# Is it All Connected? A Testing Ground for Unified Theories of Behavioral Economics Phenomena[*]

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## Abstract

We study the joint distribution of 11 behavioral phenomena in a group of 190 laboratory subjects and compare it to the predictions of existing models as a step in the development of a parsimonious, general model of economic choice. We find strong correlations between loss aversion and the endowment effect, risk aversion and discounting, compound lottery and ambiguity aversion, and between the Allais paradox and risk aversion. Our results support some, but not all attempts to unify behavioral economic phenomena through extensions to Cumulative Prospect Theory. Overconfidence and gender are also predictive of some behavioral phenomena.

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## 1. Introduction

Over the past 30 years, behavioral and experimental economists have made great strides in identifying robust phenomena that are hard to explain within the classic model of economic choice. These include high short-term discount rates and small stakes risk aversion, present bias, loss aversion, the endowment effect, aversion to ambiguity and compound lotteries,

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the common ratio and the common consequence effects in choice under objective risk, and sender/receiver behavior in trust games.[1] In response to these findings, there has been an enormous amount of research within experimental economics aimed at understanding the nature of each of these behaviors. However, much less attention has been paid to understanding the links between them.[2]

In this paper we document the empirical relationship between the 11 phenomena listed above. We use a laboratory experiment to measure each of them in a group of 190 undergraduate subjects, along with data on demographic characteristics, cognitive ability and personality. We estimate features of the joint distribution of these behaviors in the study population, and compare them to the implications of existing behavioral models.

Our primary aim is to provide data with which to test and develop *parsimonious* models of economic choice that can capture *many* features of behavior with a *small* number of parameters. The construction of such models is of first-order importance for the systematic application of behavioral economic insights to mainstream economic analysis. Previous authors have lamented the twin problems of 'model' and 'anomaly' proliferation in behavioral economics (e.g., Fudenberg [2006]). A tractable workhouse model would also greatly benefit policy-makers for policy design and cost-benefit analysis. As we discuss below, recent theoretical work has suggested that a unified behavioral economic model may be feasible. At the same time, there is no point in developing theoretical models that tie different behaviors to the same underlying parameters if these behaviors are not, in fact, related. In this paper we aim to document the empirical links between different behaviors in order to inform this important theoretical project. Our underlying assumption is that if two behaviors are driven by some common underlying parameter, then variance in this parameter in the population should lead to a correlation between these behaviors in our data.

Section 3 provides an overview of the correlations we find in our data, which we then explore in more detail using regression analysis. We organize our findings in four subsections. First, we study the relationship between choices under different types of risk (where probabilities are explicitly stated) and uncertainty (where they are not). We find a strong relationship between loss aversion and the endowment effect, and between attitudes to risky, uncertain and compound prospects, with ambiguity and compound lottery aversion particularly strongly linked. The common ratio and common consequence effect are related to each other and to risk aversion. Subjects who violate independence in the risk domain are also more likely to do so in the domain of uncertainty. However, there is no correlation between the magnitudes of these violations. Surprisingly, we also find a significant relationship between the endowment effect and ambiguity aversion. Overall, a principal component analysis identifies three factors for these choices: one related to risk, uncertainty and compound attitudes; one to the endowment effect and loss aversion; and one to the common ratio and common consequence effects.

Second, we examine the links between choices in the time domain and attitudes to risk

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[1]See section 2.1 for an explanation of these measures.

[2]Notable exceptions include Benjamin et al. [2013], Andersen et al. [2008], Burks et al. [2009b], Dohmen et al. [2010], Cohen et al. [2011], Anderson et al. [2011], Gillen et al. [2015] and Stango et al. [2016]. We refer to Section 5 for a review of the literature.

and uncertainty. We find that risk aversion (as measured by the certainty equivalence of a risky lottery) is related to both discounting and present bias. However, other aspects of risk and uncertainty aversion are not significantly related to time preferences once risk aversion has been controlled for. In particular, we find no link between violations of Expected Utility and present bias.

Third, we test for a relationship between behavior in the trust game and attitudes to risk and uncertainty. We find no systematic link between behavior in the two domains, though we do find a strong relationship between sender and receiver behavior: players that send more also return more.

Finally, we study the relationship between economic behaviors and other measurable characteristics: gender, intelligence, overconfidence, and depression and anxiety measures. We find little role for intelligence in explaining our measured behaviors (although this may be due to the selected nature of our sample). On the other hand, we find that both gender and a form of overconfidence known as overplacement[3] are strongly related to many behavioral phenomena: most notably, ambiguity aversion and the endowment effect are strongly (negatively) related to overplacement, while women tend to be much more loss averse of our economic behaviors.

One methodological innovation of our paper is that we measure the relationship between variables while accounting for measurement error using a technique that, to our knowledge, is novel in experimental economics: we measure each behavior multiple times, then use one observation as an instrument of the others, and then use the derived measure to compute the relationship between different variables. This technique provides unbias estimates in the presence of measurement error.

