoner's dilemma.)

path. However, complete inactivity is extremely rare. Players quickly learn to cooperate and become very efficient at excluding defectors.

In setup III, the introduction of the outside option allows for (non-subgame perfect) cooperative Nash equilibria: cooperation can be sustained over several periods by threatening to exit otherwise. Additionally, exiting in the first period of a supergame can serve to signal cooperative intentions. At the same time, first period exit renders some credibility to the threat to exit if cooperation is not encountered. The experimental evidence suggests that some subjects indeed play these cooperative Nash equilibria which allows us to conclude that - also in setup III - partner selection enhances cooperation.

On the other hand, the underlying prisoner's dilemma payoff matrix in setup III differs from setup I, which also affects cooperation levels (Rapoport and Chammah (1965), Lave (1965)). Based on the payoff matrix Rapoport *et al.* (1965) develop various indices whose value allows to predict whether cooperation increases or decreases in different prisoner's dilemma games. The validity of their most successful index has been confirmed systematically in later studies (Jones *et al.* (1968), Steele and Tedeschi (1967))[4]. According to this index the payoff matrix in setup III implies a lower cooperation level than in setup I.

Given the two arguments just presented we could not predict a priori whether cooperation will be higher or lower in setup III than in setup II.

We observe that cooperation levels in setup III are much lower than in setup I. Paradoxically, compared to Rapoport *et al.* (1965), the observed drop in cooperation levels lies among the biggest drops that have been observed for prisoner's dilemma matrices with similar indices[5]. How can this be given the positive effect of the outside option on cooperation levels?

Rapoport *et al.*'s (1965) index does not distinguish explicitly between positive and negative payoffs. The same number for the index can be reached by a payoff matrix in which simultaneous defection yields a positive payoff as well as by a matrix in which simultaneous defection yields a negative payoff. The index would predict the same level of cooperation in both circumstances. However, this is exactly where the index fails and the situation which occurs in our experiments[6]. Rapoport *et al.* (1965) never compared

[4]This index is calculated as the ratio of the payoff difference between simultaneous cooperation and simultaneous defection and the payoff difference between unilateral defection and unilateral cooperation. The index increases if - holding everything else constant - the payoff from simultaneous defection decreases.

[5]In the present paper the index changes from 0.46 to 0.31. Rapoport *et al.* (1965) examine several matrices with indices 0.5 and 0.3 and observe a drop in cooperation levels which lies between 0.02 and 0.18. In the present experiments the drop in total per period cooperation levels lies between 0.08 and 0.2436.

[6]Rapoport *et al.* examines only games in which the payoff for simultaneous defection is negative, while in the present paper the index 0.3 is reached in a game with a positive payoff for simultaneous defection.

matrices with negative payoffs for mutual defection to matrices with positive payoffs for mutual defection[7]. This comparison is crucial since there is substantial evidence in psychology experiments that subjects dislike losses more than they like equal-sized gains (see e.g. Tversky and Kahneman (1991)). The subgame perfect equilibrium in setup I is a loss, while in setup III the same strategy yields an equal-sized gain. The low cooperation levels of the latter seem to be evidence that subjects' loss-avoidance leads them to risk cooperation in setup I while the same force condemns them to defection in setup III. The present experiment reveals another factor influencing cooperation: the sign of the payoff for simultaneous defection. Rapoport *et al.* 's index has to be applied with care to matrices where this sign differs.

The remainder of the paper is organized as follows. In the next section the experimental setup is explained and justified. Sections 3 discusses deterministic player types. Section 4 examines the use and effect of partner selection (outside option) in setup II and III. Section 5 describes the sensitivity of subjects' behaviour towards the sign of the simultaneous defect payoff. The final section concludes.

2 Experimental setup

2.1 The underlying game

The experiments are based on the two person repeated prisoner's dilemma with the following bimatrix of the one-shot game.

	cooperate	*defect*
cooperate	5, 5	−6, 7
defect	7, −6	∓1, ∓1

Prisoner's Dilemma

During the experiment defection was coded by a and cooperation by b. The $\mp$ entry for mutual defection represents the two payoff matrices used in the different experiments.

[7]Jones *et al.* (1968) compared games with positive and negative payoffs and concluded that negative payoffs lead to higher cooperation levels. However, they argued that the index fully captures this difference, since it increases in value compared to those matrices using only positive payoffs. This argument overlooks that the same index can be reached with positive and negative payoffs for mutual defection.

The negative entry for simultaneous defection was used in the baseline experiment and in setup II, while setup III used the positive entry.

2.2 The baseline experiment

The baseline experiment (setup I) concentrates on replicating the multiplicity of human activity. For this purpose the repeated prisoner's dilemma (without exit) was played in 6 parallel partnerships[8]. Subjects did not have to commit to a supergame strategy before beginning to play nor were they forced to use the same strategy against everybody. In other words, when deciding how to play against two players with the same history, they could choose to defect against one and cooperate with the other. This freedom of choice allows us to test for the existence of deterministic player types.

Setup I is called baseline experiment since it does not allow for partner selection and additionally serves as a basis for comparison with experimental setups II and III.

2.3 Further experimental setups

The two remaining experimental setups model *voluntary* interactions. Partner selection takes place in the form of a conscious choice whether or not to play with a certain subject. Each period of a supergame has two stages: the matching stage, in which subjects express their willingness to get matched; and the game stage, in which matched pairs play the prisoner's dilemma. Not playing is equivalent to zero points.

Two setups are examined using the negative and positive payoffs for mutual defection respectively. The different payoff matrices affect the Nash equilibria of the game. In setup II the existence of the outside option shifts the only game theoretic (subgame perfect) equilibrium of the finitely repeated game from always defect to never play (and defect in the unreached game).

Setup III has the same subgame perfect equilibrium as the baseline experiment, namely, (enter and) always defect. However, this outcome has now positive payoffs for both players. This changes the underlying incentive structure in two ways: (i) the difference between the payoffs from mutual cooperation and mutual defection is smaller and (ii) subgame perfect play no longer leads to losses but to a small, secure reward. According to an index developed by Rapoport *et al.* (1965) the effect of (i) is to reduce cooperation levels. According to the theory of loss avoidance (e.g. Tversky and Kahneman (1991)), so does (ii). But setup III allows for partner selection which might increase cooperation.

[8] 7 subjects were used, since 6 partnerships seems to be few enough to keep track of every individual match, and a big enough number to allow for experimentation and a wide experience in a short time period.

The weakly dominated outside option (which is irrelevant for subgame perfect equilibrium play) adds an additional punishment for defection that is harder than defection itself. The non-credible background threat of exiting leads to the existence of further (non subgame perfect) Nash equilibria. Two of them are of special interest: enter and[9]:

1. mutual cooperation until period 9 and mutual defection in period 10[10].
2. exit in the first period of a supergame (in order to signal cooperative intentions). From period 2 as in 1.

In both cases, defection before period 9 is punished via eternal exit. This punishment threat is not credible, since once defection has occurred reoptimization dictates to continue the game and to defect. Consequently, the outside option is "irrelevant". However, if experimental subjects play the above-mentioned non subgame perfect equilibria, this seemingly irrelevant outside option would enhance cooperation. In that case it cannot be doubted that the freedom whether or not to play to prisoner's dilemma is a key element in explaining observed cooperation levels in real data.

Table I summarizes the differences in the experimental setups.

setup	exit	payoff from mutual defection	SPE	further NE
I	no	-1	defect	none
II	yes	-1	exit, defect	none
III	yes	+1	enter, defect	yes

Table I

2.4 Matching mechanism

The matching mechanism serves to select one's game partners. Partner selection is modeled in its simplest form by allowing experimental subjects to refuse to interact. A match

[9]There are other Nash equilibria, which are not interesting for the problem under examination. E.g. exiting in every period (and defect in the unreached game) is a Nash equilibrium, although it is weakly dominated.

