rbe
REVISTA BRASILEIRA DE ECONOMIA
DOI 10.5935/0034-7140.20190019
ISSN 1806-9134 (online)
FGV
FUNDAÇÃO GETULIO VARGAS

Do as I Do, Not as I Say: Incentivization and the Relationship Between Cognitive Ability and Risk Aversion*

Sergio Almeida†

Contents

Keywords
Cognitive ability, risk-preference elicitation, risk-preferences, hypothetical and real choices, incentives

JEL Codes
D12, D81

Abstract · Resumo

We study the relationship between cognitive ability and risk aversion under real and hypothetical choice conditions. Our experimental results suggest that the statistical relationship between cognitive ability and risk aversion is sensitive to incentive conditions of the choice problems used to elicit risk preferences. Individuals in the upper tail of the cognitive ability distribution are willing to take more risks. However, this holds only when choices involve hypothetical payoffs. When choices involve monetary incentives, this correlation is not significant. Results are robust to using alternative measures of cognitive ability.

1. Introduction

A large body of experimental research in psychology has demonstrated that individuals differ in their ability to reason and think.[1] Yet economic models of individual choice are often silent about how people's cognitive machinery influences their decision making. In response to this, some economists have begun paying attention to how cognitive ability affects economic behavior. There is now a growing body of empirical research showing that cognitive ability matters in a variety of contexts that are of central importance for economic theory and policy. Individuals with higher cognitive ability seem to be more patient (Sunde, Dohmen, Falk, & Huffman, 2010), more employable (Heckman, Stixrud, & Uruza, 2006), more likely to invest in stocks (Christelis, Jappelli, & Padula, 2010), and more likely to exhibit close-to-equilibrium behavior in strategic games (Burnham, Cesarini, Johannesson, Lichtenstein, & Wallace, 2009). This association

*We are grateful to Robin Cubitt, Martin Sefton and Simon Gachter for their invaluable guidance and detailed suggestions. We are also grateful to Bruno Campos and Bruno Siqueira for their excellent research assistance. We are grateful to the Brazilian Federal Research Agency (CAPES), Nottingham School of Economics (UK) and the Research Council of the State of Sao Paulo (FAPESP) for support to this study.

†Universidade de São Paulo, Faculdade de Economia, Administração e Contabilidade (USP/FEA), Departamento de Economia. Av. Prof. Luciano Gualberto 908, Sao Paulo, SP, CEP 05508-900, Brasil. 0000-0003-2561-1070

sergio.almeida@usp.br

[1] See, e.g., Neisser et al. (1996).

Received on Apr 7th, 2014
Final Acceptance on Jul 2nd, 2019

between cognitive ability and economic behavior is also found in the domain of attitudes towards risk. Frederick (2005), for example, finds that individuals with higher cognitive ability are more willing to take risks. Similar results are found by Benjamin, Brown, and Shapiro (2013), Burks, Carpenter, Goette, and Rustichini (2009), Sunde et al. (2010), and Oechssler, Roider, and Schmitz (2009). These studies focusing on the relationship between cognitive ability and attitudes towards risk have received more attention, possibly because this association has interesting policy implications: if cognitive ability affects risk-taking behavior and cognitive ability is shaped by schooling, then educational and training reforms could help improve individuals' saving and investment habits.[2]

It is not clear, though, why attitudes towards risk are correlated with cognitive ability. A bounded rationality interpretation is that individuals with higher cognitive ability can more easily compute expected value and variance of more complex risky prospects, which would enable them to make choices that more precisely reflect their preferences (see, e.g., Burks et al., 2009). Although plausible, this interpretation is at odds with the existing evidence, for it comes from experiments with arguably simple choices involving binary lotteries. Another possibility is that cognitive ability may be related to attention and intrinsic motivation to take more seriously the tasks used to measure cognitive ability and risk preferences. If that is the case, individuals with higher cognitive ability would look like less averse to risk — assuming that more attention and deliberation translate into less noisy choices that tend to favor riskier options rather than simple and degenerate lotteries with a single sure outcome.

While these interpretations are thought provoking, the existing literature does not provide much evidence of their empirical plausibility. One reason is that it is common to assess individual risk attitudes using elicitation methods that have the same level of complexity.[3] If risk preferences are elicited with simple risky prospects only, it can be argued that individuals with higher cognitive ability will not appear to be relatively more risk-loving as they would if risky prospects demanded more reasoning from subjects. While it is understandable to use methods that are easier for participants to understand, this may bias the results by not fully revealing the differences in risk preferences across the range of cognitive ability.

Another reason is that incentive conditions are mixed across the studies in this literature. Some studies use hypothetical payoffs (e.g., Frederick, 2005), while others provide real monetary incentives (Sunde et al., 2010). But, to the best of our knowledge, no single study has undertaken an analysis of how the provision of monetary incentives affects, through its effects on attention, the relationship between cognitive ability and risk preferences.

This study presents experimental evidence of the role of incentives in risk-elicitation tasks in modulating the effects of cognitive ability on risk aversion. We conducted laboratory experiments in which subjects made both real and hypothetical risky decisions, from which we elicited their willingness to take risks, so that we could observe whether the association between cognitive ability and risk aversion is sensitive to the incentive

[2]For a related view regarding financial literacy, see, for example, Lusardi (2012). See also Hryshko, Luengo-Prado, and Sørensen (2011) for a discussion on the impact of education on the intergenerational transmission of risk aversion.

[3]For a rather comprehensive review of these elicitation methods, see Charness, Gneezy, and Imas (2013).

conditions of the procedures to measure risk preferences. We also examine the robustness of the results to alternative measures of cognitive ability.

There are reasons to believe that the relationship between cognitive ability and risk preferences may be affected by incentive conditions of risk-elicitation tasks and measurement instruments of cognitive ability. Regarding the issue of incentives, a major problem is that choices in real contexts have consequences, whereas choices in hypothetical contexts have none. This could very well generate different responses depending on the context in which the decisions are made. Indeed, several studies have found a "hypothetical bias" of choices people make. This bias is a tendency to understate or overstate their preferences when compared with carefully matched real choices. This propensity to "misrepresent" choice in hypothetical problems *vis-à-vis* real ones has been found, for instance, in the valuation of goods and services (e.g., Cummings, Harrison, & Rutstrom, 1995; Harrison & Rutström, 2008) and risk-taking behavior (e.g., Harrison, 2006).[4] If choice problems with hypothetical consequences are solved in rapid, mindless, and thus less cognitively demanding ways (Kang, Rangel, Camus, & Camerer, 2011), the observed associations between measures of risk aversion (elicited through hypothetical tasks) and cognitive ability would be biased. Regarding methods used to measure cognitive ability, it is well known that the score of an individual can be significantly different between such methods. First, the cognitive domain being assessed by these psychometric tests are arguably different (for a review, see Neisser et al., 1996). Second, they can yield different results depending on format, length and timing conditions.[5]

Despite the importance of these issues, the role of incentivized and hypothetical risk-elicitation mechanisms in the relationship between cognitive ability and risk preferences has not been investigated. Nor has any study examined the sensitivity of this relationship to different cognitive tests. Our paper fills this gap.

