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ABSTRACT

Are Risk Aversion and Impatience Related to Cognitive Ability?

Is the way that people make risky choices, or tradeoffs over time, related to cognitive ability? This paper investigates whether there is a link between cognitive ability, risk aversion, and impatience, using a representative sample of the population and incentive compatible measures. We conduct choice experiments measuring risk aversion, and impatience over an annual time horizon, for a randomly drawn sample of roughly 1,000 German adults. Subjects also take part in two different tests of cognitive ability, which correspond to sub-modules of one of the most widely used IQ tests. Interviews are conducted in subjects' own homes. We find that lower cognitive ability is associated with greater risk aversion, and more pronounced impatience. These relationships are significant, and robust to controlling for personal characteristics, educational attainment, income, and measures of credit constraints. We perform a series of additional robustness checks, which help rule out other possible confounds.

JEL Classification: C93, D01, D80, D90, J24 and J62
Keywords: cognitive ability, field experiment, risk preference and time preference

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1 Introduction

Preferences and cognitive ability are fundamental determinants of decision-making in economic models. Their importance is confirmed empirically by studies showing that individual measures of risk aversion and impatience predict a wide range of important economic outcomes (e.g., Guiso and Paiella, 2005; Eckel et al., 2005), and by the literature showing that higher cognitive ability is associated with better labor market outcomes (e.g., Heckman et al., 2006).[1] In economic models and applications, cognitive ability, risk aversion, and impatience are also typically treated as independent traits. This assumption, however, has received relatively little attention in the empirical literature.

This paper tests whether risk aversion and impatience are related to cognitive ability. We use a sample of more than 1,000 adults living in Germany, randomly drawn to be representative of the population, which enhances the generalizability of our findings (List, 2003; Levitt and List, 2007). Subjects made choices in paid experiments, which provide incentive compatible and controlled measures of risk aversion and impatience. The measure of risk aversion involved choices over real-stakes lotteries, and the measure of impatience involved making tradeoffs between payments available immediately and payments available in one year. Subjects also took two different tests of cognitive ability, each based on a different sub-module of one of the most widely used IQ tests. A questionnaire collected information on various personal and background characteristics, to serve as controls in the empirical analysis. The questionnaire and experiments were conducted in subjects' own homes.

Our main finding is that risk aversion and impatience are systematically related to cognitive ability. Individuals with higher cognitive ability are significantly more willing to take risks in the lottery experiments, and are significantly more patient over the year-long time horizon studied in the intertemporal choice experiment. These results are robust to controlling for exogenous personal characteristics, such as age and gender, which could be related to cognitive ability and could also have an impact on willingness to take risks or patience. The baseline results are also robust to using different estimation methods.

[1] For additional evidence on risk aversion see: Barsky et al. (1997); Guiso and Paiella, 2001; Dohmen et al. (2005); Bonin et al. (2006). For evidence on impatience and behavior see: Ventura (2003); Kirby and Petry (2004); Borghans and Golsteyn (2005); Eckel et al. (2005). For additional evidence on cognitive ability, see: Herrnstein and Murray (1994); Murnane et al. (1995); Cawley et al. (2001); Bowles et al., (2001).

To further investigate the robustness of the main findings, we control for characteristics such as schooling, income, and credit constraints. Adding these controls helps address the question of whether there is a direct relationship between cognitive ability, risk aversion, and impatience, or whether cognitive ability is related to these traits only indirectly, through the channel of fostering greater educational attainment, or higher income. We find that the results are still strong when we include these additional controls, suggesting that cognitive ability does not operate solely through these indirect channels.

Another question is whether low cognitive ability could be unrelated to the traits of interest, but could cause people to have trouble understanding the incentives faced in our choice experiments, in a way that happens to look like, e.g., risk aversion. We check whether the results are robust to using a very simple survey question to measure willingness to take risks, for which there is little scope for such confusion. We find a significant relationship between cognitive ability and the survey measure of willingness to take risks, suggesting that the results based on the experimental measures are not due to confusion. A different concern arises in the case of the intertemporal choice experiment if people with higher cognitive ability adopt a strategy of arbitrage between high returns from the experiment and lower market interest rates. We asked subjects whether they thought about market interest rates during the experiment, however, and find that the relationship between cognitive ability and impatience is robust to excluding those individuals who thought about interest rates. We also find no indication that the baseline correlations are spurious, due to an impact of risk aversion or impatience on the way individuals take tests. For example, risk averse people might adopt an overly-cautious test-taking strategy, and impatient people might adopt an overly-hasty test-taking strategy. We find, however, that there is no significant relationship between these traits and error rates in our tests of cognitive ability.

An interesting question is whether measures of cognitive ability may partly proxy for personality traits measured by the "Big Five" scale from psychology, such as *conscientiousness*, rather than intelligence.[2] If this were the case, our results could be interpreted as showing a link between risk aversion, impatience, and personality traits studied in psychology, which would itself be an important finding. We do find that personality type

[2] See Segal (2006) and Borghans et al. (2007) for discussions on whether tests of cognitive ability may partly proxy for personality traits rather than intelligence.

is related to risk aversion and impatience in ways that are intuitive: openness to new experiences, and extroversion, are positively correlated with willingness to take risks, and impatience, respectively. Controlling for personality traits does not, however, eliminate the strong and significant correlation between test scores and risk aversion or impatience.

Finally, we explore whether the results for impatience could be explained by a link between cognitive ability and curvature of utility, rather than a direct relationship between cognitive ability and time preference. In the canonical case of Expected Utility Theory (EUT), greater concavity of utility can lead to more impatient choices, for the same annual discount rate. Given that we find greater risk aversion for people with lower cognitive ability, which is equivalent to more extreme concavity in EUT, this could potentially be a mechanism underlying the negative correlation between cognitive ability and impatience observed in the data. This would not change the importance of our finding that people with low cognitive ability exhibit more impatient *behavior*, because of the important implications for investment decisions, but it would shed a different light on the underlying mechanism. In an empirical test, where we allow concavity to affect choices in the intertemporal choice experiment, the emerging picture supports a direct impact of cognitive ability on discount rates.

In summary, this paper documents a systematic relationship between cognitive ability, risk aversion, and impatience: people with higher cognitive ability are significantly more willing to take risks, and are significantly more patient. There are a number of studies from psychology that have also explored the relationship between cognitive ability and impatience: most studies find that IQ measures or math SAT scores are positively related to patience, although some studies find no significant relationship.[3] There has been little work on cognitive ability and risk-taking. A drawback of the psychology literature is that most results are simple correlations without controls, and in some cases measures of impatience are only hypothetical. Also, the literature has focused almost exclusively on young children or students.[4] Recently, there has been some work on these topics in the economics literature. Some studies provide indirect evidence, e.g., showing that aversion

[3] For psychological evidence on the relationship between intelligence and the ability to delay gratification see, e.g., Funder and Block (1989), Shoda et al. (1990), Kirby et al. (2005), Parker and Fischoff (2005). A recent meta-analysis concludes that overall there is a weak to moderate relationship between cognitive ability and patience (see Shamosh and Gray, 2007).

[4] One exception is the study by Monterosso et al. (2001), on impatience of cocaine addicts, which finds no relationship with cognitive ability.

to losses is less pronounced among people with more education (e.g., Guiso and Paiella, 2005; Gächter et al., 2006), and that precision in probabilistic thinking relates to portfolio choice (Lillard and Willis, 2001). There are also two studies that provide evidence on a link to achievement test scores, or other more direct measures of cognitive ability. Benjamin et al. (2005) use the senior class of a Chilean high school and relate math SAT scores (or the Chilean equivalent) to choices involving real rewards. They find that students with lower math scores are more likely to make impatient choices (e.g., preferring \$0.79 today over \$1.50 in one week), and are less likely to be risk neutral (e.g., preferring \$0.40 for sure over \$1.50 or 0 with equal probability). Frederick (2006) finds results that point in a similar direction, based on samples of college students and adults in the U.S, from various studies. In particular, several measures of cognitive ability are positively correlated with different measures of patience (although math SAT is not significantly related to patience, unlike in Benjamin et al., 2005). Cognitive ability is also positively correlated with willingness to take risks in lotteries, when outcomes are in the gain domain, but negatively correlated when outcomes include losses.[5]

Different from previous papers, we investigate these issues using a large data set, carefully constructed to be representative of the adult population. In addition to being representative, the data allows us to control for various important background characteristics. The measures of risk aversion and impatience involve real monetary choices, with relatively large stakes, and relatively long time horizons in the case of the impatience measures. We combine these experiments with two measures of cognitive ability taken from a prominent IQ test. We also perform a series of additional robustness checks to rule out confounds, such as confusion about incentives, or an impact of risk aversion on test-taking strategy, that could drive our findings, and the findings of previous studies.

The findings in this paper are potentially relevant for the specification of economic models that incorporate both cognitive ability and time or risk preferences as fundamental parameters. Typically, structural models of this type do not explicitly allow for the dependency identified by our results. There are some exceptions, including Heckman et al. (2006), who allow for cognitive ability to affect the discount rate, and vice versa, in a formal model explaining labor market and behavioral outcomes. However, they do not

[5] There were different questions about tradeoffs over time, and risky choice, with various stakes. Risk measures were hypothetical. One of the impatience measures involved real money: subjects indicated the amount in 4 days that would make them indifferent to \$170 in two months.

observe the discount rate directly, so when they estimate the model they cannot identify the impact of cognitive ability on time preferences separately from its impact on other unobserved variables such as human capital productivity, and direct market productivity. Our findings provide an empirical basis for the flexible approach adopted by Heckman et al. (2006), and shed light on the specific nature of the relationship between cognitive ability and preferences regarding risk and time.

The paper also points to a different interpretation of reduced form models that have been estimated in the literature on cognitive ability and labor market outcomes. These models have typically included a measure of cognitive abilities, but not risk aversion or impatience, as explanatory variables (e.g., Cawley et al., 2001).[6] Outcomes such as educational attainment or wages may by affected by risk aversion and impatience, and thus part of the impact of cognitive ability may reflect the correlation with these traits. In other words, our findings point to a potentially important source of omitted variable bias in this type of estimation.

Given that cognitive ability is known to be transmitted from parents to children, our findings could also be relevant for the literature on intergenerational transmission of preferences and socio-economic status.[7] For example, Dohmen et al. (2006) show that attitudes towards risk are strongly correlated between parents and children, and a large literature on social mobility documents strong intergenerational correlations in important economic outcomes that are plausibly related to risk attitudes, or patience, such as wealth, income, occupation, and education (for a recent example documenting correlation in income and education, see Björklund et al., 2006).[8] To the extent that cognitive ability affects risk aversion and impatience, consistent with our findings, the transmission of cognitive ability could be one channel explaining intergenerational correlation in traits such as risk aversion and impatience, which in turn could help explain persistence of economic outcomes.

Our findings are also potentially relevant for the literature investigating the relationship between the distribution of cognitive ability and inequality in economic outcomes

[6] See also: Herrnstein and Murray (1994); Murnane et al. (1995); Neal and Johnson (1996).

[7] For evidence on intergenerational transmission of cognitive ability, see Bouchard and McGue (1981) and Plomin et al. (2000).

[8] Other examples from this large literature include: Kerckhoff *et al.* (1985), Solon (1992),Mulligan (1999), Plug and Vijverberg (2003), Black *et al.* (2005), Long and Ferrie (2005).

(e.g., Leuven et al., 2004; Blau and Kahn, 2005). If people who have high cognitive ability are more patient, and thus more likely to make investments, and if they earn a risk premium from being less risk averse, this would exacerbate differences in inequality associated with differences in cognitive ability. Reduced form models that include cognitive ability but do not control for differences in risk aversion or impatience across countries may deliver biased estimates of the impact of cognitive ability on inequality. Also, for a given distribution of cognitive ability, the degree of inequality in economic outcomes is likely to be greater than if there was not a link with risk aversion and impatience.

The rest of the paper is organized as follows. Section 2 describes the measures of cognitive ability and preferences. Section 3 presents our main results. Section 4 presents a series of additional robustness checks and results. Section 5 concludes by discussing potential mechanisms, policy implications, and directions for future research.

2 Data Description

2.1 Design of the Study

The data were collected as part of a study run between June 9th and July 4th, 2005. We conducted the study using the same professional surveying company that administers the German Socio-Economic Panel (SOEP), a large panel data set for Germany (for a detailed description of the SOEP see Haisken-DeNew and Frick, 2003; Schupp and Wagner, 2002; Wagner et al., 2007). Sampling was done according to the same procedure used to generate the SOEP sample, and individuals were visited by interviewers in their own homes.[9] Our sample was constructed so as to be representative of the adult population, age 17 and older, living in Germany. In total our data include interviews with 1,012 participants.

