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AVERAGE PLAYER TRAITS AS PREDICTORS OF COOPERATION IN A REPEATED PRISONER'S DILEMMA

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ABSTRACT

Many studies have looked at how individual player traits influence individual choice in the repeated prisoner's dilemma, but few studies have looked at how the average traits of pairs of players influence the average choices of pairs. We consider cognitive ability, patience, risk tolerance, and the Big Five personality measures as predictors of individual and average group choices in a ten-round repeated prisoner's dilemma. We find that a pair's average cognitive ability measured by the Raven's IQ test predicts average cooperation rates robustly and average earnings more modestly. Higher individual cognitive ability also predicts a greater probability of sustaining cooperation in the second round, suggesting that positive reciprocity is more likely among players with higher Raven's scores. Openness is the only control variable that predicts first-round cooperative behavior.

1. INTRODUCTION

One of the longstanding questions in social science is "What causes cooperation?". Experimental game theory has been central in attempts to answer this question. Many studies have investigated how elements of game design can influence cooperation, as Sally's (1995) literature review demonstrates. Many other studies have looked at whether *individual* traits predict greater individual cooperative choices in both the repeated prisoner's dilemma and repeated public goods games (*inter alia*, Boone et al., 1999, Kurzban and Houser 2001), but aside from gender differences, very few have asked whether average traits of *pairs* of players predict greater joint cooperation (see Balliet et al. (2011) for a meta-analysis of the gender and cooperation literature). This paper focuses on individual and pair-level traits that predict cooperation in a ten-round prisoner's dilemma. To our knowledge, ours is one of a small number of laboratory experiment to investigate whether the average traits of the pair are important predictors of

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cooperation (with the exception of the aforementioned gender studies). In the case of the pair's average Raven's IQ score, it appears that average traits help predict joint cooperation.

We explore the dynamics of this relationship in some detail below. We provide evidence that high-IQ players are more likely to reciprocate cooperative behavior in the second round of the game. Thus, we find evidence that higher intelligence is associated with positive reciprocity.

RELATED LITERATURE

Experiments that investigate the effects of average group traits on average rates of cooperation in prisoner's dilemmas and public goods games are rare. Aside from the aforementioned papers on the effects of group gender differences, some papers investigate how group traits such as religious affiliation influence *individual* cooperation (e.g., Koopmans et al. 2009), but these do not explicitly investigate aggregate cooperation. The discussion in this section focuses on IQ, patience, and risk aversion, since they are the primary traits of interest in our experiment. In the results section we include a discussion of personality traits as predictors of cooperation.

Two repeated prisoner's dilemma experiments have investigated the relationship between average cognitive skills and average cooperation. The earliest of which we are aware is Terhune (1974) who, in a 150 round prisoner's dilemma, reported a correlation of 0.1 between the average Wonderlic score of a pair of players and their average joint play of *coop-coop*; this positive correlation was statistically insignificant. Segal and Hershberger (1999), in a study of twins knowingly playing a 100 round repeated prisoner's dilemma against their own twin, found a significant positive relationship (0.31, $p < 0.01$) between average twin IQ and average joint play of *coop-coop*. Segal and Hershberger also found a negative relationship (-0.27, $p < 0.01$) between average twin IQ and plays of *defect-defect*. Jones (2008, 2013), in a meta-study of repeated prisoner's dilemma experiments run at schools with differing average SAT and ACT scores, reported that average cooperation rates are higher at universities with higher average test scores. Finally, in a related finding, Al-Ubaydli, Jones, and Weel (2013) found that when students played a ten round stag hunt against each other, the average patience of a pair of players (but not individual patience) was positively related to coordination on stag-stag, the Pareto-efficient outcome. These studies look at how average game outcomes depend on the average traits of players; the studies discussed in the remainder of this section largely report relationships between individual player traits and individual outcomes in the prisoner's dilemma and related social dilemmas.

Looking at within-game play in a repeated public goods game, Putterman et al. (2011) find that in the first period and in the first four periods, higher IQ test subjects at Brown University contributed more to a 24 period game (Appendix, Table B.9). This suggests that players with high cognitive abilities may implicitly follow the advice Axelrod (1984) offers to advocates of cooperation: cooperate early in the game.

Burks et al. (2009) likewise found that truck driving students who performed better on the Raven's IQ test were more likely to trust in the first stage of a sequential, one-round social dilemma, which they denote a prisoner's dilemma. In their game, both players are endowed with five dollars. The first mover decides whether to send $0 or $5 knowing that the experimenter will double the amount. The second mover then decides to send any amount in the range $0-5, also knowing that the experimenter will double it. As noted, high IQ first movers are more likely than lower IQ players to send money. In addition, they found that in the second stage, higher-IQ students were more likely to engage in both positive and negative reciprocity: they tended to return more when given more and return less when given less. The authors also controlled for risk tolerance, and found that more risk tolerant players sent more in the first round.