We turn in Section 4 to discuss the implications of our findings for existing models that make predictions about the relationship between the behaviors in this study. Recent theoretical work offers the possibility of a parsimonious, general model that can capture many important features of behavior built around the Cumulative Prospect Theory (CPT) of Tversky and Kahneman [1992]. CPT contains two extensions to the standard model of economic decision making: loss aversion (which leads people to weight losses larger than gains in their utility functions) and probability weighting (which leads people to overweight small probabilities). Originally, CPT was used to explain preferences over objective lotteries: loss aversion predicts increased risk aversion for lotteries involving gains and losses, while probability weighting can explain the common ratio and common consequence effects, as well as small stakes risk aversion. Subsequent papers have suggested that these two behavioral traits can explain other phenomena: Tversky and Kahneman [1991] and Koszegi and Rabin [2007] show that loss aversion can explain the endowment effect (the gap between the willingness to pay and willingness to accept for an item). Segal [1987, 1990] demonstrate that probability weighting can explain ambiguity and compound lottery aversion. Halevy [2008] shows that probability weighting can lead to present bias in intertemporal choice if the future is perceived as risky by the decision maker. Thus, an 'Extended Prospect Theory' (EPT) model, which expands the domain to which loss aversion and probability weighting

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[3]Overplacement denotes the degree to which a subject believes that they will outperform the group average on a particular task (in this case the questions used to measure cognitive ability).

is applied, could explain many of the behaviors studied in this paper while adding only two parameters to the standard model.[4]

Our results provide support for some of the elements of EPT, but not others. Our data is consistent with a unified notion of loss aversion linking the endowment effect to risk preferences for lotteries with gains and losses. It is also consistent with a probability weighting function that links risk aversion to the common ratio and common consequence effects. However, our data is not consistent with the hypothesis that the same probability weighting function explains present bias, aversion to ambiguity or aversion to compound lotteries.

Other correlations in our data have implications for theoretical links between behaviors that do not depend on probability weighting or loss aversion. The curvature of the utility function can affect attitudes to compound lotteries, uncertain prospects, intertemporal choice and risk aversion. The strong link we find between these behaviors suggests that the shape of the utility function is an important determinant of all four. Ortoleva [2010] proposes the concept of a 'fear of change' which could link the endowment effect and ambiguity aversion, as is apparent in our data. The correlation we find between ambiguity and compound lottery aversion suggests either that ambiguous prospects are seen as compound lotteries (as in Segal [1990]), or that compound lotteries are seen as ambiguous prospects. The fact that subjects who are ambiguity averse are also more likely to violate independence in risky choice is problematic for the many theories of ambiguity aversion that rely on risk independence (e.g., Gilboa and Schmeidler [1989]), suggesting the need for models that simultaneously allow for both types of violation (e.g., Dean and Ortoleva [2016]).

There exists a small but significant literature that investigates the relations between various different economic behaviors. Concurrent with our paper, Stango et al. [2016] also measure a wide range of behaviors in a study population, but doesn't focus on the correlation between them. Following our paper and building on it are Gillen et al. [2015] Camerer et al. [2016a,b]. Previous papers have focused on subsets of the behaviors we measure, including between trust game behavior and risk (for example Eckel and Wilson [2004]), discounting and risk (Andersen et al. [2008], Cohen et al. [2011], Andreoni and Sprenger [2012], Abdellaoui et al. [2013]), ambiguity and risk (Lauriola and Levin [2001], Cohen et al. [2011]), ambiguity and compound lottery aversion (Halevy [2007], Abdellaoui et al. [2015b]), and between economic behaviors and intelligence (Benjamin et al. [2013], Andersen et al. [2008], Burks et al. [2009b], Dohmen et al. [2010], Anderson et al. [2011], and Li et al. [2013]). We refer to Section 5 for an in-depth discussion of the literature.

The key innovation of our paper is that we study a wide range of behavior in the same group of subjects. This has a number of advantages over existing studies. First, it allows us to test a wide number of theoretical predictions on the same data set. This includes those that apply to relationships that to our knowledge have not been previously looked at, e.g., those relating violations of expected utility in risky choices to other behaviors. Second, we can control for one behavior when examining the relation between others (for example we can control for risk aversion when looking at the relationship between the endowment effect and loss

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[4]Such unification attempts have been discussed in Andreoni and Sprenger [2010] and Epper and Fehr-Duda [2012]. The latter in particular discusses how an extension of cumulative prospect theory may explain a number of observed anomalies.

aversion). Third, we can differentiate between explicitly bilateral relationships between two phenomena and a general tendency towards 'irrational' behavior that links all phenomena. Fourth, we can compare the importance of different estimated relationships. Fifth, our data set allows us to pick up important relationships that are not predicted by any current theory and therefore would not be the object of specific study. Finally, there are direct practical benefits in understanding the correlation between multiple behaviors independent of any modeling analysis: understanding the joint distribution of such phenomena could help with empirical analysis that allows for more than one of our behaviors of interest – for example by informing about their orthogonality. The identification of the main factors of economic decision making could help in the design of efficient tests of a person's 'economic makeup,' much in the same way that personality research has allowed psychologists to come up with efficient tests that characterize a person's personality.

