Who is "Behavioral"?
Cognitive Ability and Anomalous Preferences

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Abstract

In this paper, we ask whether variation in preference anomalies is related to variation in cognitive ability. Evidence from a new laboratory study of Chilean high school students shows that small-stakes risk aversion and short-run discounting are less common among those with higher standardized test scores, although anomalies persist even among the highest-scoring individuals. The relationship with test scores does not appear to result from differences in parental education or wealth. A laboratory experiment shows that reducing cognitive resources using a "cognitive load" manipulation tends to exacerbate small-stakes risk aversion, with similar but statistically weaker effects on short-run impatience. Explicit reasoning about choice seems to reduce the prevalence of these anomalies, especially among the less skilled. Survey evidence suggests that the role of cognitive ability may extend to adult behaviors that are related to small-stakes risk preference and short-run time preference.

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1 Introduction

Recent research argues that preference "anomalies," such as short-term discounting and small-stakes risk-aversion, are fundamental to a wide range of economic behaviors (e.g., Angeletos et al, 2001; Benartzi and Thaler, 1995). Despite intensifying interest in the role of such deviations, surprisingly little attention has been paid to the question of *which* economic agents are most susceptible to these biases. Understanding this heterogeneity is an important step in applying insights from psychology to markets, because in real-world markets, not all decision-makers carry the same weight (Friedman, 1953).[1]

In this paper, we ask whether variation in preference anomalies is related to variation in cognitive ability. We approach this question both by testing whether cross-sectional variation in cognitive skills predicts variation in expressed preferences, and by studying the effects of experimental manipulations that vary the extent to which cognitive resources are deployed in making choices. Combining these two approaches allows us to measure the extent of heterogeneity in preferences directly, and to make some progress towards understanding the cognitive processes that generate that heterogeneity.

To measure the cross-sectional relationship between anomalous preferences and cognitive skills, we conducted a laboratory study of the small-stakes risk preferences and short-run time preferences of seniors in a Chilean high school, whose standardized test scores are representative of the top half of the national test-taking distribution. We find that higher cognitive ability—especially mathematical ability—is predictive of much lower levels of small-stakes risk aversion and short-run impatience. For example, we calculate that a one-standard-deviation increase in measured mathematical ability is associated with an increase of about 8 percentage points in the probability of behaving in a risk-neutral fashion over small stakes (as against a mean probability of about 10%) and an increase of about 10 percentage points in the probability of behaving patiently over short-run trade-offs (with a mean of about 28%). Nonetheless, we find substantial levels of preference anomalies even among the most cognitively able individuals.

Evidence from a second laboratory study of Chilean high school seniors shows that the relationship between cognitive ability and patience is specific to intertemporal choices between immediate and delayed rewards, and is not present when we measure time preference using choices between two rewards that come with a significant delay. This finding is especially interesting in light of

[1] For example, the market for payday lending and check-cashing is especially sensitive to the biases of those with limited assets (Caskey, 1994; Bertrand, Mullainathan and Shafir, 2004), whereas the behavior of aggregate savings is disproportionately sensitive to the biases of those with substantial wealth (Saez and Kopczuk, 2004).

recent evidence that these two types of time preference are governed by separate neural systems, with the prefrontal and parietal cortices (which are the brain regions that appear to mediate the influence of general cognitive ability on behavior)[2] more often involved in choices between delayed rewards (McClure et al, 2004).

The data from the second study also contain a set of measures of parental education, wealth, and income, allowing us to test for a role of socioeconomic status in determining preferences. These variables have only a weak and fairly unsystematic relationship with measured preferences, and our main conclusions are robust to including them as controls. In a subsample for which we have data on the preferences of siblings, our findings are too imprecise to draw any conclusions about the within-family relationship between preferences and cognitive ability. We do show, however, that there is very little relationship among siblings' preferences, suggesting that family background factors are unlikely to explain a significant share of the variation in these preferences.

In a final laboratory study, we test directly for a causal effect of cognitive resources on measured preferences, by subjecting participants to a cognitive load manipulation designed to decrease working memory (e.g., Baddeley and Hitch, 1974; Gilbert and Silvera, 1996). The cognitive load manipulation caused a statistically significant increase in one of our two measures of small-stakes risk aversion, as well as statistically insignificant increases in all of our other measures of preference anomalies.

We also attempted to increase the use of higher-order cognitive processes by conducting a manipulation in which we asked participants to think about and express the reasons for their choices (Wilson and Schooler, 1991). Requiring additional reasoning tended to reduce anomalous behavior, especially among those with low measured cognitive ability.

The results from our three studies are largely consistent with "two-systems" models of decision-making (Bernheim and Rangel, 2004; Loewenstein and O'Donoghue, 2005; Fudenberg and Levine, 2006; Brocas and Carillo 2005), which posit that cognitive resources are needed to override impulsive instincts.[3] Only our finding that selfish behavior in a Dictator Game is positively related to cognitive ability (in study 2) stands out as inconsistent with the two-systems framework, and this correlation is relatively less robust than the other relationships between preferences and ability that we document. Moreover, we argue in the paper that other interpretations of our findings—such as reverse causality (from preferences to skills) and differences in pure computational skill—are

[2] See Gray, Chabris, and Braver, 2003.

[3] While our finding that cognitive load tends to increase selfish behavior is consistent with the predictions of these models, our finding that more cognitively able individuals tend to exhibit greater selfishness seems more difficult to reconcile. However, this correlation is less statistically robust than those we estimate find for risk and time preferences.

unlikely to provide a complete explanation for our results.

As a first look at whether our results extend beyond the laboratory, we present evidence from the National Longitudinal Survey of Youth 1979 (NLSY) on the relationship between cognitive ability (as measured by standardized test scores) and a set of real-world behaviors—low levels of asset accumulation, obesity, smoking, and low levels of financial market participation—that have been argued to arise from some form of small-stakes risk aversion or short-run impatience.[4] In all cases, we find a negative relationship between cognitive ability and the presence of the anomalous behavior, with mathematical ability playing an especially important role. These relationships survive extensive controls for income, as well as family fixed effects, which we implement by taking advantage of the presence of sibling groups in the NLSY.[5]

Our finding that cognitive ability is correlated with measured preferences (and associated behavioral outcomes) relates to a large literature in cognitive science on the correlates of cognitive ability (see Jensen, 1998, for a review). In the paper most closely related to our own, Frederick (2005) has independently shown that performance on a range of cognitive tests correlates negatively with impatience and risk-aversion. We are aware of some other existing work examining the relationship between cognitive ability and impatience (Melikian, 1959; Funder and Block, 1989; Shoda, Mischel, and Peake, 1990; Parker and Fischhoff, 2005; Bettinger and Slonim, 2005; Kirby, Winston, and Santiesteban, 2005), and one paper that studies a relationship between cognitive ability and dictator game giving (Brandstätter and Güth, 2002), but no other research that addresses the relationship between cognitive ability and risk-aversion.[6] Our work differs from these existing papers primarily in addressing possible confounds from family background and reverse causality from preferences to cognitive skills, distinguishing among discounting at different horizons, and taking steps toward identifying causal mechanisms.[7]

More broadly, our evidence on the heterogeneity in anomalous preferences relates to recent economic research into individual differences in decision-making skills and strategies (see, e.g., Lillard and Willis, 2001; Kézdi and Willis, 2002; Bernheim, Garrett and Maki, 2001; Ameriks, Caplin and Leahy, 2003; and Lusardi, 2003). A growing experimental literature argues that the

[4] For examples of alternative possible determinants of these behaviors, see Lakdawalla and Philipson (2002); Becker, Grossman and Murphy (1994); and Constantinides, Donaldson and Mehra (2002).

[5] See also, for example, Heckman, Stixrud, and Urzua (2006) for evidence on the cognitive and non-cognitive determinants of adult behaviors.

[6] Donkers, Melenberg, and Van Soest (2001) find that risk-aversion is negatively correlated with education (in hypothetical choices). There is some evidence that complexity of a choice problem influences expressed risk preference, suggesting that cognitive limitations may play a role in risk-taking behavior (Huck and Weizsäcker, 1999).

[7] A separate but related psychological literature argues that individuals with greater cognitive skills display fewer biases in judgment and decision-making (such as the sunk-cost fallacy, gain-loss framing, and the conjunction fallacy) in hypothetical choice scenarios (Stanovich, 1999; Stanovich and West, 1998)

presence of heterogeneity affects the potential for sorting into activities, which in turn may either attenuate or exacerbate the role of biases in the marketplace (see, e.g., Haigh and List, 2005; Lazear, Malmendier and Weber, 2004).

Finally, our experimental results on the effects of cognitive resources on decision making relate to a growing empirical (e.g., McClure et al, 2004; Breiter et al, 2001; Shiv et al, 2005; Chakravarty et al, 2005) and theoretical (Bernheim and Rangel, 2004; Loewenstein and O'Donoghue, 2005; Fudenberg and Levine, 2006; Brocas and Carillo 2005) literature on the cognitive and emotional foundations of economic preferences. The results of our cognitive load manipulation relate most closely to the work of Hinson, Jameson, and Whitney (2002) and Shiv and Fedorikhin (1999), who show that cognitive load increases impulsive behavior.

The remainder of the paper is organized as follows. Sections 2 and 3 present the results from our two studies of Chilean high school seniors. Section 4 analyzes the results from our experimental study of Chilean high school juniors. Section 5 presents survey evidence on the relationship between cognitive ability and adult behaviors. Section 6 concludes.

2 Evidence on Preferences and Cognitive Ability

In this section, we ask whether small-stakes risk aversion and short-run time preference are less common among individuals with greater measured cognitive ability. Using data from a laboratory study of Chilean high school seniors, we show that individuals with greater measured cognitive ability are more likely to be risk-neutral over small stakes and patient over short time horizons. We further show that preferences are much more strongly related to mathematical than to verbal ability, and that differences in cognitive ability arising in elementary school play a more important role than those arising between elementary school and high school. Finally, we argue that differences in gender or area of residence do not explain our results.

2.1 Study 1: Chilean High School Seniors

2.1.1 Participants

Participants were students at a semi-private high school in Santiago, Chile. The participants were the 92 out of 160 members of the senior class (during academic year 2004-05) who submitted the parental consent forms necessary for participation in the study. Most participants entered the school for kindergarten at age 4 or 5. Some students were admitted because older siblings had attended, but most were admitted on the basis of adequate performance on an entry exam. Most students (more than 80%) had received their entire formal education at the school. Therefore, these participants had had a similar schooling experience. None had received any formal schooling in economics. We held a single 30-minute experimental session on August 24, 2004, with participants sitting in widely-separated desks in the school gym.

2.1.2 Measured Cognitive Ability

In cognitive science, "general cognitive ability" (or g) refers to the most important common factor (as derived from factor analysis) underlying performance on a range of cognitive tests (Jensen, 1998). A variety of "intelligence tests" have been devised to measure general cognitive ability and assess its correlation with behaviors and outcomes. Although it is about 50% heritable (Plomin et al., 2001), general cognitive ability is also influenced by education and other life experiences (e.g., Cascio and Lewis, 2005). Many common measures of academic achievement largely pick up general cognitive ability, even though they also reflect personality traits such as conscientiousness (e.g., Paunonen and Ashton, 2001). For example, grades in elementary school can proxy for general cognitive ability, with a correlation coefficient around 0.70 (Jensen, 1998). Scholastic Assessment Test (SAT I) scores correlate greater than 0.80 with measures of general cognitive ability, with most of the association apparently driven by the math section of the SAT I (Frey and Detterman, 2004).