In a similar study of individuals ranging in ages from 9 to 25, van den Bos et al. (2010) found no statistically significant relationship between individual Ravens score and first-stage trust (r = 0.14, p = 0.17), and a marginally significant positive relationship between individual Ravens scores and second-stage reciprocity (r = 0.17, p = 0.08). Ben-Ner and Halldorsson (2010), in a similar experiment with students at the University of Minnesota that simultaneously included many personality and demographic controls, found an insignificant but positive relationship between IQ and self-reported trust and an insignificant and negative relationship between IQ and reciprocity.

M. Jones (2012) finds limited evidence that in a sophisticated 3x3 repeated prisoner's dilemma, an individual with an ACT in approximately the top sixth of the subject pool is more likely to cooperate and an individual with a score in approximately the bottom sixth of the subject pool is less likely to cooperate. However, the median specification suggests no relationship between individual ACT scores and individual rates of cooperation. Likewise, Hirsh and Peterson (2009) found no statistically significant relationship between individual cognitive ability as measured by the Wonderlic and individual cooperativeness in a 10-round prisoner's dilemma.

Turning to games involving cognitive load manipulations—artificially reducing the cognitive capacity of subjects by asking them to memorize unrelated facts—Milinski and Wedekind (1998) ran two-player iterated prisoner's dilemmas with one confederate, and imposed higher cognitive loads in some treatments by requiring players to stop and play a memory game. When the memory game was included between rounds, players did a poorer job recalling past rounds of prisoner's dilemma play, and were less likely to play the relatively sophisticated "win-stay, lose shift" strategy rather than the less sophisticated "generous tit-for-tat" strategy. The latter is less sophisticated because it conditions only on the opponent's recent play, while "win-stay, lose shift" relies on memory of both the opponent's play and one's own action. The authors find that players who used the more sophisticated strategy cooperated more and earned more.

Duffy and Smith (2012), in a four-player repeated prisoner's dilemma, impose higher cognitive loads on some groups of players by giving those players a seven digit number to memorize while giving others a two digit number to memorize. In 12 of the 15 runs of the game, all four players either had the high load or the low load; in the other three, players were split evenly. The authors find limited evidence that in the low load condition, players tend to cooperate more in early rounds ($p < 0.1$), and then collapse faster toward joint defection in the last five rounds. In line with Milinski and Wedekind, Duffy and Smith report that "low load subjects are better able to condition their strategy on previous outcomes" (p.4).

One study of which we are aware measures both cognitive skill and patience in a repeated prisoner's dilemma, albeit one played against a computer. Yi et al. (2005) find that an individual's IQ score is only insignificantly positively correlated with individual rates of cooperation when playing against a computer programmed with a Tit-for-Tat or purely randomized strategy. Yi et al. also test the hypothesis that delay discounting (impatience) is negatively related to cooperation in the repeated prisoner's dilemma played against a computer: they report evidence that impatience (delay discounting) over losses predicts more cooperative behavior in the Tit-for-Tat setting but not against a randomized strategy. In this experiment, no monetary rewards were offered for better game performance.

Harris and Madden (2002) also found that greater impatience predicts more defection in a 40-round prisoner's dilemma "played against a computer opponent using a tit-for-tat strategy" (p.429); these subjects had a monetary incentive for better performance. In both the Yi et al. and Harris and Madden experiments, players knew they faced a computer. And turning to risk aversion, Glöckner and Hilbig (2012) report that in repeated prisoner's dilemma experiments higher individual risk aversion predicted *higher* levels of individual cooperative play, while Sabater-Grande and Georgantzis (2002) report the opposite.

Thus, a variety of recent experiments have investigated the individual-level relationship between cognitive ability, patience, risk aversion, and behavior in social dilemma experiments. Some limitations of past experiments are that almost none have explicitly investigated which average group traits predict greater joint cooperation or higher payoffs for pairs, and none have tested for cognitive ability, patience, and risk tolerance simultaneously. Since cognitive skill, patience, and risk tolerance are positively correlated in most samples, it would be valuable to investigate which has the most robust relationship with pro-social behavior in the prisoner's dilemma.

2. Experimental Design

This section draws heavily from Al-Ubaydli, Jones and Weel (2013). That paper contains more complete explanations of the procedure.

A. Data Collection and Order

In our experiment, for each participant, the following were collected:

- Behavior in the repeated prisoner's dilemma
- Personal attributes
  - Personality traits
  - Demographic information
  - Risk-aversion
  - Patience
  - Cognitive ability

As has been demonstrated in the extensive psychology literature on framing and anchoring (Bargh 2006, Epley and Gilovich 2004), any data based on human choices is sensitive to payoff-irrelevant features of the environment and experimental procedure.

The main payoff-irrelevant feature of concern for our study is that there may be a spillover between the two data classes, e.g., the fact that we are collecting data on attributes affects how people play in a coordination game, regardless of the attributes. We will refer to this as a 'priming bias,' which includes experimenter demand effects. Our solution to this problem was for participants to play the game first, and then to collect data on their personal attributes and cognitive traits. The cognitive ability test was given last: the 45-minute Raven's test (see below) was the most mentally exhausting for participants, and accounted for the lion's share of cognitive effort expended during a session. We therefore made it the last task.

