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Higher Intelligence Groups Have Higher Cooperation Rates in the Repeated Prisoner's Dilemma

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Abstract: Intelligence affects the social outcomes of groups. A systematic study of the link is provided in an experiment where two groups of subjects with different levels of intelligence, but otherwise similar, play a repeated prisoner's dilemma. Initial cooperation rates are similar, but increase in the groups with higher intelligence to reach almost full cooperation, while they decline in the groups with lower intelligence. Cooperation of higher intelligence subjects is payoff sensitive and not automatic: in a treatment with lower continuation probability there is no difference between different intelligence groups.

JEL classification: C73, C91, C92, B83

Keywords: Repeated Prisoner's Dilemma, Cooperation, Intelligence

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1 Introduction

Intelligence is a controversial concept. We use here the widely accepted definition proposed in a 1996 report by a Task Force created by the Board of Scientific Affairs of the American Psychological Association (Neisser et al., 1996). There, intelligence is defined as "the ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought". If this definition is adopted, the relation between intelligence and outcomes for a single individual is natural and clear. Higher intelligence functions, everything else being equal, as a technological factor; it allows larger, faster and better levels of production. This prediction is natural and is also supported by extensive research in psychology and economics (Neal and Johnson, 1996; Gottfredson, 1997; Bowles and Gintis, 2001; Heckman, Stixrud and Urzua, 2006; Jones and Schneider, 2010).

The relation between intelligence and outcomes is less clear when one considers instead the link between intelligence and social behaviour, and wants to explain how the outcomes of groups are influenced. The technological factor becomes less important, since social outcomes depend less on skill compared to the behaviour of others. A conceptual link is missing.

A possible conceptual link between intelligence and behaviour in social situations can be given as a corollary to the general view that intelligence reduces behavioural biases (e.g. Frederick, 2005; Oechssler, Roider and Schmitz, 2009; Dohmen et al., 2010; Beauchamp, Cesarini and Johanneson, 2011; Benjamin, Brown and Shapiro, 2013). For example, higher intelligence may reduce violations of transitivity; or, in choice under uncertainty, the behaviour of subjects with higher intelligence is better described by expected subjective utility. When we apply this intuition to behaviour in strategic environments, we are led to the conjecture that individuals in real life, and subjects in an experiment, who have higher intelligence will exhibit a behaviour closer to the game theoretic predictions. When refinements of the Nash concept are relevant, particularly sub-game perfection, behaviour more in line with the prediction of the refinement for the individual is expected in higher intelligence subjects.

This prediction finds some support when games are strictly competitive (such as the Hit 15 game in Burks et al., 2009). Recently a related result has been shown by Gill and Prowse (2014) in a repeated beauty contest experiment where more intelligent individuals converge faster to the unique Nash equilibrium demonstrating better analytic reasoning. While these contributions provide important insights in the way cognition affects reasoning on strategic interactions, some important puzzles remain. First, in games that are perhaps more relevant for social behaviour, this prediction fails. This occurs already in the case of one-shot games. In Burks et al. (2009), the authors also study the behaviour of subjects in a sequential trust game. Using a strategy method to identify choices as first and second mover, and relating this behaviour to the intelligence of the subjects, the authors find that initial transfer is increasing with the IQ score; a behaviour which is further from the prediction of the sub-game perfect equilibrium, and so is the opposite of what we should expect according to the general hypothesis. Similarly, transfers as second movers in higher intelligence subjects are higher when the first mover transfers more, and smaller in the opposite case. Since equilibrium behaviour predicts that no transfers should occur in either case, we see that the observed behaviour is inconsistent with the prediction. Secondly, repeated games involving one-to-one interactions generally present a multiplicity of equilibria; games with a unique Nash equilibrium cannot address the crucial issue for the social sciences of how individuals coordinate to one among many possible equilibria.

Some insight into a possible association between intelligence and strategic cooperative behaviour comes from related research in the biological and social sciences. The social intelligence hypothesis (Chance and Mead, 1953; Jolly, 1966; Humphrey, 1976) tries to provide an explanation for differences in the intellectual abilities of animals. The proponents of the theory observe that the evolution of primate intelligence cannot be adequately explained on the basis of different needs to observe, gather and process information in the process of finding food, extracting it, or avoiding predators. Instead, it is the richness of the social interaction that demands the development of the ability to use flexible cognitive strategies to be used in real time, as opposed to adaptive rules of thumb. Later research has provided some support for the general hypothesis. For example, Dunbar (1998) and Dunbar and Shultz (2007) have found a positive correlation between brain size and the size of the network of relations and alliances that an animal species develops.

There is also some early analysis of experimental work that provides support for the hypothesis we test here. Jones (2008) studies the cooperation rates in experiments on repeated prisoner's dilemma games conducted at different universities and the average SAT score at the university at the time in which the experiment was run. He finds that the cooperation rate increases by 5% to 8 % for every 100 points in the SAT score. Of course, the evidence is very indirect: students at those universities differ on a large variety of characteristics, and each of them could have been taken as the variable of interest in the correlation. However, such evidence is broadly consistent with the findings we are going to present.

In our experiment we directly test the potential association between intelligence and strategic behaviour in groups. The strategic interaction takes place between two players, but in a pool of people that are relatively homogeneous in their intelligence level. We rely on a well-established methodology in the experimental analysis of repeated games. In particular, we use the same setting as in Dal Bò and Fréchette (2011) (henceforth DBF), where they show how by changing the probability of continuation and the payoffs matrix in a repeated prisoner's dilemma game with random probability of termination, subjects may collectively converge to cooperation equilbria; DBF show that in some instances different groups converge to different equilibria for the same set of parameters.

Accordingly, the hypothesis we test is that higher intelligence in a complex environment (such as repeated social interaction) favours a more flexible, effective behaviour, allowing the processing of richer information, so that higher intelligence allows more efficient equilibria to be reached.

We find that subjects in both high Raven and low Raven sessions show a similar rate of cooperation in the initial rounds, the cooperation rate then increases in the high Raven sessions to reach an equilibrium where almost everybody cooperates, while it declines in the low Raven sessions. Subjects in the high Raven sessions increase their level of reciprocation over time, while there is no significant increase in the degree of reciprocation in the low Raven sessions. Intelligence is the only significant determinant of cooperation in the first round choices; other characteristics like personality traits do not seem to play a systematic role.

Furthermore, we use a structural model to estimate the probability of adopting different strategies in the different periods and we find that in the high Raven sessions subjects converge to a probability of two thirds to play a cooperative strategy and zero to play Always Defect. In the low Raven sessions, subjects converge to a probability of playing Always Defect above fifty percent of the times. Consistently with the other results, the probabilities of playing cooperative and non-cooperative strategies at the beginning are roughly similar among subjects in the different Raven sessions. We also show that the cooperation of higher intelligence subjects is payoff-sensitive, and thus not automatic: in a treatment with lower continuation probability there is no difference between different intelligence groups. Finally, we observe that in higher intelligence subjects, cooperation after the initial stages becomes almost immediate, i.e. the default mode; defection instead requires significantly more time. For lower intelligence groups this difference is absent.

Our findings have potentially important implications for policy. While the complex effects of early childhood intervention on the development of intelligence are still currently being evaluated (e.g. Heckman, 2006; Brinch and Galloway, 2012 ; Heckman et al., 2013), our results suggest that any such effect would have beneficial consequences not just on the personal economic success of the individual, but on the level of cooperation in society. This is a positive consequence that seems to have been overlooked so far. Furthermore, considering the assortative matching between individuals (Becker, 1973; Legros and Newman, 2002) or the tendency to homophily (McPherson, Smith-Lovin and Cook, 2001; Golub and Jackson, 2011) through which people may associate with those who are similar to themselves, the different degrees of cooperation between groups and the resulting different profits achieved may result in a powerful mechanism to magnify inequalities.

To the best of our knowledge, we are the first to analyze the effect of group intelligence on the level of cooperation in a setting with repeated interactions. There is a large experimental literature on the analysis of cooperation with repeated interaction. Cooperation has been shown to be sustainable in experiments with random termination (e.g. Roth and Murnighan, 1978; Holt, 1985; Feinberg and Husted 1993; Palfrey and Rosenthal, 1994) and also in experiments with fixed termination (e.g. Selten and Stoeker, 1986; Andreoni and Miller, 1993). In experiments with fixed termination, however, the level of cooperation is substantially lower (e.g. Dal Bò, 2005). Other elements can affect cooperation in a repeated interaction. Aoyagi and Fréchette (2009) show that the level of cooperation increases with the quality of the signal if public monitoring is allowed. Duffy and Ochs (2009) find that cooperation increases as subjects gain more experience under fixed matching but not under random matching. DBF show that individuals learn to cooperate after a sufficiently large number of interactions, but only when the benefits of cooperation in the stage game are big enough. Blonski, Ockenfels, and Spagnolo (2011) emphasise the effect of the discount factor. All these contributions suggest that the strategies leading to cooperation or defection, in a repeated interaction setting, are extremely complex because they are sensitive to very large number of factors.

Furthermore, strategies leading to cooperation are unlikely to be based on a fixed rule. On the contrary they need to be flexible in the sense of adapting to the circumstances. In this respect, Fudenberg, Rand, and Dreber (2012) show that individuals adapt to mistakes when they play their strategy in order to increase the possibility of coordinating on the most profitable cooperative equilibria, while Friedman and Oprea (2012) show that when agents are able to adjust in continuous time, cooperation rates are higher. A continuous time adjustment allows subjects to work in a more flexible environment, where they can quickly adjust in order to cooperate.

All the above-mentioned contributions point out that flexibility and the capacity of adapting to a complex environment are the key factors in allowing partners to cooperate within each other. These characteristics are linked to the definition of intelligence we gave at the beginning.

The literature emphasises how subjects' heterogeneity in terms of different degrees of sophistication determines whether the strategies adopted are more or less rational (e.g. Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Costa-Gomes and Crawford, 2006). Our findings are consistent with this literature, but also go a step further by showing that intelligence plays a role in the selection of different Nash Equilibria. Other interesting insights in order to understand our results might come from the so-called "two-systems" theories of behaviour, which emphasise the tension between a long-run, patient self and a short-run, impulsive self (e.g. Bernheim and Rangel, 2004; Loewenstein and O'Donoghue, 2005; Fudenberg and Levine, 2006; Brocas and Carrillo, 2008). If in higher IQ individuals the patient self is stronger, as Burks et al. (2009) imply, cooperation might be the result of a more forward looking behaviour. This could also explain the reason why high Raven groups fail to cooperate in the treatment with lower continuation probability.

This paper is organized as follows: in section 2 we present the experimental design and its implementation; in section 3 we present the results of the main treatment; section 4 provides an analysis of the determinants of cooperation; in section 5 we estimate the probability of adopting different strategies in the two Raven sessions; in section 6 we present the main results of the treatment with lower continuation probability, hence making cooperation harder; section 7 presents the analysis of the response time of the subjects in both treatments. Section 8 concludes the paper by providing a general discussion. In the appendix, we present the timeline of the experiment, the dates and other descriptive statistics. The questionnaire completed at the end by the subjects, the experimental instructions and the recruitment letter circulated are available online as supplementary material.[1]

[1] Available from the page http://www2.warwick.ac.uk/fac/soc/economics/staff/eproto/workingpapers/supplementary_material.pdf

2 Experimental Design

We allocated participants into two groups according to their level of fluid intelligence measured by the Raven's test. The two groups created participated in two separate sessions, defined as *high Raven* and *low Raven* sessions. As we will see below in more detail, apart from two sections we will illustrate at the end, the subjects were not informed on the way the two Raven groups were formed.

They played several repetitions of a repeated prisoner's dilemma game, each repeated game with a new partner. The experiment was run over two days with a time distance of one day between the two sessions. On the first day, the subjects completed the Raven's test; on the second day they played the repeated prisoner's dilemma. We ran two different treatments: the main treatment, and another treatment where cooperation is harder. In the Appendix, we present the dates and other details of each day one and day two session for both treatments.