Participants in our study went through a computer assisted personal interview (CAPI) conducted with a laptop. The interview consisted of two parts. First, subjects answered a detailed questionnaire. The items in the questionnaire were presented in the standard format used by the SOEP. Topics included demographic characteristics, financial situation, health, and attitudes. The full questionnaire, in German and translated into

[9] For each of 179 randomly chosen primary sampling units (voting districts), an interviewer was given a randomly chosen starting address. Starting at that specific local address, the interviewer contacted every third household and had to motivate one adult person aged 17 or older to participate. For a detailed discussion of the random walk method of sampling see Thompson (2006).

English, is available upon request. The questionnaire also contained two tests of cognitive ability. At the end of the questionnaire, subjects were invited to participate in the second part of the interview, which consisted of a paid experiment. A random device in the CAPI software determined whether a subject was invited to participate in a lottery experiment designed to measure the extent of risk aversion, or an intertemporal choice experiment designed to elicit impatience over an annual horizon. Neither the interviewer nor the participant had an impact on the selection of the type of the experiment. We deliberately designed the study such that an individual could only take part in one experiment so as to avoid order effects. Of all 532 subjects who were invited to take part in the discount rate experiment 500 participated, while 452 out of 480 potential participants took part in the lottery choice experiment.

2.2 Measures of Cognitive Ability

Each of the two tests of cognitive ability in our questionnaire is similar to a different module of the Wechsler Adult Intelligence Scale (WAIS), one of the most widely-used intelligence tests worldwide (see Tewes, 1991).[10] The Wechsler test has 11 modules, 6 verbal and 5 non-verbal. One of our tests, the *symbol correspondence test*, is similar to a sub-module in the non-verbal section of the WAIS, which asks subjects to match as many numbers and symbols as possible in 90 seconds according to a given correspondence. Our other test, the *word fluency test* is similar to one of the verbal sub-modules of the WAIS, in which subjects are given a timed vocabulary test. Our tests were designed to capture the aspects of intelligence measured by these sub-modules, while also being suitable for implementation in the field as part of a CAPI interview, rather than in the usual paper and pencil format of the WAIS. Previously, the symbol correspondence test and word fluency test used in our study have been shown to be strongly correlated with the corresponding modules of the German version of the WAIS, as well as with the remaining modules, and with scores on other prominent intelligence tests (Lang et al., 2005; Lang et al., 2007).

The symbol correspondence test presented subjects with nine unfamiliar symbols, each paired with one of the digits 1 through 9. After brief instructions, subjects were presented with a screen that had this same mapping from numbers to symbols at the

[10] We used the German version of the test, which is known as the *Hamburger-Wechsler Intelligenztest für Erwachsene (HAWIE-R).*

top. A symbol, with a blank box beneath it, was presented in the center of that screen. Subjects had to type the correct corresponding number into the box. Once a number was entered, a new screen with another symbol appeared. Subjects had 90 seconds to find as many correspondences between symbols and numbers as they could, using the correct number for each symbol. Thus, speed and accuracy in applying the given correspondence under time pressure determine how well an individual does on the test. A total of 105 persons refused to participate, and procedural problems arose in some cases, so we have non-missing symbol-correspondence scores for a total of 902 subjects.

The word fluency test asked subjects to verbally list as many animals as they could in 90 seconds. After each naming, the interviewer pressed one of three keys, to indicate a correct animal name, a name repetition, or the statement of a wrong or unclear name, respectively.[11] Before the test started, subjects were asked whether they wanted to participate, and 87 subjects refused to take part. Some of the participants who had agreed to participate changed their minds just after the experiment began, and stopped. In a few other cases, procedural problems arose, mostly because interviewers made input errors, for example forgetting to press a key after the interviewee had named an animal. In total, we have word fluency scores for 848 individuals.

Figure 1 shows the resulting distributions of cognitive ability in our data. The upper graph in the figure is the histogram of correct answers on the symbol correspondence test. Overlaid is a graph of the smoothed density function of the distribution of symbol correspondence test scores, estimated using a Gaussian kernel.[12] A normal density function is also plotted in the graph, with the same mean and variance as the estimated density. The figure shows that the estimated density function for the symbol correspondence test is close to the normal density, or a "bell-shaped curve", consistent with the usual finding from the literature on cognitive ability. The lower graph of the figure shows the histogram of the number of correct recalls in the word fluency test. Graphs of the smoothed density function are estimated in the same way as in the upper graph, and a normal density is

[11] Lang et al. (2005) assessed the error-proneness of this procedure in a laboratory experiment in which they tape-recorded the tests and then compared the correct test results with those resulting from interviewers' entries. On average interviewers were slightly off, recording 0.4 fewer correct answers than the true total. Ceteris paribus this recording error makes the word fluency test a more noisy measure than the symbol correspondence test, where there is no scope for recording error, due to computerization of the procedure.

[12] The bandwidth is chosen to minimize the mean integrated squared error if the data were Gaussian.

included in the same way as well. The estimated density for the word fluency test is also close to normal.

To ease the interpretation of our results, we use standardized measures of the test scores in our analysis. The upper graph in Figure 2 shows separate kernel density estimates of the standardized distributions of the symbol correspondence test, for the participants in the lottery experiment and the intertemporal choice experiment, respectively. A standard normal distribution is overlaid on the graph. One important observation is that the distribution is very similar across sub-samples. The hypothesis that the distribution of scores is the same for both sub-samples cannot be rejected using a Kolmogorov-Smirnov test (p-value= 0.487). Also, for both sub-samples we cannot reject the hypothesis that the estimated distribution is normal at the five-percent level, using a joint test of skewness and kurtosis. The lower graph in the figure makes a similar comparison based on the word fluency test. Again, the distributions are not significantly different across the sub-samples for the lottery and intertemporal choice experiments (p-value= 0.396). Although the distributions look close to normal for both sub-samples, in the case of the word fluency test we reject normality at the five-percent level. Our results are robust if we instead use the non-standardized measures.[13]

2.3 Experimental Measures of Risk Aversion and Impatience

We used paid experiments to measure willingness to take risks and impatience. As described above, it was randomly determined whether a subject was invited to participate in the lottery experiment or the intertemporal choice experiment. The exact script and instructions used in the experiments are presented in Appendix B below, translated from German into English.

For both experiments, the first step in the procedure involved the experimenter presenting subjects with an example choice table. The experimenter explained the types of choices that the subject would make in the table, and how payment would work. In particular, subjects were informed that the experiment would involve multiple choices, one for each row of the table, and that one table row would be randomly selected after all choices had been made, and that the choice in this row would potentially be relevant for

[13] Results with the non-standardized measures are available upon request.

their payoff. Subjects also knew that at the end of the experiment a random device would determine whether they were actually paid, with the probability of being paid equal to 1/7. This procedure gives subjects an incentive to choose according to their true preferences in each row, and thus is incentive compatible. After explaining the nature of the experiment and the rules for payment, the experimenter asked subjects whether they were willing to participate. Subjects who agreed to participate were given further instructions, and then allowed to ask questions. Once there were no more questions, the experiment began, and subjects were asked to make their actual choices, referring to the choice table.

We elicited willingness to take risks using choices between a paid lottery and different safe payments. Participants made choices in a table with 20 rows. In each row they had to decide whether they preferred a safe option or playing a lottery. In the lottery they could win either 300 Euros or 0 Euros, each with 50 percent probability (at the time, 1 Euro $\sim$ \$ US 1.2). In each row the lottery was exactly the same but the safe option increased from row to row. In the first row the safe option was 0 Euros, in the second it was 10 Euros, and so on up to 190 Euros in row 20.

If subjects have monotonic preferences, they prefer the lottery up to a certain level of the safe option, and then switch to preferring the safe option in all subsequent rows of the choice table (see also Holt and Laury, 2002, who use a similar choice-table procedure) In our procedure, subjects were asked for their choices one row at a time, starting from the top of the table. Once a subject expressed a preference for the safe option instead of the lottery, the experimenter asked if the subject would also prefer all higher values of the safe option as well. If the answer was affirmative, the experimenter filled in the rest of the choices accordingly. Otherwise the subject could continue making choices in the table. In all cases, subjects responded in the affirmative. The switching point in the lottery experiment is informative about a subject's willingness to take risks. Since the expected value of the lottery is 150 Euros, weakly risk averse subjects should prefer safe options that are smaller than or equal to 150 Euros over the lottery. Only risk loving subjects should opt for the lottery when the offered safe option is greater than 150 Euros.

To create an incentive compatible index for how impatient an individual is, we posed subjects with choices between receiving different payments at different times. As in the lottery experiment, subjects were presented with a choice table and asked to make a choice in each row. The decision in the intertemporal choice experiment was always between 100

Euros "today" and a larger amount Y that would be received 12 months in the future. Moving down the table, the early payment was always 100 Euros but the size of the delayed payment Y increased in each subsequent row. The value of Y in the first row gave a return of 2.5 percent, assuming semi-annual compounding, and each subsequent value of Y implied an additional 2.5 percentage point increase in the annual rate of return.[14] Observing the value of Y (or equivalently, the implied annual rate of return) necessary to induce the individual to wait 12 months, we obtain an index of impatience.

Subjects were asked for their decisions one row at a time, starting from the first row. The first time that a subject switched from 100 Euros to the delayed payment, the subject was asked whether he or she also preferred to wait for any larger payment, which all subjects agreed upon. As in the lottery experiment, subjects knew that one row would be randomly selected at the end of the experiment, and that their decision in that row could be relevant for their payoff. Subjects also knew that all payments would be sent by mail following the interview, in the form of a check. Checks for "today" could be cashed immediately, but checks for payments in 12 months would be cashable only in 12 months.

Our focus in this paper is on the relationship between cognitive ability and impatience, rather than estimating the average level of impatience in the population, but our design does address an important challenge that arises when trying to precisely measure the level of impatience. The potential problem is that subjects could be skeptical that the experimenters will deliver on a promise to make a monetary payment available in the future. This could cause them to place a premium on payments that are available immediately at the time of the interview, and thus choose in a way that makes them appear more impatient than they truly are. In our design, however, there is little scope for credibility concerns. Subjects know that even the early payment is not available immediately, but rather is sent by mail shortly after the interview in the form of a check. The timing of the mailing is thus the same as if the subject is due to receive a check that can only be cashed in one year's time. This feature of the design helps make the early and delayed payments equally credible or "incredible", and thus mitigates the problem of overstating the level of

[14] We chose semi-annual compounding of the annual interest rate because this is a natural compromise between the two types of compounding German subjects are most familiar with: quarterly compounding on typical bank accounts, and annual reports on the rate of return from savings accounts, pension funds, or stock holdings. Using semi-annual compounding also helps avoid prominent round numbers in the choice table, which could potentially influence switching choices.

impatience.[15]

The upper graph of Figure 3 shows the histogram of switching values in the lottery experiment, which are equivalent to subjects' certainty equivalents. The main message of the figure is that there is substantial heterogeneity in willingness to take risks. It is also noteworthy that the majority of individuals are risk averse. The modal certainty equivalent is 100 Euros, well below the lottery's expected value of 150 Euros, and the median certainty equivalent is 80 Euros. These values are in line with previous evidence from laboratory experiments and field experiments that measure the degree of risk aversion.[16] Overall, the majority of subjects (77.8 percent) exhibit risk aversion in the lottery experiment, preferring a certainty equivalent strictly smaller than the expected value of the lottery to playing the lottery. The fraction of risk-seeking subjects is small (9.1 percent). As is typical in choice experiments, there is also some evidence that subjects tend to choose prominent numbers more often (e.g., 50, 100, 150). In the analysis we use estimation techniques that correct for the fact that willingness to take risks is measured in intervals, and thus is left- and right-censored, and we check robustness of our results to using broader intervals that eliminate much of the lumpiness of the distribution around prominent numbers.

The lower graph of Figure 3 shows the histogram of switching values in the intertemporal choice experiment. Again, the main message of the figure is that there is substantial heterogeneity. It is noteworthy that the implied level is similar to that in other recent studies that use behavior in the field to infer impatience.[17] Note that there is a spike in the

[15] Furthermore, experiments and payments were administered by the professional surveying agency used for the SOEP, which is highly credible and well known to the public because of its role in conducting election polls for German public television. Interviewers also left their contact details at the end of the experiment, making it easy for subjects to contact the institute. There were no reports, from any of the interviewers, about subjects expressing concerns regarding credibility of payments. Thus, it is very unlikely that subjects perceived either future or immediate payments in the experiment as being less than fully credible.