B. Procedure

All sessions were run at the Krasnow Institute computer laboratory at George Mason University (GMU). Participants were recruited from a campus database of students who had expressed an interest in economics experiments. Sessions lasted an average of approximately 100 minutes (inclusive of check-in and payment processing), and average earnings were approximately $30 per participant. Sessions had exactly 8, 10 or 12 participants.

Some of the tasks were incentivized while others were not (the detailed descriptions and explanations are below). Participants received a fixed fee for each unincentivized task. The drawback of incentivized tasks is that they potentially generate wealth effects. To minimize such wealth effects, it was common knowledge that participants would be paid for exactly one of the incentivized tasks, with a die roll at the end of the experiment determining which.

Since, by the standards of experiments in our laboratory, the experiment was quite long, cognitively intensive and involved large stakes, we wanted to convey as much payment credibility as possible. Consequently, for each of the unincentivized tasks, we paid the participants in cash immediately after they completed the task (we also paid the show-up fee in cash at the start of the experiment).

For the entirety of the experiment, participants sat at private, individual desks with other participants within eyeshot in the same room. There was no communication. Though most of the tasks were undertaken on the computer, all instructions were printed, handed out and read aloud to all participants. See the appendix for the full instructions.

Repeated Prisoner's Dilemma: Participants were anonymously and randomly assigned a partner who would be their partner for 10 rounds. Each round, the two players would play the repeated prisoner's dilemma in Figure 1 (with an exchange rate of 1 point = 1¢). Strategies were given a neutral frame (*green, blue* rather than *cooperate, defect*).

Figure 1: Prisoner's Dilemma

	Cooperate	Defect
Cooperate	$1, $1	$0, $1.50
Defect	$1.50, $0	$0.25, $0.25

In each cell, first (second) figure denotes payoff of row (column) player

At the end of each round, participants were informed of their earnings from that round rather than the actual outcome. However, each participant could infer her opponent's actions from her own earnings. The total number of rounds (10) and the number of the current round was also reported on the computer screen.

In addition to playing a prisoner's dilemma game, participants played a repeated stag hunt as part of separate study (Al-Ubaydli et al. 2013). We randomized which they played first by session, and we included session effects in all our econometric tests to control for this. As mentioned above, it was common knowledge that participants would be paid for exactly one of the incentivized tasks.

Personality survey: Participants were asked to complete a Big-5 personality survey, a standard measure of personality traits (Borghans et al. 2008). Participants responded to each of 50 statements about their personality using a 5-point Likert scale (1 = very inaccurate, 5 = very accurate). The 50 questions broke down into 10 questions corresponding to 5 personality traits:

- Openness to new experiences, e.g., *I have a vivid imagination*
- Conscientiousness, e.g., *I pay attention to details*
- Agreeableness, e.g., *I feel little concern for others*
- Extraversion, e.g., *I keep in the background*
- Neuroticism, e.g., *I get stressed out easily*

Participants were paid a fixed fee of $5 after completing this survey and the demographic survey regardless of their responses.

Demographic survey: Participants were asked a few questions about their personal demographics (gender, age, class etc.) and their self-reported scores in standardized tests (SAT, GRE etc.). Self-reported SAT (GRE) scores correlated 0.27 (0.20) with our IQ measure. Frey and Detterman (2004) found a correlation of 0.48 between actual SAT scores and a similar IQ test, the Raven's Advanced Progressive Matrices. The lower correlation is likely in part due to misreporting by students.

Risk-aversion survey: Participants completed a Hey-Orme risk preferences test (Hey and Orme 1994). (The instructions (see the appendix) are adapted from a set provided by Glenn Harrison.) Each period, the participant is faced with a choice between two lotteries, each over the same four outcomes ($0, $10, $20, $30). The participant chooses which she prefers (or expresses indifference). The participant does this for 20 pairs (periods) without knowing at the outset how many pairs they will have to ponder. To generate incentives for truthful revelation, participants were informed that—if it were the unique incentivized task for which they were paid—one of the pairs would be selected at random at the end and each participant will play out the lottery for which she declared a preference.

We selected the Hey-Orme test rather than the more conventionally deployed Holt-Laury test (Holt and Laury 2002) because it is a richer test that permits more accurate identification of economic risk-preference parameters. Using maximum likelihood estimation (see Harrison and Rutstrom (2008), Andersen et al. (2009); see Wilcox (2011) for a new microeconometric model of risk-attitudes), one can use the choice data to estimate the parameter K in the constant relative risk aversion (CRRA) von Neumann-Morgenstern utility function $u(m) = m^K$, where m denotes $ wealth. K is a measure of risk tolerance (the negative of risk-aversion).

Patience survey: Participants were presented with a multiple price list (Harrison et al. 2002, Andersen et al. 2006) with 20 rows. For each row, the participant is faced with a choice between $10.00 tomorrow and $\$Y$ in one week. The amount $\$Y$ started at $10.50 and increased in $0.50 increments to $20.00. To generate incentives for truthful revelation, participants were informed that—if it were the unique incentivized task for which they were paid—one of the pairs would be selected at random at the end of the experiment and each participant paid according to their choice.