Day One

The Raven test

On the first day of the experiment, the participants were asked to complete a Raven Advanced Progressive Matrices (APM) test of 30 tables. They had a maximum of 30 seconds for each table. Before the test, the subjects were shown a table with an example of a matrix with the correct answer provided below for one minute. For each item a 3×3 matrix of images was displayed on the subjects' screen; the image in the bottom right corner was missing. The subjects were then asked to complete the pattern choosing one out of 8 possible choices presented on the screen. The 30 tables were presented in order of progressive difficulty and were selected from Set II of the APM.

The Raven test is a non-verbal test commonly used to measure reasoning ability and general intelligence. Matrices from Set II of the APM are appropriate for adults and adolescents of higher average intelligence. The test is able to elicit stable and sizeable differences in performances among this pool of individuals. The correlation between Raven test scores and measures of intellectual achievement suggests that the underlying processes may be general rather than specific to this one test (Carpenter, Just and Shell, 1990). In the economic literature, individuals with higher Raven scores feature a learning process closer to Bayesian updating (Charness et al., 2011) and have more accurate beliefs (Burks et al., 2009).

Subjects are not normally rewarded for the Raven test. However it has been reported that there is a small increase in Raven scores after a monetary reward is offered to higher than average IQ subjects similar to the subjects in our pool (e.g. Larson, Saccuzzo and Brown, 1994). Since we wanted to measure intelligence with minimum confounding with motivation, we decided to reward our subjects with 1 British pound per correct answer from a random choice of three out of the total of 30 matrices. Always with the aim of minimising confounding with other factors, we never mentioned that Raven is a test of intelligence or cognitive abilities and, for the main treatment, the subjects were never informed that they would be separated on the basis of their performances in this test. We argue below by analysing the distribution of the subjects' characteristics in the two Raven sessions, that confounding is unlikely to be a concern in our experiment and the Raven test allowed the two groups to be separated uniquely according to the subjects' level of cognitive ability.

Other tests and questions

Following the Raven test, the participants were asked to respond to a Holt-Laury task (Holt and Laury, 2002), measuring risk attitudes. The first two experimental sessions reported here did not include the Holt-Laury task, in the sessions for the second treatment (where cooperation is harder) they did not perform this task either. The participants were paid according to a randomly chosen lottery out of their choices.

Lastly, on the first day participants were asked to respond to a standard Big Five personality questionnaire together with some demographic questions, a subjective well-being question and questions on previous experience with a Raven's test. No monetary payment was offered for this section of the session. The subjects were informed of this fact. We used the Big Five Inventory (BFI);

the inventory is based on 44 questions with answers coded on a Likert scale. The version we used was developed by John, Donahue and Kentle (1991) and has been recently investigated by John, Naumann and Soto (2008).

All the instructions given on the first day are included in the online supplementary material.[2]

Day Two

On the second day, the participants were asked to come back to the lab and they were allocated to two separate experimental sessions according to their Raven scores: subjects with a score higher than the median were gathered in one session, and the remaining subjects in the other. We will refer to the two sessions as *high Raven* and *low Raven* sessions.[3] The task they were asked to perform was to play an infinitely repeated prisoner's dilemma game. In our main treatment the participants played the game used by DBF, who found convergence of full cooperation after the game was repeated for a sufficient number of times in every repetition of the same experiment (see DBF p. 419, figure 1, bottom right-hand diagram).

Following standard practice in the experimental literature, we induced an infinitely repeated game in the laboratory using a random continuation rule: after each round the computer decided whether to finish the repeated game or to have an additional round depending on the realization of a random number. The continuation probability used in the main treatment was $\delta = 0.75$. The stage game used was the prisoner's dilemma game in table 1. We also added a second treatment with a lower continuation probability, $\delta = 0.5$, where cooperation is harder. Both the above treatments are identical to the ones used by DBF. They argue that the payoffs and continuation probability chosen in both treatments (i.e. $\delta = 0.75$ and $\delta = 0.5$) entail an infinitely repeated prisoner's dilemma game where the cooperation equilibrium is both subgame perfect and risk dominant.[4]

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[2] see note 1

[3] The attrition rate was small, and is documented in tables A.1 and A.2 in the Appendix

[4] The subgame perfect equilibrium set of subgame perfect equilibria are calculated as in

The payoffs in table 1 are in experimental units; the exchange rate applied to the payoff table was 0.004 British pounds per unit. This exchange rate was calculated in order to equalise the payoff matrix with the monetary units used in the DBF experiment. The participants were paid the full sum of points they earned through all the repetitions of the game. In the main treatment, the first 4 sessions were stopped once 30 minutes had passed and the last repeated game was concluded. For the last 4 sessions, 45 minutes were allowed to pass instead. Concerning the treatment with a lower continuation probability, we ran 4 sessions: two High Raven and two Low Raven, all of them stopped once the repeated game was over after 45 minutes. We give more details about this treatment in section 6.

The subjects in the high Raven and low Raven sessions played exactly the same game. The only difference was the composition of each group, as for the high Raven sessions the subjects had higher Raven scores compared to those in the low Raven sessions.

Upon completing the Prisoner's Dilemma game, the participants were asked to respond to a very short questionnaire about any knowledge they had of the Prisoner's Dilemma game. Additionally, in sessions 5-8, the subjects were asked questions about their attitudes to cooperative behaviour and some strategy-eliciting questions.

Implementation

We conducted a total of 8 sessions for the main experiment, with high continuation probability; four high Raven and four low Raven sessions. There were a total of 130 participants, with 66 in the high Raven and 64 in the low Raven session. The lower continuation probability treatment was conducted in 4 sessions with 60 subjects: 30 in the high Raven and 30 in the low Raven session.

All the participants were recruited from the subject pool of the Warwick

Stahl (1991) and assuming risk neutrality. The risk dominant strategy is calculated using a simplified version of the game assuming only two possible strategies following Blonksi and Spagnolo (2001). See DBF, p. 415 for more details experimental laboratory. The participants in the last six sessions of the main treatment did not include economics students. The participants in these non-economist sessions had not taken any game theory modules or classes. The recruitment was conducted with the DRAW (Decision Research at Warwick) system, based on the SONA recruitment software. The recruitment letter circulated is in the supplementary material. The dates of the sessions and the number of participants per session, are presented in the Appendix in tables A.1 and A.2.

As already noted at the beginning of this section, to allocate participants in the two Raven sessions for Day Two they were first ranked according to their Raven score. Subsequently, the participants were split into two groups. In cases where there were participants with equal scores at the cutoff, two tie rules were used based on whether they reported previous experience of the Raven task and high school grades. Participants who had done the task before (and were tied with others who had not) were allocated to the low Raven session, while if there were still ties, participants with higher high school grades were put in the high session.

Table 2 summarises the statistics about the Raven scores for each session. In the main treatment, for all but sessions 3 and 4 the cutoff Raven score was 18. In sessions 3 and 4 the cutoff was 16 because the participants in these sessions scored lower on average than the rest of the participants in all the other sessions (mean Raven score for sessions 3 and 4: 15.69, while the mean Raven score for all sessions: 17.89). Figure 1 presents the total distribution of the Raven scores and the distributions in the separate Raven sessions (in the appendix, tables A.3 and A.4 present a description of the main data in the low and high Raven sessions respectively, and table A.9 shows the correlations among individual characteristics).

The subjects on average earned 17.05 GBP (about 28 USD); the participation payment was 4 GBP. The software used for the entire experiment was Z-tree (Fishbacher, 2007). The Ethical Approval of this design was granted by the Humanities and Social Sciences Research Ethics Sub-Co at the University of Warwick under DRAW Umbrella Approval (Ref: 81/12-13).

A detailed timeline of the experiment is presented in the Appendix and all the instructions and any other pertinent documents are available online in the supplementary material.[5]

3 Cooperation with high discount

This section focuses on describing the results of the main treatment, with high continuation probability, $\delta = 0.75$.

Different degrees of cooperation in the high and low Raven sessions

Table 3 shows that the samples in the high and low Raven sessions have similar characteristics. Only the differences in the Raven score are statistically different at the 5 percent confidence level. Overall we can say that the subjects in the high and low Raven sessions differ only in their intelligence. The two groups are similar in terms of personality. In particular, there is no difference in the conscientiousness score.[6] This lends support to the fact that motivation had a negligible effect on the Raven scores, as is reasonable for subjects with higher than average cognitive ability. If this were not true, subjects with low level of conscientiousness would disproportionately belong to the low Raven sessions.[7]

A similar argument applies to the possibility that anxiety to perform well in the Raven test might have affected the performances of some subjects; if this were true more neurotic subjects should have performed worse.[8] From

[5]See note 1

[6]This is true even when we consider a non parametric test. The Kolmogorov-Smirnov test for equality of distribution functions cannot reject the hypothesis that the distribution of conscientiousness is the same in the two groups with a $p - value = 0.985$.

[7]Conscientiousness is usually defined as: *"The degree to which a person is willing to comply with conventional rules, norms, and standards.* The trait is usually measured by survey questions, some of them explicitly asking subjects to report reliability and care in work. The entire questionnaire is in the supplementary material.

[8]Neuroticism is associated with anxiety and fear of failing. Some of the statements contributing to the neuroticism score are: Is relaxed; handles stress well (R); Can be tense;

table 3 we can observe that the average level of neuroticism in the two groups is not statistically different.[9]

There is a large difference in the performances in the two Raven sessions (table 3). The final average earnings in the low Raven sessions are almost half the amount earned by the participants in the high Raven sessions. The better results of the subjects in the high Raven sessions were obtained both because they played more rounds per session and because they coordinated in more efficient equilibria in each round.

In sessions 1 and 2, there was a large difference in the proportion of economics students: one half in session 1 (high Raven), but only one fourth in session 2 (low Raven). The better performances in the Raven score for the economics students is probably a characteristic of Warwick University, where the entrance requirement for economics is more selective than for other subjects. If economists were more likely to play cooperation equilibrium in the prisoner's dilemma, it could have represented a potential confounding factor. For this reason, we excluded the economists and all subjects that declared they had taken a course of game theory when we sent the invitation to recruit subjects for sessions 3 to 8. It will become clear later that there is no qualitative difference between the sessions with and without economists.

Cooperation rates by Raven sessions over time

In our experiment, the subjects played several instances of a repeated game, each repeated game entailing a sequence of rounds. To take into account the order position of a round in the session, we numbered it as a period to take into account the rounds that had already taken place but belonged to an earlier repeated game. For example, the first round of the second repeated game in a session where the first game lasted seven rounds is labelled period 8.

In figure 2 we present the evolution of cooperation in the low and high

Worries a lot; Remains calm in tense situations (R); Gets nervous easily.

[9]The Kolmogorov-Smirnov test for equality of distribution functions cannot reject the hypothesis that the distribution of neuroticism is the same in the two groups with a $p-value = 0.780$.

Raven sessions. Each point on the line represents the proportion of subjects cooperating in blocks of 10 rounds. We took the averages over Raven sessions of the same type (high and low respectively). After the first two blocks (20 rounds overall), where there is no significant difference between the two types of Raven sessions, the cooperation rate clearly diverges: the rate in the high Raven sessions increases whereas in the low Raven sessions it declines. This is confirmed by table 4, showing in columns 1 and 2 that there is a significant difference in the trend of cooperation between the two Raven sessions, in column 3 that the odds of cooperating significantly increase 1.7 percent per period in the high Raven sessions, and in column 4 that cooperation slightly decreases in the low Raven sessions (note that throughout the paper the coefficients of the logit estimations will always be expressed in odds ratios).

The top panel of figure 2 depicts only the aggregated first rounds of each repeated game. Looking separately at the first rounds is important since different repeated games may result in a different number of rounds, and the percentage of cooperation may vary across rounds.