[16] Previous studies using lottery experiments have often assumed a CRRA utility function, and utility defined over outcomes in the experiment rather than final wealth levels, in order to infer a risk preference parameter (but see Rabin, 2000, for a criticism of this approach). Applying these assumptions to our data for the sake of comparability yields mean and median coefficients of relative risk aversion that fall in the range between 0.48 and 0.43. This is similar to the range of 0.3 to 0.5 found by Holt and Laury (2002) in laboratory experiments with college students, and is reasonably close to the value 0.67 found by Harrison et al. (forthcoming) in a field experiment with people in Denmark.

[17] Under certain assumptions it is possible to infer an annual discount rate from switching rows in the experiment, and to compare to annual discount rates estimated in previous studies that make similar assumptions. For example, with locally-linear utility and semi-annual compounding of the annual discount rate, the lower bound for the annual discount rate is given by the formula $100 * (1 + \underline{\delta}/2)^2 = Z$, where Z is the largest value of the delayed payment such that the individual still prefers 100 Euros today. The upper bound is calculated as $100 * (1 + \bar{\delta}/2)^2 = Y$, where Y is the value of the delayed pay-

figure in the highest category of impatience; this reflects individuals who are so impatient that they prefer the early payment even in the final row of the choice table. There is again some evidence that prominent numbers affect choices: switching is slightly more common in rows where the delayed payment surpasses prominent numbers, for example 110 Euros, or 120 Euros, although this feature of choices appears less pronounced than in the lottery experiment. In the analysis we take steps to correct for left and right censoring of the impatience measure, and check robustness to using intervals that mitigate lumpiness around prominent numbers.

3 Results

We begin our empirical analysis by looking at the relationship between cognitive ability, risk aversion, and impatience in the raw data. The upper graph in Figure 4 shows the average values of our indexes of willingness to take risks, and impatience, for each decile of the distribution of cognitive ability as measured by the symbol correspondence test. The lower graph displays similar information, but using performance on the word fluency test as the measure of cognitive ability. For both measures, the average degree of impatience is clearly lower for higher deciles of the ability distribution. Also, for both measures the average certainty equivalent is increasing in the level of cognitive ability, indicating greater willingness to take risks. Thus, the figure provides an initial indication that both willingness to take risks and patience are systematically related to cognitive ability.

In order to assess whether these relationships are statistically significant, and whether they are robust to controlling for personal characteristics, we next regress our measures of risk aversion and impatience on cognitive ability and controls. Table 1 presents the results. The dependent variable in columns (1) to (4) is the switching row in the lottery experiment. A higher switching row indicates a higher certainty equivalent, and thus a greater willingness to take risks. The dependent variable in columns (5) to (8) is the

ment in the next row of the table, i.e., the smallest delayed payment that makes the individual willing to switch to waiting one year. An individual's true discount rate δ lies within this interval, $\delta \in [\underline{\delta}, \bar{\delta}]$. The resulting median discount rate falls in the range of 27.5 to 30 percent. Harrison et al. (2002) make similar assumptions, except using quarterly instead of semi-annual compounding, and find an average annual discount rate of 28.1 percent in their field experiment with individuals in Denmark. Warner and Pleeter (2001) provide evidence on annual discount rates for a large number of individuals in the U.S. military, inferred from very high stakes choices between different voluntary separation options. They find an average annual discount rate ranging from 10 to 19 percent for officers and from 35 to 55 percent for enlisted soldiers.

switching row in the intertemporal choice experiment. A higher value indicates that an individual needs a higher rate of return to forgo the immediate payment and wait one year, and thus greater impatience. To account for the fact that the dependent variables are measured in intervals, and thus that all observations are right and left censored, the regressions are estimated using interval regression techniques.[18] Coefficient estimates are marginal effects; robust standard errors are reported in brackets. Unless otherwise noted, all subsequent tables in the paper also report interval regressions, and robust standard errors. In all regressions we use the standardized measures of the cognitive ability as explanatory variables.

Column (1) shows that people with better performance on the symbol correspondence test exhibit greater willingness to take risks in the lottery experiment. The effect is only slightly smaller, and is still significant at the five percent level, when we also control for personal characteristics in column (2). We find a similarly large and significant relationship between cognitive ability and risk taking if we instead use the word fluency test as the measure of cognitive ability (columns (3) and (4)). The magnitude is also economically significant: a one standard deviation increase in cognitive ability is associated with a shift of about one switching row, which corresponds to a 12.5 percent increase in the certainty equivalent for the median subject in our sample.[19]

Turning to impatience, columns (5) to (8) show that people with higher cognitive ability are significantly more patient, i.e., switch significantly earlier in the choice table in the experiment. This result is robust to controlling for personal characteristics. The magnitude of the coefficient, and the level of statistical significance, are slightly lower in

[18] The procedure maximizes a likelihood function that is a natural generalization of a Tobit, treating each value as a left and right censored observation coming from an interval with known bounds. Error terms are assumed to be normally distributed. For more information, see the STATA reference manual on the intreg procedure listed under Tobit estimation.

[19] Notably, this result does not appear to be driven by an impact of cognitive ability on understanding of expected values, or the use of expected value as a choice heuristic. If this were the case, we would expect cognitive ability to have an impact mainly by increasing the probability of switching exactly in those rows that corresponding to risk neutrality (rows 15 and 16). We do not, however, observe an especially large impact of cognitive ability on the tendency to be risk neutral. In fact, only 4 percent more subjects switch at risk neutrality among the top quartile of the symbol correspondence distribution, compared to the bottom quartile. Instead, in the data we observe that higher cognitive ability shifts the entire distribution of switching rows in the direction of greater willingness to take risks. We reach a similar conclusion if we estimate probit regressions, where the dependent variable is equal to 1 in the case of risk neutrality. Cognitive ability does not have a significant impact on the probability of being risk neutral ($p < 0.313$; detailed results available upon request). Thus, the results in Table 1 reflect a tendency for higher cognitive ability to make people less risk averse in general.

the regressions that use word fluency as the measure of cognitive ability. This could reflect greater measurement error in the word fluency test, or could indicate that impatience is less strongly related to verbal ability. The magnitude of the effects is again economically significant: the coefficients imply that a one standard deviation increase in cognitive ability leads an individual to switch about one row earlier, corresponding to a 9 percent decrease in the rate of return needed to induce the median individual to switch to preferring the delayed payment.

The results in Table 1 are robust to using different estimation techniques. For example, in Table A.1 in Appendix A we show that results are similar if we use OLS instead of interval regression. In other regressions we try a different approach to dealing with the fact that the dependent variables are censored, and use a Cox mixed proportional hazards model. We estimate the impact of cognitive ability on the hazard of switching in the choice tables, from the lottery to the safe payment in the risk experiment, and from the immediate to the delayed payment in the intertemporal choice experiment. We find similar results in this case: the coefficient estimates show that higher cognitive ability significantly decreases the hazard of switching in the risk experiment, which corresponds to greater willingness to take risks, and increases the hazard of switching in the intertermporal choice experiment, which corresponds to greater patience. Finally, we also explore the robustness of the results to collapsing the preference measures into broader intervals around prominent numbers. This makes sense if some of the people who switch at prominent numbers in fact prefer to switch a row earlier or a row later, but are "attracted" by the prominent number and switch at that point by mistake. Table A.1 in Appendix A shows that we find similar results when we use these smoothed measures, which use intervals of 3 or 4 switching rows, rather than intervals containing single rows.

Overall, the baseline results are consistent with greater willingness to take risks, and greater patience, among those with relatively high cognitive ability. This is true controlling for personal characteristics, and using various estimation strategies. In the following sub-sections we do a series of additional robustness checks, to rule out various alternative explanations for the apparent link between cognitive ability, risk aversion, and impatience.

4 Robustness Checks

4.1 The Role of Education

In this sub-section we explore whether the baseline results are robust to controlling for education. Higher cognitive ability is typically associated with higher educational attainment (see Card, 1999). In fact, both of our measures of cognitive ability are strong predictors of educational attainment: people in our sample who have higher cognitive ability are significantly more likely to go to school longer and/or to obtain advanced schooling degrees. Results from a multinomial Logit estimation, with different degree categories as the dependent variable, and cognitive ability and personal characteristics as explanatory variables, show that high cognitive ability increases the likelihood of acquiring an advanced degree.[20] One could hypothesize that education, in turn, might affect preferences, in particular discount rates (see, e.g., Becker and Mulligan, 1997). In order to see whether cognitive ability has a direct impact on preferences, or whether it operates only indirectly through the channel of education, it is desirable to investigate whether the baseline results change if we control for education.

There is also another rationale for controlling for education, namely the potential for education to determine cognitive ability. Previous evidence suggests that educational attainment affects performance on the AFQT (Hansen et al., 2004; Cascio and Lewis, 2006). This is less likely to be the case for our measures of ability, which are not as dependent on accumulated knowledge or experience. However, to the extent that our measures of cognitive ability are partly a proxy for education, some of the impact of cognitive ability in Table 1 could reflect the impact of education, which was omitted from the regressions.

Table 2 presents the same regressions as in Table 1, but adding dummy variables for different educational degrees. This is a better measure of educational attainment for Germany than years of schooling, because of the structure of the German educational system (see Card, 1999, p. 1806). In teenage years, German students select into different types of high schools, some focusing on vocational training, others intended to prepare students for college. Thus, an equal number of years of education can mean very different

[20] Results available upon request.

things depending on the type of degree. Columns (1) and (3) show that the impact of both types of cognitive ability on risk preference is only slightly smaller, and remains significant, once we control for schooling degree. In columns (2) and (4), where we also control for personal characteristics, both measures of cognitive ability are still significant, although for the symbol correspondence test significance drops to the ten percent level. Interestingly, more advanced degrees are significantly positively correlated with willingness to take risks, as shown by the coefficient on the dummy variable for "Abitur", which is the degree completed at the end of a college track high school. In columns (5) to (8), we see that the symbol correspondence test remains a strong and significant predictor of impatience, controlling for education and for personal characteristics. The word fluency test is still significant at the ten percent level when we control for education, but becomes insignificant (p-value=0.142) once we control for education and exogenous characteristics simultaneously. Interestingly, however, education is also not significantly correlated with discount rates, in any of the specifications. In summary, the baseline results are largely unchanged if we control for education, suggesting that the relationship between cognitive ability, risk aversion, and impatience does not work solely through the indirect channel of education.

4.2 The Role of Income and Credit Constraints

Another possibility is that cognitive ability could have an indirect effect through the channel of income or credit constraints. Higher cognitive ability is associated with higher income, and higher income could affect willingness to take risks, or willingness to be patient. For example, someone with higher income may be less worried about taking a risk and winning nothing, all else equal, because higher income provides a cushion against negative income shocks. It could also be the case that for people with low income, choosing the early payment in the intertemporal choice experiment is more attractive, because they are credit constrained and need the 100 Euros immediately, in order to cover some important expense. To see whether cognitive ability has a direct impact on the way that people make choices under uncertainty, or over time, above and beyond these indirect channels, we add income and a measure of credit constraints to our baseline specifications.

In Table 3 we estimate the same regressions as in Table 1, but add controls for income and credit constraints. The income variable is current household monthly income, net of taxes and benefits (for more details see the table notes). The dummy variable for credit constraints is based on a question in our questionnaire, which asked the following: "If you suddenly encountered an unforeseen situation, and had to pay an expense of 1,000 Euros within the next two weeks, would it be possible for you to borrow the money?" Columns (1) to (4) show that both measures of cognitive ability still have a strong impact on willingness to take risks, significant at the five percent level, if we control for income, credit constraints, and personal characteristics. Results in columns (5) to (8) indicate that cognitive ability measured by the symbol correspondence tests is a significant predictor of impatience, controlling for income and credit constraints. The coefficients for the word fluency measure are also statistically significant, except in column 8, where we add all controls at once and the coefficient is no longer significant (p-value=0.131). Notably, in all specifications income has a significant positive correlation with willingness to take risks, and a significant negative correlation with the degree of impatience.

The results are also similar if we control for education and income simultaneously. The symbol correspondence test has a statistically significant impact on willingness to take risks and impatience, in all specifications, and the point estimates are largely unchanged. The word fluency measure is also significant when controlling for both education and income, except in the fullest specification where it is not quite significant once we control for personal characteristics as well.[21] Thus, the relationship between cognitive ability, risk aversion, and impatience is not explained entirely by different levels of education, income, or degree of credit constraints.

4.3 Are the Results Explained by Confusion in the Choice Experiments?

Because we rely on choice experiments to measure willingness to take risks and impatience, a potential concern is that low cognitive ability could be associated with confusion about incentives faced in the experiments, in a way that happens to be observationally equivalent to greater risk aversion, or greater impatience. Confusion is unlikely, given that the experiments are relatively simple. Also, it is not clear why confusion should be systematic in a way that would appear as greater risk aversion or impatience.[22] In the case of

[21] These results are available upon request.