[10]Let h represent the payoff achieved when defecting against a cooperator. d refers to the mutual defection payoff, c to the payoff received from mutual cooperation and l to the payoff resulting from cooperating against a defector. The incentive constraint is that n_c cooperative periods followed by mutual defection lead to a higher payoff than betraying the partner followed by being exited against forever. Formally, $n_c c + (10 - n_c)d \geq h + (n_c - 1)c$, which is fulfilled as long as $n_c \leq 9$ given the payoff matrix used.

occurs *if and only if* two players have both explicitly stated their wish to interact. If only one person enters, no match occurs. Matches are reconsidered every period[11].

2.5 The end

Each supergame ends after 10 periods, which is known by the subjects.

Each experimental session consists of 10 supergames involving the same set of players.

2.6 Information

In each supergame every player is identified by a player number. This number remains the same during the supergame but changes when a new supergame begins. Throughout the experiment, players are able to look back into the history of all past supergames. This does not enable them to deduce a player's past identity but allows them to learn how to react to some reoccurring behavioural patterns.

Notice that successive trials of supergames are not completely independent which allows for strategic links between the games. Subjects will not only become more experienced with the actual prisoner's dilemma but also get a better knowledge of opponents' propensities. This might lead to "population effects", i.e. the amount of cooperation in early supergames might affect the amount of cooperation in later supergames. This linked chain of games (instead of completely separated supergames) was chosen in order to mimic most theoretical models on partner selection as closely as possible: in these models strategies evolve simultaneously in a slowly changing population.

During the experiment, players are told only whether or not a match occurred, but not the decision of the opponent. This implies that if player A said no to player B, player A will be communicated that he is not matched with B, but he will not know whether B wanted to be matched with him or not. Clearly, if B wanted to be matched with A, no match implicitly reveals to B that A did not want the match.

Players will be told their own total payoff. They will be communicated their own score from each individual match as well as the opponent's score and action. The latter two pieces of information can be deduced form the payoff matrix and are hence redundant.

[11]This simple matching mechanism is chosen since it isolates past behaviour and expectations as the causes of exiting. Any more sophisticated mechanism for partner selection would require that the number of possible game entries were restricted exogenously by the experimenter; in that case the non-occurrence of a match would no longer reveal a clear preference against this particular match; it could be due to capacity constraints. This would distort the effects of the exit option on the amount of cooperation.

2.7 Payment

Since some of the points in the prisoner's dilemma games are negative, players were given a starting capital of 1000 Pesetas. It was guaranteed to them that they did not have to give any money to the experimenter should they go bankrupt, which never happened. Points achieved in supergames were scaled by 15 when converted into Pesetas. Consequently, payoff incentives were very high in each supergame, as every player had 60 possible interactions (6 opponents, 10 periods). Hence, in expected terms, every single decision mattered. As one experimental session consisted of 600 possible interactions, not every supergame could be paid using the before-mentioned desirable incentive structure. In order to ensure that subjects tried to do their best in every supergame, subjects were told that two randomly determined supergames will be paid. At the end of the experiment every subject was asked to draw once out of two urns. One urn contained supergames 1 to 5, the other urn contained supergames 6 to 10. Consequently, every supergame had equal probability to be paid. The subdivision into two groups rewarded learning by guaranteeing the payment of some later supergame.

2.8 Experimental subjects and sessions

The subject pool consisted of students at the Universitat Pompeu Fabra Barcelona. They were either economics or business administration students in their first semester or students of humanities. Subjects were allowed to take part in only one experimental session. The experiments were done in a period of two weeks. The baseline experiment lasted two hours, while the second and third setup required 3 hours each. The experiments were conducted in a computerized laboratory and were programmed in $C++$. At the end of every experimental session subjects gave written reasons for their overall decisions. For every single experimental setup, three experimental sessions took place.

3 Results I: Deterministic types

An experimental subject uses a deterministic strategy if he chooses the same action against all opponents with an identical history of play. Hence a deterministic strategy can use different stage game actions only if the opponents themselves have behaved differently in the past. We will refer to non-deterministic behaviour as "discrimination among equals". Evidence for this type of discrimination is found, if (i) the experimental subject does not choose the same stage game action against all opponents in the first period of a supergame or (ii) if the experimental subject uses different stage game actions with identical opponents later on in the supergame[12]. Figure 1 shows the data for (i) and (ii).

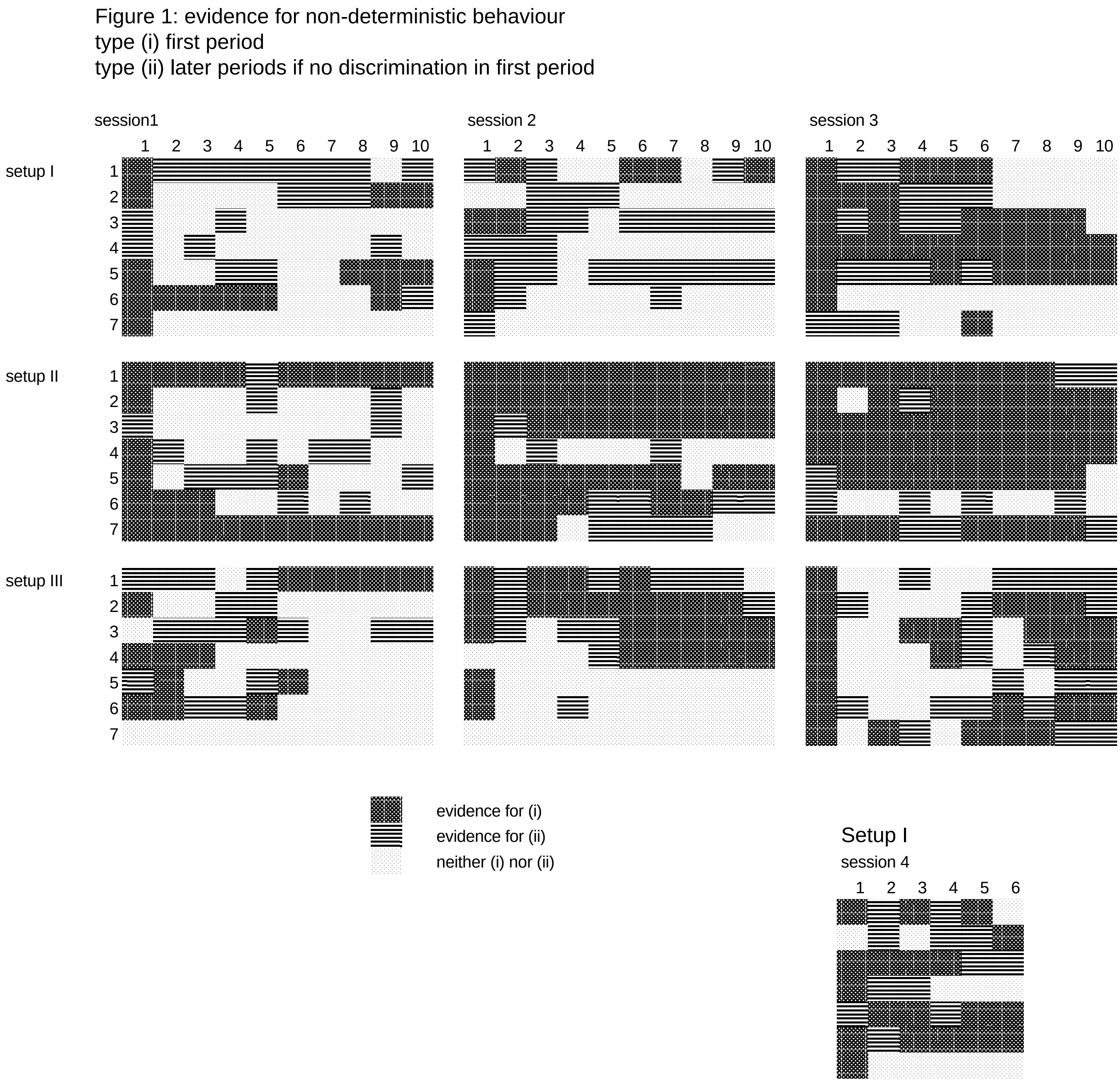

Figure 1: Evidence for non-deterministic behaviour. Rows represent different experimental subjects. Columns represent different supergames

[12]Notice, that no evidence for probabilisitic behaviour does not automatically imply deterministic behaviour: after period 1 of each supergame different histories of play exist which reduces the number of identical players and hence the possibility of observing probabilistic behaviour.