The paper has two main results. First, there are differences in the association between cognitive ability and risk aversion between real and hypothetical decisions. We confirm Frederick's (2005) findings that individuals in the upper tail of the cognitive ability distribution are significantly less risk averse than others – higher cognitive ability subjects are 17.5% more likely to choose the risky option than their counterparts in the lower end of the cognitive ability distribution. But we find that this association no longer holds when risk preferences are elicited through real risky choices. Second, the association between cognitive ability and risk aversion (or the lack thereof) is robust to using different tests of cognitive ability that capture different reasoning skills, and arguably types of intelligence.

We are not suggesting that previous studies of this issue are invalid. Rather, we simply highlight the role of incentive conditions in shaping the relationship between cognitive ability and risk preference, urging researchers to replicate these studies with different incentive conditions before the underlying association is believed.

The remainder of the paper is organized into six sections. The next section briefly reviews the related literature. Section 3 describes the design of the main experiment and

---

[4]For a literature review of settings in which hypothetical/real rewards affect choices, and more importantly, validity tests of theories of decision making, see Camerer and Hogarth (1999).

[5]See, e.g., Norris (1995) and Ackerman and Kanfer (2009).

its descriptive statistics. Section 4 presents, as a robustness exercise, a second laboratory experiment that also investigates whether cognitive ability is related to risk preference applied to a different pool of subjects. Section 5 presents the econometric methodology and the results, and discusses overall findings. The experimental instructions are available upon request from the author.

2. Related Literature

There is an increasing body of literature on the association between cognitive ability and aspects of economic behavior. Some of the papers within this body of research examine the relationship between cognitive ability and risk-taking behavior. These studies measure risk aversion using standard tasks in which subjects are asked to choose between a binary lottery and a sure amount of money. In some of these studies, choices are for real payment, while in others choices involve hypothetical gambles.

Three papers that use hypothetical gambles are Frederick (2005), Campitelli and Labollita (2010), Boyle, Yu, Buchman, Laibson, and Bennett (2011). Frederick, which is a seminal reference on this topic, examines the relation between performance in his three-item "cognitive reflection test" and risk and time preferences. Using a variety of hypothetical choices between a certain amount of money and a gamble, he finds that subjects that answered all test questions correctly, which he calls the "high CRT" group, were more willing to choose the gamble option over the safe one in the domain of gains than the "low CRT" group (those who scored zero). In the domains of losses, however, the "high CRT" group was more willing to play safe and accept a sure loss instead of playing a lottery with a worse expected value.[6] Campitelli and Labollita (2010) also use Frederick's cognitive reflection test and investigate the correlation between cognitive reflection and performance in a number of decision-making tasks, some of them measuring risk preferences. They find that cognitive reflection is positively related to risk taking behavior. Boyle et al. (2011) focus on risk aversion in aging. They use a sample of older individuals who are taking part in a longitudinal clinical-pathological study of common conditions of old age. In their study, cognitive abilities are measured by a battery of tests designed to assess cognition in a variety of domains. They find a negative association of cognitive ability with risk aversion. This finding is robust to the exclusion of individuals exhibiting signs of cognitive decline from their sample.

But there are several studies in the risk aversion and cognitive ability literature in which participants were paid for their choices in the risk-elicitation tasks. Some noteworthy papers are Benjamin et al. (2013), Burks et al. (2009), Sunde et al. (2010), Brañas-Garza, Guillen, and del Paso (2008), Oechssler et al. (2009), Bergman, Ellingsen, Johannesson, and Svensson (2010) and Eckel et al. (2012). Benjamin et al. (2013), for instance, conduct three laboratory studies with high school students in Chile in which they examine the effect of standardized test scores and school grades, proxies for cognitive ability, on risk and time preferences. They find that risk aversion is more common among students with lower cognitive ability. Similar results are found by Sunde

[6]This is the "reflection effect", a well-known pattern of risk-aversion and risk-seeking behavior depending upon whether choices involve gains or losses. See, for instance, Kahneman and Tversky (1979) and Tversky and Wakker (1995).

et al. (2010) and Burks et al. (2009). But the results are more mixed than it seems. The association between cognitive ability and risk aversion is rather weak in one study by Benjamin, Brown, and Shapiro (2013) and evidence of no association between the two is found in Brañas-Garza, Guillen, and del Paso (2008), Eckel et al. (2012), and Epper, Fehr-Duda, and Bruhin (2011).

Although most of these studies suggest that individuals with higher cognitive ability are more likely to take more risks, they do not look at the potential influence of incentives in shaping the sign or magnitude of the association between cognitive ability and risk preferences. We are not aware of any such study, despite the well-known influence of incentives on risk attitudes (see, e.g., Holt & Laury, 2002 and Harrison, Johnson, McInnes, & Rutström, 2005). This is an important gap in the literature, particularly given the rather mixed results.[7]

3. Methods and Data

3.1 Experiment 1

Our first experiment uses a within-subject design to investigate whether the relationship between cognitive ability and risk aversion is affected by whether the risk-elicitation tasks are hypothetical or real. In the remainder of this section, we describe the design, summarize its implementation, and present descriptive statistics.

3.1.1 Design

The experiment consists of a set of tasks designed to elicit subjects' cognitive ability and risk aversion. It was implemented sequentially, on a paper-and-pencil basis, in a three-part procedure, each part completed independently.[8] Figure 1 describes the timeline of this experiment.

Part one elicited measures of cognitive ability. Subjects were asked to complete a timed cognitive test. The test consisted of figures with symbolic patterns presented in the form of a 3×3 matrix with one symbol missing. Test-takers' task in each question was to identify among a set of symbols which one represents the missing element required to complete the pattern in the figure. Our test consists of 12 such questions and is identical to the one applied in the context of the Mexican Family Life Survey.[9] MxFLS describes these tests as a reduced version of Raven's *Advanced Progressive Matrices Test* (APMT).[10] In our version, subjects were given three minutes to fill out the test. We computed two

[7] We acknowledge that divergence in findings among some studies may well stem from aspects of the experimental design other than the incentive conditions.

[8] All subjects were faced with the same sequence of tasks. We did not randomize the order of tasks because performing a cognitive test and answering a socioeconomic questionnaire are, to the best of our knowledge, unrelated to risk preferences. Hence, testing for whether order effects are in fact operating in this setting seemed not necessary and it would be beyond the scope of this paper.

[9] MxFLS documentation can be found at http://www.ennvih-mxfls.org

[10] Raven's *Advanced Progressive Matrices Test* is a 48-question, untimed test that seeks to measure one component of Spearman's g measure of general intelligence, namely *eductive* ability, also known as fluid intelligence (**?**). Eductive ability involves a great deal of problem-solving skills and is one of the best single measures of g, as reported by several studies. For a survey, see Carrol (1993). On fluid intelligence, see (Cattell & Horn, 1978).

scores for each individual: a raw one, which is just the number of questions the person answered correctly, and a difficulty-corrected score, which is the weighted sum of correct answers. Weights applied to each question are given by the inverse of the proportion of correct answers considering results among MxFLS adult test takers. These scores are used as two of the three measures of cognitive ability in this experiment.