In our studies, we measure cognitive ability with standardized test scores and school grades. At the end of their senior year, Chilean high school students take a national standardized test, the Prueba de Selección Universitaria (PSU), which has two obligatory sections—Math and Verbal—as well as specific subject-area sections. The math section is very much like the SAT I Math Section, while the verbal section covers literary concepts, reading comprehension, logical paragraph organization, and vocabulary. For many Chilean universities, the PSU score together with GPA are the sole determinants of admission. Because performance on the exam is so important, seniors at this school take monthly practice tests. We obtained 5 practice test scores (for April through August, 2004) from the school for each participant. The students' scores range from the 45th percentile to the 99th percentile of the test-taking population distribution (Universidad de Chile, 2004), suggesting that our sample provides good coverage of at least the top half of the ability distribution.[8] Our primary measure of cognitive ability for these students will be the average of the

[8] Among all seniors enrolled in non-vocational schools, 31.5 percent take the PSU exam (see <http://www.demre.cl/estadisticas.htm>). For comparison, the 1.4 million students in the class of 2003 who took the SAT (College Board, 2003) represented about 32.3 percent of total grade 12 enrollment in the U.S (U.S. Census, 2003).

five practice exam scores, standardized by the sample standard deviation.[9] The school also gave us grade point averages for grades 1 through 11 for all students participating in our study for whom such data were available.

The fact that our measures of cognitive ability involves knowledge obtained through schooling raises the possibility of reverse causality in our estimates, if students' preferences determine the extent to which they invest in acquiring cognitive skills. We defer discussion of this issue to section 4.4, where we argue based on several pieces of evidence that this explanation cannot account for important portions of our findings.

2.1.3 Measured Risk and Time Preferences

Small-Stakes Risk Preference. We elicited risk preferences with five questions of the following form (dollar-equivalents at the then-current exchange rate of 632 pesos/$ are in brackets):

> Please circle either Choice A or Choice B.
> (A) You get 250 pesos [$0.40] for sure.
> (B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

where X was 400, 550, 700, 850, and 1000 pesos [$0.63, $0.87, $1.11, $1.34, and $1.58]. In each case, (A) is the safe bet, and (B) is the risky bet.

The normative benchmark for decision-making under risk is expected utility theory, with the utility function defined over wealth (or consumption) levels. In the problems we posed to participants, any reasonable expected-utility preferences imply perfectly risk-neutral behavior: choosing the safe bet for $X = 400$ pesos and choosing the risky bet for all other values of X. Following Rabin (2000), if a participant our study were an expected-utility maximizer, then choosing anything other than the expected-value-maximizing option would imply that the person would turn down a gamble that gives a 50% chance of losing $2.50 and a 50% chance of winning an infinite amount of money![10] (Put another way, an expected-utility maximizer with a constant relative risk-aversion utility function and lifetime wealth of $100,000 would make this decision only if the coefficient of

[9] In cases where one or more of the exam scores was missing, we used the mean of the non-missing values of the practice exam scores. If exam scores for a given student are draws from a distribution with the same mean, this approach will yield the maximum-likelihood estimate of that mean. In all, 9 of the 92 students were missing one mathematics score, and one student was missing two mathematics scores. Seven of the 92 students were missing one verbal exam score, and no students were missing more than one verbal score. Even without missing data, of course, some measurement error will remain in our estimate of the "population" mean of the student's exam scores, which, if anything, will tend to attenuate the relationships we estimate between preferences and cognitive skills.

[10] To be more precise, if an expected utility maximizer would choose $0.40 for sure over a 50% chance of $0.87 for all initial wealth levels, then he would turn down a gamble that gives a 50% chance of losing $2.50 and a 50% chance of winning an infinite amount of money. Even if this behavior were not required at all initial wealth levels, it still implies an enormous degree of risk aversion over large stakes.

relative risk-aversion exceeded 35,000!) The reason is that risk-aversion over such small stakes requires non-negligible local concavity that, when extrapolated, leads to extraordinary risk-aversion over larger stakes. Because this behavior over larger-stakes gambles is obviously implausible, the risk-averse choice of the safe bet when $X = 400$ pesos is quantitatively inconsistent with standard expected utility theory. Making the risk-averse choice of the safe bet when X is larger than 400 pesos implies even more extreme risk-aversion over larger stakes and is therefore even more questionable.[11] Risk-averse behavior in our experiment therefore represents a deviation from standard expected utility theory, but could be consistent with theories of risk aversion over *changes* in wealth (such as Kahneman and Tversky, 1979).[12]

Although we cannot connect our measure of risk-aversion directly with participants' market behavior, there is some evidence to suggest that risk aversion parameters elicited through choice tasks are related to real-world behaviors. For example, Barsky et al. (1997) find that measures of risk aversion derived from survey responses to hypothetical situations predict risky behaviors such as smoking, drinking, failing to have insurance, and holding stocks rather than Treasury bills.

Short-Term Time Preference. We measured time preferences with six questions of the form:

> Please circle either Choice A or Choice B.
> (A) You get 500 pesos [$0.79] right now.
> (B) You get X a week from now.

For the six questions, X was 450, 550, 650, 750, 850, and 950 pesos [$0.71, $0.87, $1.03, $1.19, $1.34, and $1.50]. Any sensible preferences imply choosing (A) when $X = 450$; this question diagnoses whether a participant understands the question and is taking the task seriously. The patient choice is always (B) for all other values of X.

[11] The risk-seeking choice of the risky bet for $X = 200$ pesos is similarly suspect. Even if risk-loving preferences are considered acceptable over larger stakes, they are inappropriate in this context of small stakes. Assuming a convex utility function, an argument analogous to Rabin's (2000) calibration theorem would show that the risk-seeking choice of the risky bet for $X = 200$ pesos is quantitatively inconsistent with standard expected utility theory. Such a choice for an expected-utility maximizer would imply a counterfactual degree of risk-seeking over somewhat larger stakes. Therefore, we take risk-neutrality as the normative benchmark in our studies.

[12] In a gamble that involves possible losses, loss aversion interacts with narrow framing—a tendency to view gambles in isolation from large pre-existing, independent financial risks (such as stock market fluctuations)—to exacerbate risk-aversion (Barberis, Huang and Thaler, 2003; Read, Loewenstein, and Rabin, 1999). With narrow framing, loss aversion makes a gamble that involves a potential loss especially unappealing. However, when combined with large independent gambles, the probability is virtually zero that the gamble at hand will be pivotal in whether the individual earns a net gain or loss. Whether narrow framing leads to more or less small-stakes risk aversion in gambles like ours that involve only gains depends on the functional form of the utility function over gains. (For example, with CARA utility over gains, narrow framing does not affect risk aversion over gambles that involve only gains.) For that reason, we do not take a strong stand on whether the preference heterogeneity we measure is due to differences in the curvature of the utility function or differences in the way agents frame risks. Nonetheless, our data provide reason to doubt that differences in choice framing play a large role in the differences in behavior across cognitive ability levels. For example, there is no detectable covariation between cognitive ability and the difference between behavior in the risk-aversion section with gains only and the section with possibility of loss.

Time-consistent exponential discounting with reasonable parameters requires behaving patiently in these questions. Under exponential discounting, an impatient choice implies an absurdly high discount rate. For example, a person indifferent between receiving 500 pesos now and 550 pesos in one week is implicitly discounting cash flows at a rate of $52 \times \ln\left(\frac{550 \text{ pesos}}{500 \text{ pesos}}\right) \approx 496\%$ per annum![13] Someone who makes the impatient choice for larger values of X is implicitly discounting at an even higher rate. Such high discount rates imply virtually no regard for the future, which seems unlikely to be the correct explanation of a participant's impatient choice in this decision problem. Although impatient behavior represents a deviation from the normative benchmark of exponential discounting, it may be consistent with hyperbolic or quasi-hyperbolic discounting (e.g., Laibson 1997).

Although our approach is a standard laboratory tool for measuring time preference (Frederick, Loewenstein and O'Donoghue, 2002), there are a number of reasons why questions like those we use may not actually measure impatience. First, it may be that participants believe that patient choices are more socially acceptable and therefore more likely to please the experimenter, which could create a confound if higher ability participants are more motivated to please the experimenter (List and Levitt, 2005). To minimize this concern, we told participants that "there are no right or wrong answers...Which choice you make is a matter of personal preference." Additionally, our measurement of risk aversion will serve as a partial robustness check against this account, since it is difficult to imagine why participants would have perceived risky gambles as the more socially acceptable choice.

Another potential concern is that participants may not trust that they will actually receive the delayed reward if they make the patient choice. In our study, we promised to pay participants in cash in a week if they made the patient choice, and in cash the next day if they made the impatient choice. At the very end of the experimental procedure, we asked them, "Did you believe that you would actually get paid in a week if you chose to take the money in a week?" Of our 92 participants, 90 said they believed they would get paid in a week. Additionally, the two participants who did not believe they would receive the money in a week actually had higher-than-average mathematical ability, suggesting that heterogeneity in trust is not likely to bias our results toward finding that more able individuals are more patient. By delivering cash payments in school to participants, we

[13] Imputing an exact discount rate over utility flows from the individual's indifference between the two cash flow streams requires assumptions about the utility function. However, Arrow (1971) and Rabin (2000) imply that, for participants with a reasonable amount of lifetime wealth, utility should be approximately linear over the small-stakes choices we offer. Within the standard model, the discount rate over small cash flows therefore approximates the discount rate over utility flows.

minimized transaction costs and equalized them across the patient and impatient choices.[14]

Most fundamentally, according to economic theory, questions involving monetary rewards should not measure impatience, since people can (in principle) borrow or lend money at the market rate of interest regardless of how they discount future utility (Fuchs, 1982). However, in most experiments like ours, most participants behave much less patiently than the market rate of interest (Frederick, Loewenstein and O'Donoghue, 2002) either because they are liquidity-constrained or because they misunderstand that money is fungible. In either case, questions involving monetary rewards do measure discounting over utility. Consistent with this interpretation, variation in discounting measured in a manner similar to the one we employ here predicts variation in discounting-related behaviors such as drug addiction (e.g., Kirby, Petry, and Bickel, 1999; Kirby and Petry, 2004), cigarette smoking (Fuchs, 1982; Bickel, Odum, and Madden 1999), excessive gambling (Petry and Casarella, 1999), use of commitment savings devices (Ashraf, Karlan, and Yin, 2004), and rapid exhaustion of food stamps (Shapiro, 2005) (see also Loewenstein, Read, and Baumeister, 2003). Of course, it is possible that lower ability individuals are more likely to be liquidity-constrained and appear to be less patient as a result. We will show later that controlling for parents' education, income, and wealth does not meaningfully affect the relationship we estimate between ability and time preference, which casts doubt on this possibility.

2.1.4 Procedures

After handing out a questionnaire booklet to each participant, an experimenter guided participants through the questionnaire in unison by reading instructions aloud. The questionnaire was divided into sections (with neutral labels such as "Choices" and "More Choices"), each of which elicited a type of preference. The questionnaire contained a section that elicited small-stakes risk preferences, followed by a section that elicited short-term time preferences, then a small-stakes risk preferences section that allowed for the possibility of losses, and finally a section that asked a few demographic questions.[15]

Participants were paid in cash for their choices in the risk-preferences sections, as well as paid a participation fee of 1250 pesos [$2.00], during lunch break the following day. Participants who

[14] Participants were told that if they missed school on the payment day, their homeroom teacher would hold their payment envelope until they came to school. Two participants who chose the immediate reward were absent in school the next day and received their payment the following day. All participants who chose the delayed reward were present in school when they were paid the next week.