Figure 3 presents a different aggregation of the rounds and repeated games. The top panels shows no differences in the first repeated games. The bottom panels show that the average cooperation considering all the rounds is significantly higher in the high Raven sessions. In particular, in the first round of each repeated game it is nearly 80%, while in the low Raven session it is just above 50%. As stated above, there is no difference in cooperation when the individuals started playing. The difference is entirely due to learning.

Figure 4 shows that the same pattern is replicated in each pair of contiguous sessions. In sessions 3 and 4 (top right-hand panel) the divergence is less significant.[10] However, the solid black line in the figure, representing the *lowess* estimate, shows that divergence was starting to take place around the 30th round, consistent with the other sessions.[11] We conclude this section with

[10]This is due in part to the fact that in session 3 a particularly slow subject prevented the group from playing a sufficiently large number of repeated games. Also recall that this session was set to last 30 minutes.

[11]Considering the bottom right-hand figure, we note a decline in cooperation in session 7. This is possibly due to the fact that the subjects might have started to understand that the

the following:

Result 3.1. *The subjects in both the high Raven and low Raven sessions show a similar rate of cooperation in the initial rounds. Cooperation then increases in the high Raven sessions to almost full cooperation, while it slightly declines in the low Raven sessions.*

4 Determinants of the degree of cooperation

In what follows we analyse the mechanisms that lead to the different patterns of cooperation in the two Raven sessions.

Effect of partners' choices

In figure 5, we plot the level of cooperation conditional on the partners' choice over different periods. The figure reports the evolution of the choice of cooperation when the partner cooperated the previous round, and the choice of cooperation after the partner's defection in the previous round. From the top left-hand panel of figure 5, we conclude that in the high Raven sessions, the subjects evolved to reciprocate cooperation. In the last few periods, reciprocation occurs almost always. In the low Raven sessions, individuals reciprocate cooperation significantly less, and the learning effect is less steep. There is no difference in the first period, so the subjects in the high Raven group learn to reciprocate faster than in the low Raven. From the bottom left-hand panel we note that the subjects in the high Raven sessions reciprocate cooperation 20 % more often than the low Raven ones.

In the top right-hand panel we note a tendency to decrease the rate of cooperation when the partner defects. In other words the subjects learn to forgive less in general. Again this reciprocation is stronger for the high Raven than for the low Raven sessions, although this difference is much smaller than the reciprocation to cooperation (bottom right-hand panel).

experiment was coming to a close, so it could be an end of game effect- the last repeated game of this session lasted unusually longer.

In table 5, we investigate further the way subjects learn to reciprocate. We estimate how the cooperation choice of a player (say player 2) in round 1 induces the same choice for her partner (say player 1) in round 2. The choice of player 1 in round 2 of a repeated game can be influenced by player 2's choice in round 1. Player 2's choice in round 1 is clearly independent of the choice of player 1 since the action is simultaneous. Hence, the coefficient of player 2's choice in round 1 over player 1's choice in round 2 can be reasonably considered an unbiased estimator of the way individuals reciprocate cooperation.

Column 1 of table 5 shows that individuals increase the level of reciprocation over time significantly more in the high Raven sessions, while in the low Raven session the reciprocation does not significantly increase. Column 2 shows that there is no significant difference between the two Raven sessions in the level of reciprocation in the first repeated game in period 2. Hence, columns 1 and 2 show that the subjects start from a similar level of reciprocation but learn to reciprocate over time only in the high Raven sessions. Column 3 suggests that the odds of reciprocating in the high Raven sessions increase to about 4 percent in each period. Once this is taken into account there is no significant increase in cooperation due to the general trend. Column 4 shows that the level of reciprocation does not change significantly in the low Raven sessions. Still from column 4, we can observe again that the sign of the coefficient of the trend (Period) is negative and significant in the low Raven session.

We summarise the results from this session with the following:

Result 4.1. *The degree of reciprocation in the subjects belonging to the high Raven sessions increases over time; there is no significant increase in the degree of reciprocation in the low Raven sessions.*

Effect of Individual characteristics

Table 6 presents the effect of the individual characteristics in the cooperation choice. We consider only the choice in the first round of a repeated game to abstract from the effect of the partner's choice. From column 1, we note that only intelligence, measured in terms of score in the Raven test, is a significant predictor of cooperation, at least at the 5 % level.[12] None of the Big Five personality traits, risk aversion or gender have a significant effect on cooperation at the 5 percent level in the first rounds of the repeated games. In column 2, we only consider the first round of the first repeated game (hence period 1 only), thus abstracting from the experience of interaction with the other players. Consistently with what was noted above, intelligence has no impact on the first-period behaviour. In conclusion, the higher level of cooperation we observe in the high Raven sessions is the outcome of a cumulative process rather than of a characteristic that produces cooperation independently of experience.

After controlling for the Raven scores, the dummy indicating the high Raven sessions is not significant, suggesting that it is the individual intelligence more than the session effect (due to the fact that individuals play with more intelligent individuals) which drives the effect on cooperation. This finds further support from the fact that the size of the two coefficients measuring the effect of the Raven scores presented in columns 3 and 4 of table 6 are similar in the two Raven sessions.

We conclude this section with the following:

Result 4.2. *Intelligence is the only significant determinant of cooperation in the first round choices. In the first round of the first repeated game there is no difference between the two groups. Hence, this effect is produced by the learning of the subjects in the sequence of repeated games.*

5 Strategies in the different Raven sessions

In the previous section, we showed how past partners' choices affects subjects' choices in the two Raven sessions; here we analyse the strategies used in the two sessions. We follow DBF, restricting our attention to a finite set of common and natural strategies. In particular, we consider the six strategies listed

[12]Sessions 1 and 2 are excluded because in these two initial sessions we did not measure the subjects' risk aversion. Including them would not change our conclusions

in table 7. They have been chosen with respect to their importance in the theoretical literature: Always Cooperate (AC), Always Defect (AD), Grim (G), Tit for Tat (TFT), Win Stay Loose Shift (WSLS) and a trigger strategy with two periods of punishment (TFT, after D C C). In table A.10, following Dal Bò and Frechette (2013), we present the same exercise with 12 possible strategies. However, our conclusions below will remain qualitatively the same.

The likelihood of each strategy is estimated by maximum likelihood, assuming that the subjects have a fixed probability of choosing one of the six strategies in the time horizon under consideration. We focus on the last 5 (columns 1 and 2 of table 7) and first 5 interactions (columns 3 and 4 of table 7). We assume that the subjects may make mistakes and choose an action that is not recommended by the strategy they are following. The likelihood that the data corresponds to a given strategy was obtained by allowing the subjects some error in their choices in any round, where by error we mean a deviation from the prescribed action according to their strategy. A detailed description of the estimation procedure is in the online Appendix of DBF.[13]

We first consider the final strategies played at the end of the session, specifically the last 5 games. The low Raven subjects play Always Defect with a probability above 50 per cent, in stark contrast with the high Raven subjects, who play this strategy with a probability statistically equal to 0. Instead, the probability for the high Raven of playing more cooperative strategies (Grim and Tit for Tat) is about 67 per cent, while for the low Raven ones this is lower (around 45 per cent).

The strategies used in the initial rounds are quite similar across the two groups (see columns 3 and 4), consistent with our earlier finding that the cooperation rates are similar across Raven sessions in the initial periods. Both groups play at the beginning Always Defect with a probability about 34 per cent and more cooperative strategies (Grim and Tit for Tat) with a probability of about 66 percent for high Raven subjects and 57 per cent for low Raven ones.

[13] See p. 6-11, available online at `https://files.nyu.edu/gf35/public/print/Dal_Bo_2011a_oa.pdf`

We summarise the main findings of this section in the following:

Result 5.1. *In the high Raven sessions, the subjects converge to a probability of two thirds for playing a cooperative strategy and never play Always Defect. In the low Raven sessions, the subjects converge to a probability of playing Always Defect with a probability of just above one half. The probabilities of playing cooperative and non-cooperative strategies at the beginning are roughly similar among the subjects in the different Raven sessions.*

6 Cooperation with low discount

Cooperation is harder with a lower continuation probability. In this treatment we set $\delta = 0.5$, while the payoff matrix in the stage game is the same as in the main treatment (as in table 1). Accordingly, differently from the case of $\delta = 0.75$, the experimental results of DBF when $\delta = 0.5$ show no evidence of convergence to cooperation (see DBF, p. 419, figure 1, top right-hand diagram). The scope of this treatment is then to test how cognitive skills affect the pattern of cooperation of the group when cooperation is harder.

As in the main treatment, the subjects were divided into low and high Raven sessions according to their Raven scores. We ran 4 sessions; 2 of them with high Raven (numbered 1ld and 3ld) and 2 low Raven (2ld and 4ld). Every session was stopped once 45 minutes had passed and the last repeated game was concluded. The high Raven session 3ld and the low Raven session 4ld are exactly like the main treatment, the only difference being the continuation probability. In the high Raven session 1ld and the low Raven session 2ld, there is a difference in the information given to the subjects. At the beginning of the session on day 2, they received, their Raven score and the summary statistics of the Raven scores of the participants in their respective sessions on a piece of paper. Hence, subjects were informed about the way they had been allocated in the Raven sessions. This treatment aimed to test whether when subjects are aware that their partner's cognitive skills are similar to their own they coordinate better.

The dates of the sessions of this treatment with low discount and the descriptive statistics of the main variables are in table A.2 and tables A.5-A.8 of the appendix. Figure 6 presents the total distribution of the Raven scores and the distributions in the separate Raven sessions for the subjects in this treatment.[14]

From figure 7, we cannot observe any convergence to full cooperation in either Raven session or in either treatment. Hence both Raven sessions are similar in this respect to the corresponding sessions in DBF. On the contrary, there seems to be a decline in both Raven sessions.[15] This is true in the sessions where we informed individuals about the allocation (1ld and 2ld) and in the sessions where we did not give this information (3ld and 4ld).

Furthermore, we note that after the first block (10 rounds overall), where there is no significant difference between the two types of Raven sessions, the cooperation rates seem to diverge. In both cases they decline, but the decline seems faster in the high Raven sessions. In figure 8, we can observe the average level of cooperation in the different Raven sessions and in the treatments with (sessions 1ld and 2ld) and without information (sessions 3ld and 4ld). In the treatment without information we only considered the first 20 periods for the sake of comparability between the two Raven sessions .[16] Figure 8 confirms the findings in figure 7: *(i)* Average cooperation overall is significantly lower than the cooperation in the first period in both Raven sessions and in both treatments (with and without information); *(ii)* the initial level of cooperation is similar in the two Raven sessions; *(iii)* in the low Raven sessions individuals cooperate more in average, this difference is significant in the session with information and borderline insignificant, at the 5 % level in the sessions without information.

Figure 9 can provide an explanation of why the low Raven subjects co-

[14]The distribution of other characteristics is similar in the two Raven sessions in this series of experiments as well. A formal test like the one performed for the main treatment in table 3 is available upon request.

[15]Session 4ld had to be stopped because a subject in period 24 shouted: "Lets Cooperate!". There was no reason to exclude the data previously collected.

[16]Recall that the low Raven session in this treatment had to be stopped after 20 rounds, see note 15.

operate more in this treatment. From the top left-hand panel of this figure, we note that there is no significant difference in the way the subjects react to the cooperative choice of the partner. Comparing this with the corresponding panel in figure 5 (top left-hand panel), we can argue that the subjects in the high Raven sessions do not seem to learn to reciprocate cooperation as they do in the main treatment. At the same time, from the top right-hand panel of figure 9, we can observe that in the low Raven session the subjects seem to cooperate more after defection by the partner for most of the session. The two groups seem to converge only at the end. This can then explain the difference in the average cooperation we observed in the two groups. Some subjects in low Raven session kept cooperating even after the partners defected for most of the session, and they learnt that this was not leading to more cooperation only toward the end. Hence, it is possible to argue that low Raven subjects need more time to predict other subjects' reactions. Finally, note that for completeness we have reported the results of the sessions with no information in the panels at the bottom of figure 9, from which we note that the pattern in the high Raven session is not dissimilar to the one with information.