Part two consisted of two sections. In section one, we asked subjects to perform a task choice under uncertainty. We asked them to choose between two bets, with real money at stake, involving two states of nature, s and t. Bet A was a constant bet that resulted in a definite outcome of 20 tokens in every state, whereas bet B yielded a higher outcome of 45 tokens in state s and a lower outcome of 10 tokens in state t.[11] The subjects were informed when they made their choices that the probability distribution over states, p_s and $p_t = 1 - p_s$, would be defined as follows: $p_s = [1 - e/10]$, where e is an uncertain event defining an integer number between 0 and 10. Hence, the expected value of act B is increasing in e.[12] Note that participants make their choices before they know the probability of each state. Bet B's uncertainty is resolved at the end of the experiment after all tasks are completed.

We then followed with section two in which we attempted to measure each subject's risk aversion. Following Bohnet, Greig, Herrmann, and Zeckhauser (2008), we did so by asking participants to state the smallest probability p of receiving 45 tokens for which they would choose the uncertain act over the degenerate one with a certain outcome of 20 tokens. A subject's stated "minimum acceptable probability" (henceforth, MAP) was binding in the sense that it was used to select the actual bet in the section one task that it is to be used to determine her payoff for this task at the end of the experiment. This was done at the end of the experiment in the following manner: if her MAP was larger than the actual p_s in her session (let that be $\hat{p}$), the subject was then assumed to opt for option A and received the sure outcome of 20. If her MAP was less than or equal to $\hat{p}$, she was assumed to select the uncertain bet, which left her with a $\hat{p}$-chance of receiving 45 tokens and a $(1 - \hat{p})$-chance of receiving 10 tokens. As long as an individual believes that $\hat{p}$ can take values within an arbitrarily close neighborhood around her MAP and conform to the substitution axiom from expected utility theory, her reported MAP will be incentive compatible. Therefore, this procedure elicits the true "least favorable" probability distribution over option B's two outcomes, 45 and 10, that the individual regards as better than the sure outcome of option A, 20. Hence, from a subject's MAP,

[11] Each token was worth 1 Brazilian Real (at the time, R$1.00=US$0.64).

[12] As part of a larger study, we implemented two treatments that varied the source of uncertainty over the state probabilities by manipulating the nature of the events. In one treatment, the events and therefore the state probabilities were defined by the profiles of choices by the ten subjects in a session as p_s (p_t) is just the proportion of the 10 subjects who chose the safe (uncertain) act. In the other treatment, the events were defined by the distribution of orange and green balls in an urn containing 10 balls of either color; subjects were told that a machine that followed an unknown process selected the distribution. In this case, p_s (p_t) was the proportion of orange (green) balls. From a descriptive point of view, there is no reason to believe that the subjective mapping of events into state probability distributions will systematically differ between the two treatments, as predicted by most models of decision making under uncertainty. Nonetheless, our data analysis controls for potential treatment effects that might affect the degree to which a subject's choice in this step is consistent with her subjective probability distribution over states of nature.

we can infer all of the probability distributions over 45 and 10 tokens that are strictly preferred to the option of 20 tokens.

Part three was implemented after the subjects had made their choices. They were asked to fill out a brief questionnaire containing information regarding their socioeconomic status. In the questionnaire, we also presented subjects with a hypothetical risk-elicitation task. In this task, a subject has to choose one of six 50-50 lotteries. Table 1 presents the hypothetical money prizes in these lotteries, with negative entries meaning losses. Note that lottery *L1* is a degenerate lottery that would pay 20 with certainty, lottery *L4* is a simple one with one nonzero outcome and the remaining lotteries are all binary prospects with nonzero outcomes. While the expected value is maximized by choosing lottery *L6*, turning down the sure 20 (*L1*) for any of the other options clearly involves some degree of risk. The "downside" and "upside" risks of choosing the other lotteries are all increasing as one moves from lottery *L2* to *L6*. In the spirit of Frederick (2005), we characterize risk-taking behavior in this task in a binary way defining risk-averse behavior as a choice for the safe gamble (*L1*) and risk-seeking behavior as a willingness to take risks at all (from *L2* to *L6*).[13]

In the same questionnaire, the subjects were also asked to undertake Frederick's (2005) cognitive reflection test. This is a simple three-item test designed to measure the ability to control impulsive thinking, that is, the ability to suppress an erroneous answer to a problem that springs "impulsively" to mind (Frederick, 2005, p.27). Scores in this test are used as an alternative measure of cognitive ability of subjects in this experiment. Since performance in this test is clearly aided by acquired knowledge, the scores provide a measure of reasoning skill that is likely distinct from the one captured by the test implemented in part one. Since correctly answering this test depends on previously acquired learning and knowledge, we believe the scores in this test can be viewed as a measure of crystallized intelligence, which, psychologists argue is very distinct from the type of the cognitive ability captured by the Raven-like test implemented in part one.[14]

Table 1. Hypothetical 50–50 Lotteries.

Lottery	Prize 1	Prize 2
L1	20	20
L2	10	40
L3	5	50
L4	0	60
L5	−10	80
L6	−30	100

[13]While loss aversion may affect the choice among the hypothetical lotteries, the simple measure of risk aversion we use isolates this issue, as it is not sensitive to the loss avoidance that may account why a subject would pick *L2* to *L3* but not *L5* or *L6*.

[14]For a discussion of the fluid and crystallized forms of cognitive ability, see Cattell and Horn (1978) and Carrol (1993).

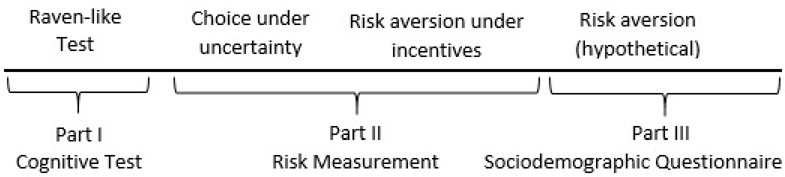

Figure 1. Timeline of Experiment 1.

3.1.2 Administration

This experiment was conducted in Sao Paulo, Brazil, with students of the University of Sao Paulo, the largest institution of higher learning in Latin America. Approximately 200 subjects took part in the experiment. We conducted 20 sessions with 10 participants in each session.[15] The experiment was conducted in paper-and-pencil format with sessions lasting no more than 80 minutes.

Upon their arrival, subjects sat at visually isolated desks. Instructions to each part of the experiment were distributed separately and read aloud by the experimenter as subjects read them along on paper. After the entire experiment was completed, we resolved the uncertainty about p in the lottery choice problem, conducted the lottery for those who chose it, and paid the subjects based on the outcome.[16] At the end, each token earned in the experiment was converted to money. A participation fee of R$5 was added to the earnings in the experiment, yielding an average payment of R$29.09 (US$18.62) per participant.

3.1.3 Descriptive Statistics

Table 2 presents overall statistics for the subjects in Experiment 1. Most are male and white with an average age of 22.3 years. Socioeconomic background corresponds to what is expected in this population at the University of Sao Paulo, with slightly more than 70% of parents having at least a college degree and 43.5% of households having per capita income above four times the minimum monthly wage.