Tests of patience involving reasonable horizons require participants to leave the laboratory and receive payments at a later time. This generates credibility issues: to what extent are differences in observed preferences the result of differences in patience (the goal) vs. differences in the perceived credibility of the experimenter with respect to payment delivery? (See Andersen et al. (2008) and Andreoni and Sprenger (2012) for an extensive discussion of these issues.)

To minimize any variation in perceived credibility, we took several steps to demonstrate our credibility at the decision-making stage. First, both options in each choice entail an amount that can only be received after exiting the laboratory, i.e., there is a front-end delay (Harrison et al. 2002).

Second, they were handed a contract on university letterhead signed by us and them confirming the earliest time that they can retrieve the envelope at a specified location on campus (in one day or in 7 days, depending on their stated preference).

Our measure of patience is therefore the number of rows where the participant preferred the amount to be received in one week (rather than the following day).

<u>Cognitive ability</u>: Borghans et al. (2008) define cognitive ability as the ability to:

- Understand complex ideas
- Adapt effectively to the environment
- Learn from experience
- Reason
- Overcome obstacles through purposeful thought

For a complete discussion of intelligence and its measurement, see Neisser et al. (1995). There are many tests of cognitive ability. We use the Raven's Progressive Matrices test of intelligence, which is one of the standard tools used in the literature (Borghans et al. 2008). We used the Standard Progressive Matrices Plus, a version intermediate in difficulty between the Standard Progressive Matrices and the much more difficult Advanced Progressive Matrices, in order to avoid ceiling and floor problems that might arise among students at a comprehensive state university.

The test is composed of 60 problems. Each problem consists of a pattern with a missing segment, and 6-to-8 segments, only one of which correctly completes the pattern (see the appendix for examples). Participants were given 45 minutes to complete the test. The test was unincentivized. Borghans et al. (2008) remark that the effect of incentivizing tests of cognitive ability is for scores in the lower tail to improve. We decided against using incentives because we wanted to maintain comparability between our results and the results reported in the psychology literature (which typically do not use incentives).

C. Research Hypotheses

The above procedure yields data on a vector of attributes that represents our explanatory variables. We investigate the effect of these explanatory variables on the following dependent variables:

- An individual's decision to play cooperate in a given period
- A pair's success in achieving a play of joint cooperation in a given period

- An individual's total earnings for the 10 period prisoner's dilemma
- A pair's total earnings for the 10 period prisoner's dilemma

Our main focus is on whether cognitive ability, patience, and risk aversion influence cooperation, but the other explanatory variables are also of independent interest. After investigating these dependent variables, we investigate how behavior in early rounds of the game is affected by individual traits.

3. RESULTS

Table 1 reports summary statistics. On average, individuals cooperated in 40% of the rounds; joint plays of *coop-coop* occurred in 22% of rounds. No participant was close to the top or the bottom of the span of possible Raven's scores, so no ceiling and floor problems arose with the Raven's IQ estimate.

Table 1: Sample Statistics

Variable	**Mean (SD)**
Earnings	$6.0 ($2.6)
Proportion of times playing *cooperate*	0.40 (0.30)
Proportion of times both play *cooperate*	0.22 (0.31)
Raven score	42 (5.5)
Patience	16 (4.2)
Risk-lovingness parameter	0.63 (0.23)
Openness (-2 to +2 likert)	0.81 (0.54)
Conscientiousness (-2 to +2 likert)	0.48 (0.65)
Extraversion (-2 to +2 likert)	0.22 (0.73)
Agreeableness (-2 to +2 likert)	1.0 (0.49)
Neuroticism (-2 to +2 likert)	-0.10 (0.74)
Age (years)	24 (4.5)
Male (dummy)	0.68 (0.47)
Game earnings ($)	5.9 (1.6)

All figures are to two significant figures. Data come from 167 observations.

Table 2 reports correlations across variables at the individual level. We replicated the standard correlation between higher IQ and greater risk tolerance, with a correlation of 0.21 ($n = 176$, $p < 0.01$). We also found a positive correlation between IQ and patience, although this was far from statistically significant at $r = 0.07$ ($n = 176$, $p = 0.4$). A statistically insignificant but positive correlation between the two occurs occasionally in the psychology literature, as Shamosh and Gray (2008) note in their literature review. We also replicate the conventional positive relationship between IQ and openness, $r = 0.15$ ($n = 176$, $p = 0.06$).

Table 2: Sample Correlation Matrix

	Proportion of times played *cooperate*	Individual earnings	Raven	Risk-lovingness	Patience	Openness	Conscientiousness	Extraversion	Agreeableness	Neuroticism	Age
Individual earnings	0.47***	-	-	-	-	-	-	-	-	-	-
Raven	0.11	0.14*	-	-	-	-	-	-	-	-	-
Risk-lovingness	0.091	0.062	0.21***	-	-	-	-	-	-	-	-
Patience	-0.0003	0.0080	0.072	-0.047	-	-	-	-	-	-	-
Openness	0.14*	0.062	0.15*	0.10	-0.10	-	-	-	-	-	-
Conscientiousness	-0.20***	-0.14*	0.11	-0.028	0.12	0.053	-	-	-	-	-
Extraversion	0.020	-0.094	0.022	-0.024	-0.12*	0.27***	0.16**	-	-	-	-
Agreeableness	0.012	0.12	0.037	0.011	-0.060	0.21***	0.19**	0.36***	-	-	-
Neuroticism	-0.095	-0.077	-0.21***	-0.14*	0.055	-0.25***	-0.21***	-0.36***	-0.10	-	-
Age	0.039	0.035	0.070	-0.029	0.010	-0.051	-0.066	-0.10	-0.0066	0.089	-
Male	0.066	0.11	0.090	0.34***	0.017	-0.084	-0.11	-0.10	-0.12	-0.19**	-0.019

Based on a sample of size 167. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

In line with the public good game literature, cooperation drops off throughout the game, starting at 52%, in the first round, averaging 40% in rounds 2-9, and falling to 23% in the final round.