We summarise the main findings of this section in the following:

Result 6.1. *With lower continuation probability the degree of cooperation declines over time in both the low and high Raven sessions.*

A final consideration in this section concerns the effect of the information. A natural conjecture is that when subjects are informed that they will be playing with individuals with a similar level of cognitive ability, they should be able to coordinate better.

From figure 8, we note that the availability of this information does not lead any group to coordinate to an equilibrium with a high level of cooperation. However, in both the high and low Raven sessions, the average cooperation is significantly higher in the treatment with information. More specifically, in the low Raven session with information there are 29.9 % cooperative choices, while in the one with no information, there are 16.3% cooperative choices in the first 20 rounds (we consider only the first 20 rounds to make this session comparable with the corresponding session with information, which we recall, had to be prematurely stopped), significantly lower with a $p-value < 0.01$; in the high Raven session with information, the percentage of cooperative choices is 11.9% with no information and 16.9% when the information was given. This last number is significantly higher with a $p - value < 0.05$.

7 Reaction times

Reaction time is defined here as the length of the time interval between the appearance of the payoff table and the moment in which the decision is entered. Analysis of reaction times, and a comparison between the high and low discount sessions, may give further insights into the way choices are made in the two cases, and how the intelligence of the group relates to the choices.

In panel A of figure 10, we analyze how the reaction time changes during the periods in the different Raven sessions, and according to the choice to cooperate or defect. There is clear evidence of general learning of the task: the response time decreases with the periods played. This decrease, however, is slower in the low Raven sessions (top graph in panel A of figure 10), especially the when these subjects choose to cooperate (top right-hand graph). The histogram in the lower panel of figure 10 shows that in the low Raven group there is no significant difference in the response time whether the subjects decide to cooperate or defect (bottom left-hand panel), but there is a significant difference of about two seconds more when the subjects in the high Raven sessions choose to defect (bottom right-hand panel). This seems to suggest that in the high Raven sessions cooperation became the norm, implemented perhaps by default.

Panel B of figure 10 shows the reaction times for the session with lower continuation probability. In panel B of figure 10, we see a smaller difference in the way reaction time decreases over time in the two different Raven sessions (top panels). Moreover, we do not observe the same difference between the choices to cooperate and defect in the high Raven sessions (bottom right-hand panels) that we observe for the main treatment in panel A of figure 10.

This further supports the idea that a norm of cooperating was created in the high Raven session in the main treatment, but not for the low continuation probability treatment.

We summarise:

Result 7.1. *In the high Raven sessions of the main treatment, the reaction times are on average smaller and decline faster over time than in the low Raven sessions of the same treatment. In the high Raven sessions, the reaction times are longer when the subjects choose defection, but are statistically equal in the low Raven sessions. There is no difference between defection and cooperation choices in the high Raven sessions in the low continuation probability treatment.*

8 Conclusions

Our experimental setup was based on a direct test of the hypothesis that groups of individuals with different levels of intelligence, but who are otherwise similar, would exhibit different levels of cooperation in bilateral interactions with others in the group. The interaction was repeated, so there was time and opportunity for each one to observe and reflect on the past behaviour of the other, and use this inference to guide future choices. A significant and sizeable difference in behaviour and insights into the way in which intelligence is relevant in strategic repeated behaviour emerged.

Everything else being equal, higher intelligence groups exhibit higher levels of cooperation. In our data, the intelligence of the group is associated with different long-run behaviour in a sequence of repeated games played within the group, and higher cooperation rates are associated with higher intelligence.

Higher cooperation rates are produced by interaction over time. Cooperation rates in the initial rounds (approximately 20) are statistically equal in the two groups. Thus, the higher cooperation rate in higher intelligence groups is produced by the experience of past interaction, not by a difference in attitude in the initial stages. There is no inherent association of higher and lower intelligence with a behaviour: the specific history of past interactions is what matters.

Higher cooperation is sensitive to the stage game payoff, so it is not an unconditional inclination of individuals with higher intelligence to cooperate. When the parameters in the experimental design were chosen to make cooperation less long-run profitable, the subjects in groups with higher intelligence also experience large and growing rates of defection over time. Environment and incentives matter: intelligence modulates the response to incentives, and does not directly determine behaviour.

Intelligence matters substantially more than other factors and personality traits. When we test for a statistical relation with the choice to cooperate, we find no significant correlation with personality traits or with high school grades: intelligence as fluid skill is the determining factor. Our design has an asymmetry in the way in which the personality traits and skills are treated, because only intelligence is used to allocate individuals into groups, and the other characteristics are used as controls. Future research should test directly the size and significance of the effect of two or more characteristics (such as, say, intelligence and agreeableness). Of course, intelligence is also in part an outcome of education, and this may involve learning about behaviour in social situations. However, the two Raven groups are similar in their degree of education, which is thus unlikely to be a confounding factor in our results.

Intelligence operates through thinking about strategic choice. Differences in behaviour could arise for different reasons. For instance, intelligence might be associated with the attitude to cooperation, considered as a behavioural inclination, or with a different utility that individuals derive from the outcomes of others. Our data provide support for the idea that intelligence is instead likely to influence the way in which subjects think about the behaviour of others, how they learn about it, and how they choose to modify it as far as possible. Intelligence is relevant for learning and teaching.

We have produced two pieces of evidence supporting this interpretation. The first is the difference in the evolution over time of the response of individuals to the choice of the current partner in the past. A small, but significant difference to the choice to cooperate with the current partner in the last period builds up over the session to produce a substantial cumulative difference in the cooperation rate. The second piece of evidence comes from response times. In higher intelligence subjects, cooperation after the initial stages becomes the default mode. Defection instead requires a specifically dedicated careful balancing of the anticipated loss of future cooperation with the necessity to retaliate to avoid future opportunistic defections of the partner. For lower intelligence groups this difference is absent.

Our data present new evidence and suggest questions for the theory of learning in games. The setup of Dal Bò and Frechette (2011) that we have adopted puts our subjects in a novel learning environment when there is a substantial lack of homogeneity among subjects. As they proceed in the experimental session, they have the opportunity to observe the behaviour of their peers in the game, and learn about the distribution of characteristics affecting choices in the sample. An adequate model of their sequential choice of actions should incorporate the history of past instances of repeated games in the definition of the strategy. The strategy should also depend on individual characteristics, intelligence being first among them. An initial prior over the distribution of characteristics in the population of the session would then be updated, and thus the distribution over the strategies the subject is facing would change.

The truly novel and interesting side of the research that opens now is the analysis of the link between strategies and intelligence. Is there a systematic pattern of association, and what produces it? A natural conjecture may be formulated ranking strategies by their complexity. For example, a very crude way to classify strategies could focus on the length of the history of moves that a strategy considers. Accordingly, a larger set of strategies is available to individuals who are able to implement the more complex ones, as well as to observe, store and process the richer information that is necessary for their execution.[17] A difficulty with this explanation is that the strategies used by

[17]Rubinstein (1986) and Abreu and Rubinstein (1988) among others suggest a natural way to explicitly introduce intelligence in theoretical models of strategic behaviour, through

the two groups in our experiment are not substantially different in complexity. Further experimental research to test these initial assumptions seems to us the best way to proceed.

the use of automata models with heterogeneous costs among players for the number of states in the automaton. Players with higher intelligence have lower costs, which will allow them to be more flexible in the sense of being able to increase the number of states in the automation. Thus they can more optimally react to different circumstances. This extension might provide a valuable insight into the way intelligence affects social behaviour.

Table 1: **Stage Game: Prisoner's Dilemma.** Payoffs are in experimental units. See the text for the conversion to monetary payoff.

	C	D
C	48,48	12,50
D	50,12	25,25

Table 2: **Raven Scores by Sessions**

Variable	Mean	Std. Dev.	Min.	Max.	N
High Raven - Session 1	20.429	1.505	18	23	14
Low Raven - Session 2	14.063	3.395	6	18	16
High Raven - Session 3	19	2	16	23	18
Low Raven - Session 4	13.188	1.94	10	16	16
High Raven - Session 5	20.444	1.79	18	24	18
Low Raven - Session 6	14.167	3.538	7	18	12
High Raven - Session 7	20.688	2.243	18	25	16
Low Raven - Session 8	15.75	1.372	13	18	20

Table 3: **Differences between the means of the main variables in the high and low Raven sessions.**

Variable	Low Raven	High Raven	Differences	Std. Dev.	N
Age	22.35938	21.24242	1.116951	.7251282	130
Female	.625	.5	.125	.0870282	130
Openness	3.642188	3.595455	.0467329	.1016391	130
Conscientiousness	3.399306	3.405724	-.0064184	.1198434	130
Extraversion	3.349609	3.244318	.1052912	.1308186	130
Agreeableness	3.840278	3.765993	.0742845	.1060675	130
Neuroticism	2.910156	2.835227	.074929	.1361939	130
Raven	14.39063	20.10606	-5.715436***	.4170821	130
Economist†	.25	.5714286 .	-.3214286*	.1753537	30
Risk Aversion	5.5625	5.5	.0625	.2865234	100
Final Profit	2774.297	4675.303	-1901.006***	258.9902	130
Periods	83.3125	116.4848	-33.17235***	5.039728 2	130
Profit × Period	33.26863	38.546693	-5.278058***	.8951038	130

† only sessions 1 and 2

Table 4: **Trends of cooperation in the high and low Raven sessions.** The dependent variable is the choice of cooperation per individual. Coefficients in columns 1, 3 and 4 are expressed as odds ratios. Standard errors in brackets. * $p-value < 0.1$, ** $p-value < 0.05$, *** $p-value < 0.01$.

	Logit FE All	OLS FE All	Logit FE High Raven	Logit FE Low Raven
Period	0.9945***	–0.0009***	1.0178***	0.9945***
	(0.0014)	(0.0002)	(0.0009)	(0.0014)
H.Rav*Period	1.0234***	0.0031***		
	(0.0017)	(0.0002)		
r2		0.028		
N	12640	13020	7468	5172

Table 5: **Effects of past partners' choice on cooperation.** The dependent variable in columns 1, 3 and 4 is the choice of cooperation per individual, in the second round of each repeated game. The dependent variable in column 2 is the choice of cooperation per individual in the second round of the first repeated game (if this exists and the game did not terminate at round 1). Coefficients are expressed in terms of odds ratio. Standard errors in brackets. * $p-value<0.1$, ** $p-value<0.05$, *** $p-value<0.01$.