The majority of the students attending the sessions were enrolled in social sciences and humanities degree programs, less than half of whom were economics majors. On average, our subjects correctly answered two out of the three questions in the cognitive reflection test. In the timed fluid-intelligence test, slightly more than 50% of the answers were correct.

Finally, Table 2 also indicates that subjects were way more likely to choose the risky option in both the incentivized and hypothetical choice contexts. Notice, however, that

[15]Except for one of the sessions, which had seven participants, leaving us with a sample of 197 subjects.

[16]Uncertainty was resolved at the end of the experiment to avoid that some of the participants, upon knowing how much they earned in the risk task, felt unmotivated to answer the socioeconomic questionnaire seriously and honestly. It is worthy noting that findings in any experiment are always conditional to the setting implemented. Order effects may be operating at any experiment. But unless the primary goal is to investigate how the sequence of every task and administration procedure interact with outcomes, the exact choice of task and overall implementation sequence tends to follow that of the other experimental papers on the same subject matter. In most risk-elicitation experiments, lotteries are resolved and paid at the end of the experiment.

Table 2. Summary Statistics for Subjects in Experiment 1.

	Mean	(se)	Standard-deviation
Demographics			
Male	0.599	(0.035)	0.491
White	0.705	(0.032)	0.457
Black	0.170	(0.027)	0.377
Age (in years)	22.249	(0.256)	3.599
Socio-economic background			
Head of household has college degree or more	0.716	(0.032)	0.452
Household per-capita income above 4 minimum-wages	0.435	(0.035)	0.497
Household with 4 or 5 members	0.533	(0.036)	0.500
Household more than 5 members	0.086	(0.020)	0.282
Field of study			
Social Sciences	0.574	(0.035)	0.496
Exact and Biological Sciences	0.066	(0.018)	0.249
Economics major	0.203	(0.029)	0.403
Cognitive ability			
Cognitive Reflection Test scores (0–3)	1,954	(0.075)	1,051
Fluid Intelligence Test raw scores (0–12)	7,827	(0.117)	1.635
Fluid Intelligence Test difficulty-weighted scores (0–12)	5,932	(0.138)	1.936
Choices			
Risky option (incentivized choice)	0.751	(0.031)	0.432
Risky option (hypothetical choice)	0.858	(0.025)	0.349
Observations		197	

Notes: Difficulty-corrected score are weighted sum of correct answers, where the weights are given by the inverse of the proportion of correct answers considering results among adult test takers in the Mexican Family Life Survey (http://www.ennvih-mxfls.org), from where we borrow the test.

conservative choices are seen more frequently in the incentivized than in the hypothetical setup.

3.2 Experiment 2

We report in this section a second experiment to examine the relationship between risk aversion and cognitive ability in an incentivized setting. Before introducing the experimental design, procedures and descriptive statistics, a caveat is in order. The experiment has the advantage of using a set of risk-elicitation tasks rather than just one, but was not primarily designed to examine the issue of hypothetical and real incentives as attitudes toward risk. We explore its results for two reasons. First, it adds weight to results from Experiment 1, in that it replicates the finding that cognitive ability does not appear to be related to risk aversion with a different pool of subjects. Second, besides eliciting risk aversion, subjects were requested to complete two different cognitive tests: Frederick's (2005) cognitive reflection test and a test that assesses quantitative and sequential reasoning (logical), to allow analyzing whether the relationship between cognitive ability and risk aversion is robust to the use of different cognitive tests.

3.2.1 Design

This experiment consists of a set of risk-elicitation tasks and a cognitive test. First, subjects face a sequence of 12 choice tasks designed to elicit their risk attitudes. Then they are asked to complete a timed cognitive test. Figure 3 describes the timeline of this experiment.

In each risk-elicitation task, a subject faces a number of pairwise choice problems in a table. Each problem is to choose between an amount of money with certainty and a given binary lottery L (chance $p(x)$ to win x and $p(y) = 1 - p(x)$ to win y, where $x > y > 0$). The certain money option is systematically decreased from x to y by a constant amount, say δ, when proceeding down the table.[17] The row at which an individual switches from choosing the sure money to L (if at all) can then be used to estimate a nonparametric measure of risk aversion: the subject's risk premium for that lottery. The risk premium for a lottery L is the certain amount of money an individual would forego in order to avoid the risk inherent to L.

Figure 2 below presents a screenshot of the set of pairwise problems presented to subjects in a given risk task. In this example, the task consists of eliciting the cash equivalent of the lottery $L\ (8.00,\ 1/5;\ 4.00,\ 4/5)$, where the fractions indicate the probabilities of winning, and the integer numbers indicate the winnings.

Each decision row on the screen constitutes a choice problem, which is to choose between option A, a sure sum, or option B, the lottery. Subjects are asked to indicate their preference for each choice problem. Under EUT, an individual will choose A in decision 1 and B in decision 17, switching from A to B at some point in between. Thus, provided a subject starts by choosing A and switches once, task responses can be reduced to a

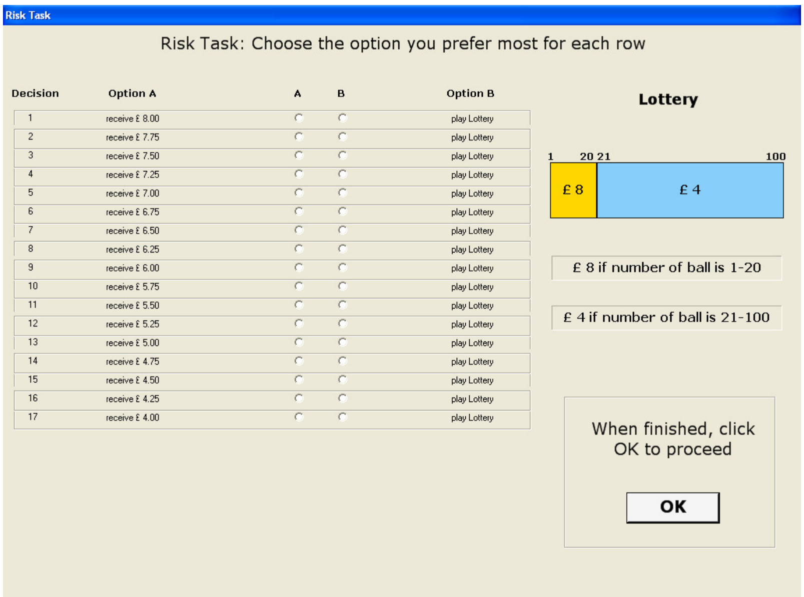

Figure 2. Timeline of Experiment 2.

[17] $\delta = 0.25$ in all lottery tasks in this experiment.

single number: the decision row number at which the subject switched from option A to option B.[18]

We summarize the risk aversion of a subject in the experiment by computing his or her *risk-propensity score*, which is simply the number of tasks in which the subject made a risk-averse choice. In a given risk-elicitation task, this amounts to having a positive risk premium for the lottery option in that task. Table 3 shows the lottery options for each risk-elicitation task.