[22] In the case of the intertemporal choice experiment, for example, confused individuals could well appear more patient. For instance, suppose that subjects ignore the time delay, and think that one of the two columns in the table is randomly selected, rather than one row. Given that payments are always

willingness to take risks, however, we are able to address this potential confound directly. Our data include a very simple survey question about risk attitudes that is immune to problems of confusion about incentives, filling out tables, etc.. The question simply asks an individual to rate his or her own "willingness to take risks, in general" on a scale from 0 to 10, where 0 is "completely unwilling" and 10 is "completely willing." In previous research, this particular question has been shown to be a good predictor of a wide variety of risky behaviors, including holding stocks, being self-employed, smoking, migrating, and participating in sports (see, for example, Dohmen et al., 2005; Bonin et al., 2006; Jaeger et al., 2007).

Table 4 presents regressions where the dependent variable is the response to the survey question about willingness to take risks. Columns (1) to (4) use the same specifications as in our baseline regressions. The coefficient estimates show that in every case, higher cognitive ability is associated with greater willingness to take risks. Coefficients on cognitive ability are always significant at the one percent level. Thus, our baseline results are unlikely to be explained by confusion about incentives in the choice experiments.

4.4 Arbitrage Between the Experiment and the Credit Market

A potential confound that is specific to the intertemporal choice experiment arises if people with high cognitive ability are more likely to engage in a specific kind of arbitrage behavior. In particular, it could be that some highly impatient subjects adopt a sophisticated strategy of arbitrage. They might make patient choices in the experiment in order to take advantage of the above-market rates of return, and then borrow outside of the experiment at market interest rates to finance their desire for immediate consumption. If use of this strategy is more likely for individuals with high cognitive ability, then intelligent people could be just as impatient as those with low ability, but simply appear more patient in the experiment because they have figured out a less expensive way to finance immediate consumption.

To identify individuals who engaged in arbitrage, we asked at the end of the experiment whether a subject had thought about market interest rates at all during the experiment. Of all participants, roughly 37 percent say that they thought about an interest

larger in the second column, which gives the delayed payments, confused subjects would tend to choose delayed payments and thus appear more patient.

rate. This suggests that most subjects are not engaging in arbitrage at all. Interestingly, however, thinking about market rates of return is significantly more likely for subjects who score higher on either measure of cognitive ability.[23] Thus, it is important to assess whether our results are driven by the minority who do think about interest rates.

Table 5 presents our baseline regression specifications for impatience, but including on the right hand side a dummy variable equal to 1 if an individual thought about market interest rates and 0 otherwise. Thinking about interest rates does lead to a large and statistically significant decrease in the discount rate observed in the experiment. This is consistent with those who think about interest rates engaging in arbitrage. The more important finding for our purposes, however, is that higher cognitive ability is still associated with a significantly lower degree of impatience.

4.5 Preferences and Test-Taking Strategy

Another potential confound would arise if risk aversion and impatience are not related to true cognitive ability, but instead influence the type of test-taking strategy that subjects adopt, in a way that leads to lower *measured* cognitive ability. For instance, suppose that risk averse individuals take more time to provide answers in the tests of cognitive ability because this preference partly reflects a desire to avoid losses, or mistakes. This would lead to a lower error rate on the test, but potentially also to a lower score because subjects answer fewer questions within the time limit. We test the hypothesis that risk aversion has an impact on the error rates in the tests. It is less plausible that impatience would affect the way that an individual approaches the tests of cognitive ability. The tests take 90 seconds, regardless of effort, so there is no incentive for an impatient individual to rush through the cognitive ability exercises. Nevertheless, we also check whether impatient individuals have higher error rates on the tests of cognitive ability.

In OLS regressions, we regress the error rates in the tests of cognitive ability on willingness to take risks and impatience, with and without controls for personal characteristics.[24] The error rate is defined as the number of incorrect answers divided by the total number of answers given by an individual. For both tests of cognitive ability, there is no

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[23] This result is based on a probit regression with a binary indicator for thinking about the interest rate as the dependent variable and cognitive ability as the explanatory variable. These results are available upon request.

[24] Results are available upon request.

significant impact of the risk aversion or impatience on error rates, in any specification.[25] Thus, there is little indication that the baseline results reflect an impact of risk aversion or impatience on test-taking strategy.

4.6 Are the Tests of Cognitive Ability a Proxy for Personality Type?

In this sub-section we investigate an interesting possibility, which is that performance on cognitive tests could partly measure aspects of a subject's personality, rather than cognitive ability. For example, conscientiousness, one of the five personality traits known as the "Big Five" in psychology, has been shown to predict performance on tests of cognitive ability (Segal, 2006). If our measures of cognitive ability in fact proxy for personality type, then our findings could be interpreted as revealing a link between fundamentally important traits in economics (risk aversion and impatience) and personality traits. If this were the case, it would be an interesting finding, with important implications.[26] In our questionnaire we included standard measures of the Big Five, so we can test whether cognitive ability has an impact on risk aversion and impatience, controlling for conscientiousness and other dimensions of personality.

Table 6 reports regressions with the same specifications as in Table 1, but adding controls for what psychologists have agreed are five key dimensions of personality: conscientiousness, extroversion, agreeableness, openness, and neuroticism.[27] The main conclusion to be drawn from Table 6 is that the coefficients on cognitive ability are still statistically significant, even controlling for personality type. Coefficients on the measures of cognitive ability are only slightly smaller than in Table 1, and are similarly significant, except in column (8) where the coefficient for the word fluency test is no longer significant. Interestingly, openness to new experience is associated with significantly greater willingness to take risks, and extroversion is associated with significantly greater impatience, although only in the regressions that use the symbol correspondence test to measure cog-

[25] Point estimates are essentially zero, and none are close to being statistically significant. These results are available upon request.

[26] See Heckman et al. (2006) for a discussion of the importance of investigating the link between economic preferences and non-cognitive skills or personality traits.

[27] The Big-Five questionnaire measures personality traits by asking subjects how much they agree with different statements about themselves. We use a fifteen item version of the questionnaire where each trait is assessed based on level of agreement with three statements. The subject indicates the level of agreement on a seven-point scale, and response are added across each set of three statements to achieve a score for that personality trait. Statements are presented in random order.

nitive ability. In summary, although there is some interesting evidence suggesting that risk aversion and impatience are related to personality type, this does not explain the relationship between our cognitive ability measures, risk aversion, and impatience.

4.7 Concavity of Utility and Impatient Behavior

In this final section of the analysis we investigate whether our results on impatience indicate a link between cognitive ability and pure time preference, or whether they could be driven by a tendency for people with lower cognitive ability to have more concave utility functions (i.e. a faster rate of diminishing marginal utility of income). Note that, regardless of whether the underlying mechanism is time preference or concavity, it is important that we find a robust tendency for people with lower cognitive ability to exhibit more impatient *behavior*, because of the far-reaching implications for the many economic outcomes that are linked to investment behavior. Nevertheless, this investigation is conceptually interesting because it is informative about the mechanisms underlying the observed pattern in behavior.

The issue of concavity arises if one considers our results in light of, e.g., standard Expected Utility Theory (EUT). We find that many people are risk averse in the lottery experiment. In the context of EUT, risk aversion is equivalent to concavity of the instantaneous utility function, and if one is willing to make particular assumptions about the functional form of utility, it is possible to calculate risk preference in terms of a parameter describing curvature. For example, assuming CRRA utility, it is possible to use the switching point in our lottery experiment to bound an individual's CRRA coefficient. A higher CRRA parameter implies a higher degree of concavity of the utility function and therefore a higher degree of risk aversion.[28] We find that risk aversion, or concavity, is more prevalent among people with low cognitive ability.[29] The question, then, is

[28] In our choice experiment, indifference between the lottery of winning 300 Euros or 0 Euros with equal probability and a safe option of y implies $0.5\frac{300^{1-\gamma}}{(1-\gamma)} = \frac{y^{1-\gamma}}{(1-\gamma)}$, and therefore $\gamma = 1 - \frac{(ln0.5)}{(lny - ln300)}$. Using the safe option from the switching row in the experiment gives the lower bound for the interval containing γ and using the safe option in the previous row gives the upper bound. Note that this calculation uses the assumption that utility is defined only over outcomes in the experiment, rather than over final wealth levels (for a similar approach see Holt and Laury, 2002). For a critique of inferring curvature from risk aversion in moderate stake lotteries, however, see Rabin (2002). Alternatively, assuming a reference point of zero when entering the experiment, the lottery choices can be interpreted as measuring the concavity of the Kahneman and Tversky (1979) value function in the gain domain.

[29] For example, coefficients in columns (2) and (4) of Table 1 imply that a one standard deviation increase in the symbol correspondence (word fluency) score is associated with a 8.16 Euro (9.08 Euro) increase

whether cognitive ability might affect impatient behavior indirectly, through the channel of concavity, rather than through a direct relationship with time preference.

To see how greater concavity of utility could lead to more impatient behavior in the intertemporal choice experiment, consider the EUT setting with exponential discounting. Assume first that utility is locally linear for the stakes used in the inter-temporal choice experiment. In this benchmark case, where concavity plays no role by assumption, the relationship between the observed switching row and δ (the discount rate over a horizon of one year) is given by the indifference condition

$$1 + \delta = \frac{x_{t+\tau}}{x_t}. \tag{1}$$

where τ is one year, x_t corresponds to 100 Euros available today, $x_{t+\tau}$ is the delayed payment of $100 + \Delta$ available one year later.[30] Under these assumptions, we can directly translate switching rows into discount rates.[31] Now consider how concave utility $u(\cdot)$, such that $u'(\cdot) > 0$ and $u''(\cdot) < 0$, affects the relationship between the switching row and the annual discount rate. The indifference condition in this case is given by

$$1 + \delta = \frac{u(x_{t+\tau})}{u(x_t)}. \tag{2}$$

This expression shows that for the same δ, greater concavity in the utility function leads to more impatient behavior, in the sense of a later switching row. This follows because $\frac{u(x_{t+\tau})}{u(x_t)} < \frac{x_{t+\tau}}{x_t}$, i.e., for a given δ, the size of the delayed payment $x_{t+\tau}$ must be larger in the case of concave utility, for the indifference to hold. Put differently, as concavity of utility increases, a smaller discount rate is needed to generate the same degree of impatience in behavior (this latter point is also made by Andersen et al., 2005). Given that we find that risk aversion, or equivalently concavity of utility, is more pronounced for people with low cognitive ability, this channel could potentially explain the results on the correlation between cognitive ability and impatience, instead of a direct link between cognitive ability

in the certainty equivalent. For an individual with the median degree of risk aversion this corresponds to a decrease in the lower bound of the CRRA parameter from 0.476 to 0.434 (0.429).

30 The choice table in the experiment were constructed using semi-annually-compounded rates $\tilde{\delta}$, which can be retrieved similarly as $\left(1 + \frac{\tilde{\delta}}{2}\right)^2 = \frac{x_{t+\tau}}{x_t}$.

31 For the median subject, who switches in row 11, the discount rate is in the interval from 25 to 27.5 percent, and the coefficients in columns (6) and (8) of Table 1 imply that a one standard deviation increase in performance on the symbol correspondence or word fluency test is associated with a 2.98 or 2.30 percentage point decrease in the annual discount rate, respectively.

and δ.[32]

If the true form of $u(\cdot)$ were known for all individuals, one could directly use condition (2) to derive the discount rate δ that implies indifference between x_t and $x_{t+\tau}$, and assess empirically whether there is a relationship between δ and cognitive ability. However, since $u(\cdot)$ is neither known nor directly observed, one has to make strong identifying assumptions about the functional form as well as about the measurement of the relevant parameters of concavity. One possibility is to assume, as above, that individuals have utility functions of the commonly-used CRRA family. Then, for participants in the lottery experiment, we can calculate CRRA coefficients. Since participants in the intertemporal choice experiment do not take part in the lottery experiment, we have to impute their CRRA coefficients based on characteristics that are observed for participants in both experiments and that capture curvature of utility. We use two different procedures. In one case we regress CRRA coefficients on responses to the survey risk measure, using participants in the lottery experiment, and then use the resulting equation to predict CRRA coefficients for participants in the intertemporal choice experiment. As an alternative approach, we use cognitive ability to predict CRRA coefficients.[33] With the predicted CRRA coefficient, γ, for each participant in the intertemporal choice experiment, one can then calculate the exponential discount rate implied by switching points in the intertemporal choice experiment. This calculation simply involves applying condition (2) to the case of CRRA preferences, i.e., $1 + \delta = (x_{t+\tau}/x_t)^{1-\gamma}$.[34] To test whether there is a relationship between cognitive ability and discount rates, we can then regress the resulting discount rates on cognitive ability and controls.