	All 2^{nd} Rounds	All 2^{nd} Period	Hig Raven 2^{nd} Rounds	Low Raven 2^{nd} Rounds
Partner Ch.[$t-1$]	6.2396***	2.5412**	7.0759***	6.2396***
	(2.2876)	(1.1483)	(2.2589)	(2.2876)
H.Rav.*Partner Ch.[$t-1$]	1.1340	1.3458		
	(0.5513)	(0.6771)		
Partner Ch.[$t-1$]*Period	1.0126		1.0395***	1.0126
	(0.0078)		(0.0066)	(0.0078)
H.Rav.*Partner Ch.[$t-1$]*Period	1.0265***			
	(0.0102)			
Period	0.9854**		0.9980	0.9854**
	(0.0058)		(0.0047)	(0.0058)
H.Rav.*Period	1.0128*			
	(0.0077)			
r2				
N	2153	112	1383	770

Table 6: **Effects of IQ and other characteristics on cooperation.** The dependent variable in columns 1, 3, 4 is the share of cooperative choices in the first rounds of all repeated games. The dependent variable in column 2 is the cooperative choice per individual in the first round of the first repeated game. Columns 3 and 4 respectively refer to all first rounds in the high and low Raven sessions separately. All coefficients in column 2 are expressed in terms of odds ratio. (Robust) Standard errors in brackets (in columns 1, 3, 4); * $p - value < 0.1$, ** $p - value < 0.05$, *** $p - value < 0.01$

	OLS 1^{st} Rounds	Logit 1^{st} Period	OLS 1^{st} Rounds HR	OLS 1^{st} Rounds LR
Raven	0.0333**	0.9768	0.0389*	0.0376
	(0.0166)	(0.1062)	(0.0228)	(0.0246)
Openness	0.0563	0.7234	0.0799	0.0237
	(0.0744)	(0.3229)	(0.0952)	(0.1246)
Conscientiousness	–0.0089	1.1203	–0.0175	–0.0165
	(0.0536)	(0.4062)	(0.0523)	(0.0999)
Extraversion	–0.0507	1.3014	–0.0687	–0.0696
	(0.0651)	(0.4549)	(0.0719)	(0.0933)
Agreeableness	–0.1041*	0.8327	–0.0380	–0.2124*
	(0.0595)	(0.3301)	(0.0721)	(0.1056)
Neuroticism	0.0119	0.9899	0.0885	–0.1030
	(0.0574)	(0.3481)	(0.0706)	(0.0945)
Risk Aversion	0.0114	0.9801	0.0414	–0.0700
	(0.0278)	(0.1603)	(0.0309)	(0.0570)
Female	–0.1301	0.3828*	–0.2079**	0.0207
	(0.0896)	(0.2062)	(0.0985)	(0.1537)
Age	–0.0048	1.0470	–0.0178	–0.0047
	(0.0063)	(0.0712)	(0.0123)	(0.0099)
High Raven Session	–0.0715	0.8139		
	(0.1319)	(0.5828)		
r2	0.163		0.290	0.148
N	100	98	52	48

Table 7: **Individual strategies in the different Raven sessions in the last 5 and first 5 repeated games** Each coefficient represents the probability estimated using ML of the corresponding strategy. Std error is reported in brackets. Gamma is the error coefficient that is estimated for the choice function used in the ML and beta is the probability estimated that the choice by a subject is equal to what the strategy prescribes.† Tests equality to 0 using the Waldtest: * $p - values < 0.1$, ** $p - values < 0.05$ **, $p - values < 0.01$ ***

Raven Session	High	Low	High	Low
Repeated Games	Last 5	Last 5	First 5	First 5
Strategy				
Always Cooperate	0.0886	0.0348	0	0.0745
	(0.1041)	(0.0574)	(0.0402)	(0668)
Always Defect	0.0417	0.5148***	0.3395***	0.3415***
	(0.0354)	(0.1049)	(0.1076)	(0.0967)
Grim after 1 D	0.3705***	0.1522**	0.6605***	0.2180***
	(0.1429)	(0.0617)	(0.1248)	(0.0783)
Tit for Tat (C first)	0.2976**	0.2982***	0	0.3540***
	(0.1418)	(0.0846)	(0.1175)	(0.0857)
Win Stay Lose Shift	0.0701	0	0	0.0121
	(0.1289)	(0.0306)	(0.0545)	(0.0473)
Tit For Tat (after D C C)††	0.1315	0	0	0
Gamma	0.3249***	0.4146***	0.5313***	0.6312***
	(0.0774)	(0.0381)	(0.0662)	(0.0525)
beta	0.956	0.918	0.868	0.830
Sessions	1,5,7	2,4, 6, 8	1,5,7	2,4,6, 8
Average Rounds	4.83	5.12	2.11583	3.875
N. Subjects	48	64	48	64
Observations	1090	1676	518	1152

† When beta is close to 1/2, choices are essentialy random and when it is close to 1 then choices are almost perfectly predicted.

†† Tit for Tat (after D C C) stands for the Tit for Tat strategy that punishes after 1 defection but only returns to cooperation after observing cooperation twice from the partner.

Figure 1: **Distribution of the Raven Scores for the main treatment.** The top panel depicts the distribution of the entire sample. The bottom panel presents the distributions in the separate Raven sessions.

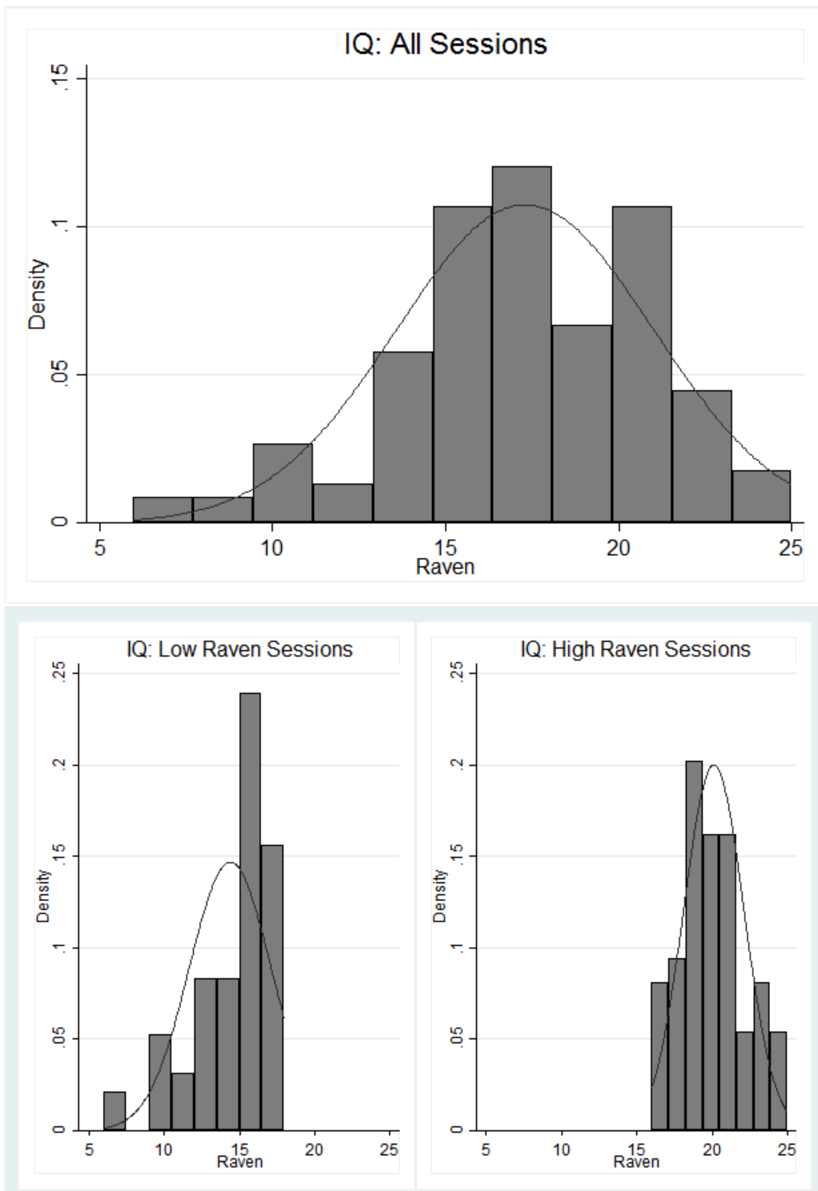


Figure 2: **Cooperation per period in the low and high Raven sessions.** The two panels report the averages computed over observations in successive blocks of ten rounds of all high and all low Raven sessions, aggregated separately. The top panel reports the average of cooperation in the first round (of a repeated game) that occurs in the block and the bottom the average of cooperation for all rounds of the game in that block. The bands represent 95% confidence intervals.

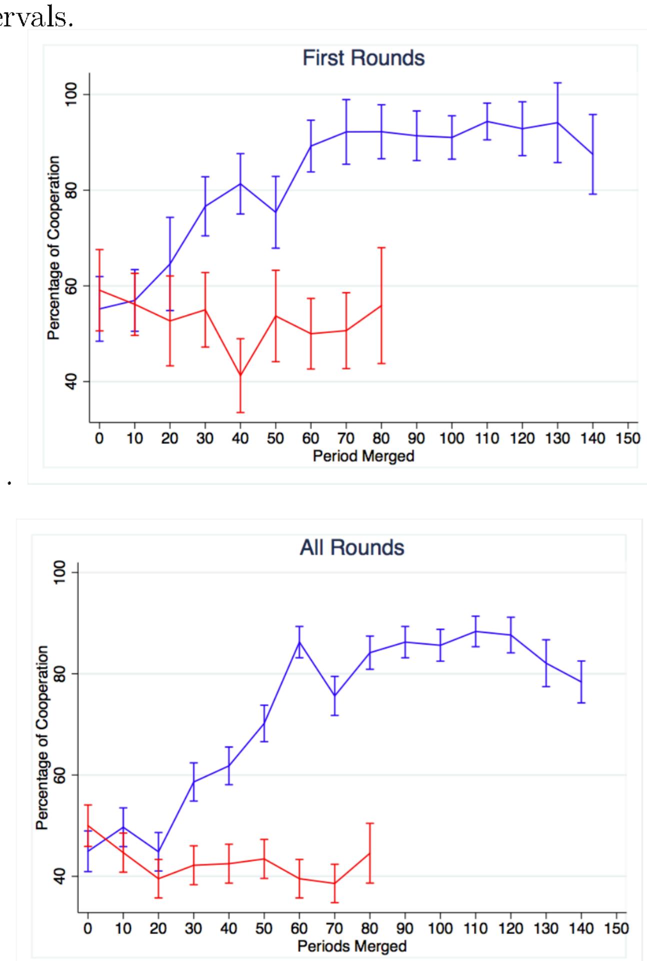


Figure 3: **Average cooperation in the low and high Raven sessions** The histograms represents the average cooperation in each session. Top panel: first repeated game; bottom panel: all games. The bands represent 95% confidence intervals.

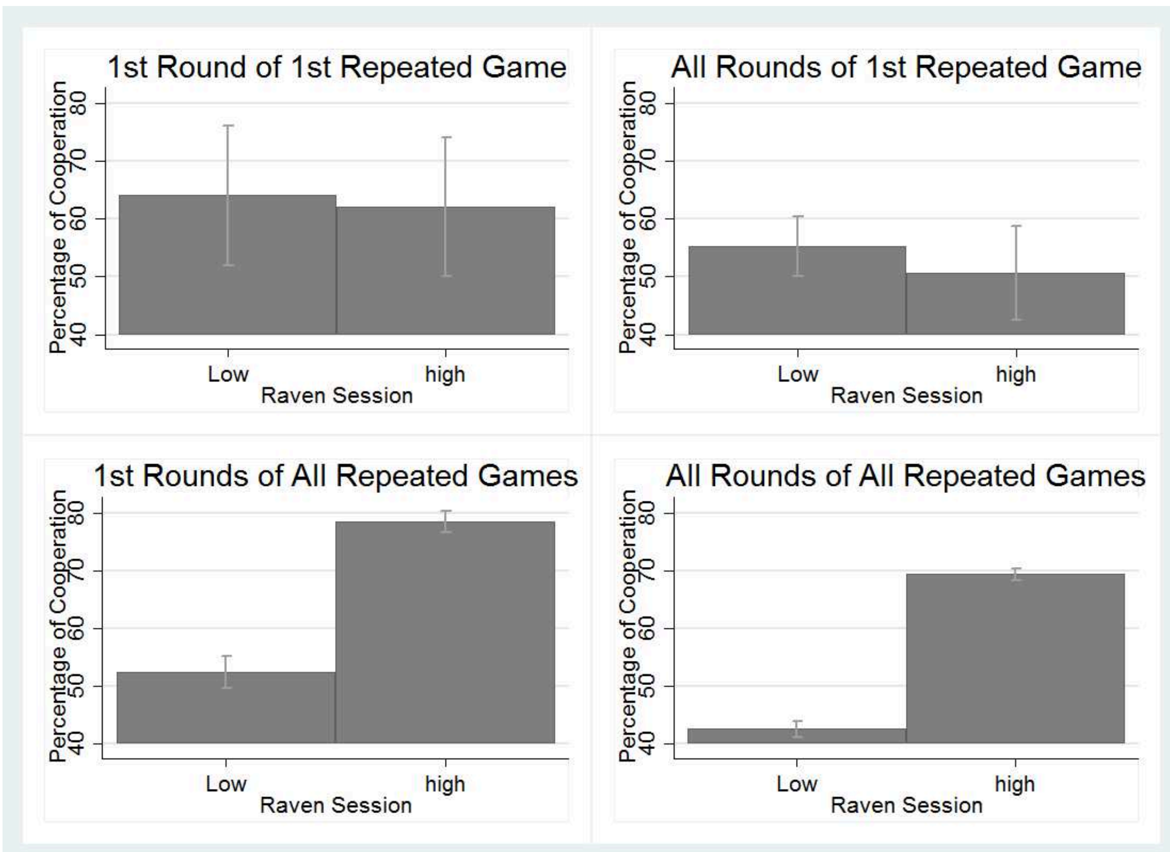


Figure 4: **Cooperation per period in all the different sessions.** The red lines represent the low Raven sessions and the blue lines represent the high Raven sessions. The black lines represent the lowess estimator.