[15] We discuss the questionnaire in English even though it was administered in Spanish. The questionnaire was written in English, translated into Spanish by a native Spanish speaker, and back-translated into English by a different native Spanish speaker. The back-translated version closely matched the original.

chose to be paid "now" in the time-preference section were also paid in cash for that section at the same time. Participants who chose to be paid "a week from now" in the time-preference section were paid in cash during lunch break one week after the experiment.

Small-Stakes Risk Preference. The section of the questionnaire that elicited risk preferences comprised exactly the five questions described above. To make sure that participants understood the choices they were making, we gave them an example question in the instructions for these sections. We also informed participants that they would answer five questions of the above form. Finally, we gave participants the opportunity to ask any questions about the instructions. There was no stated time limit for answering the questions, but we waited about 6 minutes for all participants to finish before moving on. We then rolled a die five times to determine their payment.

The questionnaire contained all five questions on the same page, with the risk reward X in ascending order. This presentation made salient to participants the strategy of choosing (A) (the safe bet) for small X and (B) (the risky bet) for large X. In fact, 70 out of 92 gave monotonic responses, choosing (A) below some threshold value of X and (B) above it.[16]

Small-Stakes Risk Preference With Possibility of Loss. This section was the same as the small-stakes risk preference section, except that each outcome paid 250 pesos less in the second risk section. That is, (A) paid 0 pesos, and option (B) gave a 50% chance of losing 250 pesos [$0.40] and a 50% chance of winning X, where X was 150, 300, 450, 600, and 850 pesos [$0.23, $0.47, $0.71, $0.94, and $1.18].

Short-Term Time Preference. We measured time preferences with six questions as described above. For each question, the participant chose between 500 pesos today and X a week from today. All six questions were on the same page, with the delayed reward X in ascending order. In the instructions for this section, the experimenter gave participants an example question, told them that a die roll would select the question to be implemented, and gave them a chance to ask questions. Participants took about 6 minutes to answer the six questions. The instructions explained that participants would receive cash to pay them for this section. The cash would be paid at lunchtime the next day if the participant had chosen (A) for the relevant question, or at lunchtime in a week if the participant had chosen (B).

We ordered the questions with the delayed reward X in ascending order to make obvious to participants the strategy of choosing (A) (the immediate payoff) for small X and (B) (the delayed payoff) for large X. As it turned out, 87 out of 92 participants chose (A) below some threshold

[16] In all cases, we present statistical results for the whole sample of subjects but note that our results are substantively unchanged if we restrict attention to only those subjects whose responses were monotonic.

value of X and (B) above it. The high degree of monotonicity in these choices serves as a check against the view that behavior in the study was random or unsystematic due to the small stakes we employed.[17] It also suggests that the variation in preferences we measure is not primarily due to variation in the degree of randomness or inconsistency in participants' choices.[18]

Demographics. Participants recorded their age, sex, course of study, and municipality of residence.

2.2 Results

2.2.1 Preferences and Mathematical and Verbal Ability

Column (1) of table 1 presents probit estimates of the effects of mathematical ability on the participant's propensity to display perfect risk-neutrality. Coefficients can be interpreted as marginal effects evaluated at the mean of the independent variables. We estimate that a one-standard-deviation increase in measured mathematical ability is associated with an 8 percentage point greater likelihood of risk-neutrality, a statistically and economically significant effect given the base rate of 11%.

Existing evidence suggests that verbal exam scores tend to be less closely related to general cognitive ability than mathematics exam scores (Frey and Detterman, 2004). If the relationship we observe in column (1) is driven by variation in general cognitive ability, we might therefore expect verbal scores to be less strongly related to preferences than mathematics scores.

In column (2), we include a measure of verbal ability in the specification. Although the two test score measures are highly correlated (with a correlation coefficient of 0.46), there is still enough independent variation to draw preliminary conclusions about their relative strength in explaining variation in measured preferences. Indeed, the coefficient on mathematical ability is far larger than that on verbal ability, and although the two coefficients cannot be distinguished statistically they are quite different economically. Controlling for mathematical ability, an increase of one standard deviation in verbal ability is estimated to raise the likelihood of risk-neutrality by less than 2 percentage points.[19]

[17] In a review of the experimental economics literature, Camerer and Hogarth (1999) find that in general variation in stakes has only a small impact on laboratory behavior. In the case of risk preferences, Holt and Laury (2002) find that increases in stakes tend to increase risk aversion, and that even questions with hypothetical stakes result in reasonably good estimates of risk preferences.

[18] In fact, we find that more cognitively able participants' choices are somewhat more monotonic in the case of risk preference, but that there is no statistically significant relationship between cognitive skills and monotonicity in the case of risk preferences with the possibility of loss, or in the case of time preference.

[19] Additional specifications (not reported) show that the univariate relationship between verbal ability and risk-neutrality is positive, smaller than the relationship with mathematical ability, and statistically insignificant, a pattern

Columns (3) and (4) repeat the specifications of columns (1) and (2) for our measure of risk-neutrality in the presence of losses. We find a somewhat weaker, but still nontrivial, relationship with mathematical ability, and again find that verbal ability has no relationship with risk-neutrality after we condition on mathematical ability. In fact, the point estimate suggests a small *negative* effect of verbal ability on risk-neutrality in this case, although this coefficient is not statistically significant.

Results are similar when we examine the relationship between cognitive ability and patience in columns (5) and (6). As column (5) shows, there is an economically large and statistically significant positive relationship between mathematical ability and the propensity to act patiently. A one-standard-deviation increase in mathematical performance raises the propensity to be patient by 10 percentage points, relative to a base of 28%. The model in column (6) shows that, as with risk-neutrality, mathematical ability is much more strongly related to measured patience than is verbal ability. As with risk preference, there is insufficient power to distinguish the coefficients statistically, but the point estimates indicate an economically much larger effect of mathematical ability than of verbal ability.[20]

It is worth noting that cognitive ability not only explains some of the variation in expressed risk and time preferences but also most of the covariation between them. In our sample, the correlation between a dummy for perfect patience and a dummy for perfect risk-neutrality is 0.1075. After regressing both dummy variables on mathematical ability and extracting residuals, the correlation between the residuals drops to 0.0092. Thus, to the extent that these two preferences are driven by a common mechanism, cognitive ability seems to explain most of the variance in that mechanism.

2.2.2 Preferences and Performance in Elementary School and High School

The estimates in table 1 show a strong and robust contemporaneous relationship between mathematical ability and two important preference "anomalies." In table 2, we investigate whether this correlation is driven primarily by heterogeneity in ability displayed in elementary school, or by skills accumulated between elementary school and high school.

To study this question, we calculate for each student the mean grade point average (GPA) in

that persists over all measures of preferences in this study. In additional unreported specifications, we find a statistically insignificant (and generally small) negative interaction effect between mathematical and verbal ability.

[20] Results are similar when we instead estimate ordered probits using as a dependent variable the number of choices consistent with risk-neutrality or perfect patience. As a further check on the sensitivity of our findings to functional form, we have also conducted Mann-Whitney rank-sum tests of the equality of the test score distributions between those making risk-neutral (or patient) choices and those making risk-averse (or impatient) choices. The results from this exercise are very similar to those from the probit models we report.

mathematics over all years in elementary school.[21] Among the 85 participants for whom these data are available, the correlation between the average elementary-school GPA in mathematics and our measure of current mathematical ability is 0.65 ($p < 0.0001$). Thus elementary school grades are strongly, but not perfectly, related to cognitive ability as measured in grade 12. To create a measure of current mathematical ability that is more directly comparable to elementary-school GPA, we compute for each participant the average mathematics GPA during high school (grades 9 through 11). This measure has a correlation of 0.83 ($p < 0.0001$) with average mathematics exam score, and therefore seems closely, but not perfectly, related to our key index of mathematical ability.[22] Finally, in a regression framework, practice exam mathematics scores are highly related to *both* elementary-school GPA and the change in GPA from elementary to high school, suggesting that both of these measures index a significant amount of real variation in ability.

Column (1) of table 2 shows that a one-standard-deviation increase in elementary-school mathematics GPA is associated with a 9 percentage points greater probability of making risk-neutral choices. This effect is both statistically significant and economically large, and comparable in magnitude to the estimates in table 1.

In column (2) we estimate jointly the relationship between preferences and elementary school GPAs and the change in GPA between elementary school and high school.[23] We can reject the equality of the two coefficients at the 10 percent level ($p = 0.0832$), giving us some statistical confidence in our conclusion that heterogeneity in ability in elementary school matters more for preference determination than skills acquired between elementary school and high school.

Columns (3) and (4) repeat these specifications for our measure of risk-neutrality with the potential for loss. Here, we find a large but statistically insignificant relationship with elementary school GPA, and a smaller though still substantial relationship between risk-neutrality and the change in grades between elementary school and high school. Overall, these results are statistically less precise than those in columns (1) and (2), but are consistent with the view that ability as expressed in elementary school is more important than skills acquired between elementary school and high school in determining risk preferences.

In columns (5) and (6), we reproduce these specifications using our patience measure as the

[21] We follow Wolff, Schiefelbein and Schiefelbein (2002) in defining elementary school to consist of grades 1 through 6. Results are similar when we define elementary school as consisting of grades 1 through 5.

[22] Our findings are similar if we use average test scores as the measure of current mathematical ability, in place of high school GPAs.

[23] Note that, because of the linearity of the latent probit variable, the coefficient on the change in GPA between elementary school and high school is also the coefficient on high school GPA we would obtain if we had included both elementary and high school GPAs in the model instead of elementary school GPA and the change in GPA.

dependent variable. We find that elementary school GPA has a large and statistically significant relationship with patience. As with risk-neutrality, the change in GPA from elementary school to high school has essentially no relationship with patience. We can reject the equality of coefficients on elementary school GPA and the change in GPA from elementary school to high school at the 10 percent level ($p = 0.0729$). The findings in table 2 therefore suggest that differences in ability arising before or during elementary school, rather than those resulting from skills acquired between elementary school and high school, are primarily responsible for the relationship between ability and preferences estimated in table 1.

2.2.3 The Role of Demographic Variation

The individuals in our sample are similar in age and have mostly been in the same school for their entire lives; thus many important sources of heterogeneity are not present in this group. Nevertheless there are some measurable demographic differences among these students that might confound the variation in test scores. For example, males (who represent about 63% of our sample) have on average much higher math exam scores. However, although male students are slightly more likely to be risk-neutral and patient than female students, these differences are small and statistically insignificant according to a Pearson Chi-squared test ($p = 0.239$ and $p = 0.770$ for risk-neutrality and patience, respectively).[24] Not surprisingly, then, adding a control for gender to our models results in only tiny changes in coefficients and statistical significance.[25]

To measure differences in neighborhood circumstances, we have also gathered data on the average income in dollars in the participant's municipality of residence, as measured from the 2000 Chilean Census. Though crude, this proxy has a statistically significant positive correlation of 0.22 with a participant's math score ($p = 0.03$). Nevertheless, we find it has a small and negative correlation with the propensity to be risk-neutral. Including it in our models therefore tends to increase the estimated relationship with mathematical ability. Individuals from wealthier municipalities are somewhat more likely to be patient, but including municipal income as a control does not significantly reduce the estimated relationship between patience and math scores. These findings indicate that omitted variation in gender and municipality of residence does not drive the

[24] We find that males are about 8 percentage points more likely to be perfectly risk neutral (i.e., less likely to be risk averse), consistent with Holt and Laury's (2002) finding of relatively small gender differences in risk-aversion for small-stakes choices. Our finding that males are only slightly (about three percentage points) more likely to be patient is consistent with Harrison, Lau and Williams' (2002) finding that discount rates do not vary significantly by gender in a survey using real rewards.

