Strategic ignorance in repeated prisoners' dilemma experiments and its effects on the dynamics of voluntary cooperation

Lisa Bruttel[1], Simon Felgendreher[2], Werner Güth[3], Ralph Hertwig[4]

Abstract

Being ignorant of key aspects of a strategic interaction can represent an advantage rather than a handicap. We study one particular context in which ignorance can be beneficial: iterated strategic interactions in which voluntary cooperation may be sustained into the final round if players voluntarily forego knowledge about the time horizon. We experimentally examine this option to remain ignorant about the time horizon in a finitely repeated two-person prisoners' dilemma game. We confirm that pairs without horizon knowledge avoid the drop in cooperation that otherwise occurs toward the end of the game. However, this effect is superposed by cooperation declining more rapidly in pairs without horizon knowledge during the middle phase of the game, especially if players do not know that the other player also wanted to remain ignorant of the time horizon.

Keywords: strategic ignorance, cooperation, prisoners' dilemma, experiment

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[1]University of Potsdam, Institute of Economics, Karl-Marx-Straße 67, 14482 Potsdam, Germany, e-mail: lisa.bruttel@uni-potsdam.de

[2]University of Gothenburg, Department of Economics, Vasagatan 1, 405 30 Gothenburg, Sweden, e-mail: simon.felgendreher@economics.gu.se

[3] LUISS Università Guido Carli, Department of Economics and Finance, Viale Romania 32, 00197 Rome, Italy, Frankfurt School of Finance and Management, Sonnemannstraße 9-11 60314 Frankfurt am Main, Frankfurt, Germany, e-mail: w.gueth@fs.de, Max Planck Institute for Collective Goods, Kurt-Schumacher-Str. 10, 53113 Bonn, Germany

[4] Max Planck Institute for Human Development, Center for Adaptive Rationality, Lentzeallee 94, 14195 Berlin, Germany, e-mail: hertwig@mpib-berlin.mpg.de

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1. Introduction

Although humans are often portrayed as informavores, with a strong urge to know and a keen desire to reduce uncertainty (Ross, 1924; Maslow, 1963), circumstances exist under which people choose not to know. Discussing the reality, functions, and rationality of this epistemological abstinence, Hertwig and Engel (2016) defined *deliberate ignorance* as a conscious individual or collective choice not to seek information in situations where acquisition costs would be negligible, and distinguished six functions of deliberate ignorance. These functions include regulation of unpleasant emotions, avoidance of regret, and maintenance or production of impartiality and fairness (Harsanyi, 1953; Rawls, 1971). Yet perhaps the most frequently investigated function is a strategic one: In some situations, strategically avoiding information may promise specific advantages. Strategic ignorance can, for instance, (1) provide a bargaining advantage (Conrads and Irlenbusch, 2013; Loewenstein and Moore, 2004; McAdams, 2012; Schelling, 1956); (2) be a self-disciplining device (when knowledge is likely to prompt reactions that a later self of the person will regret; e.g., Carrillo and Mariotti, 2000); (3) help people eschew responsibility by avoiding knowledge of how their actions and the resulting outcomes—with respect to a public good such as the environment, for instance—affect others (e.g., Dana, 2006); and (iv) help people avoid liability in a social or legal sense (e.g., Gross and McGoey, 2015).

In this article, we experimentally examine another strategic dimension of deliberate ignorance, namely, its potential to foster cooperation. To this end, we employ a finitely repeated prisoners' dilemma game in which participants decide whether they want to know the exact time horizon (i.e., the number of rounds to be played). In this setup, the potential of deliberate ignorance to enhance cooperation may unfold in two ways: First, opting for ignorance may reduce detrimental endgame effects—that is, the unraveling of cooperation—because players cannot stop cooperating in the last round of the interaction if they do not know when the interaction will terminate. Second, it may signal cooperative intentions in general, because players who commit themselves not to deviate from mutual cooperation in the endgame have to cooperate in the preceding rounds—otherwise there would be no mutual cooperation from which to deviate. Signaling such intentions may help to solve the coordination problem of two conditionally cooperative players deciding whether to cooperate in a finitely repeated prisoners' dilemma game and when to terminate cooperation.[1] However,

[1] In repeated prisoners' dilemma or public goods games in psychology and economics, it is standard practice to induce commonly known horizon certainty, that is, to inform all participants about the number of rounds to be played. For backward induction, it would suffice to guarantee a commonly known finite upper bound for the number of successive rounds. This could be made known by, for instance, publicly stating that at most $\bar{T}(< \infty)$ rounds will be played. Presenting private information about $\bar{T}$ may, however, not suffice for commonly known

such signaling is not unambiguous: Purely selfish players who do not intend to cooperate may also abstain from informing themselves about the duration of the interaction because this information is irrelevant to their strategy. It is therefore an open question whether voluntary ignorance can serve as an effective signaling tool.

Deliberately choosing ignorance implies at least three requirements: the ability (1) to overcome the natural default to consult information that is explicitly offered;[2] (2) to understand that, counterintuitively, knowing less can be mutually beneficial; and (3) to anticipate that one's counterpart, having understood the advantages of ignorance, will also opt for ignorance. Our first aim is to experimentally test whether and how frequently participants exercise voluntary cooperation in terms of maintaining ignorance about the time horizon of the prisoners' dilemma game. We do not expect deliberate ignorance to be the prevalent choice because the hurdles are high, and it is likely that one or more of requirements 1–3 are not met.

Even if signaling voluntary ignorance helps players to start the repeated game in a spirit of cooperation, the total effect of ignorance on average cooperation across all rounds is ambiguous: Conditional cooperators who have opted for ignorance may become increasingly worried about entering the final round—and any round could be the last. Consequently, it is possible that the level of cooperation does not drop in the final rounds—not because a high level of cooperation is maintained but because cooperation has already hit rock bottom. The second aim of our study is therefore to examine whether and to what extent voluntary ignorance about the horizon influences cooperation. Finally, the cooperation-enhancing effect of voluntary ignorance may depend on whether only one or all parties have horizon information and, in addition, on whether this potential asymmetry is transparent (commonly known).

We find that mutual horizon ignorance leads to higher cooperation rates in the first and the very last round of a supergame. However, this does not result in higher average payoffs for ignorant players, since the cooperation rate is lower in the middle of the game compared to pairs of players that were informed about the length of the game.

Strategic ignorance, as studied in this article, differs from the type of ignorance examined in previous studies in which the knowledge state of the *other* party is manipulated by

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horizon information (see Bruttel et al., 2012). Rather than conveying a finite upper bound, participants are commonly informed about the exact number of rounds, T (see Normann and Wallace, 2012). One likely consequence is that participants entering the final phase may be more likely to terminate mutual cooperation and to suffer from endgame effects.