If evidence for (i) is found (which is sufficient for non-deterministic behaviour) we do not look for evidence for (ii). As can be seen from the data only for 2 subjects (out of 70)[13] no evidence for (i) or (ii) was found. Looking at the last 3 supergames only, 21 subjects did not display any clearly non-deterministic behavioural pattern. On the other hand, 12 subjects re-took discrimination among equals after having stopped for at least 3 periods.

The data suggests that experimental subjects tend to discriminate among equals. This type of discrimination is not only common but also persistent over time, i.e. both non-experienced and experienced subjects use probabilistic strategies. Appendix A gives detailed data for the different motives for discrimination. The motives were partly explained by experimental subjects themselves in their written justification for their choices. These motives differ with the periods of the supergame: in early periods during a supergame discrimination is used if cooperation is not yet reached in some partnerships. Subjects either do not make cooperative first moves simultaneously in all games or they do not react to all cooperative first moves by immediate cooperation. In setups II and III, defection in early periods is punished probabilistically by opting out. It is commonly observed that subjects start to make a cooperative first move only in a few partnerships but once a successful cooperative relationship is established, they signal their cooperative intentions to others[14].

Towards the end of a supergame discrimination occurs in endeffect behaviour[15]. Subjects do not always terminate their cooperative relationships in the same period. They also punish some of early breakdowns of mutual cooperation (in setup II by opting in and defecting and in setup III by opting out). This implies losses also for themselves (self-inflicted punishment).

The above observations suggest that discrimination among equals might be a form to resolve the fundamental tension of the prisoner's dilemma between the Pareto superiority of cooperation and the strict dominance of defection; mutual cooperation is desirable but

[13]While running a session of setup I in the lab, the computers broke down and the session had to be stopped after only 6 supergames. I include these extra subjects for setup I in the data on individual behaviour.

[14]In setup III this is also done by opting out in early periods. (See section 4.2)

[15]Endeffect behaviour (play) is defined as follows:

Def. 1 *The play of a supergame is called* END-EFFECT PLAY *(Selten and Stoecker (1986)) if*

1. *both players choose the cooperative alternative in at least four consecutive periods* $k, ..., m$.
2. *In period* $m+1$ *for* $m < 10$ *at least one player chooses the non-cooperative alternative.*
3. *In all periods* $m+2$ *- if there are any - both players choose the noncooperative alternative*

making a cooperative move is risky and might be costly. Discrimination might be a form to spread this risk, an attempt to reach cooperation while exploiting some cooperative moves of one's game partners and protecting oneself against one-sided cooperative moves as far as possible. Experienced experimental subjects discriminate in start and endeffect behaviour.

Deterministic behaviour is the exception rather than the rule. This implies that all experimental studies which require subjects to submit a deterministic supergame strategy have a serious short-coming. Also, modeling agents as evolving deterministic finite automata (as most of the theoretical literature on partner selection does) is problematic; in those models automata are revised in-between "supergames". A new supergame is started after evolution has taken place. In contrast, experienced subjects use different types of behaviour during the same supergame.

Introducing any kind of probabilistic automata would also be problematic: most such automata would do really badly in an evolutionary world and be eliminated rather quickly. However, experimental subjects do not do very badly, on the contrary. They behave probabilistically, but only in specific circumstances (start and endeffect behaviour). Their probabilistic behaviour is sophisticated. Any reasonable model of economic agents should respect this sophistication.

The above results indicate that theoretical models on partner selection that use deterministic or simplistic finite automata rest on shaky grounds. They simply do not reflect how people reason and interact. It is important to examine whether this lack of "realism" affects the conclusions of the models in a substantial manner, i.e. will cooperation levels increase if interactions are voluntary? The next section shows that voluntary interactions do indeed favour cooperative behaviour.

4 Results II: The use and effect of partner selection

Partner selection is modeled in its most simplistic form, namely via an outside option which enables an experimental game partner to refuse a match. In setup II, the outside option is strictly dominant, while in setup III it is weakly dominated. Despite this strategic difference, it will be seen that in both setups its effect on cooperation is positive.

4.1 The outside option in setup II

A direct comparison[16] between setup I and II reveals the following:

[16]Note that both setups use the same underlying prisoner's dilemma payoff matrix.

Observation 1 *1. Total cooperation levels (conditional on entry) are higher in setup II than in setup I.*

2. Subgame perfect equilibrium play drops drastically when adding the outside option.

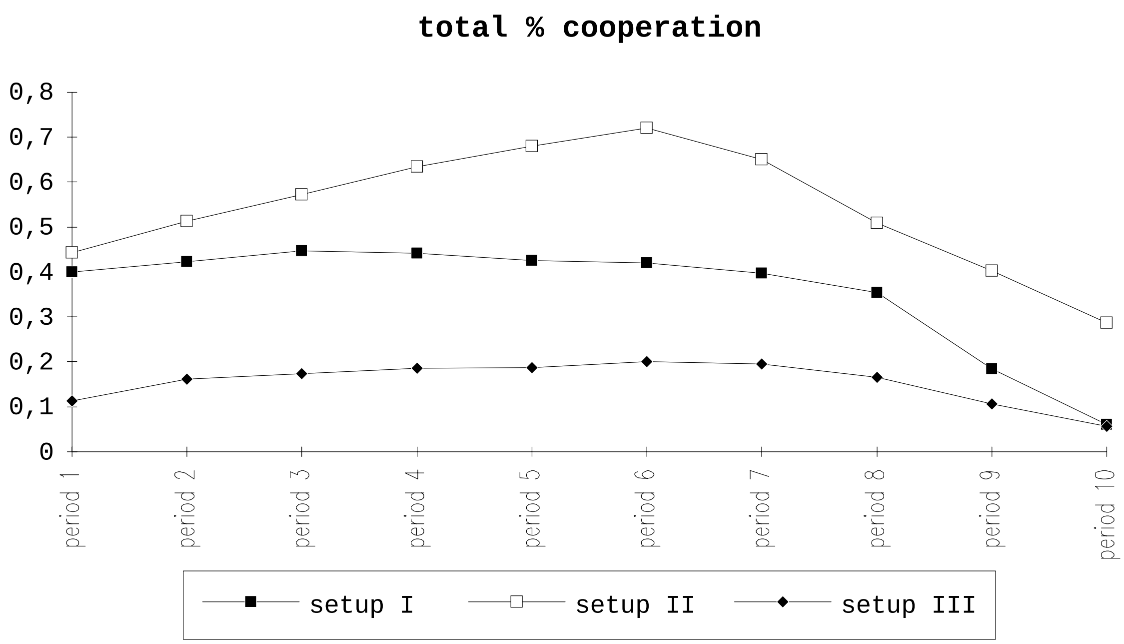

Figure 2: Total per period cooperation levels in each setup

Already a simple look at figure 2 confirms observation 1.1. That cooperation levels[17] are significantly different is confirmed by the Wilcoxon-Mann-Whitney test at significance level $\alpha = 0,05$ (see Appendix B2 for the underlying data and the calculation of the test statistics). At this significance level the hypothesis of equal amounts of cooperation in setup I and II can only be sustained with probability $p = 0.0026$.