[25] In unreported specifications, we find no statistically significant interactions between gender and mathematical ability in determining preferences, although our standard errors are too large to allow us to firmly rule out such interactions.

results in table 1.

3 Preferences, Cognitive Ability, and Family Background

The previous section established that small-stakes risk-aversion and short-run impatience are less prevalent among more cognitively able individuals. In this section, we use data from a second study of Chilean students to show that heterogeneity in parental education and wealth are unlikely to be responsible for the relationship between preferences and cognitive ability. We also investigate in greater detail the dimensions of preferences that are correlated with cognitive ability. In particular, we show that the relationship between cognitive ability and patience is stronger for trade-offs between the present and the future than for trade-offs between two future dates. We also document that greater cognitive ability is associated with greater selfishness in a Dictator Game, although this finding is somewhat weaker statistically than the relationships we estimate with risk and time preferences. Finally, we argue using evidence from an "expected value quiz" that differences in pure computational skill are unlikely to account for our findings.

3.1 Study 2: Chilean High School Seniors and their Siblings

3.1.1 Participants

We returned to the same Chilean high school the following year to conduct studies 2 and 3. Participants in study 2 were the 81 out of 103 members of the senior class (during academic year 2005-06) who turned in parental consent forms. We then identified all siblings of these participants who were also students at the school. 22 out of 27 siblings turned in parental consent forms and participated. For the seniors, we held a single 60-minute session in the school gym on November 3. We held two sessions for the siblings, on December 10 (14 participants) and December 11 (8 participants).

3.1.2 Measured Cognitive Ability

We obtained 11 PSU practice test scores (for March through November, 2005) from the school for each participant. The school also gave us grade point averages for grades 1 through 11 for all students participating in our study for whom such data were available.

3.1.3 Procedure

The procedure closely paralleled study 1, except that the questionnaire contained more sections. The questionnaire presented the sections in the following order: small-stakes risk preferences, short-term time preferences, fairness preferences, small-stakes risk preferences with equalized complexity, calculating expected values, and demographics. As in study 1, in addition to what they earned during the study, we paid a participation fee of 1200 pesos (about $2.35 at the then-exchange rate of 510 pesos/$).

Small-Stakes Risk Preference: Safe vs. Risky Options. This section is like the risk preference section from Study 1, having choices between option (A) (the safe bet) 250 pesos [$0.49], and option (B) (the risky bet) 0 pesos with probability 50% and X with probability 50%. The only difference is that the values of X differed from those in Study 1: 200, 350, 500, 650, and 800 pesos [$0.39, $0.69, $0.98, $1.27, and $1.57] (in ascending order for half the participants, descending for the other half). Out of the 81 participants, 65 chose (A) below some threshold value of X and (B) above it. For each question, a die roll determined the payment for participants who chose option (B).[26]

Small-Stakes Risk Preference: Risky vs. Risky Options. This section was the same as the above small-stakes risk preferences section, except that we replaced the sure thing option (A) of 250 pesos with a low-risk gamble that has the same expected value: "If the die comes up 1, 2, or 3, you get 200 pesos [$0.39]. If the die comes up 4, 5, or 6, you get 300 pesos [$0.59]." Option (B) remained the same. As a result, option (A) is exactly parallel to option (B) in complexity; both make the payoff depend on the outcome of a die roll.

Calculating Expected Values. In this section, we presented participants with five questions of the form,

> Please circle whichever number is larger.
> (A) 250
> (B) $(X \times \frac{1}{2}) + (0 \times \frac{1}{2})$

where X took values 200, 350, 650, and 800.[27] These values exactly match those in the risk preference section. Participants were told they would be paid 50 pesos [$0.10] for each correct answer.

[26] We have checked the relationship between the monotonicity of participants' choices (i.e., whether they follow a threshold rule) and our measure of cognitive ability. In the case of comparisons of safe and risky options, we find a marginally statistically significant relationship between the two. In the case of short-term time preference, long-term time preference, and the comparison of two risky options, we find a small and statistically insignificant relationship. These findings suggest that our results are not primarily driven by variation in the degree of randomness or inconsistency in participants' choices.

[27] Although we included $X = 500$ in the questionnaire for parallelism, we excluded participants' answers to this question from the data analysis since there was no correct answer.

Short-Term Time Preference. We measured time preferences exactly as in study 1. All but one participant made "monotonic" choices, choosing the immediate reward for values of the delayed reward below some threshold and the delayed reward for values above it.

Long-Term Time Preference. This section gave choices between (A) 500 pesos [$0.98] to be received "four weeks from now," and (B) X to be received "five weeks from now," where X took the values 450, 550, 650, 750, 850, and 950 pesos [$0.88, $1.08, $1.27, $1.47, $1.67, $1.86]. Hence the payoffs were exactly the same as in the short-term time preference section, except that they all occurred four further weeks in the future. A die roll determined which of the six choices was played out. An experimenter returned to the school four weeks and five weeks after each session to pay the participants for their choices.

Fairness Preferences. We measured selfish versus fair-minded preferences with an anonymous Dictator Game. The experimenter informed participants that we had randomly assigned each of them to one other participant at the session, but no one would ever find out who had been assigned to whom. The questionnaire explained that the participant was given a total of 200 pesos and could choose how much to "give away" to the assigned other participant: 0, 50, 100, 150, or 200 pesos (presented to half the participants in ascending order, half in descending order). As is typical in Dictator Game experiments, a majority of participants (60.5%) chose either to give away nothing (behaving "selfishly") or to give away half of the total (behaving "fairly").

Demographics. As in study 1, we asked participants their age, sex, course of study, and municipality of residence. In addition, on the parent permission form, we asked parents several questions about socioeconomic status, most importantly family income and the number and make of cars owned by the household.

3.2 Results

3.2.1 Additional Dimensions of Preferences

Table 3 shows the relationship between math scores and choices in a number of preference elicitation exercises. Columns (1) and (2) present results for risk-neutrality. As column (1) shows, in contrast to study 1, here we do not find that more mathematically skilled individuals make significantly more risk-neutral choices when presented with a choice between safe and risky options. The point estimate is small and statistically insignificant. The difference between the two studies may result from the inclusion of a greater number of "dominated" gambles (risky gambles with expected value below the safe choice) in study 2, which tended to reduce the variability in participants' choices.

Indeed, when we restrict attention to the gamble with the most attractive risky option—a 50 percent probability of winning 800 pesos versus a sure thing of 250 pesos—we do find that students with higher scores were significantly more likely to choose the risky, and higher expected value, option. (The coefficient in this case is very similar in magnitude to the analogous estimate from study 1.)

Column (2) shows that those with higher scores were much more likely to make risk-neutral choices when presented with a choice between two alternative risky options. A one-standard-deviation increase in math scores is associated with a 13 percentage point greater likelihood of a risk-neutral choice, which is economically large and statistically significant at the 5 percent level.

Turning next to intertemporal choices, in column (3) we show estimates of the relationship between math scores and the propensity to choose a larger delayed payment over a smaller immediate payment. Here we find that a one-standard-deviation increase in math scores is associated with a 9 percentage point increase in the propensity to act patiently, which is statistically significant at the 5 percent level and comparable in magnitude to the estimate from study 1.

Consistent with the hypothesis of a hyperbolic curvature in the discounting function (Laibson, 1997), comparing the means in columns (3) and (4) shows that participants were more willing to accept delays from four weeks to five weeks than to accept delays from the present to one week in the future (although this difference is not statistically significant). Indeed, in a quasi-hyperbolic model of time preference, the measure in column (3) approximates the short-run discount rate, whereas the measure in column (4) is more closely related to the long-run or exponential discount rate. In this sense, it is interesting that column (4) shows no significant relationship between math scores and patience at a four-week horizon. Of course, given the standard errors, we cannot rule out a relationship of nontrivial size, but it is nevertheless interesting that our point estimates show a much tighter relationship with discounting in the present than with discounting in the future. This is true despite the fact that the two patience measures are moderately correlated with one another (with a correlation coefficient of 0.4986, $p < 0.0001$). This finding may be related to McClure et al's (2004) argument that separate neural systems are involved in choices between immediate and delayed rewards.[28]

The last column of table 3 shows that selfish behavior in a dictator game appears to be more common among those with higher math scores.[29] However, the relationship is only marginally

[28] Interestingly, we also find that the number of time preference reversals (differences in choices between parallel questions in the immediate vs. delayed and four-week vs. five-week questionnaires) is lower for higher-ability students, although the correlation with math scores is not statistically significant.

[29] To check the sensitivity of our findings to functional form assumptions, we have also conducted Mann-Whitney rank-sum tests of the equality of test score distributions for the groups who make patient, risk-neutral, or selfish choices and those who do not. Results are very similar to the probit models, with the exception that the results for

statistically significant, and, as we will see in the next section, appears to be sensitive to the inclusion of controls.[30]

3.2.2 Controls for Parental Education, Income, and Wealth

In table 4, we investigate the role of possible confounds from unmeasured variation in parental characteristics. We collected three sets of controls. First, we asked each participant to tell us the highest level of schooling completed by her parents. All but one participant chose to answer these questions. We have converted each student's answers into an index of the number of years of completed schooling. The measures of father's and mother's schooling years have correlations of 0.77 ($p = 0.0011$) and 0.67 ($p = 0.0001$), respectively, with the average report of the students' siblings (in cases where the student's sibling participated in our study), suggesting a reasonable amount of reliability in these measures.

Second, we included in our parental consent form a request for the parent to indicate the household's monthly income in terms of a set of income categories, from which we imputed (at the midpoint of each category) the household's monthly income in pesos. We standardized this variable to have a mean of zero and a standard deviation of one. The parents of 19 participants refused to answer this question.

Finally, we asked each parent to list the year, make and model of all of the household's automobiles. We used the *Tasación Fiscal de Vehículos*,[31] a Chilean analogue to the Kelley Blue Book, to estimate the value of each car, from which we computed the household's total automobile wealth. When we were unable to estimate the value of an automobile, we imputed its value as the average value of the other automobiles that the household reported. We computed total automobile wealth and standardized this variable to have a mean of zero and a standard deviation of one within the sample. The parents of 20 participants refused to provide information on their automobiles.

To address the missing data problem, which is especially significant with the income and wealth proxies, we imputed missing data at the sample mean of the non-missing observations. This technique is obviously imperfect, but robustness checks suggest it does not dramatically affect the results, and that the point estimates on the controls are similar when we restrict to individuals with non-missing values. The advantage of this approach is that it allows us to control for sev-

selfishness are not statistically significant in the Mann-Whitney tests.

[30]We find that males in our sample are about seven percentage points less likely to be selfish. This contrasts with Eckel and Grossman's (1998) finding that women are more altruistic in a dictator game environment, but our estimate of the gender difference is too imprecise to rule out sizable effects in the direction suggested by Eckel and Grossman's (1998) evidence.

[31]See <http://www.sii.cl/pagina/actualizada/noticias/tasacion_vehiculos.htm>.

eral parental characteristics at once without throwing out the information from variation in the non-missing variables.