[2] According to the Gricean maxims of conversation and, in particular, the Cooperative Principle, a contribution to an exchange delivers what is required at the stage at which it occurs (Grice, 1975).

concealing or not releasing information. For instance, in strictly competitive situations such as matching pennies games, the first mover will take great care not to let the second mover learn her choice. Similarly, in ultimatum bargaining, the proposer, who is privately informed about the (large) pie size, will strive to hide this information from the responder in order to conceal her own greed behind the possibility that the pie to be split between the two of them is only small (see Güth and Kocher, 2014). Participants with dictator power prefer to leave the relationship between their actions and resulting outcomes to others uncertain, and giving them the moral "wiggle room" to behave with (more) self-interest (Dana et al, 2006).

Our experimental design is related to but not identical to the study of ultimatum bargaining by Conrads and Irlenbusch (2013). Their experimental design reversed the usual information asymmetry (e.g., Mitzkewitz and Nagel, 1993) by letting the responder's payoff depend on the (randomly determined) state of nature. In one state, players' payoffs are aligned; in the other state, they are not. Unlike the proposer, the responder is always informed about the actual state of nature. Conrads and Irlenbusch found that proposers benefit from (deliberate) ignorance because responders accept almost all offers, including unfavorable ones, when payoffs remain opaque to the proposer. In other words, the proposer in their experiment actually sends a negative signal by choosing to remain uninformed; in our prisoners' dilemma, in contrast, remaining uninformed signals positive, cooperative intentions. The study by Kandul and Ritov (2017) is also related to our experiment in some respects. In their dictator game, dictators were given the option to avoid information about the realization of their own payoffs, whereas receiver's payoff was known. A considerable proportion of dictators ignored the information about their own payoff in order to avoid the temptation of choosing a potentially selfish option over a pro-social allocation. In our setting, choosing not to be informed about the exact horizon might also have a self-disciplining effect on individuals, helping them to maintain cooperation even in the last rounds of the game.

In Section 2, we introduce and discuss our experimental workhorse, a finitely repeated two-person prisoners' dilemma game, and describe the four treatments implemented. Section 3 presents the three hypotheses tested. Section 4 summarizes the experimental procedures. Section 5 reports our results, and Section 6 discusses their implications.

2. Experimental Design

Players 1 and 2 repeatedly play the asymmetric base game of the prisoners' dilemma type: for $i = 1,2$ choice $s_i = D_i$ is strictly dominant. Both players gain when playing (C_1, C_2) rather than (D_1, D_2). Table 1 lists the possible payoffs.

Table 1. Payoffs in the prisoners' dilemma game (payoffs are listed in natural order)

		Player 2	
		C_2	D_2
Player 1	C_1	11, 14	2, 21
	D_1	15, 1	6, 8

We opted for an asymmetric setup, because we believe that most interactions in real life are asymmetric to some extent. The specific parameters of the base game were selected for the following reasons. First, we imposed that, given the other's choice, for two players $i = 1{,}2$, deviating (D_i) yields the same absolute gain over cooperating (C_i), namely 4 (15 – 11 = 6 – 2) for $i = 1$, and 7 (21 – 14 = 8 – 1) for $i = 2$.[3] Second, the cooperation incentives—that is, the payoff differences between (C_1, C_2) and (D_1, D_2)—are rather moderate, at 5 (11 – 6) for player 1 and 6 (14 – 8) for player 2. As a consequence, endgame behavior may be expected to unfold across more than the last period, enabling us to study any treatment differences in endgame behavior.[4]

The experimental instructions induce common knowledge of both the lower bound $(\underline{T} = 7)$ and the upper bound $(\overline{T} = 17)$ of the number of rounds to be played, T. Unless permitted by the specific treatment, participants in our study, who are put into pairs and assigned to role 1 or 2 throughout, do not learn which number T of rounds $t = 1 \dots T$ in the range $T \in \{7,8, \dots 16,17\}$ is to be played out. They are informed only that durations T of 11, 12, and 13 rounds are substantially less likely than are longer or shorter durations.[5] In the following, we refer to the actual number of rounds T as the "horizon," with T being an integer satisfying $\underline{T} \leq T \leq \overline{T}$. This guarantees a commonly known finite upper bound for the horizon: Because in round $\overline{T} = 17$ both players are aware that no future interaction will occur, they should both defect. This, in turn, suggests mutual defection in round 16 and so on—and, ultimately, constant defection. Strategically avoiding horizon certainty thus does not rule out

[3] Future research may investigate how—possibly asymmetric—decomposition of the prisoners' dilemma base game (see Pruitt, 1967) affects whether players want to be informed about the horizon.
[4] The "myth" of significant cooperation in one-off play of prisoners' dilemma games is, in our view, based on games where mutual cooperation is unrealistically more profitable than mutual defection.
[5] The experiment was programmed so that durations of 11, 12, and 13 rounds had a probability of 4% each and all other durations had an equal probability of 11%. This design choice was initially made to afford a clear distinction between short and long durations; however, this variable proved not to be decisive for our findings and we do not consider it further.

endgame behavior altogether[6] but may avoid or delay it.[7] Such deliberate ignorance of the horizon has not been addressed in the experimental literature mentioned above.

Before round $t = 1$, each player $i = 1,2$ can individually choose whether to be informed about the horizon length ($\delta_i = 1$) or to remain ignorant ($\delta_i = 0$). In our analysis of the data, we compare situations in which both players, one player, or neither of them knows the duration of the interaction (categories "Both," "Mixed," and "Neither," respectively). Further, we differentiate according to whether players are aware of the other's knowledge choice (additional categories "Y" and "N"). Table 2 summarizes and describes the resulting situations.

[6] Even reputation equilibria (Kreps and Wilson, 1982) do not allow for voluntary cooperation in the last possible round $\overline{T} = 17$.

[7] In case of $T = \underline{T} = 7$, for instance, both participants might have cooperated throughout the whole game.

Table 2. Overview of subgroups

Abbreviation	Description
Neither_Y	Neither knows the duration; both know that their partner did not want to know.
Neither_N	Neither knows the duration; neither knows whether their partner wanted to know.
Both_Y	Both know the duration; both know that their partner wanted to know.
Both_N	Both know the duration; neither knows whether their partner wanted to know.
Mixed_Y	One knows the duration, the other does not; both know whether their partner wanted to know.
Mixed_N	One knows the duration, the other does not; neither knows whether their partner wanted to know.