A. Main Results

In terms of our formal econometric testing, when the dependent variable is a player's (or a pair's) total earnings, we estimate the following OLS model:

$$Y_{is} = \alpha + \beta X_i + \lambda_s + \varepsilon_{is}$$

Where i denotes player (pair), X_i is the player's (pair's) time-invariant demographic traits, and λ_s is a session dummy. All non-dummy independent variables are standardized (i.e., transformed so that they have a mean of zero and a standard deviation of one).

When the dependent variable is a choice dummy, we estimate the following probit model:

$$Y^*_{its} = \alpha + \beta X_i + \mu_t + \lambda_s + \varepsilon_{its}$$

Where Y^*_{its} is the standard probit latent variable, t denotes the round, μ_t denotes a round dummy, and the error is clustered at the individual player level. Estimated marginal effects are reported at the mean value of the explanatory variables.

Result 1: Cognitive ability, patience, and risk tolerance do not predict individual cooperation in the prisoner's dilemma game.

As seen in Table 3, across five specifications, none of the three key variables of interest is statistically significant, nor are the magnitudes of the coefficients particularly large.

Table 3: Probit of Decision to Play *Cooperate* as a Function of Player's Attributes

	Model				
	1	2	3	4	5
Cognitive Ability	0.026 (0.025)			0.021 (0.025)	0.020 (0.025)
Patience		0.011 (0.026)		0.008 (0.026)	0.024 (0.026)
Risk Tolerance			0.021 (0.025)	0.015 (0.024)	-0.00086 (0.026)
Openness					0.038 (0.026)
Conscientiousness					-0.066*** (0.024)
Extraversion					0.0065 (0.026)
Agreeableness					0.0058 (0.026)
Neuroticism					-0.019 (0.026)
Male (dummy)					0.046 (0.057)
Age (not standardized)					0.0017 (0.0045)
Pseudo R^2	0.04	0.04	0.04	0.05	0.08
Observations	1670	1670	1670	1670	1670

Dependent variable in all probit models is a dummy variable that takes the value "1" when a player plays *cooperate*. Standard errors are corrected for clustering at the individual level. All models include round and session dummies. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

Result 2: The average cognitive ability of a pair of players has a positive relationship with joint cooperation. Average patience and average risk tolerance have no statistically significant relationship with joint cooperation.

As seen in Table 4, across three specifications that include average cognitive ability of a player pair, if the Raven's score of each player rises by one standard deviation, joint cooperation is predicted to rise by approximately 10% ($p < 0.05$). Neither patience nor risk tolerance are significant in any specification.

Table 4: Probit of Both Players Simultaneously Playing *Cooperate* as a Function of the Pair's Average Attributes

	Model				
	1	2	3	4	5
Cognitive Ability	0.10** (0.046)			0.091** (0.042)	0.096** (0.038)
Patience		0.015 (0.050)		0.017 (0.056)	0.051 (0.041)
Risk Tolerance			0.077 (0.049)	0.063 (0.044)	-0.030 (0.048)
Openness					0.12** (0.047)
Conscientiousness					-0.080** (0.037)
Extraversion					-0.031 (0.044)
Agreeableness					0.036 (0.041)
Neuroticism					-0.091** (0.047)
Male (dummy)					0.21** (0.096)
Age (not standardized)					0.012* (0.0070)
Pseudo R^2	0.13	0.10	0.12	0.14	0.24
Observations	830	830	830	830	830

Dependent variable in all probit models is a dummy variable that takes the value "1" when a both players simultaneously play *cooperate*. Explanatory variables are the simple average of the attribute of the two players in the pair. Standard errors are corrected for clustering at the individual level. All models include round and session dummies. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

Together, Results 1 and 2 suggest that the link between intelligence and cooperation may be emergent in the repeated prisoner's dilemma: the relationship appears among *pairs* of higher-scoring players.

Since plays of *coop-coop* occur 22% of the time on average in our sample (Table 1), this implies that two players with IQs one standard deviation above the mean will jointly cooperate approximately 32% of the time, whether or not one includes additional controls. Among other variables in the joint cooperation regression, higher openness, lower conscientiousness, lower neuroticism, and higher age also predict greater joint cooperation, and pairs of males also cooperate more often.