The coefficients on the controls are of intrinsic interest, as they provide information on the role of parental characteristics in determining the preferences we measure. Although the controls are correlated with one another, no two control variables have a correlation coefficient above 0.5, suggesting that we can reliably separate the effects of these different variables. We find that students with more educated fathers are somewhat more likely to be risk-neutral, patient, and selfish, although only in one case is this effect even marginally significant. Students with more educated mothers are, if anything, slightly less likely to be risk-neutral and patient, and slightly more likely to be selfish; none of these relationships is statistically significant.[32] Participants whose parents report a higher monthly income are less likely to be risk-neutral, patient, and selfish, whereas those whose parents report greater automobile wealth are more likely to display these preferences.[33]

Overall, then, we do not find evidence that parental characteristics play an important role in determining the preferences we measure, after we control for a student's mathematics score. In no case is any of the control variables individually statistically significant at the 5 percent level, and in no case does a χ^2 test reject the null hypothesis that the parental characteristics are unrelated to measured preferences.[34]

Given the relatively limited role that parental characteristics seem to play in explaining variation in measured preferences, it is not surprising that including these controls does not have a dramatic impact on the estimated relationship with math scores. We continue to find a large and statistically significant relationship between math scores and risk-neutrality (in the comparison of two risky options), and a large relationship with patience (in the comparison of immediate and delayed rewards) that is statistically significant at the 10 percent level. The relationship between selfishness and math scores, though still large, is now statistically insignificant, perhaps indicating

[32] To check that the inconsistent signs on the parental education measures are not due simply to collinearity, we have also estimated specifications in which we replace these two measures with a single measure of the average education of the student's two parents. We continue to find no consistent relationship between preferences and parental education, and the coefficients and statistical significance of our cognitive ability measure are essentially the same as in the specification that uses both education measures.

[33] The inconsistent effects of income and wealth also suggest that variation in liquidity constraints is unlikely to drive our results on time preference. If our time preference measurement were driven largely by variation in cash on hand, we would expect greater parental wealth to strongly predict greater patience, which it does not.

[34] These χ^2 tests, of course, do not aggregate information across the different probit models we have estimated. To check the robustness of our finding that the controls do not have a statistically significant relationship with measured preferences, we have also estimated our models jointly using a seemingly unrelated regression (Zellner, 1962; results not shown). A joint test of the null hypothesis that the parental characteristics are unrelated to preferences fails to reject at any conventional level ($p = 0.2041$), and only the income control is individually statistically significant ($p = 0.0260$).

that cognitive ability is more reliably related to risk and time preferences than to other-regarding preferences.

3.2.3 Comparisons within Sibling Groups

The fact that 21 students in our sample of seniors had siblings who attended the same high school allows us to compare preferences across individuals from the same family. Because we do not have information on practice exam scores for students below their senior year, we rely on a student's average mathematics GPA over her entire tenure in the school as our measure of cognitive ability.[35] Unfortunately, both ordinary least squares (between-family) and fixed-effects (within-family) estimates of the relationship between standardized math grades and expressed preferences produce large standard errors, making it difficult to make precise statements about the likely magnitude of the relationship. (A table with results for this subsample is available on request from the authors.)[36]

Evidence from our sibling subsample does, however, support the conclusion of the previous subsection that family background characteristics play a limited role in determining the preferences we measure. In no specification are we able to reject the null hypothesis that the coefficients on the sibling group fixed effects are jointly equal to zero. Additional estimates from random effects models support the view that there is relatively little sibling-group-specific variation in expressed preferences. We have also estimated the correlation between a given senior's preferences and the average preferences of her siblings, and find no statistically significant relationship, with generally very small correlation coefficients.

3.2.4 The Role of Computational Skill

One possible explanation for our results is that every participant "wanted" to make the risk-neutral or patient choice, but that some were unable to perform the computations necessary to determine which option was "correct." On this view, our estimates merely show that one measure of mathematical ability is correlated with another. Several pieces of evidence argue against such an interpretation. First, the computations necessary to make patient choices in the time preference exercises involve only ordinal comparisons (greater than, less than, or equal to), which the

[35] This variable has a correlation of 0.8724 ($p < 0.0001$) with average practice PSU mathematics score among the 21 seniors for whom we have data on siblings, suggesting that it is a reasonably reliable proxy for mathematical ability.

[36] In models with family fixed effects, our point estimates indicate a positive within-family relationship between math grades and risk-neutrality, and in the case of safe vs. risky gambles the coefficient is statistically significant at the 10 percent level. The point estimate for selfishness is directionally consistent with the earlier estimates from the full sample, as is the estimate for long-run patience. Only a negative point estimate for short-run patience stands out as directionally inconsistent with our hypotheses.

students in our sample are clearly capable of making. Of the 81 seniors who participated in the study, only 3 chose the "dominated" option of 450 pesos in one week rather than 500 today in the first intertemporal choice questionnaire, and only 3 made the analogous choice in the second intertemporal choice questionnaire.

The computation of expected values is slightly more cumbersome, so to check this possibility we also asked each participant to make comparisons that involved calculations equivalent to those necessary to compute the expected values in our risk questionnaires, such as comparing 250 to $(200 \times \frac{1}{2}) + (0 \times \frac{1}{2})$. Only 5 participants made even one error in the set of five questions of this form. Additionally, only 3 students chose the stochastically dominated gamble in our first risk questionnaire, and none chose the stochastically dominated gamble in our second risk questionnaire. These facts seem difficult to reconcile with the hypothesis that the students in our sample who made choices inconsistent with patience and risk-neutrality were merely unable to make the necessary calculations.

4 Evidence on Causal Mechanisms

In this section, we investigate possible explanations for our finding that more cognitively able individuals make more patient, risk-neutral decisions. We begin by presenting direct evidence on the hypothesis that making patient, risk-neutral choices requires the application of cognitive resources to suppress emotional temptations. We report findings from a laboratory experiment, in which we borrow a technique from Shiv and Fedorikhin's (1999) study of the role of cognitive resources in determining impulsivity. "Working memory" is the cognitive system that actively and consciously attends to, rehearses, and manipulates information. Working memory capacity is almost perfectly correlated with general cognitive ability (Colom et al., 2004). In our experiment, we randomly apply a "cognitive load" manipulation that is designed to reduce working memory capacity. Although the manipulation appears to have been relatively weak, we find a statistically significant reduction in risk-neutrality and less precise reductions in short-run patience in response to cognitive load.

We then turn to another experimental procedure, adapted from Wilson and Schooler's (1991) study of instinctive judgment, in which we encourage participants to think about and express the reasons for their choices. We show that this manipulation led to increased patience and risk-neutrality, especially among participants with lower measured cognitive ability. This finding seems to further support the hypothesis that cognitive resources are required to make patient, risk-neutral choices.

Next, we interpret the findings from these two manipulations in light of recent developments in "two-systems" approaches to decision theory (e.g., Bernheim and Rangel, 2004; Loewenstein and O'Donoghue, 2005; Fudenberg and Levine, 2006; Brocas and Carillo 2005) as well as recent evidence that intertemporal and risk preferences have a strong emotional component (Shiv and Fedorikhin, 1999; Shiv et al, 2005). Although not all of our findings are fully consistent with a "two-systems" framework, these approaches do organize the broad patterns in the data quite well.

Lastly, we discuss the possibility that our earlier results are driven by reverse causality from preferences to accumulated cognitive skills. We argue that this explanation fails to account for important portions of our findings.

4.1 Study 3: Chilean High School Juniors

4.1.1 Participants

Participants in study 3 were the 37 out of 108 members of the junior class (during academic year 2005-06) who turned in parental consent forms. We held seven sessions in the school gym that lasted between 60 and 75 minutes: December 14 (15 participants), December 15 (6 participants), December 16 (5 participants), December 17 (2 participants), December 20 (4 participants), December 21 (4 participants), and December 22 (1 participant).

4.1.2 Measured Cognitive Ability

Because the participants were juniors, they had not taken PSU practice tests. We use grade point averages for grades 1 through 10 provided by the school.

4.1.3 Procedure

The procedure mirrored study 2, except that we added several new sections to the end of the questionnaire (in this order): reasons for small-stakes risk preference, reasons for short-term time preference, and math quiz. Moreover, during half of the sections, participants were put under cognitive load. In addition to what they earned during the study, we paid a participation fee of 1200 pesos, as before. Here we describe only the sections that are new in study 3.

Reasons for Small-Stakes Risk Preference. In this section, we told participants they would face the same questions they had answered previously (in the small-stakes risk preferences section). The difference was that, after choosing the safe option (A) or the risky option (B) in each question, participants were required to give reasons for why they made their choice.[37] As before, a die roll for each question determined the payoff to choosing the risky option.

Reasons for Short-Term Time Preference. Participants answered the same questions as in the short-term time preference but were required to give reasons for why they made their choice.[38] We rolled a die to pick which of the six question would be carried out.

Math Quiz. We administered to participants two 10-minute, six-question quizzes that contained SAT-like math problems (arithmetic, algebra, geometry, and probability). Participants were told we would pay them 50 pesos [$0.10] for each correct answer. Half of the participants were under cognitive load (as described below) during one of the math quizzes, and the other half during the other math quiz.

Cognitive Load Manipulation. During all of the sections except for the two reasons sections, about half of the participants were put under cognitive load.[39] Specifically, they were required to remember a string of seven numbers while they were answering the questions and recall that string of numbers (in order) after the section. This is a common "cognitive load" manipulation in the psychology literature (e.g., Shiv and Fedorikhin, 1999; Hinson, Jameson, and Whitney, 2003). To incentivize participants to remember the numbers, participants were paid for their responses in that section only if they correctly recalled the sequence of numbers.[40]

4.2 Experimental Results

4.2.1 Effects of the Cognitive Load Manipulation

Our cognitive load manipulation was designed to test the effects of a reduction in cognitive resources on the preferences we measure. In all, we had 37 participants in this study. In a few cases, some of the participants failed to answer all of the preference-elicitation sections, presumably because of the distraction of the cognitive load task. We conduct our analysis on the sample who answered all the questions, but note that our results are robust to treating non-responders as though they

[37] For example, a respondent who chose the safe option of 250 pesos instead of a 50 percent chance of winning 650 pesos wrote, "It seems safer to me."

[38] For example, a respondent who chose to receive 500 pesos immediately instead of receiving 650 pesos in one week wrote that it was "very little silver to wait one week."

[39] Although we do not believe it is a major concern, it is possible that putting participants under cognitive load affects preferences via "wealth effects." That is, participants under cognitive load in a given section expect to earn less from that section, so cognitive load directly could affect the marginal utility of "experimental wealth" if participants frame payoffs narrowly. We therefore counterbalanced the cognitive load manipulation, so that the number of sections under load was relatively constant across participants. This meant that the negative effect of cognitive load on expected payoffs was relatively constant across participants.

[40] Due to an error by the local Kinko's, a page was omitted from some of the copies of two of our questionnaire versions. As a result, there was a slight imbalance in the number of each version we used, resulting in a slight lack of balance in the number of participants in the different cognitive load conditions.

made the "non-normative" (risk-averse or impatient) choice.

To test for an effect of cognitive load, we have computed Fisher exact p-values of the null hypothesis that there is no effect of cognitive load on the distribution of the dependent variable. These tests perform well in small samples and rely only on the random assignment of the treatment condition. To check that our assignment was indeed uncorrelated with student characteristics, we also conducted Fisher tests of the relationship between cognitive load and the probability of an above-average math GPA. In no case can we reject the null that having an above-average GPA is unrelated to our cognitive load assignment. For a few of the cognitive load manipulations, t-tests of differences in mean GPAs show a marginally significant difference in mean math GPA between treated and untreated individuals, but a regression analysis shows very similar results on the effect of cognitive load when we control flexibly for math GPA.