To obtain observations of all these situations, we ran treatment variants that differed in the consequences of $\delta = (\delta_1, \delta_2)$ as follows:

Intransparent **"*I*"**: Players $i = 1,2$ with $\delta_i = 1$ learn about T but do not learn about δ_i for $j \neq i$. That is, information about T is private, and it is not transparent who knows T. Treatment *I* can generate observations of Neither_N, Both_N, and Mixed_N.

Transparent **"*Tr*"**: As in treatment *I*, but $\delta = (\delta_1, \delta_2)$ is known by both players before the first round $t = 1$. That is, when the game begins, it is transparent who does and does not know T. Treatment *Tr* can generate observations of Neither_Y, Both_Y, and Mixed_Y.

Unanimously plus **"U_+"**: Only when $\delta_1 \delta_2 = 1$, both players $i = 1,2$ are informed about T and can infer that $j = 1$ and $j = 2$ also opted for $\delta_j = 1$. That is, players have to unanimously vote for horizon certainty. In addition, only when choosing $\delta_i = 1$ can player $i = 1,2$ unambiguously infer the choice $\delta_j \in \{0,1\}$ of the other player $j \neq i$. Treatment U_+ can generate observations of Neither_N and Both_Y.

Unanimously minus **"U_-"**: Only when $\delta_1 + \delta_2 = 0$, both players $i = 1,2$ are *not* informed about T (otherwise both learn T) and can infer that neither $j = 1$ nor $j = 2$ opted for $\delta_j = 1$. That is, only when choosing $\delta_i = 0$ can player $i = 1,2$ unambiguously infer the choice $\delta_j \in \{0,1\}$ of the other player $j \neq i$. Treatment U_- can generate observations of Neither_Y and Both_N.

Similar to Conrads and Irlenbusch (2013), who distinguished between transparent and intransparent information and permitted one player to remain deliberately uninformed, we implemented all possible variations of transparency: In I transparency is exogenously excluded; in Tr it is exogenously imposed. In U_+ and U_- players always have the same information, but their ability to infer the other's information depends on their own information choice.[8]

3. Hypotheses

According to backward induction, neither the differences in information conditions nor the differences in treatment matter for the cooperation decision when sufficient[9] common knowledge of monetary opportunism is assumed. In $t = \overline{T} = 17$ both players $i = 1{,}2$ would choose $s_i = D_i$. Thus, behavior in $t = \overline{T}$ does not depend at all on earlier choices, and this renders $s_i = D_i$ also optimal for $t = \overline{T} - 1$, etc. Accordingly, in all treatments, backward induction implies constant play of (D_1, D_2) in all rounds $t = 1, \ldots, \overline{T}$, irrespective of whether t is reached or not. Nevertheless, the robust evidence of initial cooperation and endgame effects (see the review by Embrey, Frechette, and Yuksel, 2017) suggests strong effects of horizon information in terms of endgame behavior and, through the anticipation of the endgame, also in earlier rounds.

Our first hypothesis concerns endgame behavior: If both players are ignorant—and if mutual ignorance about the horizon has not yet destroyed cooperation—then the pair will not succumb to endgame behavior in the (unknown) final round.

[8] Initially, we implemented these two treatments hoping for further differentiation according to whether the other player *voluntarily* opted for the final state of duration knowledge. However, as some cells had very few observations, we had to aggregate the data to the present level.

[9] For $t = \overline{T}$ common opportunism suffices because for $i = 1, 2$ the choice D_i is strictly dominant; for $t = \overline{T} - 1$ this common opportunism also has to be known by both; for $t = T = \overline{T} - 2$ this knowledge also has to be commonly known, etc., until $t = 1$ is reached. In other words, the number of iterations of both players knowing that they both know that both are opportunistic is linearly linked to T, respectively $\bar{T}$.

Mutual horizon ignorance shields players from endgame behavior (Hypothesis 1)

If both participants are ignorant (by choice or design), no endgame behavior will occur. In contrast, if both participants are informed about the horizon, endgame behavior will increasingly occur in later rounds (e.g., in rounds $t = T - 2$ and $T - 1$ or just T). Finally, if only one participant knows the horizon, this participant will likely defect in the final round.

The next hypotheses concern the level of cooperation throughout the game. In this context, we need to distinguish between the different information conditions that can arise endogenously in the different treatments and between distinct phases of the game. Let us start by focusing on the first round. Depending on whether a player has horizon information and knows/does not know the other's demand for horizon information status, cooperation may be fostered or hindered. Positive effects on cooperation rates will likely be most pronounced if a lack of horizon information is voluntary and is known to the other player. This situation can occur in two treatments: Tr and U_{-}. Here, some participants may distance themselves from the choice of knowing and try to signal cooperative intentions to their counterpart by opting for voluntary ignorance. To the extent that the counterpart understands this signal, higher cooperation rates can be expected in situations where participants are both uninformed and know that the other is voluntarily uninformed (Neither_Y).

Mutual horizon ignorance, known to both, boosts the level of cooperation in the early phase of the interaction (Hypothesis 2)

If both participants are ignorant by choice about the horizon and aware that the other is likewise voluntarily ignorant, the level of cooperativeness in the early phase will be higher than in pairs who are ignorant about the horizon but do not know if the choice of their counterpart was voluntary.

It is an empirical question how lasting this signal and its effects are. Although mutual horizon ignorance promises to increase cooperation rates at the beginning of the interaction, it may exact a price. Specifically, it may undermine the propensity to cooperate in later rounds. For somebody unaware of the horizon, any round after passing the lower bound could be the last. Conditional cooperators who have opted against removing the veil of ignorance may therefore become increasingly afraid of entering the final round. Echoing the increasing urge to preempt receiving the "sucker's payoff" in the (unknown) last round, the likelihood of terminating cooperation may therefore increase across rounds. In fact, it is possible that the poison of mistrust will already have eroded cooperation to a minimum before the final rounds. In contrast, participants with horizon certainty may keep up some measure of cooperation throughout all rounds before the final ones.

> **Mutual horizon ignorance chips away at cooperation throughout (Hypothesis 3)**
> If both participants are ignorant (by choice or design) about the horizon, the level of cooperativeness prior to the final rounds will be lower than in pairs in which both participants are informed.

4. Procedures

We ran a total of 12 sessions with 32 participants each (N = 384), with 128 participants in treatments *I* and *TR* and 64 participants in treatments U_+ and U_-, respectively. As there were only two plays of the repeated game, we were able to match groups of four participants each—two being assigned to role 1 and two to role 2—who then exchanged partners in the second play of the game (perfect stranger matching). We refer to the first play of the repeated game as "supergame 1" and to the second as "supergame 2."