In other tests (omitted for brevity) we investigated whether the maximum or minimum scores for IQ had notably stronger or weaker relationships with cooperation than the average values for the two players. Results were nearly identical for maximum scores in terms of coefficients and p-values. Results were weaker for minimum scores but still with $p < 0.05$ in the regression with full personality controls but $p < 0.1$ when controlling for IQ alone, and $p = 0.17$ when controlling for IQ, patience, and risk tolerance. Thus we find modest evidence that maximum and average pair IQ are better predictors of cooperation than minimum pair IQ.

Result 3: Cognitive ability, patience, and risk tolerance do not predict higher levels of individual earnings in the prisoner's dilemma game.

Table 5: OLS Regression of Individual Earnings as a Function of Individual Attributes

	Model				
	1	2	3	4	5
Cognitive Ability	0.33 (0.21)			0.31 (0.22)	0.30 (0.22)
Patience		0.082 (0.23)		0.048 (0.23)	0.12 (0.23)
Risk Tolerance			0.13 (0.22)	0.050 (0.22)	-0.13 (0.24)
Openness					0.10 (0.23)
Conscientiousness					-0.42* (0.23)
Extraversion					-0.45* (0.25)
Agreeableness					0.55** (0.23)
Neuroticism					-0.22 (0.25)
Male (dummy)					0.62 (0.52)
Age (not standardized)					-0.0075 (0.051)
R^2	0.07	0.05	0.06	0.07	0.14
Observations	167	167	167	167	167

Dependent variable in all OLS models is an individual's earnings. All models include session dummies. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

As seen in Table 5, individual cognitive ability, patience, and risk tolerance do not reliably predict individual earnings.

Result 4: There is modest evidence that higher average cognitive ability of a pair of players predicts higher total pair earnings.

In Table 6, average cognitive ability of a player pair predicts greater earnings in the specification with full controls (p = 0.073). Since earnings average \$11.90 in this experiment, a one standard deviation rise in each player's cognitive ability predicts an 11% increase in earnings according to the specification with full controls.

Table 6: OLS Regression of a Pair's Total Earnings as a Function of the Pair's Average Attributes

	Model				
	1	2	3	4	5
Cognitive Ability	1.1 (0.71)			1.0 (0.70)	1.3* (0.71)
Patience		0.27 (0.85)		0.26 (0.92)	0.79 (0.92)
Risk Tolerance			0.61 (0.78)	0.47 (0.73)	-0.65 (0.89)
Openness					0.75 (0.87)
Conscientiousness					-1.5** (0.72)
Extraversion					-0.35 (0.78)
Agreeableness					1.2 (0.84)
Neuroticism					-0.95 (0.77)
Male (dummy)					2.1 (1.7)
Age (not standardized)					0.098 (0.15)
R^2	0.11	0.08	0.08	0.11	0.27
Observations	83	83	83	83	83

Dependent variable in all OLS models is a pair's total earnings. Explanatory variables are the simple average of the attribute of the two players in the pair. All models include session dummies. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

As noted above, our primary interest is in the economic traits of cognitive skill, patience, and risk tolerance, but the relationship between personality traits, cooperation, and earnings is of independent interest. We find that higher conscientiousness predicts lower levels of individual (Table 3) and joint (Table 4) cooperation. This is consistent with Lönnqvist et al. (2011) who found evidence that in a one-shot prisoner's dilemma played for money, conscientious players were less individually cooperative ($p < 0.1$), the only other such result we are aware of in the modest literature on the Big Five personality traits in prisoner's dilemmas. Turning to individual earnings, a one standard deviation rise in agreeableness, the strongest predictor of individual earnings, predicts a 55 cent rise in earnings, approximately a fifth of a standard deviation. This may be related to the findings of Volk et al. (2012) where agreeableness was the best predictor of being a conditional cooperator in a repeated public goods game.

At the joint level (Table 4), lower average neuroticism and greater average openness predicted higher levels of joint cooperation (plays of *coop-coop*). Lönnqvist et al. find the same correlation at the individual level ($p < 0.05$ in both cases). However, Hirsh and Peterson (2009) report a contrary result: in a ten round prisoner's dilemma, Hirsh and Peterson found that greater individual neuroticism predicted more individual cooperation ($p < 0.01$), the only factor of the Big Five that predicted cooperation in their study.

B. Predictors of Cooperation and Defection in Early Rounds

If player jointly cooperate in a given round, an individual player will continue to cooperate in the next round 82% of the time (standard deviation = 38%). Since the average rate of individual cooperation is only 40%, joint cooperation is persistent. This suggests searching for predictors of cooperation in early rounds of the game.

Result 5: Cognitive ability, patience, and risk tolerance do not predict individual cooperation in early rounds.

Table 7 reports the effect of attributes on the probability of an individual player playing cooperatively in the first round. Only greater openness predicts greater individual first-round cooperation: a one standard deviation rise in openness predicts 11% more individual first-round cooperation ($p < 0.05$).