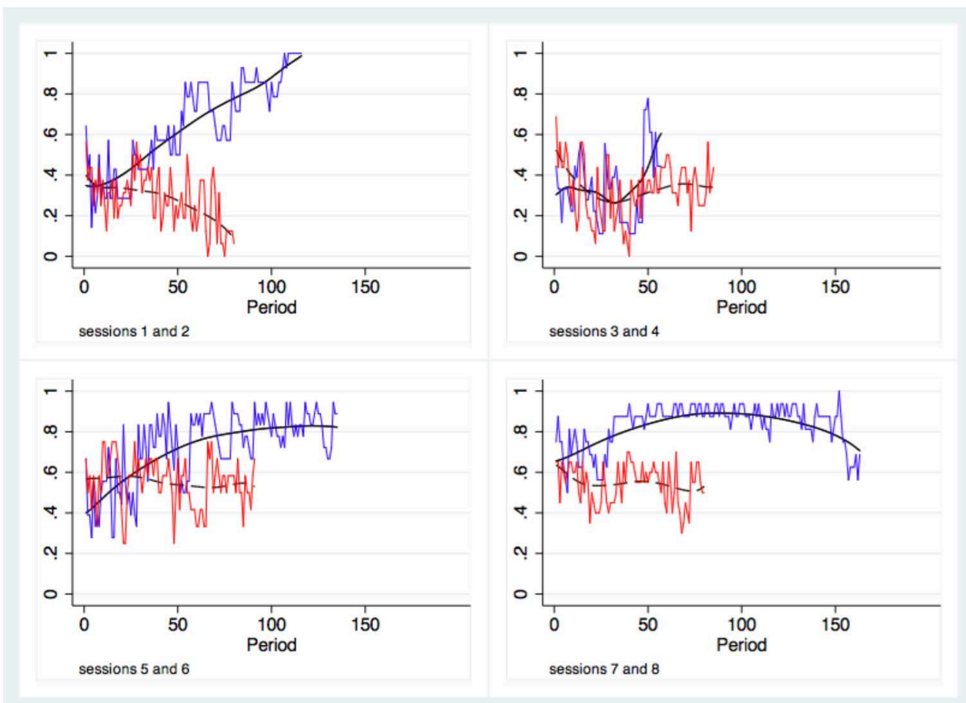


Figure 5: **Conditional cooperation per period in the high and low Raven sessions.** Left-hand panels: cooperation choice by the subject at t after a cooperation choice by the other player at $t-1$. Right-hand panels: cooperation choice after a defection choice by the other player at $t-1$. The red lines represent the low Raven sessions and the blue lines represent the high Raven sessions. The bands represent 95% confidence intervals.

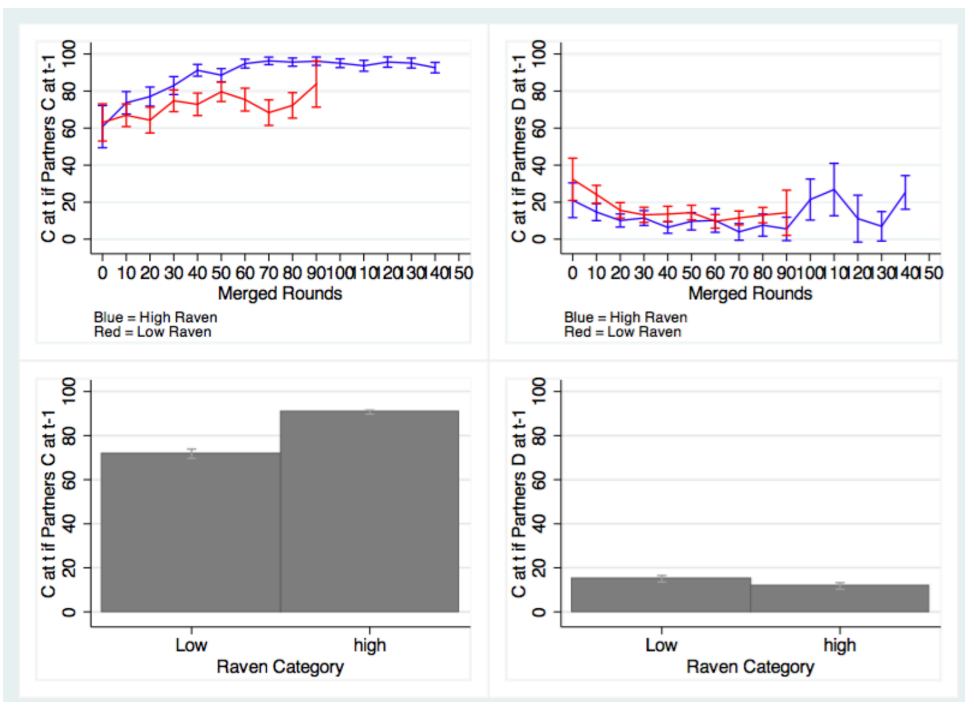


Figure 6: **Distribution of the Raven scores in the low discount treatments.** The top panel depicts the distribution of the entire sample. The bottom panel presents the distributions in the separate Raven sessions.

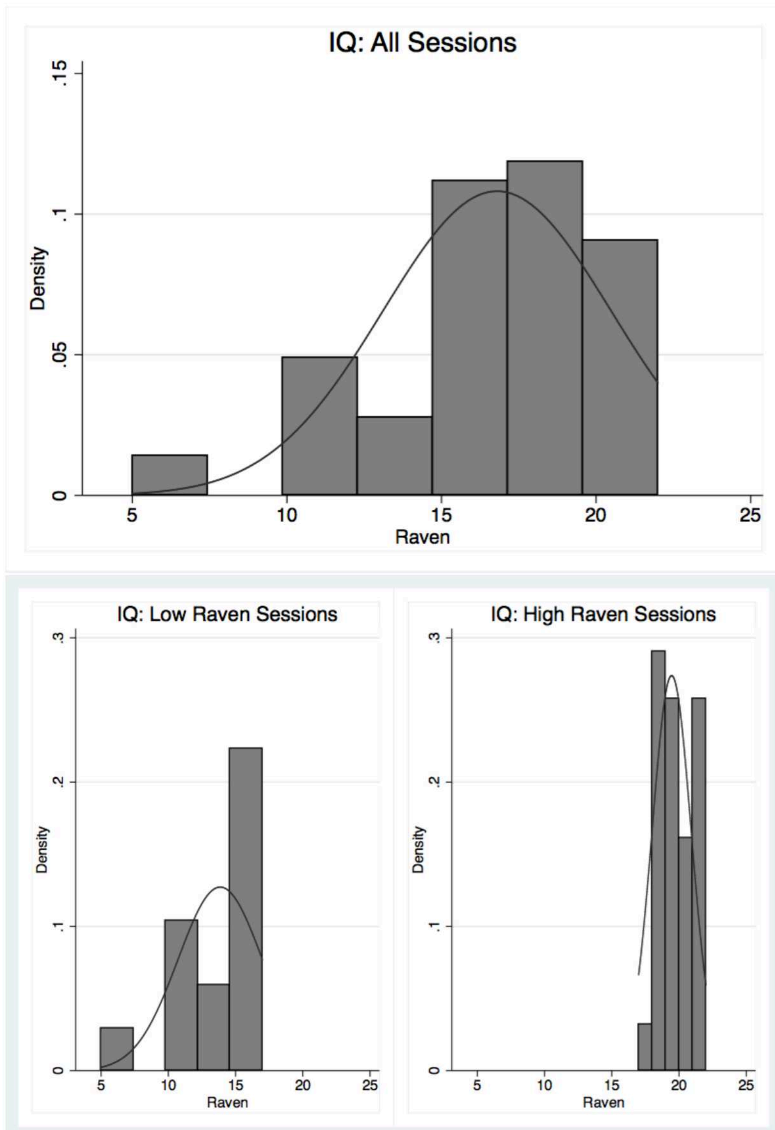


Figure 7: **Cooperation per period in the low and high Raven sessions with low discount.** The red lines represent the low Raven sessions and the blue lines represent the High Raven Sessions. In the left-hand panels, the black lines represent the lowess estimator. The two right-hand panels report the averages computed over observations in successive blocks of ten rounds of all high and all low Raven sessions, aggregated separately. The bands represent 95% confidence intervals.

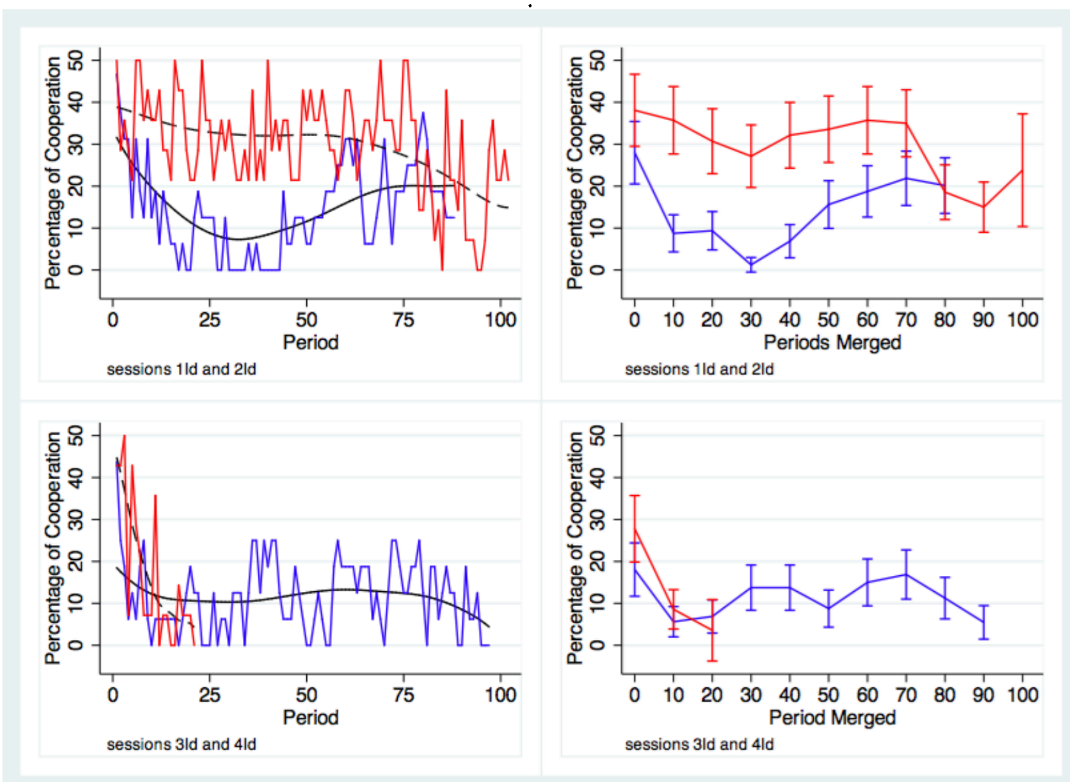


Figure 8: **Average cooperation in the low and high Raven sessions with low discount** The histograms represent the average cooperation in each session. The top panels represent sessions 1ld and 2ld, where the subjects are informed about the way the Raven sessions were formed. The bottom panels represent sessions 3ld and 4ld where – as in the main treatment with high discount– the subjects are not informed. For sessions 3ld and 4ld only the first 20 rounds have been considered. The bands represent 95% confidence intervals.