The cognitive test, like other psychometric tests, is a set of questions that seek to assess a range of reasoning skills. The test contains nine questions. Subjects were given 60 seconds per question. The test is divided into three sections: three for each of cognitive reflection, mathematical reasoning and sequential reasoning sections. The cognitive reflection section is the three-item test designed to measure ability to control impulsive thinking (Frederick, 2005) also completed by subjects in Experiment 1. The mathematical section is very much like the GRE-Quantitative test, requiring understanding of elementary arithmetic and algebra.[19] The sequential reasoning section, in turn, covers the analysis of patterns and deductive reasoning in arithmetic and geometric contexts. We derive two measures of cognitive ability from this test: one from the raw scores obtained in the cognitive reflection section, and another from the raw scores obtained in the mathematical and sequential reasoning sections.

It is worth noting that the reasoning skills measured by this test are, arguably, not very different from the ones measured by the cognitive tests used in Experiment 1, since reflectiveness and mathematical and sequential reasoning could all be reduced to either crystallized or fluid forms of intelligence (see, e.g., Horn & Cattell, 1966). This overlap is a desirable feature, since it provides us with a cleaner test of the robustness of the association between cognitive ability and risk aversion to the instruments used to measure cognitive ability and not to different types of intelligence at work, which is always hard to identify and distinguish.

Table 3. Lottery Options.

Lottery	Prize 1 (x)	Pr(x)	Prize 2 (y)	Pr(y)
L1	8	0.3	4	0.7
L2	16	0.2	10	0.8
L3	6	0.4	3	0.6
L4	9	0.3	4	0.7
L5	9	0.2	3	0.8
L6	6	0.3	3	0.7

[18] The piece of software we created for this task allowed the subjects to economize on "clicking effort", and in doing so guaranteed a maximum of one switch. We view this feature as an advantageous one, as it prevents boredom and guarantees usable data while still leaving plenty of scope for cognitive ability to affect behaviour.

[19] A great deal of research has been conducted to investigate reasoning abilities measured by the GRE, see (Powers & Kaufman, 2004) and (Kuncel, Hezlett, & Ones, 2001), and references therein.

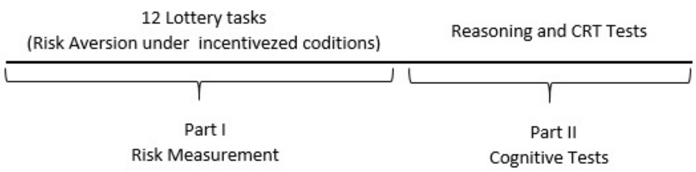

Figure 3. Timeline of Experiment 3.

3.2.2 Administration

This experiment was conducted at CeDEx laboratory of the University of Nottingham, England. A total of 106 subjects took part in the experiment. Most were undergraduate students with different majors. The experiment was computerized and used a proprietary program developed for this experiment. We ran the experiment in 16 sessions over four days. Sessions lasted about 60 minutes.

Upon their arrival, the subjects sat at visually isolated desks. Instructions for each part of the experiment were distributed separately and read aloud by the experimenter as the subjects read them on paper. After we explained what risk-elicitation tasks would look like, the subjects started completing a series of twelve risk-elicitation tasks with the understanding that only one of their choices would be selected at random at the end of the experiment to determine their earnings. For the selected task, earnings were determined according to the option they chose in the selected choice problem. If they chose Option A, they received the amount of money it specified, whereas if they chose Option B, the risky option, they played the lottery, where the risk was resolved by drawing a chip from a bag containing 10 numbered chips and receiving the payoff according to what the lottery specified in British pounds (at the time, £1.00 = US$1.98). On average, the subjects earned £6.70 (US$13.27).

3.2.3 Descriptive Statistics

Table 4 presents overall statistics for the subjects in Experiment 2. There are slightly more female students engaging on the activities, and most are white with average age of 20 years. The socioeconomic background information indicated that approximately 30% of parents had at least a MSc degree and 17% had yearly household income above £15 thousand.

Forty percent of students attending the sessions were from the University's social sciences division, with another 19% coming from the exact sciences. On average, our subjects responded correctly to one out of the three questions in the cognitive reflection test. The same pattern was also seen in the quantitative reasoning test. Students did extremely well on the sequential reasoning test, scoring on average 2.5 out of 3 points. Table 4 also indicates that in the 12 incentivized choices they faced in the experiment, the average student picked the risky option 70% of the time.

Table 4. Summary Statistics for Subjects in Experiment 2.

	Mean	(se)	Standard-deviation
Demographics			
Male	0.472	(0.049)	0.502
White	0.623	(0.047)	0.487
Age (in years)	19.943	(0.154)	1.585
Socio-economic background			
Head of household has MSc degree or more	0.302	(0.045)	0.461
Household income > £15,000	0.170	(0.037)	0.377
Field of study			
Social Sciences	0.406	(0.048)	0.493
Exact Sciences	0.189	(0.038)	0.393
Cognitive ability			
Cognitive Reflection Test scores (0–3)	0.915	(0.096)	0.987
Quantitative reasoning raw scores (0–3)	0.915	(0.075)	0.770
Sequential reasoning raw scores (0–3)	2.500	(0.057)	0.590
Choices			
Proportion of risky options in 12 tasks (incentivized choice)	0.691	(0.025)	0.462
Observations		106	

4. Empirical Method and Results

4.1 Econometric Specifications

We examined the data from the experiments using simple linear regression techniques (ordinary least squares). We measured the impact of cognitive ability over the propensity to opt for the risky option by computing dichotomic indicator functions that classified individuals either as above or below the median performance in each of our tests. For the case of Experiment 1, we also performed empirical analyses with continuous versions of the cognitive test scores. More specifically, we fitted the following models[20] to the data:

$$y_{is} = \alpha_1 HighScore_i + \alpha_1 LowScore_i + \eta_s + \phi_{is}, \quad (1)$$

$$y_{is} = \beta_0 + \beta_1 Score1_i + \beta_1 Score2_i + \theta_s + \epsilon_{is}, \quad (2)$$

where y_{is} is a binary variable taking the value one when individual i in session s picks the risky option. As presented above, $HighScore_i$ and $LowScore_i$ are indicators for above and below the median score in cognitive tests, respectively. $Score1_i$ and $Score2_i$ stand for the continuous scores in alternative cognitive tests.

These models compute raw differences in means (or associations, in the continuous case). We also estimated alternative versions that included covariates aiming at reducing

[20]There are a variety of estimation techniques that can be used to analyze these data. Although a random utility model, within the class of discrete choice models, can be used to estimate risk aversion, we opted for using the willingness to take risks elicited in our choice problems (arguably, a raw measure) to maintain comparability with most of the experimental literature on risk aversion

the chance of omission biases in our estimates. That is:

$$y_{is} = \alpha_1 HighScore_i + \alpha_1 LowScore_i + \delta' X_i + \eta_s + \psi_{is}, \tag{3}$$

$$y_{is} = \beta_0 + \beta_1 Score1_i + \beta_1 Score2_i + \delta' X_i + \theta_s + \lambda_{is}, \tag{4}$$

with X_i as a vector with control variables that includes age, gender and household socioeconomic status. In the estimation of standard errors in all models, we took into consideration the possible correlation of unobservables (η_s) within each session by clustering.