Table 7: Probit of Decision to Play *Cooperate* in the First Round as a Function of Player's Attributes

	Model				
	1	2	3	4	5
Cognitive Ability	-0.000081 (0.041)			-0.0087 (0.043)	-0.022 (0.045)
Patience		-0.027 (0.042)		-0.028 (0.044)	-0.019 (0.046)
Risk Tolerance			0.045 (0.042)	0.048 (0.044)	0.052 (0.048)
Openness					0.11** (0.047)
Conscientiousness					-0.073 (0.045)
Extraversion					-0.050 (0.051)
Agreeableness					0.0025 (0.046)
Neuroticism					-0.050 (0.051)
Male (dummy)					-0.12 (0.10)
Age (not standardized)					0.0030 (0.012)
Pseudo R^2	0.09	0.09	0.09	0.09	0.14
Observations	167	167	167	167	167

Dependent variable in all probit models is a dummy variable that takes the value "1" when a player plays *cooperate* in the first round. All models include session dummies. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

Result 6: Greater cognitive ability helps sustain cooperation from the first to the second round.

Table 8 reports the effects of attributes on the probability of second-round individual cooperation if both players chose *coop* in the first round. Among our controls, only cognitive ability predicts greater cooperation in this setting: a one standard deviation rise in cognitive ability predicts a 26% increase in cooperation ($p < 0.05$) when using probits and only IQ, patience, and risk tolerance as controls. Including the full suite of controls causes the probit to fail to converge, and using OLS (Model 5) results in a an estimated causal effect of 11% ($p < 0.1$).

Table 8: Probit of Decision to Play *Cooperate* in the Second Round, Given that Both Players Played *Cooperate* in the First Round, as a Function of Player's Attributes

	Model				
	1	2	3	4	5
Estimation	Probit	Probit	Probit	Probit	OLS
Cognitive Ability	0.28** (0.12)			0.26** (0.13)	0.11* (0.059)
Patience		-0.051 (0.097)		-0.046 (0.092)	0.00054 (0.062)
Risk Tolerance			0.16 (0.11)	0.041 (0.11)	0.045 (0.064)
Openness					0.053 (0.069)
Conscientiousness					-0.045 (0.067)
Extraversion					0.0040 (0.063)
Agreeableness					-0.058 (0.076)
Neuroticism					0.051 (0.060)
Male (dummy)					0.12 (0.15)
Age (not standardized)					-0.015 (0.010)
Pseudo R^2 / R^2	0.35	0.10	0.17	0.37	0.61
Observations	25 [51]	25 [51]	25 [51]	26 [51]	51

Dependent variable in all models is a dummy variable that takes the value "1" when a player plays *cooperate* in the second round given that both players played *cooperate* in the first round. All models include session dummies. OLS (linear probability model) used in Model 5 because probit estimates did not converge. In probit models (1-4), observations in square brackets are the original number, whereas those not in brackets represent the ones used in the probit after perfectly predicted observations (mostly due to session dummies) were dropped. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

Result 7: Greater patience predicts switching to the other player's first-round strategy when the two players made different first-round choices.

A patient player is more likely to play *coop* in the second round if that player defected while the other cooperated in the first round; and a patient player is more likely to defect if she chose to cooperate but her partner defected in the first round. In the full controls OLS model (Model 5; again the probits do not converge due to the limited observations) in Tables 9 and 10, a one standard deviation rise in patience predicts 27% greater cooperation if the patient player "betrayed" his opponent in the first round, and approximately 43% less cooperation of the patient player "was betrayed" in the first round. These behaviors may appear consistent with both "win-stay/lose-shift" strategies and Tit-for-Tat, but better accord with the former since the patient player's choices are contingent on *both* player's actions. There were no significant economic or personality predictors of second-round behavior when both players defected in the first round, under any specification.

Table 9: Probit of Decision to Play *Cooperate* in the Second Round, Given that the Player Played *Defect* and the Partner Played *Cooperate* in the First Round, as a Function of Player's Attributes

	Model				
	1	2	3	4	5
Estimation	Probit	Probit	Probit	Probit	OLS
Cognitive Ability	0.039 (0.14)			-0.021 (0.16)	0.11 (0.11)
Patience		0.62* (0.32)		0.72 (0.043)	0.27** (0.12)
Risk Tolerance			0.026 (0.18)	-0.14 (0.26)	-0.17 (0.12)
Openness					-0.059 (0.15)
Conscientiousness					-0.19 (0.14)
Extraversion					0.21* (0.10)
Agreeableness					0.027 (0.13)
Neuroticism					0.00019 (0.11)
Male (dummy)					0.25 (0.31)
Age (not standardized)					-0.018 (0.040)
Pseudo R^2 / R^2	0.02	0.29	0.02	0.31	0.77
Observations	16 [37]	16 [37]	16 [37]	16 [37]	37

All models include session dummies. OLS (linear probability model) used in Model 5 because probit estimates did not converge. In probit models (1-4), observations in square brackets are the original number, whereas those not in brackets represent the ones used in the probit after perfectly predicted observations (mostly due to session dummies) were dropped. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

Table 10: Probit of Decision to Play *Cooperate* in the Second Round, Given that the Player Played *Cooperate* and the Partner Played *Defect* in the First Round, as a Function of Player's Attributes