The experiment was run in the computer laboratory of the Max Planck Institute of Economics in Jena. Students of different fields of study at Jena University were recruited through ORSEE (Greiner, 2015). The software used was programmed in z-Tree (Fischbacher, 2007). A translation of the instructions (originally in German) in the four treatments is provided in the Appendix. A session typically lasted 60 minutes (about 15 minutes for reading the instructions, 5 minutes for answering control questions, 10 minutes for each supergame, and 20 minutes for answering the post-experimental questionnaire and payment). Table 3 provides information on earnings by treatment, supergame (1 and 2), and participant role (1 and 2). Earnings were significantly higher in the second supergame than in the first (see Table A1 in the Appendix), probably because experience helped participants to cooperate more efficiently. Payoffs did not differ significantly between treatments. Participants in the role of player 2 earned consistently more than those in the role of player 1, with their earnings advantage being slightly less than their payoff advantage of 3 units in case of (C_1, C_2). Especially, participants in the role of player 2 did not suffer from their more widely varying payoffs (see Table 1).

Table 3. Average earnings in each supergame (in euro)

		Treatment			
Role	Supergame	I	Tr	U_+	U_-
1	1	7.48	7.76	7.74	7.68
	2	8.46	8.21	8.62	8.91
2	1	10.19	9.94	10.32	10.48
	2	10.95	11.04	11.34	11.69

5. Results

In this section, we first give an overview of our participants' horizon information choices. We then present the results concerning our hypotheses, focusing on the cooperation rate as the target variable. Finally, we address the payoff consequences of deliberate ignorance.

How frequent is the choice to remain ignorant?

Table 4 lists the percentages of participants who chose to stay ignorant about the horizon. Most participants preferred to be informed. Controlling for participant role and supergame, the proportion of participants who chose to be informed was significantly higher in Tr than in I. Choices in U_- and U_+ did not differ significantly from those in baseline treatment I (see Table A2 in the Appendix). In the following analyses of the cooperation rate, we therefore focus on differences between participants with endogenous differences in horizon choice rather than on differences between treatments.

Table 4. Percentage of participants who chose to stay ignorant of the time horizon by treatment, supergame, and role of player

		Treatment			
Role	Supergame	I	Tr	U_+	U_-
1	1	28.13	17.19	18.75	31.25
	2	32.81	10.04	28.13	25.00
2	1	29.69	18.75	15.63	25.00
	2	21.88	17.19	21.88	18.75

Despite the clear preference for being informed, a nontrivial number of participants wished to remain ignorant. Their proportion ranged from 10% to 33% across conditions. On average, 22% opted against receiving information. Table 5 provides an overview of how many observations fall into each of the categories defined in Section 2. Unfortunately, the numbers of observations in the most interesting categories, Neither_Y and Neither_N, were extremely low. We thus evaluate the data at an aggregate level across treatments.

Table 5. Summary statistics of sub-groups

Information constellation	% of all pairs in supergame 1	% of all pairs in supergame 2
Neither_Y	2.08	1.04
Neither_N	2.08	5.21
Both_Y	32.29	34.90
Both_N	25.52	28.13
Mixed_Y	11.98	7.29
Mixed_N	15.10	10.94
Not classified*	10.93	12.50

* Observations in the “Not classified” category are from specific cases in the treatments U_+ and U_-, where a player could not infer whether or not the counterpart was voluntarily uninformed.

Table 6. Ordered logit regression: Difference in cooperation

Dependent variable	Difference in cooperation T – (T – 1) (1)	Difference in cooperation (T – 1) – (T – 2) (2)
No Info	1.357***	0.220
	(0.371)	(0.392)
Mixed Info	0.610**	0.542**
	(0.266)	(0.228)
Supergame	–0.609***	–0.0457
	(0.196)	(0.202)
Role	–0.0161	–0.0761
	(0.136)	(0.215)
Rounds	–0.0213	–0.0132
	(0.0261)	(0.0305)
Baseline category	*Both Info*	*Both Info*
Treatment controls	*Yes*	*Yes*
Observations	768	768
Number of participants	384	384

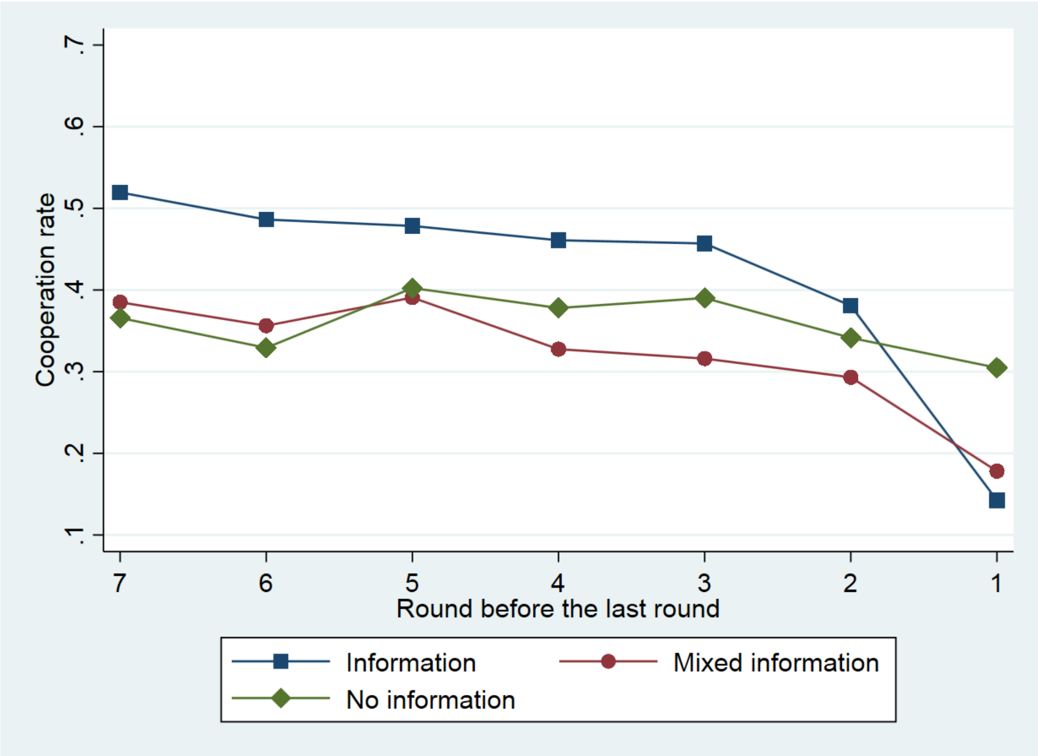
Notes: Ordered logit model with subject random effects. The dependent variable is the difference in chosen action in the respective rounds, where the value 1 stands for C (cooperate) and 0 for D (deviate). No Info takes the value 1 for pairs where both participants are not informed about the horizon and 0 otherwise. Mixed Info takes the value 1 for pairs where only one participant is informed about the horizon and 0 otherwise. The omitted baseline category is "Both Info," representing pairs where both participants are informed about the horizon. The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2. Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.1. Does mutual horizon ignorance shield from endgame behavior?