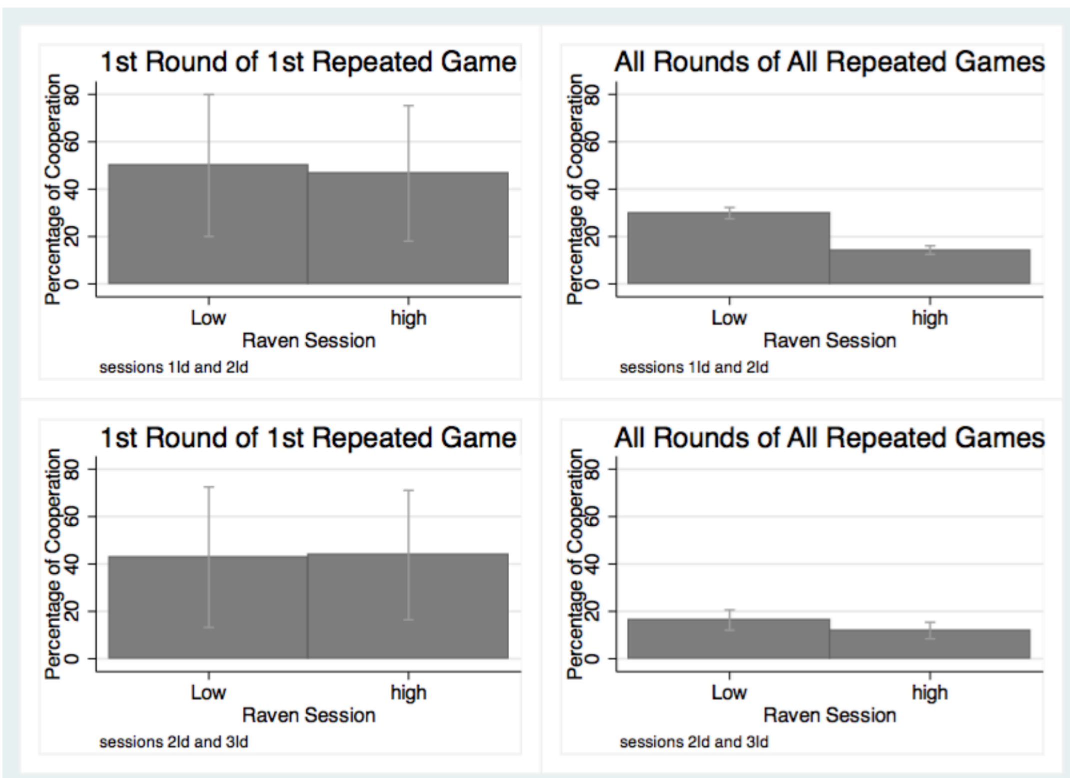


Figure 9: **Conditional cooperation per period in the high and low Raven sessions with low discount** Left-hand panels: cooperation choice of the subject at t after a cooperation choice by the other player at $t-1$. Right-hand panels: cooperation choice after a defection choice by the other player at $t-1$. The bottom panels represent sessions 3ld and 4ld where – as in the main treatment with high discount– the subjects are not informed. For sessions 3ld and 4ld only the first 20 rounds have been considered. The red lines represent the low Raven sessions and the blue lines represent the high Raven sessions. The bands represent 95% confidence intervals.

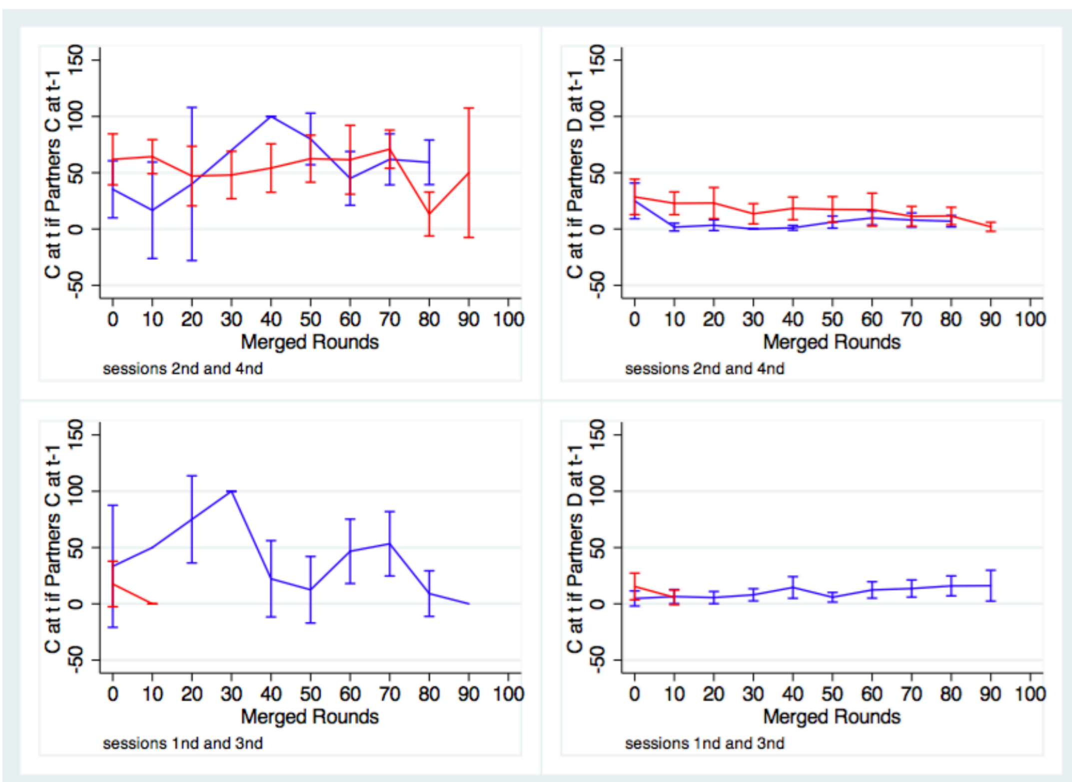
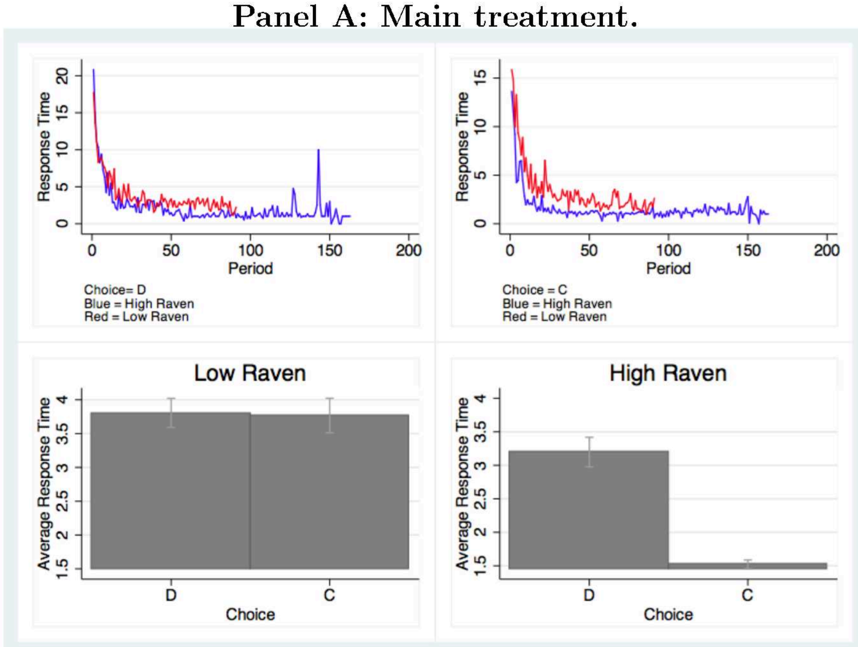
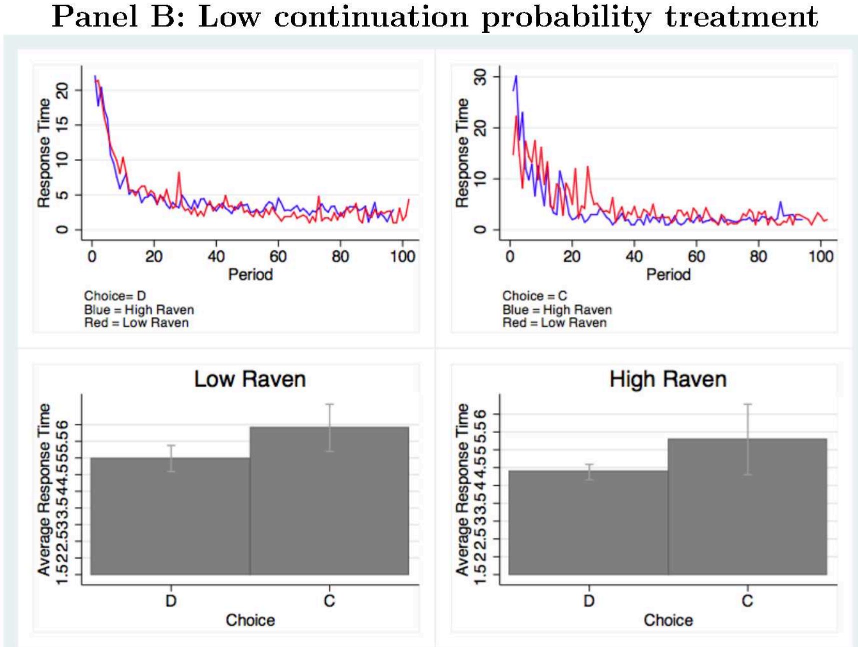


Figure 10: **Reaction Time by choice, period and Raven sessions.** C denotes the Cooperation choice, D Defection. The bands represent 95% confidence intervals.

Panel A: Main treatment.



Panel B: Low continuation probability treatment



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Appendix

Timeline of the Experiment

Day One

1. Participants were assigned a number indicating session number and specific ID number. The specific ID number corresponded to a computer terminal in the lab. For example, the participant on computer number 13 in session 4 received the number: 4.13.

2. Participants sat at their corresponding computer terminals, which were in individual cubicles.

3. Instructions about the Raven task were read together with an explanation on how the task would be paid.

4. The Raven test was administered (30 matrices for 30 seconds each matrix). Three randomly chosen matrices out of 30 tables were paid at the rate of 1 GBP per correct answer.

5. The Holt-Laury task was explained on a white board with an example, as well as the payment for the task.

6. The Holt-Laury choice task was completed by the participants (10 lottery choices). One randomly chosen lottery out of 10 played out and paid (Subjects in sessions 1 & 2 did NOT have this).

7. The questionnaire was presented and filled out by the participants.

Between Day One & Two

1. Allocation to *high* and *low* groups made. An email was sent out to all participants listing their allocation according to the number they received before starting Day One.

Day Two

1. Participants arrived and were given a new ID corresponding to the ID they received in Day One. The new ID indicated their new computer terminal number at which they were sat.

2. The prisoner's dilemma game was explained on a white-board, as was the way the matching between partners, the continuation probability and how the payment would be made.