	Model				
	1	2	3	4	5
Estimation	Probit	Probit	Probit	Probit	OLS
Cognitive Ability	0.065 (0.13)			0.47 (0.36)	0.14 (0.11)
Patience		-0.84* (0.43)		-0.90** (0.41)	-0.43** (0.16)
Risk Tolerance			-0.10 (0.16)	-0.56 (0.40)	0.0029 (0.16)
Openness					0.23 (0.13)
Conscientiousness					0.23 (0.13)
Extraversion					-0.10 (0.20)
Agreeableness					-0.048 (0.092)
Neuroticism					0.40*** (0.12)
Male (dummy)					0.042 (0.28)
Age (not standardized)					0.034 (0.047)
Pseudo R^2 / R^2	0.08	0.33	0.09	0.41	0.81
Observations	23 [36]	23 [36]	23 [36]	23 [36]	36

All models include session dummies. OLS (linear probability model) used in Model 5 because probit estimates did not converge. In probit models (1-4), observations in square brackets are the original number, whereas those not in brackets represent the ones used in the probit after perfectly predicted observations (mostly due to session dummies) were dropped. All coefficients and standard errors are displayed to two significant figures. Asterices denote statistical significance: * = 10%, ** = 5%, *** = 1%.

4. DISCUSSION

We find that cognitive ability, as measured by the Raven's Progressive Matrices, a conventional IQ test, is a robust predictor of cooperation: but this is only true at the pair level, not at the individual level. By contrast, when players played a 10-round repeated coordination game in Al-Ubaydli, Jones, and Weel (2013) during the same laboratory experiment, the Raven's score did not predict plays of *stag* either at the individual or the pair level. Is the prisoner's dilemma game more cognitively demanding than a coordination game? Mueller (2003, p.15), in his classic textbook states that:

> …Pareto-optimal sets of strategies can be expected to emerge when coordination games are repeated, under far less demanding behavioral assumptions than are needed to sustain Pareto-optimal outcomes in prisoners' dilemma supergames…

Mueller then considers an example of a pure coordination game where the players recall only a few recent rounds of play: With that information alone, each player can potentially coordinate on the higher paying strategy and will never have an incentive to defect from it. The repeated prisoner's dilemma (or prisoner's dilemma supergame, in Mueller's words) may require more knowledge for a successful outcome. In part, it may require players to have a better model of the mind of the other player.

Evidence from Burnham et al. (2009) suggests that higher IQ individuals tend to have more accurate models of the thoughts of others at least in one setting: They are more successful in a Keynesian beauty contest. In their version of the game, each player attempts to guess a number between 0 and 100 that is half the average response of all other participants. The unique Nash equilibrium of such a game is zero, but very few participants in any such game ever offer the Nash equilibrium as their submission. In the Burnham et al. experiment the mean choice was 34.12; thus, the winning choice should be 17.06. Players in the two highest IQ deciles offered both the lowest average submissions and the average submission closest to 17 (with average submissions of between 18 and 20). Players in the three lowest scoring IQ deciles offered submissions of approximately 45. Gill and Prowse (2012, p.1) in a similar beauty contest setting find that subjects with higher cognitive skills engage in more *k*-level thinking, considering the reaction of their fellow test subjects when deciding which number to choose: "[T]he average level of more cognitively able subjects responds positively to the cognitive ability of their opponents, while the average level of less cognitively able subjects does not respond at all."

In studies of team tasks, average IQ is generally a statistically significant predictor of outcomes (Devine and Philips 2001), and a psychometric estimates of a "*c* factor" that predicts strong team performance found statistically significant correlations between *c* and both the average and the maximum intelligence of team members (Woolley et al. 2010). Team activities typically offer an incentive to shirk not unlike the temptation to defect in a one-shot prisoner's dilemma; and likewise team activities last long enough to offer some similarities to the repeated prisoner's dilemma.

More broadly, measures of social and emotional intelligence are usually found to be positively correlated with conventional IQ scores (Mackintosh 2011; 242, 246). The tendency of players with higher cognitive abilities to positively reciprocate cooperation in the second round of this experiment, like the similar tendency documented in truck driving students in Burks et al. (2009)

may be an example of such social and emotional intelligence applied to the experimental laboratory.

5. CONCLUSION

Results presented here suggest that it is cognitively demanding to sustain cooperation in a ten-round repeated prisoner's dilemma. In our experiment, as in the twin study of Segal and Hershberger (1999), pairs of players with higher cognitive ability are substantially better at cooperating. Further, we find that is the cognitive ability of a *pair* of players, and not the ability of an individual player, that predicts cooperation. Our result more statistically significant than the early positive relationship between average player IQ and cooperation in the 150-round experiment of Terhune (1974). One possible reason for the difference between these two studies is that learning effects are more likely to overwhelm the effects of pair IQ in longer games; this may be related to the finding that worker IQ is a stronger predictor of performance in the early months on a new job while IQ's predictive power for worker performance weakens after years spent in the same job (Hunt 1995). We further find that patience and risk tolerance do not predict higher rates of individual or joint cooperation on average in our ten-round game.

Future work can investigate whether these relationships apply to shorter or longer repeated prisoner's dilemmas, games with stochastic end points, or repeated public goods games. More broadly, future work can investigate the possibility that average cognitive and preference traits across players are robust predictors of average group outcomes.

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