4.2 Results and Discussion

Our first set of results regarding Experiment 1 is presented in two panels in Table 5. Panel A focuses on specifications that utilize dichotomized versions of cognitive test results while Panel B explores continuous versions of the test scores. Two sets of three columns are presented. Columns 1 to 3 show results from the incentivized risk-elicitation task, while Columns 4 to 6 are related to the hypothetical risk-elicitation task.

Results from the first three columns suggest there is no statistically significant difference between cognitive groups with regard to propensity to take risks. The second set of columns (Columns 4 to 6), however, indicates that based on choices in the hypothetical task our conclusion would have been dramatically different. For both measures of cognitive ability, high scores are significantly associated with larger probability of risky choices. The difference in choices between individuals with high CRT and low CRT scores amounts to 13.8 percentage points (or 18.8% in relative terms). In the case of fluid intelligence scores, such difference amounts to 10.6%. These differences are significant even when the impact of both cognitive tests is examined using joint-significance statistics.

Our non-significant results in incentivized settings are corroborated by findings from Experiment 2 (run with a different population of subjects). Table 6 reproduces econometric results, which overwhelmingly indicate there is no reason to believe that higher cognitive ability is statistically associated with higher propensity to opt for risk lotteries. This is the case for any of the cognitive tests employed in Experiment 2. This result is a robustness check of the ones presented above for Experiment 1.

Our final set of results is presented in Table 7. We reproduce the estimations of differences between high- and low-ability individuals in both experiments, but this time we include controls for demographic and socioeconomic characteristics of subjects. There is no qualitative change in the conclusions presented above. We have reason to believe that incentivization eliminates the positive statistical relation between cognitive ability and risk taking behavior seen in hypothetical tasks. To sum up, within the same group of subjects, we find that while higher cognitive ability (measured by different tests) leads to more risk taking behavior in hypothetical tasks, there is no such relation when real money is at stake.

Nevertheless, some caution is in order regarding these conclusions. A potential problem with our design regarding the existence of a "hypothetical bias" driving the relationship between cognitive ability and risk aversion is that specificities of the risk-elicitation tasks differ between real and hypothetical treatments. While one might

Table 5. Risk-Taking Behavior by Cognitive Ability Group (Experiment 1).

	Incentivized risk-elicitation task			Hypothetical risk-elicitation task		
	Proportion picking risky option (1)	Proportion picking risky option (2)	Proportion picking risky option (3)	Proportion picking risky option (4)	Proportion picking risky option (5)	Proportion picking risky option (6)
Panel A: Dichotomized cognitive-ability measures						
High-ability (above median CRT score)	0.792 **	–		0.872 **	–	
	(0.0515)			(0.0474)		
Low-ability (below median CRT score)	0.736 **	–		0.733 **	–	
	(0.0833)			(0.0551)		
High Vs. Low Difference	0.056	–	0.055	0.138 **	–	0.132 *
	(0.0786)		(0.0792)	(0.0698)		(0.0731)
High-ability (above median Fluid-intelligence score)	–	0.788 **		–	0.876 **	
		(0.0659)			(0.0474)	
Low-ability (below median Fluid-intelligence score)	–	0.764 **		–	0.792	
		(0.0557)			(0.0445)	
High Vs. Low Difference	–	0.024	0.0203	–	0.084 **	0.0740 *
		(0.0554)	(0.0550)		(0.0392)	(0.0386)
F-Test joint significance			0.0320			7.2900
p-value			0.7325			0.0045 **
Panel B: Continuous measures of cognitive ability						
CRT score (0-3)			0.0309			0.0733 **
			(0.0361)			(0.0250)
Fluid-intelligence z-score			0.0079			0.0701 **
			(0.0416)			(0.0248)
F-Test joint significance			0.37			11.84
p-value			0.6981			0.0005 **

Notes: Standard-errors in parentheses are clustered at the session level. Controls include gender, age, education of household head, household income and number of household members.
* indicates significance at 10%, and ** significance at 5%.

Table 6. Risk-Taking Behavior by Cognitive Ability Group (Experiment 2).

	Incentivized risk-elicitation tasks			
	Proportion picking risky option (CRT only) (1)	Proportion picking risky option (Quant. Reasoning only) (2)	Proportion picking risky option (Seq. Reasoning only) (3)	Proportion picking risky option (All cognitive) (4)
High-ability (above median CRT score)	0.713** (0.0389)	–	–	
Low-ability (below median CRT score)	0.683** (0.0240)	–	–	
High Vs. Low Difference	0.030 (0.0480)	–	–	0.027 (0.0478)
High-ability (above median quantitative reasoning score)	–	0.710** (0.0498)	–	
Low-ability (below median quantitative reasoning score)	–	0.685** (0.0207)	–	
High Vs. Low Difference	–	0.025 (0.0553)	–	0.0218 (0.0525)
High-ability (above median sequential reasoning score)	–	–	0.682** (0.0404)	
Low-ability (below median sequential reasoning score)	–	–	0.701** (0.0400)	
High Vs. Low Difference	–	–	−0.019 (0.0699)	−0.0201 (0.0698)
F-Test joint significance				0.34
p-value				0.7945

Notes: Standard-errors in parentheses are clustered at the session level. Sample has 106 observations.
* indicates significance at 10%, and ** significance at 5%.

Table 7. Risk-Taking Behavior by Cognitive Ability Group (Models with controls).

	Incentivized risk-elicitation tasks			Hypothetical risk-elicitation task		
	Proportion picking risky option (1)	Proportion picking risky option (2)	Proportion picking risky option (3)	Proportion picking risky option (4)	Proportion picking risky option (5)	Proportion picking risky option (6)
Panel A: Experiment 1 (197 subjects), linear probability regression analysis						
High CRT Vs. Low CRT Difference	0.031		0.033	0.128 *		0.123 *
	(0.0747)		(0.0776)	(0.0689)		(0.0719)
High fluid-intelligence Vs. Low fluid-intelligence Difference		0.020	0.017		0.061	0.049
		(0.0606)	(0.0595)		(0.0386)	(0.0392)
F-Test joint significance			0.1300			5.1000
p-value			0.8806			0.0168 **
Panel B: Experiment 1 (197 subjects), linear probability regression analysis with continuous measures of cognitive ability						
CRT score (0-3)			0.021			0.068 **
			(0.0345)			(0.0245)
Fluid-intelligence z-score			0.004			0.051 **
			(0.0479)			(0.0236)
F-Test joint significance			0.1900			11.2700
p-value			0.8256			0.0006 **
Panel C: Experiment 2 (106 subjects), generalized linear model analysis						
High CRT Vs. Low CRT Difference	−0.006	–	−0.006			
	(0.0526)		(0.0529)			
High quantitative-reasoning Vs. Low quantitative-reasoning Difference	–	0.002	0.004			
		(0.0633)	(0.0605)			
High sequential-reasoning Vs. Low sequential-reasoning Difference	–		−0.015			
			(0.0708)			
F-Test joint significance			0.07			
p-value			0.9955			

Notes: Standard-errors in parentheses are clustered at the session level. Controls in Experiment 1 include gender, age, educaton of household head, household income and number of household members. Controls in Experiment 2 include gender, age, race, educaton of household head, and household income.
* indicates significance at 10%, and ** significance at 5%.

be concerned with the threat to internal validity that this poses, it should be noted that using the same task between incentive conditions would have the disadvantage of either forcing the adoption of a between-subject design, which is a less powerful comparison, or creating a confounding problem, since subjects could think we were testing for consistency and respond accordingly.