Table 5 presents the results of our cognitive load manipulation.[41] We find that cognitive load reduces the likelihood of risk-neutral choices, although only in the case of risky vs. risky choices is this reduction statistically significant. We find nontrivial reductions in short-run patience (immediate vs. delayed reward), but this difference is not statistically significant. By contrast, the distribution of patience in the delayed vs. delayed reward case is virtually identical between the load and no-load conditions, complementing McClure et al's (2004) finding that different cognitive processes are involved in decisions about immediate and delayed rewards. The connection with McClure et al (2004) is especially relevant because the prefrontal and parietal cortices, which are more often involved in choices between two delayed rewards, are also the brain regions that appear to mediate the influence of general cognitive ability on behavior (Gray, Chabris, and Braver, 2003).

In the case of other-regarding preferences, we find a statistically insignificant increase in measured selfishness as a result of the cognitive load manipulation. This result contrasts qualitatively with our finding in study 2 that more cognitively able individuals are more selfish, although that correlation is much less robust statistically than the others that we estimate.

In columns (6) and (7), we report tests of the effect of cognitive load on the participant's performance on the math quizzes we administered. In both cases, cognitive load reduced performance, but neither of the reductions is statistically significant. Since our quiz clearly required cognitive resources to complete (there was significant heterogeneity in performance), these findings imply that our cognitive load manipulation was relatively weak. Our results should therefore be taken

[41] We have also checked whether cognitive load affected the consistency of participants' choices, measured by whether they follow a threshold rule in the risk and discounting tasks. As in our earlier studies, the vast majority of participants do follow such a rule. Additionally, there is no economic or statistical difference in the frequency of using a threshold rule between participants under cognitive load and those not under load.

with caution.[42]

As a final caveat to these results, we note that a pilot study using Harvard undergraduates as participants failed to find any significant effect of cognitive load on expressed preferences (see supplemental appendix for details). Because of differences in sample populations and procedures, it is impossible to directly compare these findings, but we mention them here for completeness.

4.2.2 Effects of Additional Reasoning on Stated Preferences

As a second test of the hypothesis that the application of additional cognitive resources will lead to more risk-neutral and patient behavior, we added modules to the end of our study 3 questionnaire. These sections asked participants to repeat their earlier decision tasks, but this time to think about and articulate the reasons for their choices. Among the participants who were not under cognitive load (in the non-reasoning task), the number of choices consistent with risk-neutrality (safe vs. risky) increased from the non-reasoning to the reasoning task (Wilcoxon signed-rank test, $N = 13, p = 0.2043$). The number of choices consistent with perfect patience (immediate vs. delayed reward) increased to a statistically significant degree from the non-reasoning to the reasoning task (Wilcoxon signed-rank test, $N = 20, p = 0.0063$).

Table 6 shows how the *increase* in risk-neutral and patient choices for a given participant is related to math score. The effect of additional reasoning on expressed preferences was greatest for those with the lowest measured mathematical ability. In the case of risk-aversion, an additional standard deviation in math GPA was associated with a reduction of 0.5 in the "gain" from additional reasoning, which is statistically significant and economically large relative to the baseline mean increase of about 0.3.[43] In the case of patience, the point estimate is smaller and statistically insignificant, but the point estimate still suggests that lower-ability participants experienced a greater increase in expressed patience as a result of the reasoning manipulation.

[42] We do find some negative effects of cognitive load on the math quiz performance of students with above-average math grades. In general, the effects of cognitive load tend to be somewhat stronger for high-ability students, but small samples make it difficult to draw precise conclusions about the interaction between ability and cognitive load.

[43] If a participant behaved perfectly risk-neutrally in the initial risk questionnaire (without the reasoning task), then it would have been impossible for the reasoning manipulation to increase this participant's measured risk-neutrality. Because students with higher math grades were more likely to be perfectly risk-neutral in the initial questionnaire, this raises the concern that our results on the differential treatment effects between students with high and low math grades are driven by mechanical "ceiling" effects. However, when we restrict the sample to those who showed at least some deviation from perfect risk-neutrality in the initial (non-reasoning) questionnaire, we still find a negative and statistically significant relationship between the effect of the reasoning manipulation and the participant's math grades.

4.3 Discussion

Although not conclusive, the results from these two experimental manipulations suggest that the application of additional cognitive resources results in more risk-neutral, patient, and (possibly) selfish behavior. These findings suggest that the relationship we find between preferences and cognitive ability may therefore be due to the application of more cognitive resources to these preference elicitation tasks among the more cognitively able. This hypothesis fits naturally with recent "two-systems" models of individual decision making (e.g., Bernheim and Rangel, 2004; Loewenstein and O'Donoghue, 2005; Fudenberg and Levine, 2006; Brocas and Carillo 2005). These models treat decision-making as a result of a strategic interplay between a rational, forward-looking, player and an impulsive, myopic one.

If greater cognitive ability results in greater strength of the former system relative to the latter, these models would predict correlations similar to the ones we observe in studies 1 and 2. Since patience requires suppressing an impulsive desire for immediate gratification (Shiv and Fedorikhin, 1999), and since risk-neutrality requires suppressing the fear of an adverse outcome (Shiv et al, 2005), those with greater "system one" resources would be more likely to act patiently and risk-neutrally. Additionally, if our cognitive load manipulation reduced the strength of the forward-looking player relative to the myopic player, these models would predict our tentative finding that cognitive load reduces measured risk-neutrality and patience.

The most significant fact that stands out as inconsistent with these models is the finding in study 2 that more cognitively able individuals are more likely to be selfish. Since the impulsive, short-run player is less likely to be altruistic, a two-systems interpretation of our findings would seem to predict, if anything, the opposite relationship. On the other hand, the relationship between selfish behavior and math grades is statistically fragile in response to the introduction of controls, and is contradicted by the fact that cognitive load seems, if anything, to reduce the likelihood of selfish behavior.

4.4 Reverse Causality from Preferences to Cognitive Ability

In light of extant evidence that early-life measures of patience predict standardized test scores much later in life (Mischel, Shoda and Rodriguez, 1989; Shoda, Mischel, and Peake, 1990), a natural alternative explanation for our findings is that variation in underlying preferences—especially time preferences—drives both the preferences we measure *and* our measure of cognitive ability. On this view, more patient individuals invest more in developing cognitive skills, resulting in the types of correlations we estimate.

Several of our findings suggest that this cannot be the whole story. First, it is not entirely clear how this hypothesis explains the relationship between cognitive ability and risk preferences. Second, we show in study 2 that the relationship between cognitive ability and patience is present only when we measure patience using trade-offs between immediate and delayed rewards, not when we measure it using trade-offs between two delayed rewards. This finding seems difficult to resolve with the reverse-causality model unless *only* short-run discounting plays a role in human capital investment. Yet it seems likely that both short-run and long-run discounting would influence human capital investment. Third, the reverse-causality model cannot explain our results from study 3 that experimentally increasing the application of cognitive resources results in choices that more closely approximate those of our high-ability participants. By contrast, the hypothesis that cognitive resources have a direct, causal impact on preferences provides a parsimonious explanation of both the cross-sectional relationship with ability and the effect of the experimental manipulations from study 3.

Finally, and most directly, in study 1 we found that the most relevant heterogeneity in cognitive ability arises in elementary school, and that the change in grades from elementary to high school has almost no relationship with measured preferences. If the cross-sectional relationship is driven by more patient individuals accumulating skills at a faster rate, then cognitive ability should have been strongly correlated with skills accumulated between elementary school and high school, controlling for ability in elementary school. Our contrary finding casts doubt on the reverse-causality explanation.[44]

5 Cognitive Ability and Behavioral Anomalies

The evidence presented thus far shows a strong and robust relationship between standardized exam performance and the presence of preference anomalies. Based on these findings, it is natural to hypothesize a further relationship between cognitive skills and real-world behaviors that are themselves a result of these preference anomalies. In this section, we take a first look at this question, and investigate the relationship between measured cognitive ability and a set of behaviors—low levels of asset accumulation, obesity, smoking, and low levels of financial market participation—that

[44] To check the robustness of this finding, we have estimated parallel models for study 2, relating preferences to elementary-school grades as well as the change in grades from elementary school to high school. We find a larger role for the change in skills than in study 1, but the standard errors are much larger in study 2 (due in part to a smaller sample), so we cannot rule out differences of the kind we observe in study 1. Also, our coefficient estimates continue to point to an important role for elementary school grades, especially in risk and other-regarding preferences.

have been explicitly connected in the economics literature with either small-stakes risk aversion or short-term time preference. Even after controlling extensively for income and family background, we generally find a strong and robust relationship between measured ability and the behavior in question, as we would predict based on our laboratory findings.

5.1 The National Longitudinal Survey of Youth

The National Longitudinal Survey of Youth 1979 (NLSY) is compiled from repeated interviews of a sample of 12,686 Americans. All respondents were between the ages of 14 and 22 in 1979, the first survey year. Interviews were conducted annually through 1994 and biennially thereafter.

In 1980, 94% of survey respondents were administered the Armed Services Vocational Aptitude Battery (ASVAB), which consists of 10 exams designed to measure different areas of knowledge and ability.[45] On the basis of each respondent's ASVAB results, data processors constructed an approximation to the respondent's percentile in the Armed Forces Qualifying Test (AFQT), a measure developed by the U.S. Department of Defense.[46] Each constructed score was then compared to the overall distribution of scores for respondents age 17 and over to yield a percentile score ranging from 0.01 to 0.99. This percentile score will serve as our primary measure of cognitive ability in this section.[47]

We will also be interested in separating the effects of mathematical and verbal ability. We have therefore computed a mathematical ability score as the sum of performance on the arithmetic reasoning, numerical operations, and mathematical knowledge sections of the ASVAB and a verbal ability score as the sum of performance on the word knowledge and paragraph comprehension sections.

We will estimate the relationship between AFQT score and our dependent measures—financial market participation, asset accumulation, obesity, and smoking—using linear probability models.[48] We have chosen these dependent variables because each has been explicitly connected in the eco-

[45] These areas are: general science, arithmetic reasoning, word knowledge, paragraph comprehension, numerical operations, coding speed, auto and shop information, mathematics knowledge, mechanical comprehension and electronics information.

[46] In particular, for each respondent a score was calculated by summing the raw scores from arithmetic reasoning, word knowledge, and paragraph comprehension, plus one-half of the score from the numerical operations exam.

[47] The AFQT score has a correlation of over 0.94 with the first principal component of the scores on the ten sections of the ASVAB, which cognitive psychologists believe to be a good measure of "general cognitive ability." This principal component is highly correlated with SAT scores (Frey and Detterman, 2004). SAT scores in turn have a very strong correlation with scores on a Raven's Matrices Task, another common tool for measuring general cognitive ability (Frey and Detterman, 2004).

[48] We use linear probability models to facilitate including "sibling group" fixed effects. The relationships we document are robust to using logit and conditional logit models to estimate the specifications without sibling fixed effects and with sibling fixed effects, respectively.

nomics literature with one of the two preference anomalies we study in the laboratory. We restrict our dependent measures in this way in order to lessen concerns about bias due to the selective inclusion or exclusion of behaviors from the set we consider.

Since respondents were at different ages when taking the ASVAB, we will include dummies for age in 1979 in all specifications. We also include a dummy for gender in all models.[49] For all outcomes measured in multiple years, we include dummies for survey year to control for time trends. We also adjust standard errors for within-individual correlation in the error structure whenever we have repeated measures for a given individual.[50]

As a proxy for human capital wealth, we will control for the log of family income in every available survey year from 1979 to 2000 (18 years of data in all), with dummies proxying for missing data.[51] Though such controls will not perfectly capture permanent income, the availability of so many years of data allows for much richer specifications than would be possible in purely cross-sectional data.[52]

To account for family background characteristics that may be correlated with cognitive ability, we will take advantage of the fact that many of the respondents in the NLSY are siblings (53.8% have at least one sibling who is also a respondent). We will therefore be able to estimate our models with "sibling group" fixed effects to difference out family-specific factors that might be correlated with both cognitive ability and our dependent measures. To make comparisons across specifications more straightforward, we restrict the sample in all cases to respondents with siblings in the NLSY sample. (Results are nearly identical when we employ the full sample to estimate the specifications that do not include sibling group fixed effects.)