The data for subgame perfect equilibrium play in setup I (and III) can be found in appendix C. Its minimum lies at 21.4% and its maximum at 42.8%[18]. In contrast, in setup II, only 3 subjects (out of 21) played the subgame perfect equilibrium: 2 of them played it occasionally in early supergames but stopped once the possibility of mutual cooperation was experienced[19]. Only one subject stopped playing completely. This occurred in the

[17]The overall cooperation levels are calculated without distinguishing players or sessions, since it is a common criteria found in the literature, e.g. Sally (1995) uses this citerion in a meta-analysis of experiments from 1958-1992. We also checked 2 different criteria for total cooperation levels which confirm the result, namely (i) total average cooperation levels of a single player and (ii) total cooperation levels per supergame. The underlying data for those criteria is summarized in appendix B.

[18]This data refers to subgame perfect equilibrium play looking at each player's own strategy only.

[19]This happened in session III in supergame 2 and 3

second session in which little cooperation occurred due to high defection levels in the initial supergames (population effect). The subject explained her behaviour by stating that the only possible outcome in the game is mutual defection which is worse than staying out.

Why is cooperation higher and subgame perfect equilibrium play lower in setup II? A rational risk-neutral subject should enter the game in setup II if and only if the expected payoff from playing the game is positive (since the outside option yields 0 payoff). Payoff expectations will be determined by initial beliefs and the experience gathered during the experiment. In psychology, substantial research has been done on how subjects formulate their initial beliefs about unknown partners; they tend to project their own intentions onto others and expect others to behave like themselves (c.f. the so-called "false consensus literature")[20]. If we accept this theory, it is easy to understand why subjects enter the first period of the first supergame: as shown in section 3 unexperienced subjects behave probabilistically. This means that purely defective intentions are extremely rare. Hence, most subjects when projecting their own intentions onto others will expect some cooperation.

Given that different supergames in the present experimental study are not independent, the false consensus idea can no longer be applied to later supergames. Since subjects know that the subject pool has not changed, they can form some well-founded belief about the average behaviour of their potential game partners. The following simple argument reveals that the past discovery of one single cooperator can be sufficient to destroy all future subgame perfect equilibrium play (i.e. always exit). In the argument two cases have to be distinguished: (i) the subject intends to defect always and, (ii) the subject is willing to cooperate.

In case (i), the subject is willing to play all games of the first period of a new supergame as long as he expects to meet at least one cooperator. In that case he will make a loss of -1 in 5 partnerships and a gain of $+7$ in one partnership. Hence his expected payoff from entering is $+2$ which is better than 0 from staying out.

In case (ii), the subject will enter the first period of a supergame in order to find the potential cooperator. During the supergame initial losses will be off-set by the cooperative partnership. Further losses are avoided by opting out in later periods of the supergame if the game partner defected. Subgame perfect equilibrium play is rare, because subjects believe (initial supergame) or have learned (later supergames) that they can do better.

[20]This behaviour was also found by Orbell *et al.* (1993) in experiments on the one-shot prisoner's dilemma with an exit option. In these experiments, cooperation increased in the setup where exit was possible because intending cooperators expect others to cooperate and hence enter the game, while intending defectors expect defection and exit.

But, if they learn that they cannot do better with a specific partner, they stop interacting with this partner.

The main use of the outside option is protection against defectors that have been discovered as such. Also defectors tend to exclude each other. Figure 3 confirms this observation; it reveals that non-cooperative play leads to inactive relationships[21].

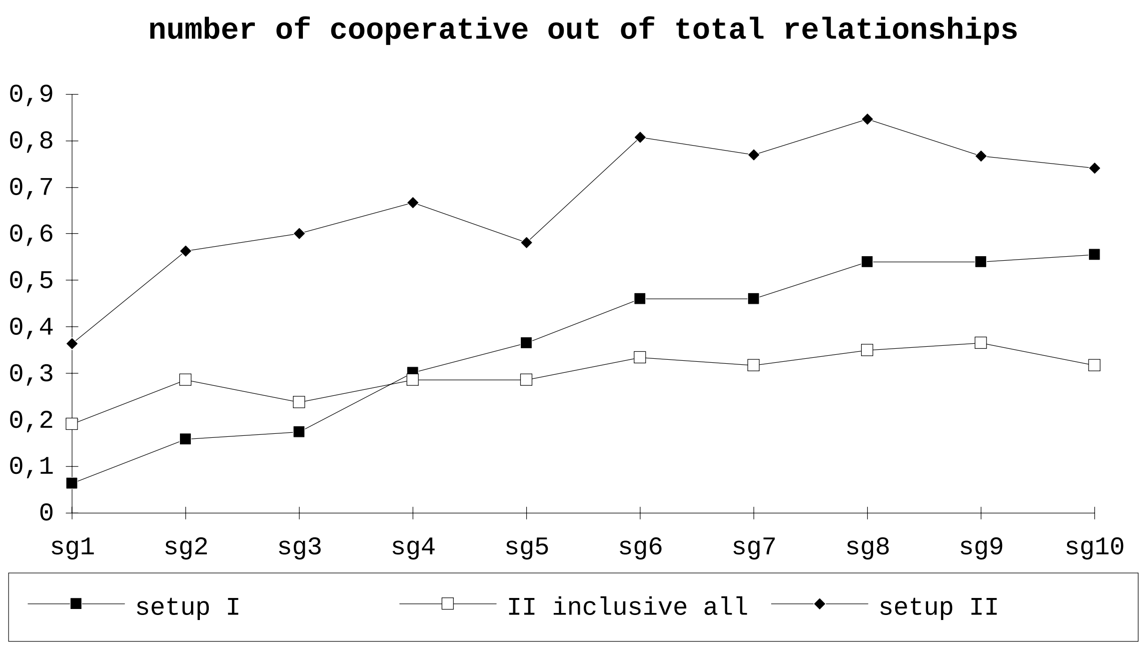

Figure 3: percentage of cooperative relationships in setup I and II. In setup II we distinguish between possible relationships and active relationships

Figure 3 displays the percentage of cooperative relationships in each supergame that occurred in setup I and II. In setup II we distinguish between cooperative relationships out of active relationships and cooperative relationships out of all possible relationships (including inactive ones). While the former is always higher in setup II than in setup I (this hypothesis is accepted by the robust rank order test at significance level $\alpha = 0.01$), the latter drops below the level of setup I from supergame 4 onwards. This happens because experimental subjects quickly learn to exclude defectors. The Spearman rank order coefficient relating the number of the supergame with the total number of defect choices confirms this learning effect at a significance level of $\alpha = 0.01$ (for the underlying data and the calculation of the coefficient see appendix B4). This learning effect is especially

[21]In accordance with Selten and Stoecker (1986)) a partnership is called cooperative if both players choose the cooperative alternative at least during 4 subsequent periods. Following this definition, we will call a parntership active, if the individuals interact in at least 5 periods during a supergame (which is half the supergame.)

strong in the beginning. The number of defect choices out of all possible choices in setup II drops drastically from supergame 1 to 2 (355 choices in supergame 1 against 250 choices in supergame 2).