When using the discount rate calculated using the first CRRA measure (imputed

[32] Frederick (2006) also notes that concavity of the utility or value function could affect intertemporal choice.

[33] The following results are based on linear OLS prediction equations. The 12 percent of individuals who have unbounded intervals for the CRRA coefficient (those who never switch in the lottery choice table, or switch immediately) are excluded from the regressions. Results are similar when, instead of basing predictions on regression equations, we take average CRRA coefficients for different ranges of cognitive ability (survey measure of willingness to take risks), and assign these to individuals in the intertemporal choice experiment who fall in the same range of cognitive ability (willingness to take risks).

[34] When using the survey risk measure to impute CRRA coefficients, the median imputed discount rate is in the interval from 13.14 to 14.76 percent, as compared to the interval from 25 to 27.5 percent implied by assuming local linearity. When using the symbol correspondence score (word fluency score) to impute CRRA coefficients, the corresponding median imputed discount rate is in the interval from 10.87 to 12.20 (10.70 to 12.26) percent. Andersen et al. (2005) find a similar result that eliciting risk preference and time preference jointly leads to lower estimates of the exponential discount rate.

using the survey risk question), we find that cognitive ability has a significant impact on time preference, in the sense of the discount rate.[35] When we use the discount rates based on the other CRRA measure (imputed based on cognitive ability), the results become weaker, and sometimes insignificant (detailed results are displayed in Table A.2 in the Appendix). When interpreting both sets of results, however, one has to keep in mind that they rely on strong assumptions. For example, the results become difficult to interpret if the assumption of CRRA utility is incorrect. Also, there is a generated regressand problem: discount rates are obtained after imputation (and estimation), and thus discount rates exhibit less variation than if they were calculated using the wider range of true CRRA parameters. This problem in the dependent variable tends to increase standard errors of coefficient estimates, making it less likely to find a significant impact of cognitive ability on discount rates.[36]

As a way of circumventing the need to make strong assumptions about the form of utility, and problems with generated regessands, we also conducted the same regressions of impatient behavior on controls as in Table 1, but adding a control for directly observed risk attitudes measured by the survey risk question. We allow risk attitudes to enter non-parametrically, with a dummy variable for each value on the risk scale (the results are displayed in columns (7) and (8) of Table A.2 in the Appendix).[37] This approach implicitly assumes that the survey risk measure captures the curvature of the unknown utility function. This assumption is supported by the fact that responses to the question are significantly related to CRRA coefficients in the lottery experiment sample, and by previous evidence that the question predicts risky behaviors.[38] In this case we find a strong and significant impact of cognitive ability on impatient behavior, controlling for curvature of utility using the survey measure of risk attitudes.

Taken together, the picture emerging from the results in this section suggests that

[35] A one-standard deviation increase in the symbol correspondence test score (word fluency test score) is associated with a 1.5 (1.2) percentage point decrease in the discount rate.

[36] The generated regressand problem, which exaggerates standard errors, has the opposite effect of the generated regressor problem, where the result is standard errors that are too small (Pagan, 1984). Note that heteroscedasticity of the errors is also likely to arise as a consequence of the generated regressand problem. We account for this in our estimation and report robust standard errors in Table A.2.

[37] Unreported results obtained with a linear specification of the survey risk measure as control are virtually identical.

[38] See Dohmen et al. (2005), who show that responses to the general risk question predict measures of curvature obtained from survey questions about lottery choices.

there is a relationship between cognitive ability and pure time preference, although we cannot completely rule out that curvature plays a role in explaining the results on impatience. In any case, we find strong evidence that cognitive ability and risk preference are related, and that cognitive ability is related to impatient choices.

5 Conclusion

The goal of this paper was to investigate a simple but fundamentally important question: whether the key traits of risk aversion and impatience are systematically related to cognitive ability. In order to test this hypothesis, we used a large representative sample of the population, incentive compatible measures of willingness to take risks and impatience, and two tests of cognitive ability. The main finding is that people with lower cognitive ability are significantly more risk averse, and significantly more impatient. This is true controlling for personal characteristics, educational attainment, income, and credit constraints. The relationship also survives a series of additional robustness checks.

The fact that risk aversion and impatience are correlated with cognitive ability has important implications for theoretical and empirical research in economics. These traits are usually assumed to be independent in economic models, but the results in this paper suggest that this is a potentially important source of model miss-specification. In particular, it may be appropriate to allow for a positive correlation between cognitive ability and risk preference, and a negative correlation between cognitive ability and discount rates. Our findings also suggest a different interpretation of reduced form models that are estimated with cognitive ability as an explanatory variable but not measures of risk aversion or impatience. For example, consider a regression of schooling choice on cognitive ability: the coefficient on cognitive ability will partly reflect the correlation with omitted risk aversion and impatience, which are both relevant for investments in human capital. Given the importance of risk aversion and impatience for many other economic decisions, this is likely to be true more generally for regressions of economic decisions on cognitive ability. Given that cognitive ability is passed on from one generation to the next, our results also have implications for understanding intergenerational correlation in preferences and life choices: children may end up with similar preferences to their parents, and thus make similar choices in life, partly due to similarity in cognitive ability. Finally, the relationship raises important issues for policy. For example, in early-childhood interventions, focused on improving cognitive and non-cognitive skills, there may be important feedback effects between cognitive ability and preferences.

An interesting topic for future research is investigating the psychological or neurophysiological mechanisms explaining why risk aversion and impatience are associated with lower cognitive ability. One possibility is that cognitive ability affects a person's capacity for integrating choices. For example, previous research on "choice bracketing" suggests that when some people make choices, they bracket broadly and consider the consequences of all of the choices taken together, whereas others bracket narrowly and make each choice in isolation (Read et al., 1999). In the context of risky choice, this can lead people to choose to play one collection of lotteries that is first order stochastically dominated by another available collection (Tversky and Kahneman, 1981). It could potentially explain risk aversion even in small stakes lotteries, because people fail to integrate a small individual risky decision with broader considerations, e.g., regarding the expected value of future lifetime income. In the context of intertemporal choice, impatience could also reflect narrow bracketing, in the form of making choices about present consumption without fully accounting for future consequences. Further research is needed on whether narrow bracketing is more likely for people with lower cognitive ability, but two recent studies provide some preliminary evidence: Rabin and Weizsäcker (2007) show that narrow bracketing is less likely in risky choice when the experimenter lowers cognitive costs for subjects by working out the math, and Abeler and Marklein (2007) find that math grades are related to narrow bracketing in consumption choices.

Another possibility is that choices over time, or choices between risky and safe options, are determined by the interplay of two separate decision-making systems: a cognitive system that is relatively risk neutral, and takes into account longer-term considerations, and an affective system that generates fear impulses in response to potential risks, or impulses for immediate consumption. Consistent with this view, research on patients with brain lesions shows that damage to affective areas is associated with increased willingness to take risks (Shiv et al., 2005). Brain imaging also shows that greater activation of affective systems in the brain, relative to cognitive systems, increases the likelihood that someone chooses an immediate monetary reward over a larger, delayed reward (McClure et al., 2004). It could be that our measures of cognitive ability proxy for the resources available to individuals for suppressing affective urges, such that higher cognitive ability indicates greater resources. This could then explain why people with lower cognitive ability are more likely to pursue immediate consumption opportunities, or to avoid risks.

Importantly, however, establishing that cognitive ability affects risk aversion and impatience would not rule out the potential for a more complicated relationship, in which preferences have feedback effects on cognitive ability. For example, it could be that patience, and willingness to take risks, are traits that are conducive for the accumulation of cognitive skills over the lifetime. Heckman (2006) and Heckman et al. (2006) argue along these lines, suggesting the relationship between cognitive and non-cognitive skills is complex, such that non-cognitive skills and personality traits cause people to endogenously create environments that foster faster cognitive development. Our measures of cognitive ability capture something closer to innate ability than, say, the accumulated knowledge measured by an SAT test score. Thus there is relatively less scope for preferences to affect performance through a channel of greater accumulated experience or knowledge.[39] This is suggestive of a causal impact of cognitive ability on preferences, but does not rule out that there could be important feedback effects as well.[40]

For the ultimate cause of the relationship, it may even be necessary to think in terms of a feedback process occurring in the evolutionary environment of humans. It could be that more ambitious behaviors characterized by risk taking, and long-term planning, were evolutionarily more successful when combined with high cognitive ability. On the other hand, for types with lower cognitive ability, more conservative preferences for immediate rewards, and safe bets, could have been the right traits for survival. Types with a taste for risk-taking, and delay of gratification, but also low cognitive ability, may have been less successful. Notably, evidence discussed above shows that emotional aversion to risks, and urges for immediate consumption, are rooted in the evolutionarily older, affective system of the brain, which was the main driver of decision making in our animal forebears, before

[39] For example, the mapping in the symbol correspondence test is arbitrary, and has not been encountered in previous education or training settings.

[40] The finding from previous studies, that cognitive ability is correlated with impatience for young children, provides an additional indication that ability causes preferences and not the other way around, to the extent that young children have relatively little scope to shape their environments according to their own preferences. Also, Benjamin et al. (2005) show that preferences of high school students are significantly correlated with grades in elementary school, but do not find a statistically significant correlation with the change in grades between elementary school and high school, suggesting that preferences do not lead to faster accumulation of ability.

the development of the neocortex and higher cognitive ability (see, e.g., Cohen, 2005). This provides one tentative piece of evidence that in the case of lower cognitive ability, a conservative preference for sure bets, and immediately available rewards, may have been adaptive. Whether risk aversion and impatience are a good combination with low cognitive ability in the present day, where conditions have changed substantially relative to the adaptive environment, is an interesting open question.

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Tables

Table 1: The Link Between Cognitive Ability, Risk Aversion, and Impatience

Dependent Variable:	Willingness to take risks (Experimental Measure)				Impatience (Experimental Measure)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	1.142***	0.816**			-1.296***	-1.193**		
	[0.277]	[0.351]			[0.448]	[0.518]		
Standardized word fluency score			1.189***	0.908***			-1.080**	-0.918*
			[0.306]	[0.313]			[0.474]	[0.481]
1 if female		1.075		1.168		2.217*		2.648**
		[0.806]		[0.826]		[1.233]		[1.262]
Age (in years)		-0.020		-0.029		0.000		0.028
		[0.021]		[0.018]		[0.031]		[0.028]
Height (in cm)		0.113**		0.099**		0.010		-0.016
		[0.045]		[0.048]		[0.069]		[0.071]
Constant	8.992***	-10.062	9.045***	-7.165	12.060***	9.174	12.006***	12.043
	[0.319]	[8.282]	[0.324]	[8.676]	[0.482]	[12.481]	[0.490]	[12.975]
log Pseudo-Likelihood	-1246.42	-1235.34	-1160.19	-1152.29	-1304.05	-1296.09	-1240.12	-1229.42
Observations	413	411	383	382	457	455	434	432

Dependent variable in (1) to (4) is the switching row in the lottery experiment. Dependent variable in (5) to (8) is the switching row in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 2: Controlling for Education

Dependent Variable:	Willingness to take risks (Experimental Measure)				Impatience (Experimental Measure)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	0.823***	0.600*			-1.262***	-1.084**		
	[0.312]	[0.350]			[0.474]	[0.542]		
Standardized word fluency score			0.823**	0.675**			-0.908*	-0.729
			[0.327]	[0.325]			[0.500]	[0.497]
University-track high school degree	2.408***	2.154**	1.975**	1.483	-0.313	-0.585	-1.552	-1.507
	[0.923]	[0.980]	[0.916]	[0.998]	[1.291]	[1.288]	[1.275]	[1.292]
Vocational high school degree	0.677	0.547	0.868	0.408	1.398	1.003	1.209	1.067
	[0.842]	[0.902]	[0.830]	[0.915]	[1.197]	[1.200]	[1.213]	[1.230]
Other (e.g., remedial education degree)	-2.531**	-2.029*	-1.981	-1.569	0.032	-0.029	1.053	0.886
	[1.204]	[1.228]	[1.254]	[1.261]	[2.072]	[2.029]	[2.113]	[1.954]
No degree, still enrolled in school	0.380	-0.331	0.795	-0.469	1.063	1.166	0.816	1.892
	[1.415]	[1.655]	[1.499]	[1.743]	[2.465]	[2.660]	[2.501]	[2.691]
No degree	-2.745	-2.571	-3.841	-3.86	5.635	5.458	9.808	8.843
	[2.733]	[2.688]	[2.934]	[2.781]	[6.320]	[6.166]	[7.553]	[7.477]
1 if female		0.578		0.861		2.309*		2.833**
		[0.799]		[0.826]		[1.250]		[1.263]
Age (in years)		-0.019		-0.028		0.009		0.036
		[0.023]		[0.021]		[0.033]		[0.030]
Height (in cm)		0.079*		0.076		0.027		0.014
		[0.046]		[0.049]		[0.070]		[0.072]
Constant	8.345***	-4.633	8.415***	-3.462	11.576***	5.481	11.846***	6.286
	[0.589]	[8.482]	[0.596]	[8.909]	[0.887]	[12.773]	[0.891]	[13.197]
log Pseudo-Likelihood	-1237.80	-1228.84	-1153.99	-1148.19	-1302.17	-1294.50	-1235.92	-1225.58
Observations	413	411	383	382	457	455	434	432