We think that even considering this caveat, our findings are informative in that they suggest an additional instance of how the "hypothetical choice bias" can lead to misleading conclusions. Also, they are in line with the recent literature on this topic.

The claim seems striking in light of several experimental studies that since Frederick (2005), have documented evidence that greater risk aversion is associated with lower cognitive ability (Sunde et al., 2010, Burks et al., 2009, Benjamin et al., 2013 and Booth, Cardona-Sosa, & Nolen, 2014). But the evidence on how attitudes toward risk relates to cognitive ability is not so clear-cut in studies using observational data on risky behavior. Boyer (2006) and Müller et al. (2013), for instance, find that those with higher cognitive ability tend to engage in behavior that is *less* risky, while Brañas-Garza, Guillen, and López del Paso (2008) and Taylor (2013) find no relation between computational and cognitive ability and measured risk aversion. Also, and perhaps more importantly, our results are in line with recent results from Andersson, Holm, Tyran, and Wengström (2016). They show that noisy decision making can bias individual responses in risk-elicitation tasks in ways that are related to cognitive ability, such that a correlation between risk attitudes and cognitive ability can be entirely spurious. This supports the claim that our results are informative about the relationship between cognitive ability and risk aversion.

5. Conclusions

There is now a large body of both theoretical and empirical work in psychology indicating a fair amount of heterogeneity exists among individuals in their mental capabilities.[21] It is hardly controversial that the ability to reason, plan, learn, and think abstractly indeed differs from one person to another. However, standard economic models assume that individuals deploy the same "cognitive machinery" to find solutions to all the economic problems they face. As a consequence, individual behavior in a real-world setting can look very different from that based on theoretical models that disregard differences in cognitive abilities.

An increasing number of studies have been addressing this issue empirically. They investigate how economic behavior differs between cognitive groups. Part of this literature has focused on the role played by cognitive ability on attitudes towards risk. The majority of those studies use laboratory experiments to investigate whether those with greater cognitive ability are more or less likely to take risks. In some of these studies, individuals' risk aversion is elicited through a set of hypothetical choices that have no real money at stake. Hypothetical choices are common in experimental psychology but tend to be viewed with suspicion by economists as a good forecast of the actual course of action one would see in real decisions. We believe they are right in taking the evidence with a grain of salt.

[21] For a comprehensive review of the literature on intelligence testing, see, e.g., Neisser et al. (1996).

Our study investigated this issue in the context of risk-taking behavior and its relationship with cognitive ability. A simple laboratory experiment was designed and implemented to test the hypothesis that the association between cognitive ability and risk aversion is not affected by whether risk aversion is measured through hypothetical or real choices. We also looked at the sensitivity of the relationship between cognitive ability and risk aversion to differences in cognitive tests. In particular, we employed tests that differ in their degree of association with "crystallized intelligence" (intelligence reliant on accumulated knowledge).

The evidence from our two laboratory studies indicates that higher cognitive ability is *not* associated with lower levels of risk aversion measured through real risky choices, even after controlling for demographic and socioeconomic heterogeneity. Furthermore, and perhaps more surprisingly, the results of our main experiment show that individuals with higher cognitive ability are less likely to display risk averse behavior, but only when hypothetical risky-elicitation tasks are employed. This result suggests an additional instance of how the "hypothetical choice bias" can lead to misleading conclusions.

While we acknowledge that differences in risk-elicitation tasks between the experimental designs we use may create a confounding variable, we tried to mitigate this by using a discrete-choice-based risk aversion measure that is less sensitive to differential random errors in decision making that could arise from each preference-elicitation task at hand in each experiment. The recent findings by Andersson et al. (2016) showing evidence that any association between measured risk preferences and cognitive ability can be spurious and produced, in fact, by an association of cognitive ability and the propensity to make mistakes in risk-elicitation tasks (and not risk preferences) may be seen as some assurance that our qualitative results are not off the mark. In light of this,

Our results have immediate implications for studies concentrated on investigating whether cognitive capacity has a bearing on aspects of human economic behavior: some of the aspects that may account for the individual differences in performance for particular levels of cognitive ability, such as performance errors, heuristic decision-making, and computational limitations, can be mitigated if decisions have real economic consequences. The reason is simple: individuals might deploy different combinations of effort and analytical reasoning depending on the stakes at play. This is consistent with recent findings that the documented association between cognitive ability and risk preferences may be driven by noisy decision making, which proper incentivization can help to reduce.[22] More specifically, our study provides some tentative evidence that if risk-elicitation tasks used in the literature do capture risk preferences, and the cognitive tests we use are reliable measurement instruments of reasoning skills, then the finding that individuals with higher cognitive ability are willing to take more risks should be further examined.

References

Ackerman, P. L., & Kanfer, R. (2009). Test length and cognitive fatigue: An empirical examination of effects on performance and test-taker reactions. *Journal of Experimental Psychology Applied*, *15*(2), 163–181. http://dx.doi.org/10.1037/a0015719

[22]For evidence, see Camerer and Hogarth (1999).

Andersson, O., Holm, H. J., Tyran, J.-R., & Wengström, E. (2016). Risk aversion relates to cognitive ability: Preference or noise? *Journal of the European Economic Association*, *14*(5), 1129–1154. http://dx.doi.org/10.1111/jeea.12179

Benjamin, D. J., Brown, S. A., & Shapiro, J. M. (2013). Who is "behavioral"? Cognitive ability and anomalous preferences. *Journal of the European Economic Association*, *11*(6), 1231–1255. http://dx.doi.org/10.1111/jeea.12055

Bergman, O., Ellingsen, T., Johannesson, M., & Svensson, C. (2010). Anchoring and cognitive ability. *Economics Letters*, *107*(1), 66–68. http://dx.doi.org/10.1016/j.econlet.2009.12.028

Bohnet, I., Greig, F., Herrmann, B., & Zeckhauser, R. (2008). Betrayal aversion: Evidence from Brazil, China, Oman, Switzerland, Turkey, and the United States. *American Economic Review*, *98*(1), 294–310. http://dx.doi.org/10.1257/aer.98.1.294

Booth, A., Cardona-Sosa, L., & Nolen, P. (2014). Gender differences in risk aversion: Do single-sex environments affect their development? *Journal of Economic Behavior & Organization*, *99*, 126–154.