4.2 The outside option in setup III

As explained in section 2.3 the outside option in setup III is weakly dominated and hence irrelevant for subgame perfect equilibrium play. But, the game has several cooperative non-subgame perfect Nash equilibria in which the outside option is used either on or off the equilibrium path. From the data, evidence for two such equilibria (mentioned in section 2.3) was found. The use of the outside option serves two purposes:

1. *severe punishment for defection*

   As explained in Section 2.3. cooperation can be sustained till period 8 (inclusive) by threatening eternal punishment via exit. Since in equilibrium this threat is not implemented, the increase in cooperation due to the threat[22] cannot be assessed directly. Its impact is seen indirectly when examining endeffect behaviour. If the above equilibrium is relevant, cooperation should not break down before period 9. If it does, it should give rise to self-inflicted punishment via exit. Indeed we can document:

   Observation 2 *The actual endeffect period of setup III is later than the actual endeffect period of setup I.*

   The Wilcoxon-Mann-Whitney test rejects the hypothesis H_0 of the same endeffect period in favour of the alternative hypothesis H_1 that the endeffect period of the third experimental setup lies above the baseline experiment. At a significance level $\alpha = 0.05$ the probability that H_0 is true is $p = 0.0267$ (for details and the underlying data see Appendix D1).

   Moreover, 11 out of 41 cases of too early endeffect behaviour (i.e. cooperation broke down earlier than in period 9 corresponding to the non-subgame perfect cooperative equilibrium) were punished by exiting[23].

2. *signal for cooperative intentions*

   The Nash equilibrium that allows for mutual cooperation is based on the threat of

[22]exit after first period defection is common, but eternal exit is rare ($\frac{1}{21}$).

[23]If we separate the different experimental sessions, it was used with frequency $\frac{1}{6}$ in session 1, $\frac{4}{5}$ in session 2 and $\frac{1}{5}$ in session 3. Averaging over the sessions yields a frequency of $\frac{7}{18}$.

self-inflicted punishment, which is fairly weak. One way to increase the credibility of the threat is to opt out in the first period and to start cooperating in the second. It is easily seen that opting out in the first period, followed by mutual cooperation until period 8 inclusive, and mutual defection afterwards, is a Nash equilibrium sustained by the now more credible background threat of quitting[24]. Opting out in early periods of a supergame serves as an equilibrium selection device. It reveals that the player in question is willing to use self-inflicted punishment. Moreover, opting out is a less costly signal for cooperative intentions than cooperation itself[25]. 7 out of 21 experimental subjects used and understood this signal. In the first experimental session, nearly all the cooperation arose due to this behaviour[26].

The outside option does not turn out to be irrelevant: it is used[27] and its use does not disappear and sometimes even increases over time.

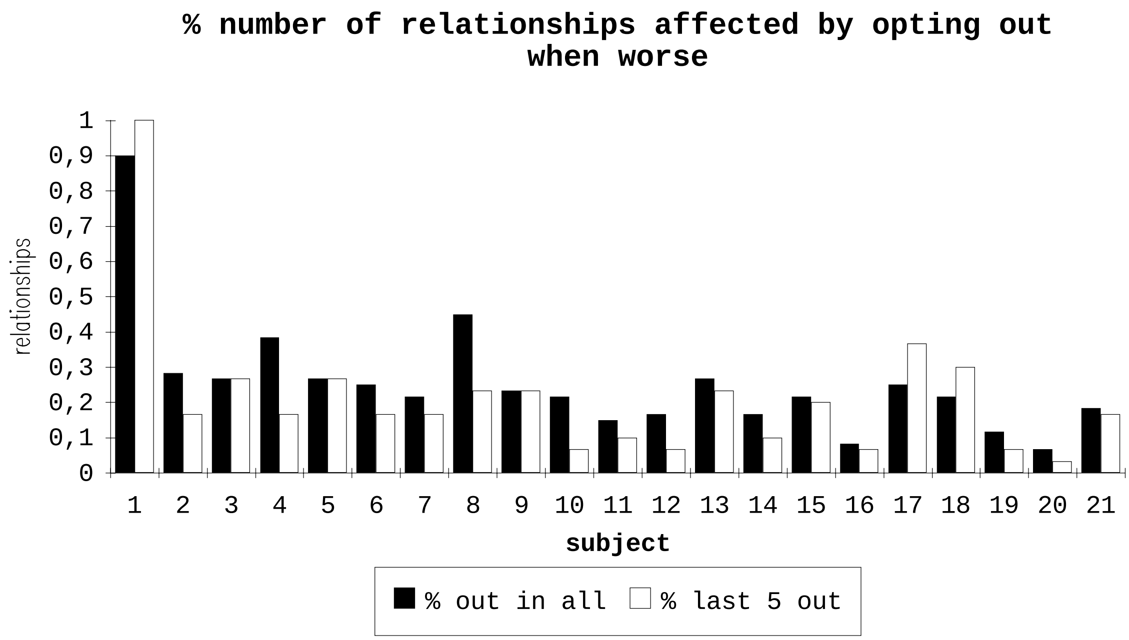

Figure 4: setup III: percentage relationship per subject in which the outside option was used

Figure 4 summarizes the percentage of all relationships per experimental subject in which at least one of the partners used the outside option. The figure contrasts the overall

[24]Formally, $n_c c + (9 - n_c)d \geq h + (n_c - 1)c$.

[25]Only subjects who are willing to risk a cooperative first move opted out in early periods.

[26]100% cooperation was due to signalling by opting out from supergame 6 onwards.

[27]18 out of 21 subjects exited at some point during the session.

experiment with the last 5 supergames only. It can be seen that for $\frac{1}{3}$ of the subjects the number of relationships affected by the outside option did not diminish or even increased over time. Figure 5 illustrates the percentage of all relationships per supergame in which some opting out occurred. On average over all sessions, this percentage fluctuates around 20%.

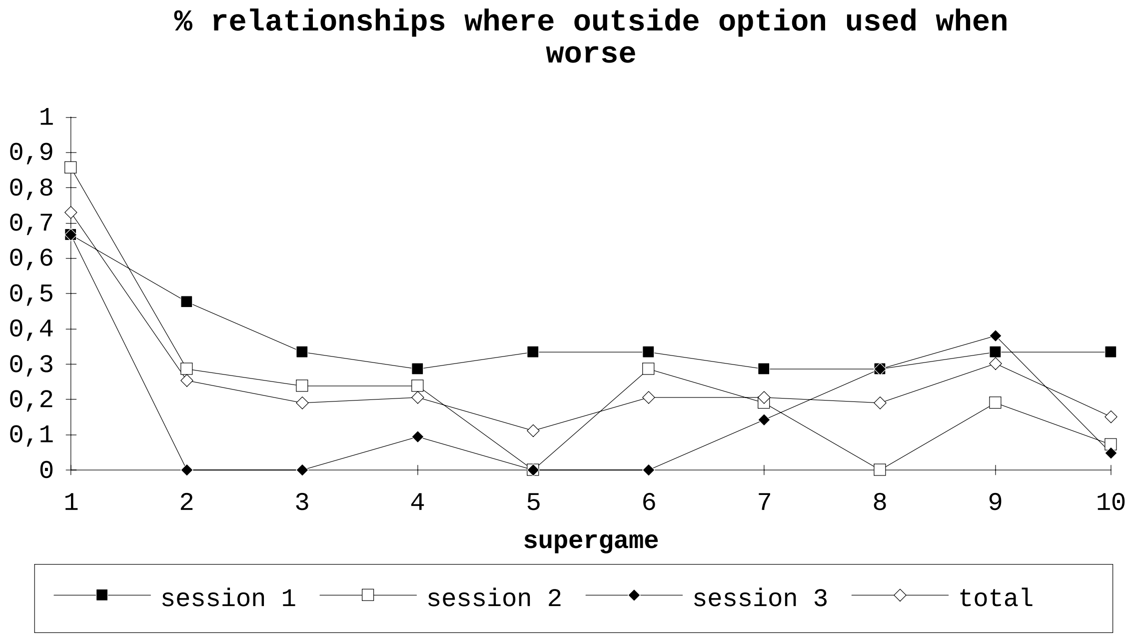

Figure 5: setup III: percentage relationships per supergame in which the outside option was used

In the light of the above evidence, it is clear that the outside option is used *within* setup III in order to achieve and sustain the cooperative non-subgame perfect equilibria. However, we have the following paradox: comparing setup I and III reveals that overall cooperation levels in the latter are significantly lower. What is going on?