3. The infinitely repeated prisoner's dilemma game was played. Each experimental unit earned corresponded to 0.004 GBP.

4. The questionnaire was presented and filled out by the participants.

5. Calculation of payment was made and subjects were paid accordingly.

Dates and Details

Tables A.1 and A.2 below illustrate the dates and timings of each session. In the top panels the total number of subjects that participated in Day 1 of the experiment is listed and by comparing with the corresponding 'Total Returned' column from the bottom panels it becomes apparent that there is relatively small attrition between Day 1 and Day 2. For example, for the main treatment, only 10 subjects out of 140 did not return on Day 2.

Table A.1: **Dates and details for main treatment**

Day 1: Group Allocation

	Date	Time	Subjects
1	18/06/2013	10:00	15
2	18/06/2013	11:00	19
Total			34
3	5/11/2013	11:00	18
4	5/11/2013	12:00	18
Total			36
5	26/11/2013	10:00	18
6	26/11/2013	11:00	17
7	26/11/2013	12:00	18
8	26/11/2013	13:00	17
Total			70

Day 2: Cooperation Task

	Date	Time	Subjects	Group
Session 1	20/06/2013	10:00	14	High Raven
Session 2	20/06/2013	11:30	16	Low Raven
Total Returned			30	
Session 3	7/11/2013	11:00	18	High Raven
Session 4	7/11/2013	12:30	16	Low Raven
Total Returned			34	
Session 5	27/11/2013	13:00	18	High Raven
Session 6	27/11/2013	14:30	12	Low Raven
Session 7	28/11/2013	13:00	16	High Raven
Session 8	28/11/2013	14:30	20	Low Raven
Total Returned			66	

Table A.2: **Dates and details for low continuation probability treatment**

Day 1: Group Allocation

	Date	Time	Subjects
1	11/06/2013	10:00	17
2	11/06/2013	11:00	17
3	11/06/2013	12:00	19
4	11/06/2013	13:00	14
Total			67

Day 2: Cooperation Task

	Date	Time	Subjects	Group
Session 1ld	13/06/2013	10:00	14	High Raven
Session 2ld	13/06/2013	11:30	16	Low Raven
Session 3ld	13/06/2013	13:00	16	High Raven
Session 4ld	13/06/2013	14:30	14	Low Raven
Total Returned			60	

Table A.3: Low Raven Sessions, Main Variables

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Choice	0.426	0.494	0	1	5332
Partner Choice	0.428	0.495	0	1	5332
Age	22.345	4.693	18	51	5332
Female	0.624	0.484	0	1	5332
Period	42.264	24.242	1	91	5332
Openness	3.639	0.527	2.5	5	5332
Conscientiousness	3.404	0.645	2	5	5332
Extraversion	3.35	0.729	1	4.75	5332
Agreableness	3.84	0.583	2	4.778	5332
Neuroticism	2.899	0.8	1	5	5332
Raven	14.367	2.709	6	18	5332
Economist	0.06	0.238	0	1	5332
Risk Aversion	5.559	1.149	3	8	4052
Final Profit	2774.297	397.304	1731	3628	64
Profit x Period	33.269	4.216	21.638	45.075	64
Total Periods	83.313	4.272	80	91	64

Table A.4: High Raven Sessions, Main Variables

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Choice	0.694	0.461	0	1	7688
Partner Choice	0.694	0.461	0	1	7688
Age	20.865	2.746	18	36	7688
Female	0.461	0.499	0	1	7688
Period	65.538	42.27	1	163	7688
Openness	3.612	0.59	1.9	4.9	7688

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... table A.4 continued

Variable	Mean	Std. Dev.	Min.	Max.	N
Conscientiousness	3.361	0.739	1.444	4.889	7688
Extraversion	3.228	0.738	1.875	4.5	7688
Agreableness	3.768	0.621	2.333	5	7688
Neuroticism	2.799	0.72	1.25	4.5	7688
Raven	20.331	1.947	16	25	7688
Economist	0.121	0.326	0	1	7688
Risk Aversion	5.541	1.721	2	9	6064
Final Profit	4675.303	2034.416	1447	7752	66
Profit x Period	38.547	5.834	25.386	47.558	66
Total Periods	116.485	40.093	57	163	66

Table A.5: High Raven Session 1ld , Main Variables

Variable	Mean	Std. Dev.	Min.	Max.	N
Choice	0.143	0.35	0	1	1407
Partner Choice	0.143	0.35	0	1	1407
Age	22.688	2.418	18	27	1407
Female	0.5	0.5	0	1	1407
Period	44.531	25.393	1	88	1407
Openness	3.481	0.373	2.7	4.2	1407
Conscientiousness	3.291	0.556	2.111	4.222	1407
Extraversion	3.235	0.716	1.875	4.625	1407
Agreableness	3.541	0.58	2.444	4.444	1407
Neuroticism	2.789	0.625	1.875	4.25	1407
Raven	19.439	1.368	18	22	1407
Economist	0.25	0.433	0	1	1407
Final Profit	2401	151.452	2076	2655	15

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... table A.5 continued

Variable	Mean	Std. Dev.	Min.	Max.	N
Profit x Period	27.284	1.721	23.591	30.17	15
Total Periods	88	0	88	88	15

Table A.6: Low Raven Session 2ld , Main Variables

Variable	Mean	Std. Dev.	Min.	Max.	N
Choice	0.299	0.458	0	1	1428
Partner Choice	0.299	0.458	0	1	1428
Age	23.286	4.08	18	34	1428
Female	0.714	0.452	0	1	1428
Period	51.5	29.454	1	102	1428
Openness	3.736	0.461	3.2	4.600	1428
Conscientiousness	3.857	0.663	2.889	5	1428
Extraversion	3.732	0.526	2.625	4.375	1428
Agreableness	4.024	0.570	2.889	4.778	1428
Neuroticism	2.429	0.919	1.125	4.625	1428
Raven	13.429	3.757	5	17	1428
Economist	0.071	0.258	0	1	1428
Final Profit	3040.143	213.331	2670	3450	14
Profit x Period	29.805	2.091	26.176	33.824	14
Total Periods	102	0	102	102	14

Table A.7: High Raven Sessions 3ld, Main Variables

Variable	Mean	Std. Dev.	Min.	Max.	N
Choice	0.116	0.32	0	1	1552
Partner Choice	0.116	0.32	0	1	1552
Age	22.5	1.937	18	26	1552
Female	0.75	0.433	0	1	1552
Period	49	28.009	1	97	1552
Openness	3.45	0.52	2	4.3	1552
Conscientiousness	3.674	0.504	3	4.667	1552
Extraversion	3.344	0.637	2.125	4.25	1552
Agreableness	3.819	0.602	2.222	4.667	1552
Neuroticism	2.758	0.638	1.75	3.75	1552
Raven	19.375	1.495	17	22	1552
Economist	0.313	0.464	0	1	1552
Final Profit	2601.25	126.24	2380	2810	16
Profit x Period	26.817	1.301	24.536	28.969	16
Total Periods	97	0	97	97	16

Table A.8: Low Raven Sessions 4ld, Main Variables

Variable	Mean	Std. Dev.	Min.	Max.	N
Choice	0.163	0.37	0	1	294
Partner Choice	0.163	0.37	0	1	294
Age	21.071	2.157	18	25	294
Female	0.5	0.501	0	1	294
Period	11	6.066	1	21	294
Openness	3.679	0.72	2.3	4.9	294
Conscientiousness	3.54	0.542	2.222	4.444	294

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... table A.8 continued

Variable	Mean	Std. Dev.	Min.	Max.	N
Extraversion	3.268	0.707	2.25	4.625	294
Agreableness	3.619	0.387	3.111	4.222	294
Neuroticism	2.839	0.859	1.625	4	294
Raven	14.286	2.123	10	17	294
Economist	0.214	0.411	0	1	294
Final Profit	575.571	79.642	480	750	14
Profit x Period	27.408	3.792	22.857	35.714	14
Total Periods	21	0	21	21	14

Table A.9: Correlations Table (p−*values* in brackets)

Variables	Raven	Female	Risk Aversion	Openness	Conscientiousness	Extraversion	Agreableness	Neuroticism
Raven	1.000							
Female	-0.160	1.000						
	(0.068)							
Risk Aversion	0.030	-0.039	1.000					
	(0.764)	(0.699)						
Openness	-0.152	-0.017	-0.086	1.000				
	(0.084)	(0.844)	(0.396)					
Conscientiousness	0.085	0.004	0.073	0.157	1.000			
	(0.337)	(0.965)	(0.470)	(0.075)				
Extraversion	-0.076	-0.086	0.004	0.319	0.054	1.000		
	(0.391)	(0.330)	(0.970)	(0.000)	(0.539)			
Agreableness	-0.020	-0.052	-0.106	0.183	0.269	0.183	1.000	
	(0.823)	(0.554)	(0.296)	(0.038)	(0.002)	(0.037)		
Neuroticism	-0.036	0.424	0.072	-0.130	-0.305	-0.315	-0.351	1.000
	(0.684)	(0.000)	(0.478)	(0.141)	(0.000)	(0.000)	(0.000)	

Table A.10: **Individual strategies in the different Raven sessions in the last 5 and first 5 repeated games** Each coefficient represents the probability estimated using the ML of the corresponding strategy. Std error is reported in brackets. Gamma is the error coefficient that is estimated for the choice function used in the ML and beta is the probability estimated that the choice by a subject is equal to what the strategy prescribes.† Tests equality to 0 using the Waldtest: * $p-values < 0.1$, ** $p-values < 0.05$ **, $p-values < 0.01$ ***

Raven Session	High	Low	High	Low
Repeated Games	Last 5	Last 5	First 5	First 5
Strategy				
Always Cooperate	0	0	0	0.0410
	(0.0055)	(0.0079)	(0.0068)	(0.0436)
Always Defect	0.0417	0.4130***	0.3165***	0.3107***
	(0.0318)	(0.1024)	(0.1076)	(0.0884)
Grim after 1 D	0.3269***	0.1069*	0.5374**	0.2226***
	(0.1050)	(0.0646)	(0.1144)	(0.0772)
Tit for Tat (C first)	0.2316**	0.2890***	0	0.2396***
	(0.1059)	(0.0774)	(0.0790)	(0.0673)
Tit For Tat (D First)	0.0000	0.0600	0.0478**	0.0819
	(0.0010)	(0.0457)	(0.0480)	(0.0649)
Win Stay Lose Shift	0.0623	0	0.0377	0.0159
	(0.0660)	(0.0548)	(0.0423)	(0.0549)
Grim after 2 D	0.0000	0	0.0313	0
	(0.0553)	(0.0100)	(0.0533)	(0.0378)
Tit for Tat (after D D C)††	0.1201*	0.0953**	0.0000	0.0739
	(0.0616)	(0.0453)	(0.0139)	(0.0979)
Tit For Tat (after D C C) †††	0.1223	0	0.0000	0
	(0.0864)	(0.0129)	(0.0207)	(0.0332)
Tit For Tat (after D D C C)	0	0	0.0292	0
	(0.0302)	(0.0584)	(0.0528)	(0.0021)
Grim after 3 D	0.0951	0	0.0000	0
	(0.0645)	(0.0042)	(0.0124)	(0.0402)
Tit For Tat (after D D D C)	0	0.0358	0	0
Gamma	0.3179***	0***	0***	0.0410***
	(0,0553)	(0.0079)	(0.0068)	(0.0436)
beta	0.959	0.936	0.881	0.839
Sessions	1,5,7	2,4, 6, 8	1,5,7	2,4,6, 8
Average Rounds	4.83	5.12	2.11583	3.875
N. Subjects	48	64	48	64
Observations	1090	1676	518	1152

† When beta is close to 1/2, the choices are essentialy random and when it is close to 1 then choices are almost perfectly predicted.

†† Tit for Tat (after D D C) stands for the lenient Tit for Tat strategy that punishes only after observing two defections from the partner and returns to cooperation after observing cooperation once.

††† Tit for Tat (after D C C) stands for the Tit for Tat strategy that punishes after 1 defection but only returns to cooperation after observing cooperation twice from the partner.