Dependent variable in (1) to (4) is the switching row in the lottery experiment. Dependent variable in (5) to (8) is the switching row in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. The university-track category includes"Abitur" and Fachabitur, the most advanced pre-university degrees in Germany; these degrees require the completion of an exam, which is taken at the end of university-track high-schools (Gymnasium or Sekundarstufe II of Gesamtschule). University-track education takes 12 to 13 years (depending on the federal state schooling laws). Vocational high school degree includes "Fachoberschulreife", a less advanced degree, which is completed after only 10 years of schooling. It qualifies for entering advanced vocational education and for obtaining additional schooling at university-track high-schools. The reference category is "Hauptschulabschluss", which is a degree that is less advanced than Fachoberschulreife and qualifies for enrolling in basic vocational schooling. Other degrees comprise qualifications obtained at specialized schools that, for example, provide remedial education. These degrees are typically less advanced than the Hauptschulabschluss. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 3: Controlling for Income and Credit Constraints

Dependent Variable:	Willingness to take risks (Experimental Measure)				Impatience (Experimental Measure)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	0.737**	0.687**			-1.058**	-0.955*		
	[0.337]	[0.337]			[0.519]	[0.526]		
Standardized word fluency score			0.696**	0.713**			-0.843*	-0.735
			[0.317]	[0.314]			[0.486]	[0.486]
Net monthly household income	2.223***	1.645***	2.230***	1.725***	-2.104***	-1.825**	-2.147***	-1.796**
	[0.540]	[0.542]	[0.582]	[0.579]	[0.706]	[0.727]	[0.760]	[0.787]
1 if respondent is credit constrained		-2.704***		-2.370***		2.112*		2.179*
		[0.757]		[0.772]		[1.208]		[1.216]
1 if female	1.054	1.081	1.259	1.251	2.965**	2.820**	3.115**	2.876**
	[0.799]	[0.786]	[0.823]	[0.804]	[1.262]	[1.276]	[1.283]	[1.291]
Age (in years)	-0.025	-0.037*	-0.034**	-0.044**	0.011	0.026	0.026	0.04
	[0.020]	[0.021]	[0.017]	[0.018]	[0.032]	[0.033]	[0.029]	[0.029]
Height (in cm)	0.103**	0.092**	0.096**	0.078*	0.045	0.047	0.006	0.002
	[0.045]	[0.044]	[0.047]	[0.046]	[0.069]	[0.069]	[0.071]	[0.070]
Constant	-24.843***	-17.550*	-23.302**	-15.583	18.207	14.812	24.365*	21.507
	[8.771]	[9.034]	[9.265]	[9.534]	[13.669]	[13.710]	[14.199]	[14.194]
log Pseudo-Likelihood	-1171.23	-1152.61	-1090.34	-1075.45	-1231.30	-1216.49	-1170.29	-1154.24
Observations	393	388	365	361	434	430	413	408

Dependent variable in (1) to (4) is the switching row in the lottery experiment. Dependent variable in (5) to (8) is the switching row in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. The variable "net monthly household income" refers to the current monthly income in Euros of all household members, net of taxes and benefits. For less than 29 percent of respondents, income was only reported in intervals (0 – 750; 750 – 1,500; 1,500 – 2,500; 2,500 – 3,500; 3,500 – 5,000; >5,000). In these cases we used the interval midpoints (7,500 in case of income exceeding 5,000). The indicator for credit constraints is a question that asks: "If you suddenly encountered an unforeseen situation, and had to pay an expense of 1,000 Euros in the next two weeks, would you be able to borrow the money?" Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 4: Robustness Check: Survey Measure of Risk Preference

Dependent Variable:	Willingness to take risks (Survey Measure)			
	(1)	(2)	(3)	(4)
Standardized symbol correspondence score	0.489***	0.268***		
	[0.082]	[0.097]		
Standardized word fluency score			0.445***	0.333***
			[0.090]	[0.091]
1 if female		-0.327		-0.334
		[0.218]		[0.223]
Age (in years)		-0.021***		-0.023***
		[0.006]		[0.005]
Height (in cm)		0.018		0.015
		[0.012]		[0.012]
Constant	4.430***	2.533	4.478***	3.229
	[0.085]	[2.275]	[0.087]	[2.278]
log Pseudo-Likelihood	-2043.99	-2019.81	-1921.23	-1897.10
Observations	902	898	848	845

The dependent variable in columns (1) to (4) is a survey measure of willingness to take risks. Respondents rate their willingness to “take risks, in general” on a scale from 0 to 10, where 0 indicates “not at all willing” and 10 indicates ”very willing”. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table 5: Robustness Check: Arbitrage Between Experiment and Market Interest Rates

Dependent Variable:	Impatience(Experimental Measure)			
	(1)	(2)	(3)	(4)
Standardized symbol correspondence score	-1.178***	-0.982**		
	[0.429]	[0.494]		
Standardized word fluency score			-0.994**	-0.782*
			[0.447]	[0.455]
1 if respondent thought about interest rate	-5.894***	-5.810***	-5.725***	-5.616***
	[0.857]	[0.886]	[0.879]	[0.894]
1 if female		2.324**		2.926**
		[1.158]		[1.192]
Age (in years)		0.022		0.047*
		[0.030]		[0.027]
Height (in cm)		0.050		0.033
		[0.068]		[0.070]
Constant	14.188***	3.45	14.067***	4.745
	[0.617]	[12.198]	[0.630]	[12.693]
log Pseudo-Likelihood	-1279.94	-1272.91	-1219.79	-1209.46
Observations	455	453	433	431

Dependent variable in (1) to (4) is the switching row in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. The independent variable of interest is an indicator for whether a subject reported thinking about market interest rates while making decisions in the experiment measuring impatience. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **, * indicate significance at 1-, 5-, and 10-percent level, respectively.

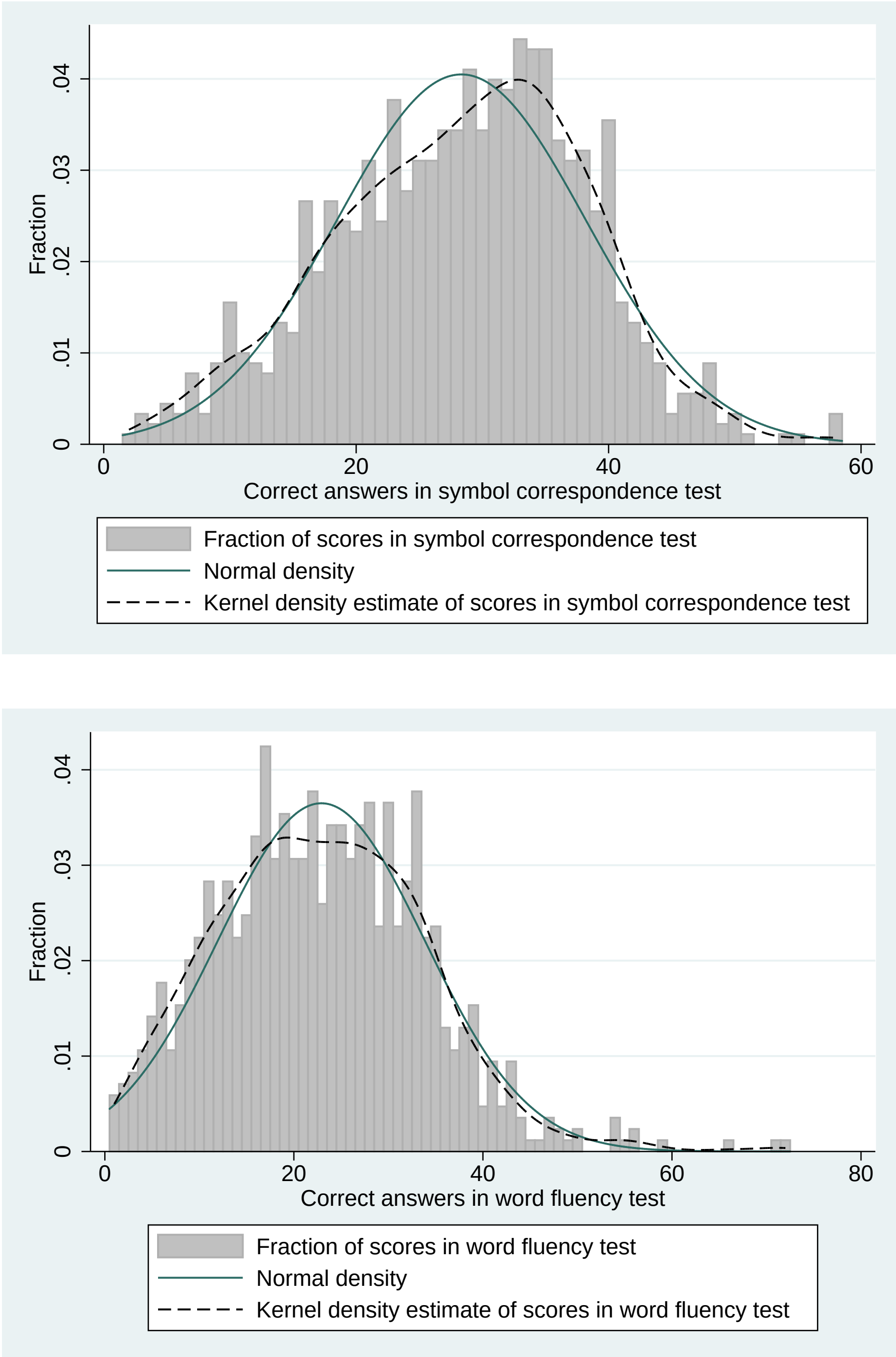
Table 6: Controlling for the Big Five

Dependent Variable:	Willingness to take risks (Experimental Measure)				Impatience (Experimental Measure)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	0.872***	0.668*			-1.172**	-1.085**		
	[0.286]	[0.346]			[0.466]	[0.525]		
Standardized word fluency score			0.959***	0.776**			-0.920*	-0.827
			[0.326]	[0.328]			[0.505]	[0.503]
Conscientiousness	-0.216	-0.085	-0.196	-0.047	0.418	0.325	0.439	0.207
	[0.325]	[0.334]	[0.331]	[0.346]	[0.483]	[0.486]	[0.495]	[0.497]
Extraversion	0.152	0.048	0.262	0.167	1.111**	0.998*	0.398	0.332
	[0.357]	[0.350]	[0.378]	[0.371]	[0.518]	[0.529]	[0.529]	[0.539]
Agreeableness	-0.2	-0.261	-0.174	-0.199	0.277	0.258	0.418	0.353
	[0.315]	[0.302]	[0.334]	[0.326]	[0.509]	[0.509]	[0.539]	[0.537]
Openness	0.923**	0.843**	0.681	0.646	-0.484	-0.575	-0.076	-0.150
	[0.409]	[0.401]	[0.430]	[0.428]	[0.531]	[0.533]	[0.515]	[0.515]
Neuroticism	-0.395	-0.324	-0.252	-0.239	0.622	0.534	0.511	0.362
	[0.324]	[0.337]	[0.341]	[0.354]	[0.472]	[0.468]	[0.513]	[0.509]
1 if female		0.957		1.048		1.908		2.230*
		[0.811]		[0.839]		[1.263]		[1.296]
Age (in years)		-0.013		-0.018		-0.006		0.019
		[0.022]		[0.019]		[0.032]		[0.029]
Height (in cm)		0.106**		0.093*		-0.003		-0.031
		[0.046]		[0.049]		[0.071]		[0.073]
Constant	8.993***	-9.215	9.098***	-6.583	11.973***	11.782	11.980***	15.256
	[0.318]	[8.338]	[0.326]	[8.812]	[0.484]	[12.837]	[0.494]	[13.365]
log Pseudo-Likelihood	-1221.39	-1211.86	-1132.65	-1126.36	-1274.73	-1267.55	-1206.50	-1197.19
Observations	406	404	375	374	447	445	422	420