5 Results III: negative versus positive equilibrium payoffs

Setup I and III have to be compared with care since the underlying prisoner's dilemma payoff matrix differ. Rapoport *et al.* (1965) developed the following index r_1 in order to assess in which way a change in the payoff matrix affects expected cooperation levels [28]:

$$r_1 = \frac{c-d}{h-l}$$

A higher index r_1 implies higher cooperation levels[29]. Given that r_1 is higher in setup I than in setup III ($r_1 = \frac{6}{13}$ compared to $\frac{4}{13}$ in setup III), cooperation in setup I should be higher than in setup III. However, compared to Rapoport *et al.* (1965) the observed difference is very high[30].

Rapoport *et al.* (1965) test the index only for matrices with negative payoffs for mutual defection. In this paper, we contrast games with positive equilibrium payoffs with games with negative equilibrium payoffs. This comparison is important, since former research has found considerable psychological differences in how gains and losses are conceived[31]. Tversky and Kahneman (1991) show that people tend to have a loss-aversion, i.e. they dislike losses more than they like equal-sized gains. The authors also observe the phenomenon of *reflection*: people avoid risks that can yield gains but often seek risks to avoid equal-sized losses. These results from individual choice find their game-theoretic cousin in different principles of loss avoidance. In its most general form, the principle states that people choose strategies that *might* result in gains and *expect* others to do the same. Cachon and Camerer (1996) find substantial evidence for the use of this principle in experiments on coordination games.

For our setup the type of loss avoidance which Cachon and Camerer (1996) refer to as *losing-equilibrium avoidance* is of interest: subjects avoid strategies with negative equilibrium payoff[32]. While in the baseline experiment, the sure loss of the subgame perfect equilibrium might be avoided by risking cooperation, in setup III a sure gain is put under risk once subjects move away from subgame perfection. Subjects' tendency to avoid losses leads them to try to achieve cooperation in setup I while the same force locks

[28] c is the payoff from simultaneous cooperation, d the payoff from simultaneous defect, h the payoff from one-sided defection and l the payoff from one-sided cooperation.

[29] Several later studies (Jones *et al.* (1968), Steele and Tedeschi (1967), (Roth and Murnighan (1987)) have confirmed that the index is a good indicator of cooperation levels.

[30] see footnote 5.

[31] Jones *et al.* (1968) already found a difference in cooperation levels with negative and positive payoffs. They also observed that cooperation was higher in the presence of negative payoffs. However, they argued that the index could capture this difference, since with negative payoffs it increases in value when compared with those matrices where the payoffs are positive. This argument is only partially true: the same value of the index can be achieved in games with positive and in games with some negative payoffs. Indeed, our setup III has the same index (0.3) as several PD matrices in Rapoport *et al.* where the payoff for mutual defection is negative.

[32] Cachon and Camerer examine games with multiple equilibria whereas I use the principle also in situation with only one equilibrium.

them into simultaneous defection in setup III. Therefore, it is not surprising that lower cooperation levels are observed in setup III than in setup I. (see Figure 2)

Besides these loss-avoidance factors, the following simple calculation shows another reason why subjects are more willing to risk one-sided cooperation is setup I than in setup III. In the worst case a player who always defects gets ten times the defect payoff d. Imagine that in the case of mutual cooperation the endeffect would strike in period 9. Also suppose it were mutual[33]. How high has the probability p that a player responds to a cooperative first move in the next period to be for a risk neutral player to consider this cooperative first move to be worthwhile? The incentive constraint with $d = \mp 1$, $l = -6$ and $c = 5$ is as follows:

$$10d < l + p(7c + 2d) + (1 - p)(l + 8d)$$

which requires $p > \frac{10}{47}$ for setup I while $p > \frac{2}{5}$ is required in setup III. Clearly the latter probability is considerably higher (more than double). Thus the incentive to start cooperation is significantly lower. Rapoport *et al*'s (1965) index has to be used with care in our setup, because it is not sufficiently sensitive to the sign of the payoff for simultaneous defections. The present experiment has revealed that this is an important (and so far neglected) factor influencing the level of cooperation in prisoner's dilemma games.

6 Conclusions

The above experiments allow us to draw the following conclusions:

1. Deterministic behaviour is the exception rather than the rule. Both inexperienced and experienced experimental subjects discriminate against opponents with an identical history of play. This probabilistic behaviour is used in very specific circumstances, namely in start- and end-effect behaviour.

2. The probabilistic behaviour of experimental subjects casts serious doubts on the adequateness of experimental methods that require subjects to submit a deterministic supergame strategy during an experiment. It also questions the usefulness of theoretical models that are (directly or indirectly) based on deterministic or simple probabilistic[34] finite automata. These type of models are very common when the possibility of partner selection is introduced into prisoner's dilemma environments.

[33]These assumptions are made because they correspond to the break-down period of cooperation in the non-subgame-perfect Nash equilibrium of setup III.

[34]probabilistic behaviour in the laboratory only occurs in specific circumstances and is rather sophisticated.

3. Our experiments confirm the qualitative results of most theoretical models on partner selection: partner selection enhances cooperation and thus might be a key element in explaining high cooperation levels in real data. The way experimental subjects use the outside option (refuse a match) confirms further that their behaviour is rather sophisticated. E.g. in setup III refusal is used as a coordination device to signal cooperative intentions.

4. The experiments confirm a well-known fact that the payoff matrix influences the degree of cooperation. However, it also reveals the limitation of existing indices that help predict the relative change in cooperation levels when the underlying prisoner's dilemma matrix is altered. Namely, these indices are only adequate if the payoffs for simultaneous defections have the same sign. In our setup I the subgame perfect equilibrium yields a loss while in setup III it yields an equal-sized gain. The tendency in human beings to avoid losses (as reported in several experimental studies) gives them an incentive to try to improve their situation in setup I and risk cooperation while the same force locks them into simultaneous defection in setup III, because its payoff is positive and a one-sided cooperative move results in a loss. Thus, cooperation levels in setup I are higher than in setup III.

The above experiments can be helpful in guiding the construction of economic models: they should respect the sophistication of human agents[35]; games with and without a voluntary interaction structure have to be distinguished carefully; and situations with negative or positive (equilibrium) payoffs should be treated differently.