Does horizon ignorance mitigate the detrimental effects of endgame behavior, consistent with Hypothesis 1? Figure 1 shows the proportion of cooperative choices, averaged across all conditions and roles, in the last seven rounds of each supergame. The cooperation rate of pairs in which either or both participants have horizon knowledge dropped from 38% (both) and 29% (either) in the penultimate round to 14% and 18% in the final round. In contrast, the average cooperation rate of pairs without horizon knowledge was 33% in the penultimate round and remained nearly constant in the last round, with a 30% rate of cooperation. Thus, mutual ignorance seems to pay off in terms of more cooperation in the last round, albeit at a rather low level.

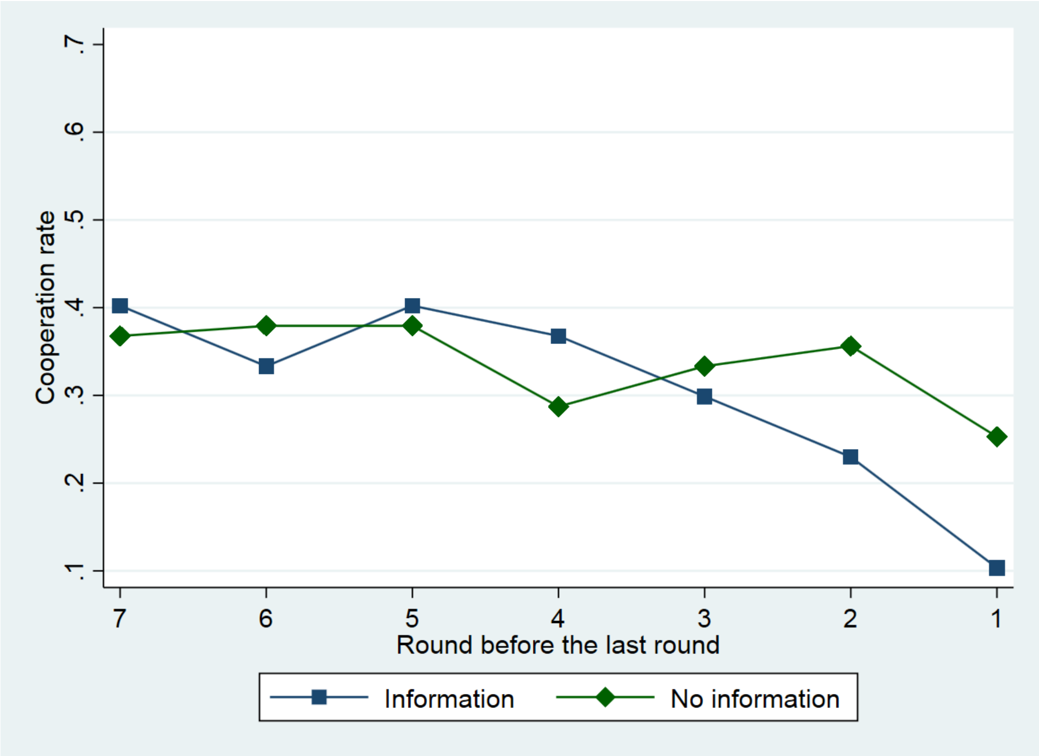
Table 6 reports change in cooperation rates from the penultimate to the last round (column 1) and from the antepenultimate to the penultimate round (column 2). Pairs with no horizon information appear to be shielded from the endgame effect: Their cooperation rate was significantly higher in the last round than was that of pairs where both participants had horizon information (column 1, positive coefficient for “No Info”).

Figure 1. Average cooperation rate for pairs with different horizon information in the last seven rounds (rates are averaged across all treatments, roles, and both supergames)



The cooperation rate for pairs with mixed information was also significantly lower than for pairs with no horizon information. Do informed participants exploit their information advantage, making them more likely to deviate unilaterally from cooperation? Figure 2 plots the cooperation rates of pairs with mixed information, separately for participants with and without horizon information. The informed participants did indeed exploit the information asymmetry in the last round. The difference in the two groups’ cooperation rates was statistically significant (Table A3 in the Appendix). In sum, we found evidence for our first hypothesis, namely, that mutual horizon ignorance shields players from endgame behavior in the last round of each supergame.

Figure 2. Average cooperation rate for the player with and the player without information in pairs with mixed horizon information in the last seven rounds of each supergame (rates are averaged across all treatments, roles, and both supergames)



5.2. Does mutual horizon ignorance boost the level of cooperation in the early phase of the interaction?

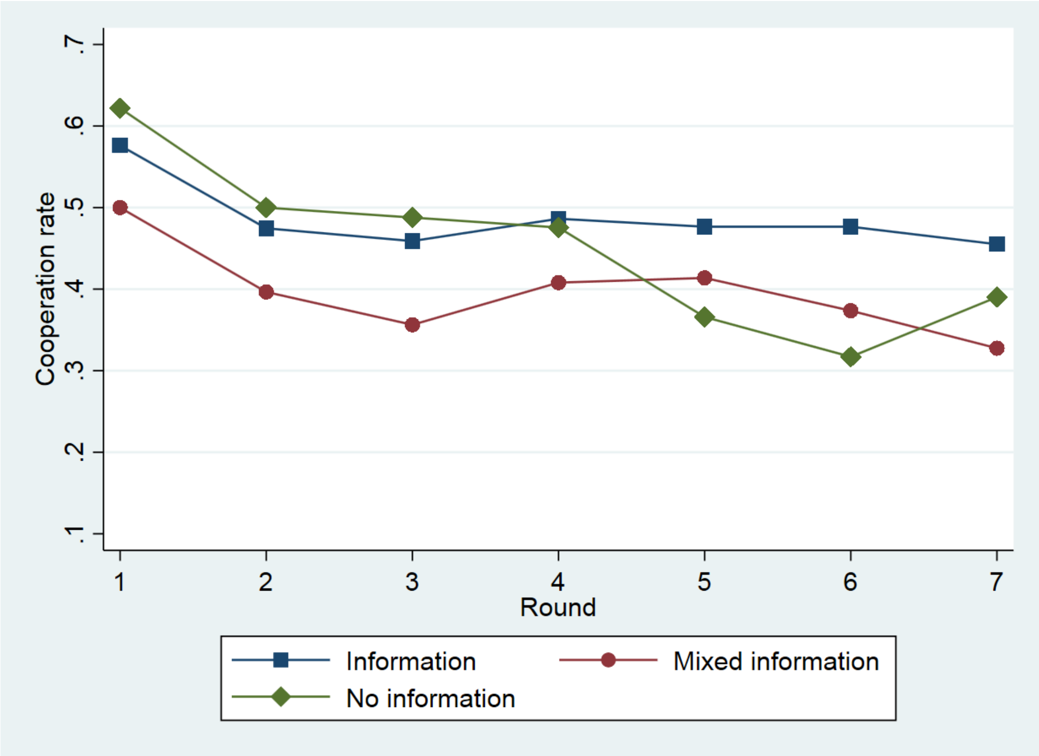
Figure 3 shows the first seven rounds in each supergame. Pairs in which both participants were ignorant of the horizon reached significantly higher levels of cooperation than pairs with horizon information in the first round of each supergame (see Table 7: coefficient "No Info*First Round" in column 2 and 3). This finding confirms that mutual horizon ignorance boosts cooperation levels in the early phase of the interaction.