Dependent variable in (1) to (4) is the switching row in the lottery experiment. Dependent variable in (5) to (8) is the switching row in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. Personality traits –conscientiousness, extraversion, agreeableness, openness, neuroticism – are measured using a short version of the standard "Big Five" questionnaire from psychology. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

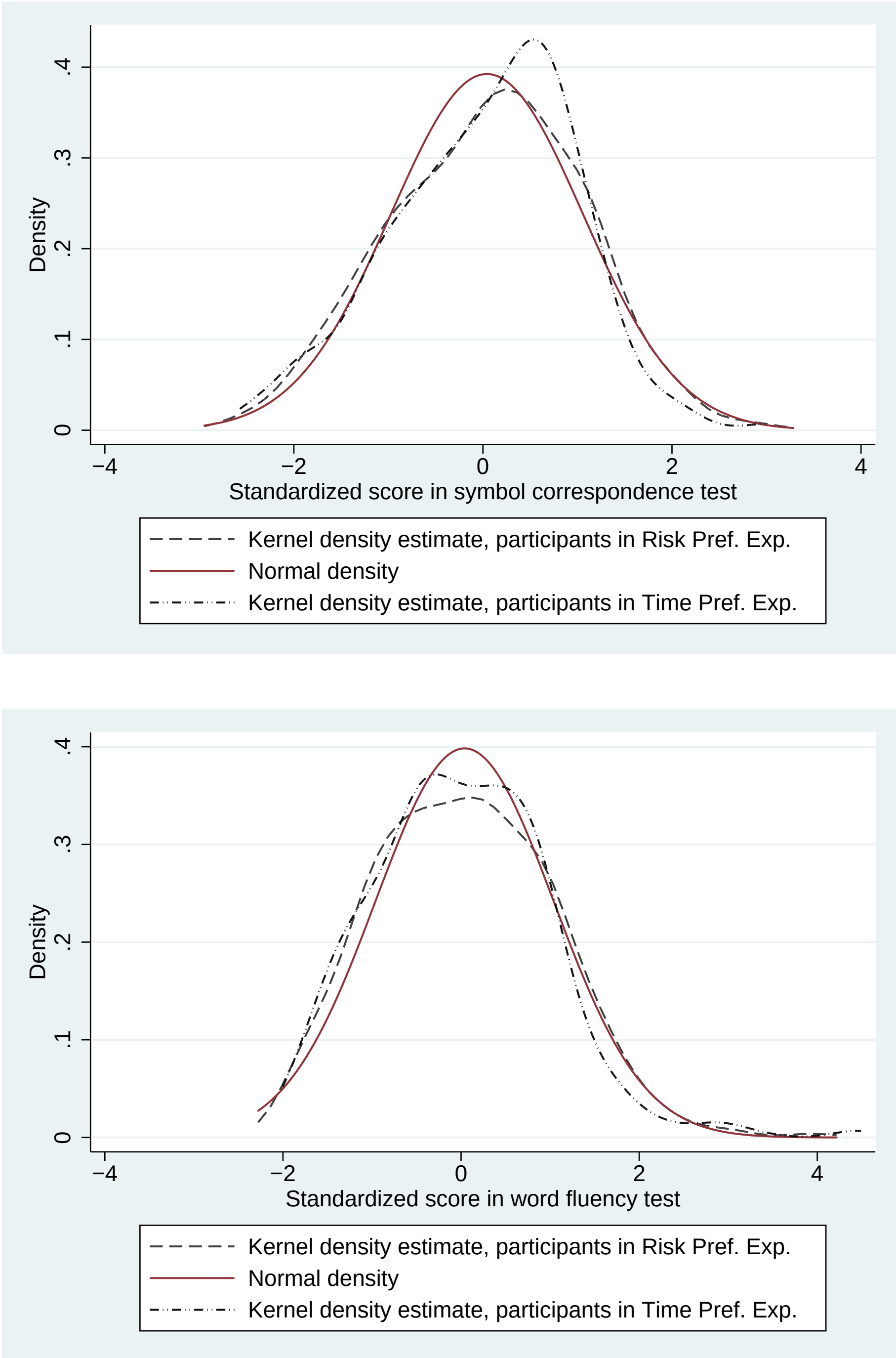
Figures

Figure 1: Distribution of Scores in the Cognitive Skills Tests



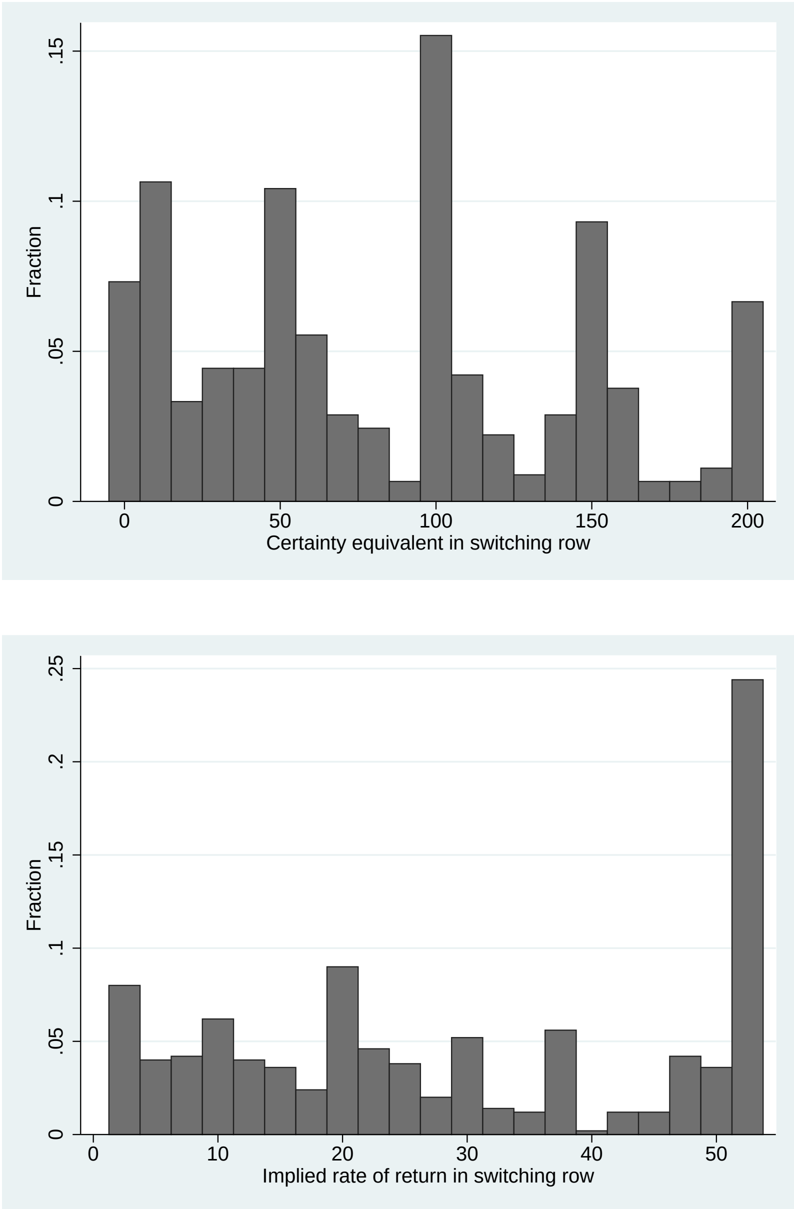
Note: The upper panel shows the histogram of correct responses in the symbol correspondence test. Overlaid is the smoothed density function of the distribution of scores, estimated using a Gaussian kernel. The bandwidth is chosen to minimize the mean integrated squared error if the data were Gaussian. A normal density is also plotted in the graph, with the same mean and variance as the estimated function. The lower panel of the figure shows the histogram of the number of correct recalls in the word fluency test. Graphs of the smoothed density function, and normal density, are estimated in the same way as in the upper panel.

Figure 2: Comparison of Standardized Distributions of Cognitive Skills for Participants in Lottery and Intertemporal Choice Experiments



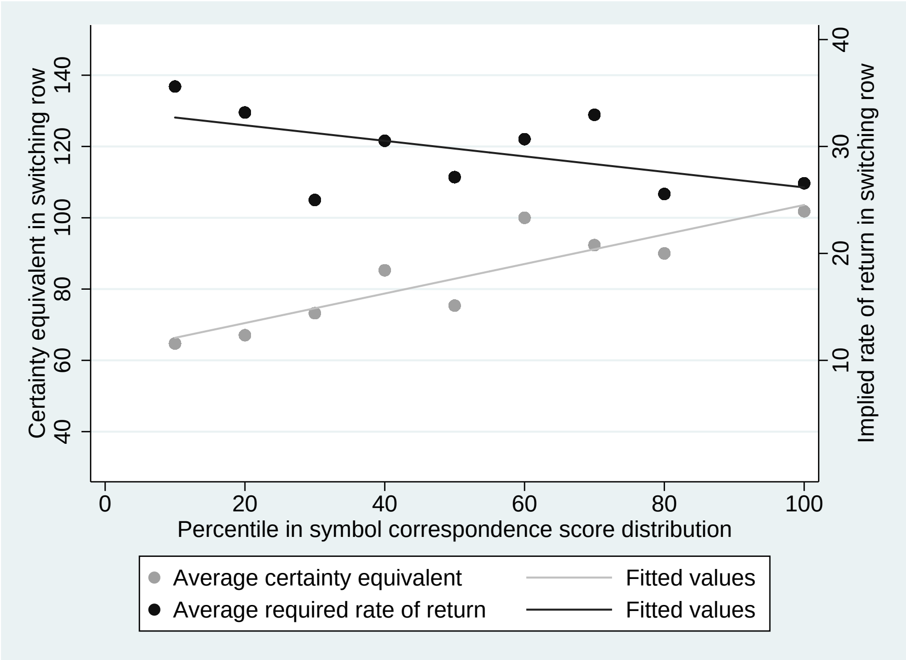
Note: The upper panel shows the smoothed density function of the distribution of standardized scores in the symbol correspondence for two sub-groups: participants in the lottery choice experiment and participants in the intertemporal choice experiment. These density functions are estimated using a Gaussian kernel with a bandwidth chosen to minimize the mean integrated squared error if the data were Gaussian. A normal density function is overlaid for comparison. The lower panel shows the analogous density functions for the word fluency test, separately for participants in the lottery experiment and participants in the intertemporal choice experiment.

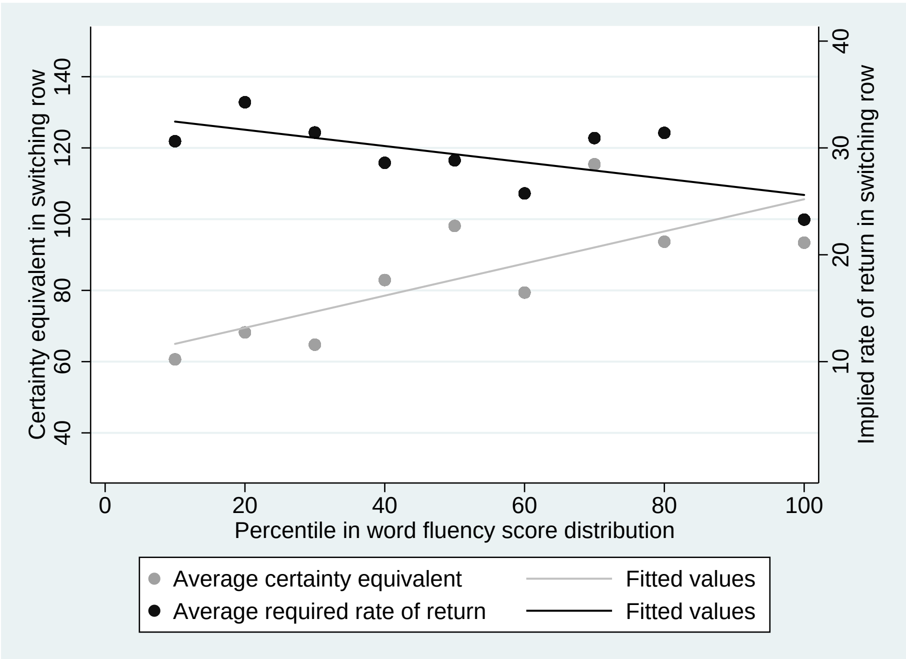
Figure 3: Distributions of Choices in the Lottery and Intertemporal Choice Experiments



Notes: The upper panel of the figure shows the distribution of choices in the lottery experiment. Values are the safe payment necessary to induce a subject to forgo the chance to play the lottery involving 300 Euros or 0 Euros with equal probability. The lower panel shows the distribution of decisions in the intertemporal choice experiment. Values indicate the rate of return, paid one year in the future, necessary to induce a subject to forgo the chance to receive 100 Euros immediately.