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A Discrimination

The following tables (II to V) report data on non-deteriminstic behaviour. They report how many experimental subjects (*Total*) used probabilistic behaviour in each supergame and under which circumstances. *Random* means that no specific reason for the use of non-deterministic behaviour could be deduced. *First move* refers to probabilistic behaviour when the subject cooperates if no cooperation has been encountered with this game partner so far. *Response* refers to probabilistic behaviour with game partners that made a one-sided cooperative move. *Endeffect* refers to probabilistic behaviour when terminating a cooperative partnership. For experimental setups II and III further circumstances are considered, namely *punish* which refers to probabilistic behaviour when opting out if the partner defected and *signal* in setup III which refers to probabilistic behaviour when opting out in order to signal cooperative intentions. Notice that the same subject can discriminate for different reasons. *s1, s2, s3* refer to session1, session 2, session 3 respectively. Table II summarizes probabilistic behaviour in setup I.

probabilsitic behaviour: setup I															
	total			random			first move			response			endeffect		
supergame	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3
1	7	6	7	5	4	6	0	1	0	2	1	1	0	0	0
2	2	5	6	0	2	4	2	2	0	0	0	2	0	1	0
3	3	5	6	0	0	3	2	3	2	0	2	1	1	1	0
4	4	2	5	0	0	0	1	1	4	2	0	0	1	1	1
5	3	2	5	0	0	1	1	0	5	2	1	1	0	1	0
6	2	3	6	0	0	1	1	1	5	1	1	0	2	1	0
7	2	4	3	0	0	1	1	3	2	1	1	0	1	1	0
8	3	2	3	0	0	1	1	0	3	2	1	0	3	1	0
9	4	3	3	0	0	1	3	1	3	1	1	0	3	2	1
10	4	3	2	0	0	1	2	1	3	1	1	0	4	1	0

Table II

In session 3 of setup I random behaviour continues because one subject cooperates probabilistically in the last period of each supergame.

Table III describes probabilistic behaviour in setup II.

probabilistic behaviour: setup II																		
	total			random			first move			response			endeffect			punish		
supergame	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3
1	7	7	7	4	5	2	2	2	4	0	0	0	0	0	0	1	0	2
2	4	6	5	1	1	1	3	3	4	1	0	0	0	0	0	0	4	0
3	4	7	6	0	0	1	3	2	5	1	0	0	0	0	1	1	5	1
4	3	5	7	0	0	0	2	2	5	0	0	2	2	0	1	1	6	1
5	5	6	6	0	0	0	2	3	4	1	1	1	0	0	2	2	5	1
6	4	6	7	0	0	0	2	2	4	1	0	3	0	0	1	1	4	1
7	3	7	6	0	0	0	2	3	5	1	1	1	1	0	1	0	6	0
8	4	5	6	0	0	0	2	3	5	1	0	0	1	0	2	1	4	0
9	4	5	7	0	0	0	2	2	5	0	0	1	1	0	1	1	5	1
10	3	5	6	0	0	0	2	2	3	0	0	0	1	0	1	0	5	2

Table III

Table IV describes probabilistic behaviour in setup III.

probabilistic behaviour: setup III																					
	total			random			first move			response			endeffect			punish			signal		
supergame	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3	s1	s2	s3
1	5	5	7	3	5	7	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
2	5	3	2	1	1	1	2	2	1	1	0	0	0	0	0	2	1	0	0	0	0
3	4	2	1	1	0	0	2	2	1	0	0	0	0	0	0	0	0	0	1	0	0
4	3	4	3	0	0	0	2	2	2	0	0	1	0	0	0	0	2	0	1	0	0
5	5	4	3	0	0	0	3	4	1	0	0	0	0	0	0	0	0	0	2	0	0
6	3	4	5	0	0	0	1	4	3	0	0	1	0	0	2	1	1	0	1	0	0
7	1	4	5	0	0	0	0	4	5	0	0	1	0	0	3	0	0	1	1	0	0
8	1	4	6	0	0	0	0	4	5	0	0	1	0	0	3	0	0	0	1	0	0
9	2	4	7	0	0	0	0	4	5	0	0	1	0	0	3	1	0	0	1	0	0
10	2	3	7	0	0	0	1	3	6	0	0	1	0	0	2	1	0	0	1	0	0

Table IV

Table V summarizes the different setups

probabilistic behaviour: comparison setups I, II and III																		
	total			random			first move			response			endeffect			punish		signal
supergame	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	II	III	III
1	20	21	17	15	11	15	1	8	0	4	0	1	0	0	0	3	1	0
2	13	15	10	6	3	3	4	10	5	2	1	1	1	0	0	4	3	0
3	14	17	7	3	1	1	7	10	5	3	1	0	2	1	0	7	0	1
4	11	15	10	0	0	0	6	9	6	2	2	1	3	3	0	8	2	1
5	10	17	12	1	0	0	6	9	8	4	3	0	1	2	0	8	0	2
6	11	17	12	1	0	0	7	8	8	2	4	1	3	1	2	6	2	1
7	9	16	10	1	0	0	6	10	9	2	3	1	2	2	3	6	1	1
8	8	15	11	1	0	0	4	10	9	3	1	1	4	3	3	5	0	1
9	10	16	13	1	0	0	7	9	9	2	1	1	6	2	3	6	1	1
10	9	14	12	1	0	0	6	6	10	2	0	1	5	2	2	7	1	1

Table V

B Cooperation

B.1 Percentage cooperation per supergame

		supergame									
setup	session	1	2	3	4	5	6	7	8	9	10
	1	0.2214	0.2429	0.3167	0.3452	0.5214	0.6405	0.6357	0.6857	0.6619	0.6524
I	2	0.2214	0.2119	0.2619	0.3	0.3310	0.4214	0.3129	0.3929	0.4238	0.3881
	3	0.2690	0.2095	0.2	0.2929	0.1857	0.2357	0.3190	0.2738	0.2429	0.2429
	average	0.2373	0.2214	0.2595	0.3123	0.3460	0.4325	0.4230	0.4508	0.4428	0.4278
	1	0.4444	0.5940	0.4658	0.5882	0.5234	0.5728	0.5921	0.6652	0.6598	0.6327
II	2	0.1734	0.0945	0.18	0.1512	0.1512	0.5128	0.2255	0.5	0.3846	0.3810
	3	0.5405	0.8203	0.8532	0.7569	0.7820	0.7460	0.7232	0.7023	0.6277	0.5902
	average	0.3947	0.5707	0.5550	0.5760	0.5722	0.6169	0.5536	0.6236	0.5773	0.5484
	1	0.1152	0.0783	0.0624	0.0634	0.1069	0.2087	0.2568	0.2630	0.2356	0.1709
III	2	0.1070	0.0597	0.0719	0.0487	0.1143	0.1695	0.2611	0.3	0.2798	0.1105
	3	0.1053	0.0106	0.0732	0.0941	0.1589	0.4338	0.5082	0.5043	0.4533	0.4247
	average	0.1091	0.0495	0.0692	0.0687	0.1267	0.2707	0.3421	0.3558	0.3229	0.2354

Table VI

B.2 Total cooperation levels per period

Total cooperation levels per period are calculated in two ways: (i) for each period the total number of cooperative plays are summed and divided by the possibilities (1260). This is reported in the table VII under *total.*(ii) for each player the percentage cooperation per period is calculated and averaged over players and sessions. This is reported under *per* *player.*

type	setup	period 1	2	3	4	5	6	7	8	9	10
total	I	0.4	0.4222	0.4468	0.4412	0.4262	0.4198	0.3976	0.3547	0.1849	0.0603
	II	0.4428	0.5134	0.5730	0.6337	0.6804	0.7197	0.6505	0.5089	0.4033	0.2871
	III	0.1129	0.1616	0.1736	0.1860	0.1869	0.2002	0.1960	0.1661	0.1069	0.0573
per player	I	0.3833	0.4079	0.4302	0.4246	0.4095	0.4024	0.3786	0.3421	0.1817	0.0579
	II	0.3999	0.4426	0.4936	0.5164	0.5455	0.5489	0.4905	0.4002	0.3259	0.2168
	III	0.1113	0.1624	0.1735	0.1843	0.1847	0.1993	0.1942	0.1661	0.1075	0.0595

Table VII

From table VII it can be seen that in the baseline setup, total cooperation starts to decrease by period 4 while in setup II it only starts falling in period 6. Furthermore, cooperation levels increase less and fall more strongly in the baseline setup.