[49] Controlling for gender does not meaningfully affect our results, since gender and AFQT score are statistically unrelated in our sample. When we split the sample by gender, in most cases the estimated effect of AFQT score is similar for male and female respondents.

[50] Results are virtually identical when we instead average the dependent measure across all years for a given individual and regress this average on AFQT score.

[51] To check the role of the assumption that these controls have linear effects on the outcome variables, we have computed for each respondent an average annual family income, and divided this variable into 20 categories, each representing five percentiles of the average income distribution. We have then re-estimated our models using dummies for these 20 categories in place of our linear log(income) controls. Results are quite similar to the specifications with linear controls.

[52] Controlling for years of schooling is less well motivated conceptually, since presumably some of the effects of schooling work through increased cognitive ability. Nevertheless, all of our results except for the result on smoking remain statistically strong after controlling for completed years of schooling. In the case of smoking, once we include income controls, sibling fixed effects, and years of schooling, the point estimate on AFQT score is positive, close to zero, and statistically insignificant. Including dummy variables for family size as controls leaves our results substantively unchanged, both in terms of coefficient estimates and statistical significance.

5.2 Cognitive Ability and Behavior in the NLSY

Asset accumulation. Bernheim (1991) argues that Americans have anomalously low levels of retirement savings, a phenomenon that Angeletos et al (2001) attribute to short-run impatience. To measure asset accumulation, we code a dummy equal to one if the respondent said that she would have "something left over" in response to the following question:

> Suppose you [and your spouse] were to sell all of your major possessions (including your home), turn all of your investments and other assets into cash, and pay all of your debts. Would you have something left over, break even, or be in debt?

The first column of table 7 shows the strong, statistically significant, and positive relationship between AFQT score and the propensity to have positive net assets.[53] As specification (4) shows, even within a group of siblings and after controlling for family income from all available survey years, an additional 10 percentile points of AFQT is associated with an increase of about 1.5 percentage points in the propensity to have positive net assets.[54] This is economically nontrivial when compared to the mean of about 66 percent. Moreover, while the introduction of income controls between specifications (1) and (2) decreases the estimated relationship with AFQT score significantly, the introduction of sibling group fixed effects in specification (4) has a relatively small impact on the AFQT coefficient despite increasing the R^2 of the model from 0.18 to 0.36. In specification (5) we attempt to separate the AFQT coefficient into mathematical and verbal components. The estimated coefficient on verbal ability is essentially zero, whereas the relationship with mathematical ability is statistically strong and on the same order of magnitude as the overall AFQT coefficient.

Smoking. O'Donoghue and Rabin (1999) and Gruber and Köszegi (2001) have argued that short-run impatience plays an important role in the decision to begin smoking and in the difficulty of quitting (see also O'Donoghue and Rabin, 2000). We create a dummy equal to one if the

[53] We have also estimated models with a dependent variable equal to the log of the amount by which the household would be "ahead" if it liquidated all assets and paid off all debts. Although this variable seems more likely to be confounded with income and also does not capture the variation on the margin of having or not having positive assets, it is still strongly related to AFQT. We estimate a large and statistically significant effect of AFQT in every specification except for the specification with both income and sibling group fixed effects, where the coefficient is nontrivial but is only statistically significant at the 10 percent level.

[54] Since one might question the wisdom of significant saving in early adulthood, we have confirmed that our results are robust to restricting attention to respondents who are 35 and over. Moreover, it might be argued that standard economic models prescribe not only *more* asset accumulation among middle-aged individuals but also *less* asset accumulation (or even borrowing) among younger individuals. In fact, when we include an interaction between age and AFQT score in the regression, the interaction is positive and strongly statistically significant. This suggests that higher AFQT respondents are more likely to have the profile of low saving in early adulthood and high saving later on, in accordance with the prescriptions of life-cycle savings models.

respondent is a daily smoker, as reported in the answer to the survey question, "Do you now smoke daily, occasionally, or not at all?" The second column of table 7 presents our estimates of the relationship between AFQT score and the propensity to smoke regularly. After including income and sibling group controls, we estimate that an increase of ten percentile points in the AFQT score is associated with a decrease of about 1.3 percentage points in the probability of smoking, relative to a baseline of about 26 percent. As with asset accumulation, while including income controls does reduce the estimated AFQT coefficient considerably, including sibling group fixed effects has much less impact. Indeed, in this case the coefficient on AFQT actually increases slightly (in absolute value) between specifications (2) and (4). In specification (5), we report that the estimated coefficient on mathematical ability is much larger than the coefficient on verbal ability, consistent with the findings for asset accumulation.

Obesity. Cutler, Glaeser, and Shapiro (2003) argue that the rise in obesity in the last several decades has resulted from an interaction between falling time costs of eating and consumers who display short-run impatience. In some survey years, NLSY respondents were asked to report their weight in pounds and their height in inches. We calculate the respondent's average reported height and then, for each response to the weight question, we calculate the respondent's body mass index (BMI) as the ratio of her weight in kilograms to the square of her height in meters. We then follow standard practice and define an obesity dummy equal to one if the respondent's BMI exceeds 30.

As the third column of table 7 shows, the negative relationship between AFQT score and obesity becomes statistically insignificant when we control for sibling group fixed effects in specifications (3) and (4). We do, however, estimate a marginally statistically significant relationship with mathematical ability in specification (5), in contrast to a point estimate of about zero on verbal ability. The coefficient on mathematical ability implies that an increase of 10 percentile points in mathematical ability reduces the probability of being obese by about half a percentage point (about 16 percent of our sample are obese).

Financial market participation. A large literature on the equity premium puzzle (Mehra and Prescott, 1985) documents that "even though stocks appear to be an attractive asset—they have high average returns and a low covariance with consumption growth—investors appear very unwilling to hold them" (Barberis and Thaler, 2003). Some authors have contended that myopic loss aversion can explain this reluctance to participate in financial markets (Benartzi and Thaler, 1995; Barberis, Huang and Thaler, 2003). Myopic loss aversion is an elaboration of prospect theory, which predicts risk aversion over small stakes (Kahneman and Tversky, 1979).

We measure financial market participation using respondents' answers to the following question:[55]

> Not counting any individual retirement accounts (IRA or Keogh) 401K or pre-tax annuities...Do you [or your spouse] have any common stock, preferred stock, stock options, corporate or government bonds, or mutual funds?

The fourth column of table 7 shows the strong positive relationship between AFQT score and financial market participation. As specification (4) shows, even after controlling for sibling group fixed effects and family income from all survey years, we estimate that an increase of 10 percentile points in AFQT score is associated with an increase of two percentage points in the probability of owning a financial asset, as against a sample mean of about 19 percent. Specification (5) shows that the relationship with math and verbal ability is similar, with the verbal ability coefficient slightly higher.

Summary. In all cases we find that the AFQT-behavior relationship has the expected sign, and in all but one case (that of obesity), the estimated coefficient on AFQT score is strongly statistically and economically significant even when we control extensively for income and only compare individuals within sibling groups. Moreover, we find in all but one case (that of financial market participation) that mathematical ability has a stronger relationship with the behavior than verbal ability, although in general we cannot distinguish the two coefficients statistically.

Each of the behaviors we have examined may be correlated with cognitive ability for separate reasons. The hypothesis that anomalous preferences provide the common mechanism predicts that cognitive ability should correlate with the common component across the behaviors (Cutler and Glaeser, 2005). Consistent with this hypothesis, the correlation between cognitive ability and the first principal component of our four dependent variables is 0.53 ($p < 0.0001$).

6 Conclusions

This paper showed that two fundamental deviations from normative decision theory—short-term discounting and small-stakes risk-aversion—are less common among more cognitively able individuals. Evidence from three laboratory studies indicated that higher cognitive ability is associated with lower levels of measured short-run discounting and small-stakes risk-aversion. Results from

[55] Myopic loss aversion predicts less investment in equities relative to bonds, so it would be better for our purposes if this question did not include "corporate or government bonds." We do not believe this inclusion meaningfully affects our results.

the NLSY showed that individuals with greater cognitive ability are less likely to display behaviors that have been associated with these anomalous preferences, even controlling for income and family fixed-effects.

So who is "behavioral"? We find that the more cognitively skilled are less biased. We therefore conclude that behavioral biases are likely to be especially important in contexts where individuals with low cognitive ability carry the most weight. Yet we also find that the most cognitively skilled are far from fully normative decision-makers. For example, in our pilot study of Harvard undergraduates (described in the supplemental appendix to this paper), only 36 percent of those scoring a perfect 800 on the Math SAT are risk-neutral, and only 67 percent are perfectly patient. Therefore sorting on cognitive ability alone seems unlikely to completely eliminate the effects of anomalous preferences.

Our results also suggest additional reasons why the overall returns to cognitive ability may be underestimated by focusing solely on the labor market returns (Haveman and Wolfe, 1984; Elias, 2004). For example, we calculate that, in a portfolio choice problem, an investor with standard expected utility preferences would be willing to give up about 5% of lifetime wealth in order to avoid having her investment decisions made in accordance with myopic loss-aversion.[56] Evidence presented in table 1 suggests that an increase of one standard deviation in measured cognitive ability corresponds to a 6 percentage point decrease in the probability of loss aversion. Hence, if this coefficient can be interpreted as causal, we might conjecture that a one-standard-deviation increase in cognitive ability is worth about 0.3% of lifetime wealth due to improved portfolio allocation alone.[57] Since portfolio choice is only one of many important household decisions that are affected by cognitive ability, the total value of cognitive ability's effect on decision-making could be quite substantial.

Though crude, such calibrations also suggest that our results may have potentially important policy implications. To the extent that education can increase cognitive ability (Cascio and Lewis, 2005), human capital policy may be an important tool for addressing biases in decision-making in a wide range of contexts. On the other hand, our findings on the role of elementary and high school grades in determining preferences suggest that much of the important heterogeneity in skills may arise early in life.

[56] We assume a constant coefficient of relative risk aversion $\rho = 5$, an exponential discount rate $\gamma = 0.08$, and log-normal portfolio returns in an infinite-horizon model. We use Campbell and Viceira's (2002, p. 104) estimates of equity and bond returns and Benartzi and Thaler's (1995) calculation that a loss-averse investor would hold around 40% equities. Details are available from the authors upon request.

[57] For comparison, Cawley, Heckman, and Vytlacil (2001) estimate that a one-standard-deviation increase in cognitive ability corresponds to an increase in wages of 10-16%.

Finally, our results suggest that the expression of anomalous preferences may be a mistake due to cognitive limitations, rather than a manifestation of fundamental desires. This raises the question of whether social welfare should be evaluated on the basis of the anomalous preferences, or instead on the preferences an individual would express after further deliberation.