Table 7. Logit regression: Cooperation in the whole game, in the first round, and in the last round

Dependent Variable	Chosen Action (1 for Cooperate and 0 for Deviate)		
	(1)	(2)	(3)
First Round		0.837***	0.659***
		(0.130)	(0.134)
No Info	–0.0144	–0.0750	–0.221
	(0.429)	(0.443)	(0.463)
Mixed Info	0.0267	0.0152	–0.0471
	(0.306)	(0.319)	(0.332)
No Info*First Round		0.754**	0.900**
		(0.355)	(0.359)
Mixed Info*First Round		0.158	0.224
		(0.212)	(0.222)
Last Round			–2.540***
			(0.227)
No Info* Last Round			1.899***
			(0.319)
Mixed Info*Last Round			1.032***
			(0.335)
Supergame	0.987***	1.002***	1.059***
	(0.138)	(0.140)	(0.149)
Role	–0.142***	–0.146***	–0.152***
	(0.0319)	(0.0324)	(0.0343)
Rounds	0.0411*	0.0488**	0.0376
	(0.0244)	(0.0248)	(0.0261)
Baseline category	*Both Info*	*Both Info*	*Both Info*
Treatment controls	*Yes*	*Yes*	*Yes*
Observations	9,440	9,440	9,440
Number of participants	384	384	384

Notes: Logit model with subject random effects. The dependent variable is the chosen action, taking the value 1 for C (cooperate) and 0 for D (deviate). No Info takes the value 1 for pairs where both participants were not informed about the horizon and 0 otherwise. Mixed Info takes the value 1 for pairs where only one participant was informed about the horizon and 0 otherwise. The omitted baseline category is "Both Info," representing pairs where both participants were informed about the horizon. The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2. Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Figure 3. The beginning of the game: Average cooperation rate for pairs with different horizon information in the first seven periods of each supergame



It appears as if mutual ignorance about the game horizon allows participants to trust each other and start the interaction by cooperating. Because choosing to remain ignorant about the horizon is endogenous, it is interesting to explore how this choice depends on the precise context: Are participants who prefer uncertainty more trusting or is their trust conditioned on being paired with a participant who is also voluntarily uninformed?

Table 8. Logit regression: informed and uninformed pairs in the first seven rounds of each supergame

Dependent Variable	Chosen Action (1 for Cooperate and 0 for Deviate)		
	(1)	(2)	(3)
Both_Y	0.988	0.990	0.878
	(0.769)	(0.770)	(0.934)
Both_N	0.789	0.791	0.804
	(0.839)	(0.840)	(0.856)
Neither_Y	1.673*	1.672*	1.626
	(0.982)	(0.984)	(1.012)
First Period	1.278***	1.279***	1.280***
	(0.356)	(0.356)	(0.357)
First Period* Both_Y	–0.778**	–0.778**	–0.779**
	(0.383)	(0.384)	(0.384)
First Period* Both_N	–0.402	–0.403	–0.404
	(0.384)	(0.384)	(0.385)
First Period* Neither_Y	–1.082	–1.083	–1.084
	(0.926)	(0.927)	(0.926)
Supergame	0.991***	0.991***	0.993***
	(0.250)	(0.251)	(0.251)
Role		–0.174***	–0.173***
		(0.0535)	(0.0535)
Baseline subgroup:	*Neither_N*	*Neither_N*	*Neither_N*
Treatment controls :	*No*	*No*	*Yes*
Observations	3,528	3,528	3,528
Number of participants	334	334	334

Notes: Logit model with subject random effects. The dependent variable is the chosen action, taking the value 1 for C (cooperate) and 0 for D (deviate). Both_Y, Both_N, and Neither_Y are dummies for the respective subgroups. The omitted baseline group is Neither_N. The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2. Robust standard errors clustered by matching group in parentheses.*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

To further explore this question, we distinguished pairs with horizon information from pairs with no information (leaving aside pairs with mixed information). The regression results presented in Table 8 classify these pairs according to whether or not they knew that their partner made this horizon choice voluntarily (see Table 2). The regressions take the Neither_N subgroup as the baseline group. The cooperation level for those who were not informed about the horizon and who knew that their partner did not want to be informed either (Neither_Y) was higher throughout the first seven rounds of each supergame, although the difference was only statistically significant at the 10%-level and no longer significant when the full set of control variables was included (column 3). On average, the cooperation rate was 56% for the Neither_Y subgroup and only 37% in the Neither_N subgroup across the first seven rounds. Somewhat surprisingly, in the very first round, the cooperation level was lower in the Neither_Y subgroup than in the Neither_N subgroup, although the difference was not statistically significant (see the coefficient "First Period*Neither_Y" in Table 8).

Thus, the higher cooperation rate in the first round of non-informed pairs can be attributed to the Neither_N subgroup rather than the Neither_Y subgroup. Later, when the cooperation rate declines rapidly, this effect is again due to the behavior of the Neither_N subgroup. Hence, we did not find evidence for our second hypothesis that players may try to signal cooperative intentions to their partner by choosing to remain uninformed. Rather, the findings indicate that players who opt against information are more trusting in general.