Figure 4: Distributions of Experimental Measures of Willingness to Take Risks and Impatience, by Quantiles in the Cognitive Ability Distribution





Note: The upper panel of the figure shows the average value of certainty equivalent (black dots, left vertical axis) and average annual rate of return (light grey dots, right vertical axis) necessary to induce switching, by quantiles of the score distribution of the symbol correspondence test. The lower panel of the figure shows average certainty equivalents and annual rates of return for individuals in different quantiles of the score distribution of the word fluency test.

A Appendix

A.1 Additional Tables

Table A.1: The Link Between Cognitive Ability, Risk Aversion, and Impatience: Different Estimation Methods

Risk Aversion

Dependent Variable:	Willingness to take risks (Experimental measure)							
Estimation Method:	OLS Regression		Cox Proportional Hazards Model		Interval Regression using wider intervals			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	0.809**		-0.109**		0.264***		0.285***	
	[0.326]		[0.055]		[0.096]		[0.102]	
Standardized word fluency score		0.850***		-0.132**		0.250***		0.274***
		[0.290]		[0.052]		[0.081]		[0.086]
1 if female	1.014	1.107	-0.172	-0.184	0.269	0.281	0.269	0.308
	[0.729]	[0.760]	[0.118]	[0.122]	[0.213]	[0.221]	[0.219]	[0.225]
Age (in years)	-0.019	-0.029*	0.002	0.003	-0.005	-0.009*	-0.007	-0.011**
	[0.019]	[0.016]	[0.004]	[0.003]	[0.006]	[0.005]	[0.006]	[0.005]
Height (in cm)	0.112***	0.099**	-0.017***	-0.015**	0.032***	0.027**	0.030**	0.026*
	[0.041]	[0.044]	[0.006]	[0.007]	[0.012]	[0.013]	[0.012]	[0.013]
Constant	-9.381	-6.768			-3.227	-2.249	-2.389	-1.457
	[7.523]	[7.994]			[2.149]	[2.263]	[2.278]	[2.388]
R-squared - log Pseudo-Likelihood	0.06	0.06	-2030.33	-1860.31	-684.57	-638.91	-724.15	-673.82
Observations	411	382	411	382	411	382	411	382

Impatience

Dependent Variable:	Impatience (Experimental measure)							
Estimation Method:	OLS Regression		Cox Proportional Hazards Model		Interval Regression using wider intervals			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	-0.844**		0.140**		-0.242**		-0.189*	
	[0.373]		[0.057]		[0.113]		[0.104]	
Standardized word fluency score		-0.630*		0.109*		-0.230**		-0.163
		[0.345]		[0.056]		[0.110]		[0.099]
1 if female	1.704*	2.044**	-0.243*	-0.265*	0.586**	0.698**	0.435*	0.561**
	[0.907]	[0.934]	[0.135]	[0.141]	[0.281]	[0.286]	[0.251]	[0.255]
Age (in years)	-0.006	0.016	-0.001	-0.003	-0.002	0.004	0.000	0.006
	[0.022]	[0.020]	[0.003]	[0.003]	[0.007]	[0.006]	[0.006]	[0.006]
Height (in cm)	-0.003	-0.020	-0.002	0.001	0.001	-0.003	0.000	-0.005
	[0.051]	[0.052]	[0.008]	[0.008]	[0.016]	[0.016]	[0.014]	[0.014]
Constant	11.611	13.272			2.231	2.696	2.995	3.448
	[9.234]	[9.566]			[2.884]	[2.950]	[2.499]	[2.535]
log Pseudo-Likelihood	0.03	0.04	-1941.34	-1832.76	-871.05	-824.00	-883.45	-834.65
Observations	455	432	455	432	455	432	455	432

The dependent variable in column (1) of the upper table is the switching row in the lottery experiment. Coefficients are from an OLS regression. The regression in column (2) of the upper table is a Cox mixed proportional hazards model, estimating the impact of the independent variables on the hazard rate of switching from the lottery to the safe payment. The dependent variables in column (3) and column (4) of the upper table are constructed using two-row and three-row intervals, respectively, rather than single switching rows for the lottery experiment, to minimize the potential impact of prominent numbers on switching decisions. Dependent variables in columns (1) to (4) of the lower table are defined analogously, except that they are based on switching rows in the intertemporal choice experiment. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

Table A.2: The Link Between Cognitive Ability, Discount Rates, and Curvature of Utility

Dependent Variable:	Imputed Discount Rate (using survey risk measure)		Imputed Discount Rate (using symbol correspondence)		Imputed Discount Rate (using word fluency)		Impatience (Experimental Measure)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Standardized symbol correspondence score	-0.015**		0.004		-0.014*		-1.284**	
	[0.008]		[0.007]		[0.007]		[0.517]	
Standardized word fluency score		-0.012*		-0.006		0.002		-0.897*
		[0.007]		[0.007]		[0.007]		[0.477]
1 if female	0.029	0.035*	0.034**	0.041**	0.039**	0.038**	2.806**	3.052**
	[0.018]	[0.019]	[0.017]	[0.018]	[0.018]	[0.017]	[1.206]	[1.237]
Age (in years)	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.029
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.031]	[0.028]
Height (in cm)	0.000	0.000	0.000	0.000	0.000	0.000	0.030	-0.003
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.069]	[0.071]
Constant	0.146	0.184	0.103	0.108	0.134	0.157	5.377	9.434
	[0.184]	[0.191]	[0.173]	[0.179]	[0.180]	[0.179]	[12.727]	[13.199]
log Pseudo-Likelihood								
Observations	455	432	455	412	412	432	455	432

The dependent variable in columns (1) to (6) is an imputed annual discount rate, based on assuming CRRA utility and using CRRA coefficients to capture curvature of the utility function. CRRA coefficients are predicted using one of the following: answers to a survey question about risk attitudes (columns (1) and (2)); the symbol correspondence score (columns (3) and (4)); or the word fluency score (columns (5) and (6). The dependent variable in columns (7) and (8) is the switching row in the intertemporal choice experiment. Columns (7) and (8) control for curvature of utility using a survey question about willingness to take risks. The specification is non-parametric, including a dummy variable for 10 of the 11 response categories for the survey question, with 0 (not at all willing to take risks) as the omitted category. Scores on the symbol correspondence and word fluency tests are measures of cognitive ability, standardized to have mean 0 and standard deviation 1. Coefficients are marginal effects, estimated using interval regressions to correct for the fact that dependent variables are elicited in intervals. Robust standard errors in brackets; ***, **,* indicate significance at 1-, 5-, and 10-percent level, respectively.

B Experiment Instructions and Choice Tables

In the following we present a translation of the German instructions. Instructions were presented to the interviewer on the screen of the laptop computer, and were read aloud to the subjects by the interviewer.

Screen 1

Now that the interview is over we invite you to participate in a behavioral experiment, which is important for economic science. The experiment involves financial decisions, which you can make in any way you want to. The questions are similar to those asked in the questionnaire with the exception that THIS TIME YOU CAN EARN REAL MONEY!

I will first explain the decision problem to you. Then you will make your decisions. A chance move will then determine whether you actually earn money.

Every 7th participant wins!

HOW MUCH MONEY YOU WILL EARN AND AT WHICH POINT IN TIME WILL DEPEND ON YOUR DECISIONS IN THE EXPERIMENT.

If you are among the winners, your amount will be paid by check. In this case the check will be sent to you by post.

Screen 2

Participants are now shown a choice table for the respective experiment as an example. The table is printed on a green piece of paper and is handed to participants for them to study.

The experimenter continues explaining how the experiment will work.

In the lottery experiment, the interviewer gave the following explanation:

In each row you see two alternatives. You can choose between

- A fixed amount that you get "for sure"
- and an "all or nothing" lottery, where with 50 percent probability you can win 300 Euros and with 50 percent probability you win nothing.

You start with row 1 and then you go down from row to row. In each row you decide between a safe payment (column A) and the lottery (column B). The lottery is the same in all rows. Only the amount on the safe payment (left) increases from row to row.

Which row will be relevant for your earnings will be determined by a random device later.

In the intertemporal choice experiment, the interviewer gave the following explanation:

In each row you see two alternatives. You can choose between

- A fixed amount of 100 Euro (column A "today")
- and a somewhat higher amount, which will be paid to you only "in 12 months" (column B).

Payment "today" means that the check you get can be cashed immediately.
Payment "in 12 month" means that the check you get can be cashed only in 12 months.

You start with row 1 and then you go down from row to row. In each row you decide between 100 Euro today (column A) and a higher amount (column B); please always keep the timing of the payments in mind. The amount on the left side always remains the same, only the amount on the right side increases from row to row.

Which row on one of the tables will be relevant for your earnings will be determined by a random device later.

<u>Screen 3</u>

As you can see, you can earn a considerable amount of money. Therefore, please carefully consider your decisions.

Can we start now?

If the participant agreed, the experiment started. If not, the experimenter said the following:

The experiment is the part of the interview where you can earn money! Are you sure that you DO NOT WANT TO PARTICIPATE?

If the participant still did not want to participate, the experiment was not conducted and the participant answered a few final questions. In case the subject wanted to participate the experiment began.

The choice table was presented to the subject on a white piece of paper. For the elicitation of willingness to take risks, the subjects were asked to make the decisions that are listed in Table A.3below:

Participants studied their table. Then the experimenter asked for the subject's decision in each row, whether they preferred the option in column A or B, starting with the first row. In case a participant preferred the fixed payment the experimenter asked:

You have decided in favor of the fixed payment. We assume that this implies that for all higher amounts you also prefer the safe payment, meaning that for all remaining rows all higher amounts will be selected (i.e., column A)

If the participant did not agree, he kept on deciding between columns A and B.

In the intertemporal choice experiment, impatience over a year-long time horizon was inferred from subjects' choices Table A.4 shown below.

A similar procedure to the lottery experiment was followed, such that the experimenter

Table A.3: Choices in the Risk Preference Experiment

	safe payment		lottery
1)	€0 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
2)	€10 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
3)	€20 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
4)	€30 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
5)	€40 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
6)	€50 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
7)	€60 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
8)	€70 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
9)	€80 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
10)	€90 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
11)	€100 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
12)	€110 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
13)	€120 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
14)	€130 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
15)	€140 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
16)	€150 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
17)	€160 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
18)	€170 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
19)	€180 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0
20)	€190 for sure	or	50 percent chance of winning €300 and 50 percent chance of getting €0

Table A.4: Choices in the Intertemporal Choice Experiment

	Column A		Column B
1)	€100 today	or	€102.5 in 12 months
2)	€100 today	or	€105.1 in 12 months
3)	€100 today	or	€107.6 in 12 months
4)	€100 today	or	€110.2 in 12 months
5)	€100 today	or	€112.8 in 12 months
6)	€100 today	or	€115.5 in 12 months
7)	€100 today	or	€118.2 in 12 months
8)	€100 today	or	€121.0 in 12 months
9)	€100 today	or	€123.7 in 12 months
10)	€100 today	or	€126.5 in 12 months
11)	€100 today	or	€129.3 in 12 months
12)	€100 today	or	€132.2 in 12 months
13)	€100 today	or	€135.1 in 12 months
14)	€100 today	or	€138.0 in 12 months
15)	€100 today	or	€141.0 in 12 months
16)	€100 today	or	€144.0 in 12 months
17)	€100 today	or	€147.0 in 12 months
18)	€100 today	or	€150.0 in 12 months
19)	€100 today	or	€153.1 in 12 months
20)	€100 today	or	€156.2 in 12 months

asked for the subject's decision in each row, whether they preferred the option in Column A or B, starting with the first row. In case a participant preferred the higher, delayed amount the experimenter asked:

You have decided in favor of the higher amount of in months. We assume that this implies that for all higher amounts you also prefer the later payment, meaning that for all remaining rows all higher amounts will be selected (i.e., Column B)

Then it was determined whether the participant was among those who would be paid. Participants could choose their "lucky number" between 1 and 7. They could then press on one out of seven fields on the computer, which represented numbers from 1 to 7. If they hit "their" number they won, otherwise they did not win. In case they won, it was determined which of the tables was selected and which row of the respective table. This was done again by pressing on fields presented to participants on the computer screen. In the end subjects who had won were informed that they would be sent the check by mail.