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Table 1 *Preferences and Mathematical and Verbal Ability*

Source: Laboratory study 1

Dependent variable	Risk neutral (gains)		Risk neutral (gain/loss)		Patient	
	(1)	(2)	(3)	(4)	(5)	(6)
Standardized math score	0.0776	0.0707	0.0579	0.0676	0.1030	0.0951
	(0.0279)	(0.0305)	(0.0280)	(0.0329)	(0.0475)	(0.0533)
Standardized verbal score		0.0144		-0.0223		0.0172
		(0.0313)		(0.0343)		(0.0546)
Mean of dependent variable	0.1087	0.1087	0.1087	0.1087	0.2826	0.2826
Pseudo-R^2	0.1480	0.1513	0.0688	0.0755	0.0444	0.0453
N	92	92	92	92	92	92

Notes: Results are from probit models with coefficients expressed as marginal effects evaluated at the sample mean of the independent variables. Standard errors in parentheses. Data are from study 1 (laboratory study of Chilean high school seniors). Test scores standardized by the sample standard deviation.

Risk neutral (gains) indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure.

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Risk neutral (gain/loss) indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 0 pesos for sure.

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you lose 250 pesos.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now.

(B) You get X a week from now.

Table 2 *Preferences and School Performance*

Source: Laboratory study 1

Dependent variable	Risk neutral (gains)		Risk neutral (gain/loss)		Patient	
	(1)	(2)	(3)	(4)	(5)	(6)
Standardized math GPA	0.0854	0.0857	0.0500	0.0614	0.1481	0.1525
(elementary school)	(0.0326)	(0.0339)	(0.0359)	(0.0369)	(0.0560)	(0.0592)
High school GPA -		0.0012		0.0436		0.0157
Elementary school GPA		(0.0386)		(0.0439)		(0.0691)
Mean of dependent variable	0.1059	0.1059	0.1059	0.1059	0.2824	0.2824
Pseudo-R^2	0.1171	0.1171	0.0343	0.0516	0.0742	0.0747
N	85	85	85	85	85	85

Notes: Results are from probit models with coefficients expressed as marginal effects evaluated at the mean of the independent variables. Standard errors are in parentheses. Data are from study 1 (laboratory study of Chilean high school seniors). Sample includes only those students for whom elementary school grades were available. Average GPA in elementary school (grades 1-6) standardized by sample standard deviation. Average GPA in high school (grades 9-11) standardized by sample standard deviation.

Risk neutral (gains) indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure.

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Risk neutral (gain/loss) indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 0 pesos for sure.

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you lose 250 pesos.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now.

(B) You get X a week from now.

Table 3 *Preferences and Cognitive Ability*

Source: Laboratory study 2

Dependent variable	Risk neutral		Patient		Selfish
	Safe vs. Risky	Risky vs. Risky	Now vs. One week	Four vs. Five weeks	
	(1)	(2)	(3)	(4)	(5)
Standardized math score	0.0134	0.1255	0.0930	0.0121	0.0857
	(0.0529)	(0.0591)	(0.0448)	(0.0506)	(0.0491)
Mean of dependent variable	0.3333	0.4321	0.2222	0.2963	0.2593
Pseudo-R^2	0.0006	0.0429	0.0514	0.0006	0.0343
N	81	81	81	81	81

Notes: Results are from probit models with coefficients expressed as marginal effects evaluated at the sample mean of the independent variables. Standard errors in parentheses. Data are from study 2 (laboratory study of Chilean high school seniors). Test scores standardized by the sample standard deviation.

Risk neutral indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure [safe vs. risky]. / If the die comes up 1, 2, or 3, you get 200 pesos. If the die comes up 4, 5, or 6, you get 300 pesos [risky vs. risky].

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now (in four weeks).

(B) You get X a week from now (five weeks from now).

Selfish indicates that the participant kept all 200 pesos for herself in an exercise in which she could choose to give part of a 200 peso allocation to an anonymous participant.

Table 4 *Preferences, Cognitive Ability, and Parental Characteristics*

Source: Laboratory study 2

Dependent variable	Risk neutral		Patient		Selfish
	Safe vs. Risky	Risky vs. Risky	Now vs. One week	Four vs. Five weeks	
	(1)	(2)	(3)	(4)	(5)
Standardized math score	-0.0066	0.1265	0.0791	0.0013	0.0743
	(0.0545)	(0.0617)	(0.0435)	(0.0516)	(0.0495)
Father's years of schooling	0.0527	0.0027	0.0087	0.0331	0.0048
	(0.0287)	(0.0307)	(0.0249)	(0.0281)	(0.0263)
Mother's years of schooling	-0.0175	-0.0240	-0.0021	-0.0100	0.0118
	(0.0308)	(0.0329)	(0.0252)	(0.0291)	(0.0285)
Monthly income	-0.1333	-0.1120	-0.1570	-0.0713	-0.0900
(standardized)	(0.0821)	(0.0879)	(0.0767)	(0.0740)	(0.0735)
Total value of automobiles	0.1194	0.1304	0.0212	0.0232	0.0371
(standardized)	(0.0751)	(0.0794)	(0.0702)	(0.0680)	(0.0670)
Mean of dependent variable	0.3333	0.4321	0.2222	0.2963	0.2593
Pseudo-R^2	0.0727	0.0429	0.1187	0.0255	0.0526
χ^2_4 test of effect of controls	6.81	3.80	4.77	2.37	1.59
(p-value)	0.1463	0.4338	0.3112	0.6672	0.8105
N	81	81	81	81	81

Notes: Results are from probit models with coefficients expressed as marginal effects evaluated at the sample mean of the independent variables. Standard errors in parentheses. Data are from study 2 (laboratory study of Chilean high school seniors). Test scores standardized by the sample standard deviation. Father's and mother's years of schooling were reported by participants. Monthly income and make and model of automobiles were reported by parents; we computed the value of household automobiles from this information. For all control variables, we impute missing values with the sample mean of the non-missing values.

Risk neutral indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure [safe vs. risky]. / If the die comes up 1, 2, or 3, you get 200 pesos. If the die comes up 4, 5, or 6, you get 300 pesos [risky vs. risky].

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now (in four weeks).

(B) You get X a week from now (five weeks from now).

Selfish indicates that the participant kept all 200 pesos for herself in an exercise in which she could choose to give part of a 200 peso allocation to an anonymous participant.

Table 5 *Effects of Cognitive Load on Expressed Preferences*

Source: Laboratory study 3

Dependent variable	Risk neutral		Patient		Selfish	Math quiz	
	Safe vs. Risky	Risky vs. Risky	Now vs. One week	Four vs. Five weeks		One	Two
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Not under load	0.3077	0.5882	0.2857	0.3333	0.0000	0.1333	0.3182
Under load	0.1429	0.2000	0.1333	0.3158	0.1176	0.0909	0.2000
Fisher exact p-value	0.387	0.021	0.424	1.000	0.204	1.000	0.481
No. of observations	34	37	36	37	37	37	37
No. not under load	13	17	21	18	20	15	22
No. under load	21	20	15	19	17	22	15

Notes: Data are from study 3 (laboratory study of Chilean high school juniors). Cognitive load indicates that the participant was asked to remember a seven-digit number while performing the task.

Risk neutral indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure [safe vs. risky]. / If the die comes up 1, 2, or 3, you get 200 pesos. If the die comes up 4, 5, or 6, you get 300 pesos [risky vs. risky].

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now (in four weeks).

(B) You get X a week from now (five weeks from now).

Selfish indicates that the participant kept all 200 pesos for herself in an exercise in which she could choose to give part of a 200 peso allocation to an anonymous participant.

Math quiz indicates that the respondent answered all questions correctly in one of two math quizzes.

Table 6 *How Effects of Reasoning on Expressed Preferences Vary With Cognitive Ability*

Source: Laboratory study 3

Dependent variable	*Difference* between reasoning and non-reasoning task in number of choices consistent with...	
	Risk-neutrality (Safe vs. Risky)	Patience (Now vs. One Week)
	(1)	(2)
Standardized math grades	-0.5099	-0.1054
	(0.1571)	(0.2100)
Cognitive load in non-reasoning task	0.5049	-0.2150
	(0.3064)	(0.4220)
Constant	0.2858	0.8258
	(0.2367)	(0.2655)
R^2	0.2694	0.0128
No. of observations	34	34

Notes: Data are from study 3 (laboratory study of Chilean high school juniors). Reasoning task indicates that the participant was asked to think about and express the reasons for her choice.

Risk neutral indicates that participant made six decisions of the following form in a way consistent with expected-value maximization:

Please circle either Choice A or Choice B.

(A) You get 250 pesos for sure.

(B) If the die comes up 1, 2, or 3, you get X. If the die comes up 4, 5, or 6, you get nothing.

Patient indicates that participants made six decisions of the following form in a way consistent with the maximization of undiscounted wealth:

Please circle either Choice A or Choice B.

(A) You get 500 pesos right now.

(B) You get X a week from now.

Table 7 *Behavior and Cognitive Ability in the NLSY*

Source: NLSY

	Controls	Positive net assets	Smoking	Obesity	Financial market participation
		Dependent variable is dummy for...			
(1)	Baseline	0.5420	-0.2566	-0.1362	0.5033
		(0.0147)	(0.0186)	(0.0128)	(0.0185)
		$R^2 = 0.10$	$R^2 = 0.03$	$R^2 = 0.07$	$R^2 = 0.13$
(2)	Income	0.2013	-0.1146	-0.1014	0.2801
	(1979-2000)	(0.0179)	(0.0244)	(0.0162)	(0.0233)
		$R^2 = 0.18$	$R^2 = 0.06$	$R^2 = 0.08$	$R^2 = 0.19$
(3)	Sibling group	0.3416	-0.2180	-0.0280	0.3355
	fixed effects	(0.0253)	(0.0334)	(0.0210)	(0.0322)
		$R^2 = 0.34$	$R^2 = 0.49$	$R^2 = 0.39$	$R^2 = 0.47$
(4)	Income	0.1481	-0.1270	-0.0306	0.2200
	+ Sibling group	(0.0250)	(0.0346)	(0.0219)	(0.0331)
		$R^2 = 0.36$	$R^2 = 0.50$	$R^2 = 0.39$	$R^2 = 0.49$
(5)	Income				
	+ Sibling group				
	Math	0.1740	-0.1296	-0.0422	0.0920
	percentile	(0.0275)	(0.0379)	(0.0226)	(0.0319)
	Verbal	0.0047	-0.0291	0.0082	0.1320
	percentile	(0.0299)	(0.0379)	(0.0246)	(0.0363)
		$R^2 = 0.37$	$R^2 = 0.50$	$R^2 = 0.39$	$R^2 = 0.49$
Mean of dep. var.		0.6544	0.2647	0.1563	0.1938
No. of observations		31608	12980	66663	8386
No. of respondents		5350	4752	5561	4459
No. of sibling groups		2379	2126	2394	2088

Notes: Data from NLSY. Standard errors in parentheses are clustered by individual. Samples include respondents with at least one sibling in NLSY. AFQT score is a percentile ranging from 0.01 to 0.99. Math score is the sum of performance on the arithmetic reasoning, numerical operations, and mathematical knowledge sections of the ASVAB, expressed as a percentile in sample distribution. Verbal score is the sum of performance on the word knowledge and paragraph comprehension sections of the ASVAB, expressed as a percentile in sample distribution. All specifications include a dummy for gender, dummies for age in 1979, and dummies for survey year. Income controls include controls for log of family income for all available years of data, 1979-1998, with dummies for missing values. Asset accumulation variable available for 1990, 1992, 1993, 1994, 1996, 1998, and 2000. Smoking variable available for 1992, 1994, and 1998. Obesity variable available for 1981, 1982, 1985, 1986, 1988, 1989, 1990, 1992, 1993, 1994, 1996, 1998, 2000, and 2002. Financial market variable participation available for 1998 and 2000.