5.3. Does mutual horizon ignorance chip away at cooperation throughout?

The high level of cooperation between participants ignorant of the horizon did not survive long. As Figure 3 shows, after round 4—and thus before the lower bound (7) for T is reached—their cooperation rate dropped below that of pairs with mutual horizon knowledge. It then remained consistently but not significantly lower (Table 7). As discussed in section 5.2, this drop in cooperation over time can be attributed to the Neither_N subgroup rather than the Neither_Y subgroup. These findings are confirmed by Table A4 in the Appendix, which replicates Table 8 but includes all rounds in each supergame. Thus, we found that the cooperation rate of non-informed pairs was lower in the middle rounds of the game, although the difference was not statistically significant.

5.4. Summary

There is no straightforward answer to the question of whether embracing horizon ignorance is beneficial for cooperation in a repeated prisoners' dilemma game. We found two advantageous effects. First, pairs without information were able to avoid endgame behavior in the strict sense; there was no sudden drop in cooperation in the last round of the interaction. Second, the cooperation rate in the very first round was highest for pairs without information: They were more likely to cooperate in the first round than were either pairs with full information or pairs with mixed horizon knowledge. However, ignorance also has a drawback: the initial edge in cooperation declined, particularly for pairs who lacked the knowledge that the counterpart was also voluntarily ignorant of the horizon. Together, these findings suggest that the choice to forego horizon knowledge has benefits in the final round (no endgame) and correlates with a high initial level of cooperation at the start of the prisoners' dilemma game. The price, however, is that mutual horizon ignorance chips away at the willingness to cooperate during the middle phase of the supergame.

5.5. The payoff consequences of deliberate ignorance

In light of these conflicting effects, does it pay in monetary terms to remain ignorant about the horizon? Table 9 summarizes the payoffs in each round for pairs with horizon information, without information, and with mixed information. The results correspond to the findings in Table 7. Pairs without information earned more in the first round and the last round than did pairs with information or pairs with mixed information. In total, earnings throughout the game were lower for pairs without information than for pairs in which both knew the horizon, but this difference was not significant. Thus, differences between information conditions occur temporarily in the different phases of a supergame. However, given our calibration of the parameters, these differences tend to cancel each other out across the whole supergame.

Table 9. Earnings in each round depending on the information of players

Dependent variable	Round profit		
	(1)	(2)	(3)
First round		0.785***	0.605***
		(0.153)	(0.158)
No Info	–0.349	–0.404	–0.542
	(0.345)	(0.358)	(0.368)
Mixed Info	–0.327	–0.338	–0.418
	(0.283)	(0.290)	(0.302)
No Info*First		0.706*	0.850**
		(0.393)	(0.400)
Mixed Info*First		0.138	0.212
		(0.278)	(0.287)
Last Round			– 1.889***
			(0.151)
No Info* Last Round			1.600***
			(0.293)
Mixed Info*Last Round			0.896***
			(0.229)
Supergame	0.964***	0.964***	0.969***
	(0.155)	(0.155)	(0.155)
Role	2.585***	2.585***	2.585***
	(0.0875)	(0.0875)	(0.0875)
Rounds	0.0301	0.0365	0.0242
	(0.0237)	(0.0237)	(0.0237)
Baseline category	*Both Info*	*Both Info*	*Both Info*
Treatment controls	*Yes*	*Yes*	*Yes*
Observations	9,440	9,440	9,440
R-squared	0.090	0.093	0.102

Notes: OLS model. The dependent variable is the profit for each player in the respective round. No Info takes the value 1 for pairs where both participants are not informed about the horizon and 0 otherwise. Mixed Info takes the value 1 for pairs where only one participant is informed about the horizon and 0 otherwise. The omitted baseline category is "Both Info," representing pairs where both participants are informed about the horizon. The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2. Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In line with this finding, average cooperation rates across the whole supergame did not differ significantly across information conditions either. Table 7 shows how cooperation depends on the state of knowledge about the horizon. Across conditions, we compared fully informed pairs (baseline group), pairs with mixed information status, and pairs in which neither participant was informed. As the results presented in column 1 of Table 7 show, there were no significant differences between pairs of participants across the whole game.

6. Concluding remarks

The consequences of the choice to embrace uncertainty about the interaction horizon are complex, at least in the experimental setting implemented here. The total effect of (mutual) voluntary ignorance on cooperation was a combination of counteracting dynamics. On the one hand, voluntary ignorance is associated with higher cooperation in the early phase of the interaction and prevents a final drop in cooperation due to endgame effects. On the other hand, ignorance about the length of the interaction appears to make participants anxious about getting the short end of the stick, prompting them to defect preemptively. In sum, voluntary ignorance prevents the endgame drop in cooperation, but the resulting uncertainty results in earlier defections, eroding the positive effect.

Further work is needed to examine a potential signaling effect of voluntary ignorance with respect to cooperativeness in general. Evidence for such an effect would be interesting, because it might help to solve the coordination problem of conditionally cooperative individuals in the prisoner's dilemma. In our dataset, there were only very few pairs in which both players were uninformed about the time horizon—too few to distinguish between players who voluntarily opted to remain ignorant and those who had no choice.

Future research should also consider how the cooperation-enhancing effect of voluntary ignorance could be fostered without simultaneously increasing the "anxiousness" that offsets its benefits. We varied only the rules for endogenously determining horizon (un)certainty and its transparency but not the numerical parameters determining these incentives or the horizon interval from $\underline{T}$ to $\bar{T}$. The length of this interval may also affect the desire to be informed and the effectiveness of voluntary ignorance. Lastly, our effects may also interact differently, for example, with an option to communicate before the interaction. Much about how deliberate ignorance may shape cooperation thus remains to be discovered.