Boyer, T. W. (2006). The development of risk-taking: A multi-perspective review. *Developmental Review*, *26*(3), 291–345. http://dx.doi.org/10.1016/j.dr.2006.05.002

Boyle, P. A., Yu, L., Buchman, A. S., Laibson, D. I., & Bennett, D. A. (2011). Cognitive function is associated with risk aversion in community-based older persons. *BMC Geriatrics*, *11*(article 53), 1–8. http://dx.doi.org/10.1186/1471-2318-11-53

Brañas-Garza, P., Guillen, P., & del Paso, R. L. (2008). Math skills and risk attitudes. *Economics Letters*, *99*(2), 332–336. http://dx.doi.org/10.1016/j.econlet.2007.08.008

Brañas-Garza, P., Guillen, P., & López del Paso, R. (2008). Math skills and risk attitudes. *Economics Letters*, *99*(2), 332–336. http://dx.doi.org/10.1016/j.econlet.2007.08.008

Burks, S. V., Carpenter, J. P., Goette, L., & Rustichini, A. (2009). Cognitive skills affect economic preferences, strategic behavior, and job attachment. *PNAS – Proceedings of the National Academy of Sciences of the USA*, *106*(19), 7745–7750. http://dx.doi.org/10.1073/pnas.0812360106

Burnham, T. C., Cesarini, D., Johannesson, M., Lichtenstein, P., & Wallace, B. (2009). Higher cognitive ability is associated with lower entries in a p-beauty contest. *Journal of Economic Behavior & Organization*, *72*(1), 171–175. http://dx.doi.org/10.1016/j.jebo.2009.05.015

Camerer, C. F., & Hogarth, R. M. (1999). The effects of financial incentives in experiments: A review and capital-labor-production framework. *Journal of Risk and Uncertainty*, *19*(1-3), 7–42. http://dx.doi.org/10.1023/A:1007850605129

Campitelli, G., & Labollita, M. (2010, June). Correlations of cognitive reflection with judgements and choices. *Judgement and Decision Making*, *5*(3), 182–191. http://journal.sjdm.org/10/91230/jdm91230.pdf

Carrol, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. New York: Cambridge University Press.

Cattell, R. B., & Horn, J. L. (1978). A check on the theory of fluid and crystallized intelligence with description of new subtest designs. *Journal of Educational Measurement*, *15*(3), 139–164. http://dx.doi.org/10.1111/j.1745-3984.1978.tb00065.x

Charness, G., Gneezy, U., & Imas, A. (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization*, *87*(March), 43–51. http://dx.doi.org/10.1016/j.jebo.2012.12.023

Christelis, D., Jappelli, T., & Padula, M. (2010). Cognitive abilities and portfolio choice. *European Economic Review*, *54*(1), 18–38. http://dx.doi.org/10.1016/j.euroecorev.2009.04.001

Cummings, R. G., Harrison, G. W., & Rutstrom, E. E. (1995). Homegrown values and hypothetical surveys: Is the dichotomous choice approach incentive-compatible? *American Economic Review*, *85*(1), 260–266. http://dx.doi.org/https://www.jstor.org/stable/2118008

Eckel, C. C., Grossman, P. J., Johnson, C. A., Oliveira, A. C. M. d., Rojas, C., & Wilson, R. K. (2012). On the development of risk preferences: Experimental evidence. , *45*(3). http://dx.doi.org/10.1007/s11166-012-9156-2

Epper, T., Fehr-Duda, H., & Bruhin, A. (2011). Viewing the future through a warped lens: Why uncertainty generates hyperbolic discounting. *Journal of Risk and Uncertainty*, *43*(3), 169–203. http://dx.doi.org/10.1007/s11166-011-9129-x

Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives*, *19*(4), 25–42. http://dx.doi.org/10.1257/089533005775196732

Harrison, G. W. (2006). Hypothetical bias over uncertain outcomes. In J. List (Ed.), *Using experimental methods in environmental and resource economics.* Northhampton, MA: Elgar.

Harrison, G. W., Johnson, E., McInnes, M. M., & Rutström, E. E. (2005). Risk aversion and incentive effects: Comment. *American Economic Review*, *95*(3), 897–901. https://www.jstor.org/stable/4132748

Harrison, G. W., & Rutström, E. E. (2008). Experimental evidence on the existence of hypothetical bias in value elicitation methods. In C. R. Plott & V. L. Smith (Eds.), *Handbook of experimental economics results* (pp. 752–767). Elsevier.

Heckman, J. J., Stixrud, J., & Uruza, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics*, *24*(3), 411–482.

Holt, C. A., & Laury, S. K. (2002). Risk aversion and incentive effects. *American Economic Review*, *92*(5), 1644–1655.

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized general intelligences. *Journal of Educational Psychology*, *57*(5), 253–270. http://dx.doi.org/10.1037/h0023816

Hryshko, D., Luengo-Prado, M. J., & Sørensen, B. E. (2011, 03). Childhood determinants of risk aversion: The long shadow of compulsory education. *Quantitative Economics*, *2*(1), 37–72.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–291.

Kang, M. J., Rangel, A., Camus, M., & Camerer, C. F. (2011). Hypothetical and real choice differentially activate common valuation areas. *The Journal of Neuroscience*, *31*(2), 461–468. http://dx.doi.org/10.1523/JNEUROSCI.1583-10.2011

Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2001). A comprehensive meta-analysis of the predictive validity of the graduate record examinations: Implications for graduate student selection and performance. *Psychological Bulletin*, *127*(1), 162–181.

Lusardi, A. (2012, February). *Numeracy, fiancial literacy, and financial decision-making* (Working Paper No. 17821). National Bureau of Economic Research (NBER). http://dx.doi.org/10.3386/w17821

Müller, M., Kowalewski, R., Metzler, S., Stettbacher, A., Rössler, W., & Vetter, S. (2013). Associations between IQ and alcohol consumption in a population of young males: a large database analysis. *Social Psychiatry and Psychiatric Epidemiology*, *48*(2), 1993–2005. http://dx.doi.org/10.1007/s00127-013-0666-2

Neisser, U., Boodoo, G., Bouchard, T. J., Boykin, W. A., Brody, N., Ceci, S. J., … Urbina, S. (1996, February). Intelligence: Knowns and unknowns. *American Psychologist*, *51*(2), 77–101. http://dx.doi.org/10.1037/0003-066X.51.2.77

Norris, M. (1995). *Assessing intellectual ability: A comparison between computer based nd paper-pencil format using Raven's standard progressive matrices test* (B.Sc. Dissertation). School of Computer Science and Information Systems Engineering, University of Westminster, London.

Oechssler, J., Roider, A., & Schmitz, P. W. (2009). Cognitive abilities and behavioral biases. *Journal of Economic Behavior & Organization*, *72*(1), 147–152.

Powers, D. E., & Kaufman, J. C. (2004). Do standardized tests penalize deep-thinking, creative, or conscientious students? Some personality correlates of graduate record examinations test scores. *Intelligence*, *32*(2), 145–153.

Sunde, U., Dohmen, T., Falk, A., & Huffman, D. (2010). Are risk aversion and impatience related to cognitive ability? *American Economic Review*, *100*(3), 1238–1260.

Taylor, M. (2013). Bias and brains: Risk aversion and cognitive ability across real and hypothetical settings. *Journal of Risk and Uncertainty*, *46*(3), 299–320. http://dx.doi.org/10.1007/s11166-013-9166-8

Tversky, A., & Wakker, P. (1995). Risk attitudes and decision weights. *Econometrica*, *63*(6), 1255–1280.