In order to test whether or not cooperation levels are higher in setup II than I, we use the Wilcoxon-Mann-Whitney test. In table VIII cooperation levels are ranked from highest to lowest:

ranking: type	setup	period 1	2	3	4	5	6	7	8	9	10
total	I	6	9	13	11	10	8	5	4	2	1
	II	12	15	16	17	19	20	18	14	7	3
per player	I	7	11	14	13	12	10	6	5	2	1
	II	8	15	17	18	19	20	16	9	4	3

Table VIII

With the help of table VIII the Wilcoxon-Mann-Whitney test statistics are easily calculated. They are (i) $W_x = 69$ ($W_y = 141$) for total cooperation levels and (ii) $W_x = 81$ ($W_y = 129$) for per player cooperation levels. This implies that there is no difference between cooperation levels in setup I and II with probability $p = 0.0026$ in (i) and $p = 0.0376$ in (ii). The hypothesis that cooperation is higher in setup II is accepted at a significance level $\alpha = 0.05$.

B.3 Percentage of cooperative relationships

In experimental setup II, I distinguish between the percentage of cooperative relationships out of active ones referred to as II(active) and the percentage of cooperative relationships out of all possible partnerships.

setup	supergames 1	2	3	4	5	6	7	8	9	10
I	0.0635	0.1587	0.1746	0.3016	0.3651	0.4603	0.4603	0.5397	0.5397	0.5556
II(active)	0.3636	0.5625	0.6000	0.6667	0.5806	0.8077	0.7692	0.8462	0.7667	0.7407
II(all)	0.1905	0.2857	0.2381	0.2857	0.2857	0.3333	0.3175	0.3492	0.3651	0.3175
III	0	0.0317	0.0476	0.0794	0.1270	0.2698	0.3175	0.3333	0.2857	0.2540

Table IX

B.4 Number of defect choices in setup II

Table X shows how many defect choices were made in setup II per supergame. In each supergame 1260 (21 players, 6 partnerships, 10 periods) choices were made

supergames	number of defect choices in setup II 1	2	3	4	5	6	7	8	9	10
setup II	355	250	239	219	233	189	234	177	217	210

Table X

With the help of table X the Spearman rank order coefficient can be calculated that relates the number of the supergame with the defect choices. We expect defect choices to fall in later supergames. The Spearman rank order coefficient is $r_s = -0.76$ which confirms the hypothesis at significance level $\alpha = 0.05$

C Percentage of only defect play in experimental setup I and II

type	setup	supergames 1	2	3	4	5	6	7	8	9	10
one-sided	I	0.2143	0.4286	0.3492	0.4206	0.3968	0.3413	0.3095	0.2381	0.2698	0.2857
	III	0.3254	0.7381	0.7778	0.7857	0.7540	0.5794	0.5476	0.5238	0.4841	0.5238
mutual	I	0.0476	0.2222	0.1746	0.3016	0.2698	0.2857	0.2063	0.1270	0.1746	0.1905
	III	0.1111	0.6190	0.6667	0.6984	0.6508	0.4921	0.4286	0.4127	0.3651	0.4762

Table XI

D Endeffect behaviour

D.1 Actual (observed) endeffect period

These averages are calculated by dividing the sum of actual endeffect periods by the number of actual endeffect play.

	supergames									
setup	1	2	3	4	5	6	7	8	9	10
I	9.25	8.91	9.5008	8.5556	8.3913	9.2069	8.5517	8.25	7.8182	7.8571
II	10.8182	10.25	9.8667	9.6667	9.1667	8,4286	8.05	7.7727	7.5417	7.15
III		9.5	10.3333	10.2	10	10	9.45	9.2174	7.9473	7.6471

Table XII

In order to test whether or not the endeffect period in setup I lies above the endeffect period in setup III, we use the Wilcoxon-Mann-Whitney test. Ranking the observations starting from the smallest number, we get $W_x = 114$ for setup III. With 9 observations in setup III and 10 observations in setup I, this implies that the hypothesis of the same endeffect period in both setups is true with probability $p = 0.0267$ at a significance level of $\alpha = 0.05$.

D.2 Intended endeffect period

The intended endeffect period is the period in which an experimental subject intends to break up a cooperative relationship[36]. Probabilistic behaviour in this period is very common[37]. A shift of the endeffect to earlier periods ought to be reflected in intended end-effect periods. The hypothesis that the (intended) endeffect period is negatively correlated with the number of the supergame is supported in all three experimental setups[38]. Table XIII shows the mean and standard deviation of intended deviation period in end-effect plays for supergames and experimental sessions separately. It also shows the Spearman rank correlation coefficient between the mean[39] of the intended deviation period and the

[36]The intended endeffect period can be inferred from subjects' overall enedeffect behaviour and the written statements they made at the end of the experiment explaining their choices.

[37]Tables on intended and observed endeffect periods of each subjects can be obtained from the author upon request.

[38]Selten and Stoecker (1986) get slightly higher correlation coefficients. However, they look for correlation from supergame 13 onwards while I start with the first supergame.

[39]If players had different endeffect periods with different partners they were averaged in the calculation of the mean.

number of the supergame. The values in brackets refer to the one-tailed and two-tailed level of significance respectively.

experimental session	Supergames 1	2	3	4	5	6	7	8	9	10	Spearman rank correlation coefficient
baseline I											
mean	10.875	10.125	9.9	9.44	9.239	9.47	9.407	9.24	8.314	8.29	-0.903
standard dev.	0.217	1.023	0.49	0.46	0.25	0.75	0.628	0.603	0.757	0.683	(0.0005) (0.001)
baseline II											
mean	11	9.5	10.33	10	9.7	9.61	7.56	8.875	9.42	8.83	-0.794
standard dev.	0	1.47	0.47	0.63	0.871	0.45	2.307	1.078	0.607	1.344	(0.005) (0.01)
baseline III											
mean		11	10.17	9.6	8.83	9.5	9.7	8.9	8.6	8.33	-0.833
standard dev		0	0.373	0.66	1.21	0.867	0.458	0.7	0.49	0.624	(0.05) (0.1)
better I											
mean	10.6	10	10	9.3	9.4	8.3	7.96	8.17	8.13	7.3	-0.96
standard dev.	0.49	0.894	0.707	0.56	0.8	1.599	1.80	1.07	0.39	0.417	(0.0005) (0.001)
better II											
mean		11	10	10		10.33	9	9	8.67	7.67	-0.9157
standard dev.		0	1	0		0.47	0	0	0.47	1.88	(0.0025) (0.005)
better III											
mean	11	10.83	10.42	10.03	9.4	8.7	8.08	7.84	7.21	7.667	-0.994
standard dev.	0	0.37	0.449	0.58	0.447	0.5	0.61	1.32	0.74	0.408	(0.0005) (0.001)
worse I											
mean		9.17		10		9.5	9.5	9.5	9	8.5	-0.891
standard dev.		0.63		0		0.5	0.5	0.5	0	0.5	(0.01) (0.02)
worse II											
mean		11	11	11	11	10.8	11	10.8	10	9.67	-0.844
standard dev.		0	0	0	0	0.4	0	0.4	0.89	0.47	(0.0025) (0.005)
worse III											
mean			10.333	10.667	10.25	10.12	9.07	8.82	7.98	7.357	-0.976
standard dev.			0.4714	0.4714	0.433	0.33	0.678	0.437	0.846	0.58	(0.0005) (0.001)

Table XIII