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Appendix

Table A1: Panel regression with earnings per supergame as dependent variable

Dependent variable	Total profit	
	(1)	(2)
Tr	–0.0287	–0.0287
	(0.288)	(0.284)
U_-	0.422	0.407
	(0.359)	(0.365)
U_+	0.238	0.223
	(0.305)	(0.302)
Role	2.611***	2.611***
	(0.0956)	(0.0957)
Supergame	0.909***	0.831***
	(0.143)	(0.146)
Rounds		0.0411*
		(0.0244)
Observations	768	768
R-squared	0.302	0.305

Notes: OLS model. The dependent variable is the total profit for each player in the whole supergame. Tr, U_-, and U_+ are dummies for the respective treatment. The baseline category is treatment I.The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2.Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2: Logit regression with
opting for horizon information as dependent variable

Dependent variable	Horizon Choice
Tr	1.587***
	(0.593)
U_-	0.318
	(0.631)
U_+	0.826
	(0.773)
Role	0.259
	(0.258)
Supergame	0.215
	(0.156)
Observations	768
Number of participants	384

Notes: Logit model with subject random effects. The dependent variable is horizon choice in each supergame, taking the value 1 when the player chose to reveal the information and 0 otherwise. Tr, U_-, and U_+ are dummies for the respective treatment. The baseline category is treatment I.The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2.Robust standard errors clustered by matching group in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A3: Logit regression: average cooperation rate for pairs with mixed information

Dependent variable	Chosen Action (1 for Cooperate and 0 for Deviate)		
	(1)	(2)	(3)
Info	–0.0505	–0.0453	–0.0184
	(0.0981)	(0.0975)	(0.0955)
Last round	–0.989***	–0.988***	–0.957***
	(0.232)	(0.232)	(0.236)
Info*Last Round	–2.088***	–2.091***	–2.116***
	(0.616)	(0.615)	(0.608)
Role	0.103	0.0994	0.105
	(0.0792)	(0.0789)	(0.0789)
Supergame	1.267***	1.261**	1.102**
	(0.490)	(0.491)	(0.511)
Tr		–0.548	–0.543
		(0.535)	(0.541)
Rounds			0.0694
			(0.0765)
Baseline treatment:	I	I	I
Baseline category :	*No Info*	*No Info*	*No Info*
Observations	2,054	2,054	2,054
Number of participants	144	144	144

Notes: Logit model with subject random effects. The dependent variable is the difference in chosen strategy in the respective rounds, where the value 1 stands for C (cooperate) and 0 for D (deviate). Tr is a dummy for the respective treatment. The baseline category is treatment I.The variable "Supergame" takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2.Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4: Logit regression: informed and uninformed pairs,

all rounds of each supergame

Dependent Variable	Chosen Action (1 for Cooperate and 0 for Deviate)			
	(1)	(2)	(3)	(4)
Both_Y	0.739	0.740	0.580	0.608
	(0.999)	(1.000)	(1.171)	(1.260)
Both_N	0.478	0.479	0.476	0.450
	(1.131)	(1.133)	(1.144)	(1.208)
Neither_Y	1.409	1.407	1.343	1.405
	(1.210)	(1.211)	(1.247)	(1.330)
First Period	1.644***	1.645***	1.649***	1.546***
	(0.439)	(0.439)	(0.440)	(0.462)
First Period* Both_Y	–0.968**	–0.968**	–0.973**	–1.043**
	(0.470)	(0.470)	(0.471)	(0.493)
First Period* Both_N	–0.513	–0.514	–0.518	–0.569
	(0.482)	(0.482)	(0.482)	(0.505)
First Period* Neither_Y	–1.507	–1.507	–1.511	–1.617
	(1.041)	(1.042)	(1.032)	(1.106)
Supergame	1.034***	1.034***	1.035***	1.101***
	(0.231)	(0.231)	(0.232)	(0.254)
Role		–0.157***	–0.155***	–0.168***
		(0.0398)	(0.0397)	(0.0433)
Last Round				–2.592***
				(0.288)
Baseline subgroup:	*Neither_N*	*Neither_N*	*Neither_N*	*Neither_N*
Treatment controls :	*No*	*No*	*Yes*	*Yes*
Observations	6,178	6,178	6,178	6,178
Number of participants	334	334	334	334

Notes: Logit model with subject random effects. The dependent variable is the chosen action, taking the value 1 for C (cooperate) and 0 for D (deviate). Both N, Neither Y, and Neither N are dummies for the respective subgroups. The variable “Supergame” takes the value 0 for supergame 1 and 1 for supergame 2. Role is a dummy for participant role and takes the value 0 for player 1 and 1 for player 2. Robust standard errors clustered by matching group in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Translation of the study instructions

Welcome! You are about to take part in an experiment funded by the Max Planck Institute of Economics. Please turn off your mobile phones and remain silent. We ask you not to talk to other participants during the experiment. It is very important that you follow these rules. Otherwise we will have to exclude you from the experiment and you will not receive any payment. If you have any questions or comments, please raise your hand and one of the experimenters will help you.

In this experiment you will interact repeatedly with another participant. This other participant will be paired with you at random. Moreover, you and the other participant will be randomly allocated the roles X and Y. Which role you take on (X or Y) affects the payments associated with certain decisions. You will play the same role for your entire interaction with this participant.

In each round of the experiment, you and the other participant have to choose between two alternatives: option 1 and option 2. Your earnings in each round depend on your choice and on the choice made by the other participant. Earnings for participants playing role X are shown in the third column of the following table. Earnings for participants playing role Y are shown in the fourth column.

After each round you will found out how the other participant decided and how much you have earned.

Each point in the table is worth €0.0833. The amount you are paid at the end of the experiment will be calculated from the total number of points you have earned in all rounds of the whole experiment, plus €2.50 for having shown up on time.

X chooses	Y chooses	X earns	Y earns

Option 1	Option 1	11	14
Option 1	Option 2	2	21
Option 2	Option 1	15	1
Option 2	Option 2	6	8

The number of rounds played—that is, how often you interact with the same participant in the decision situation described above—will be somewhere between a minimum of 7 rounds and a maximum of 17 rounds. The interaction can end after any number of rounds within this range. However, it is much less probable that the interaction will end in rounds 11, 12, or 13 than in the other rounds before or after.

Before the interaction begins, you and the other participant can choose to find out when the interaction will end. In other words, you and the other participant will be asked whether you want to be informed about the exact number of rounds in the interaction.

Treatment *I*:

If you decide to find out the exact number of rounds, you will be told the number of rounds. However, you will not be told how the other participant decided.

Treatment *Tr*:

If you decide to find out the exact number of rounds, you will be told the number of rounds. In addition, you will be told whether the other participant chose to find out about the exact number of rounds.

Treatment U_{+}:

Only in the case that both of you decide to find out the exact number of rounds will you and the other participant be told the exact number of rounds. If at least one participant decides not to find out the number of rounds, <u>neither</u> participant will be told when the interaction will end.

Treatment U_{-}:

If at least one participant decides to find out the exact number of rounds, <u>both</u> participants will be told when the interaction will end. Only in the case that both participants decide against finding out the exact number of rounds will neither of you be informed.

After you and the other participant have decided, the interaction will begin as described above.

After the last round in the interaction, you will be randomly paired with a different participant and the interaction will start again from the beginning, with exactly the same procedure. You will again be allocated either role X or role Y in the interaction, and you will again be asked whether you want to know the number of rounds in the interaction.

After that, the experiment is finished.