There are two limitations of our current approach. The first is the selective nature of our sample, comprised of undergraduate students; while typical in experimental economics, this limits the external validity of our findings. The second is the lack of evidence linking the constructs measured in our experiment to economic choices of interest, such as financial decisions or employment decision. In ongoing work we are collecting data designed to address both of these issues.

Section 2 describes our experimental method, including what we measure in our subjects. Section 3 describes our empirical results. Section 4 describes existing theories on the relations between our phenomena of interest and tests their predictions with our data set. Section 5 reviews the existing literature. Section 6 concludes.

# 2. Experimental Design

## 2.1 What We Measure, and How

The analysis in this paper is based around the measurement of 11 economic behaviors, as well as cognitive and personality measures, all of which are listed in Table 1. For all economic behaviors, other than those involving the trust game, our measures are based on indifferences elicited using a multiple price list method. Subjects were presented with a sequence of between 12 and 18 binary choices on the screen. In each choice, the option on the left remained the same, while the option on the right improved as the subject moved further down the screen. Subjects had to make a choice on each line (although at most one of these choices would be actualized; see Section 2.2 below). Indifference is estimated as the point at which the subject switched from choosing the option on the left to the option on the right. If the subject did not make exactly one switch, then data from that question was discarded (we discuss the issue of missing data in Section 2.4.3 below). A sample screen shot is shown in the appendix, along with the experimental instructions.

We now describe how we construct each measure. We emphasize that we take an explicitly non-structural approach in this paper. Each phenomenon is measured directly from behavior, without assuming any specific model or functional form whenever possible (this is the case

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for all our measures except for loss aversion, for which we are not aware of a model-free measure that can be actualized with a small number of choices). For example, we define 'risk aversion' as the difference between a subject's certainty equivalence for a lottery and its expected value, rather than the estimated curvature of the utility function under some model. Thus, while the tasks we used have been designed to isolate a particular form of behavior (for example violations of expected utility), the degree of expression could be related to many underlying causes - curvature of the utility function, probability weighting and so on.

The main advantage of this approach is that it means our results are not dependent on a particular functional form or parametric assumption. We study the empirical connection at a fundamental, behavioral level, which we believe to be instructive per se in the study of human behavior. Yet this approach still allows us to evaluate models that make predictions about these relationships, as we do in section 4. Moreover, we can do so independently of the specifics of each model. This is particularly crucial for those behaviors for which we have multiple different models, or for which most existing models have a limited empirical match with the experimental data. Put differently, we can test one feature of these models — their predictions about the relationships between the behaviors — independently from other assumptions or from the specific functional form. In addition, our approach allows us to study relationships that have not been analyzed by existing models. We therefore see this work as complimentary to a more structural analysis of the data, which we are currently pursuing in other work.

We use two other principles in designing our measures. First, we tried to conform to the most standard way we could find to capture each behavior. Second, in most cases we use multiple questions to measure each behavior, allowing us to control for measurement error (see Section 2.4.1). The following describes each measure in more detail (the knowledgeable reader could skip to the next subsection).

*Discount Rate and Present Bias.* We measure each subject's discount rate using three questions in which we elicit indifferences of the form $(x, t) \sim (y, s)$ where $(x, t)$ is the amount $x$ received in $t$ weeks. We used three different sets of values for $\{t, y, s\}$ ($\{5,6,6\}$, $\{6,8,7\}$ and $\{5,10,7\}$), and in each case we identify $x$ using the multiple price list method. For each triple, we calculate the equivalent annualized discount rate. For this section of the experiment, payment was made by cheque that was mailed to the subject. The date of payment was the date that the cheque was mailed.

Present bias refers to the phenomena in which subjects tend to exhibit higher discount rates when the soonest available payment is available immediately. To measure it, we repeat the above analysis, but 'shift' everything forward so the date of the sooner payment is immediate: in other words, we use the values $(0, 6, 1)$, $(0, 8, 1)$ and $(0, 10, 2)$ for $(t, y, s)$. Following recent practice in the literature (e.g. Andreoni and Sprenger [2012]), in case of payment in '0' days, cheques were mailed on that day (rather than the subject receiving the cash immediately): this is done to reduce any effect due to differing transaction costs between current and future payments.

We call the discount rate measured using these questions 'Discount Rate (Present)' to discriminate from the degree of discounting elicited when all payments were in the future.

Table 1: Summary of Measures

| Characteristic | How measured |
|---|---|
| Discount Rate | Value x in t weeks of amount y in t + s weeks, annualized interest rate |
| Discount Rate (Present) | Value z today of amount y in s weeks, annualized interest rate |
| Present Bias | (x-z)/y |
| Risk Aversion | x/2 minus the certainty equivalence of lottery $(0.5,x; 0.5,0)$ as a percentage of x/2 |
| Common Consequence | Difference between z such that x for sure is indifferent to $(0.89,x; 0.10,z; 0.01,0)$ and y such that $(0.11,x; 0.89,0)$ is indifferent to $(0.10,y; 0.90,0)$ as a percentage of x |
| Common Ratio | Difference between z such that x for sure is indifferent to $(0.80,z; 0.20,0)$ and y such that $(0.25,x; 0.75,0)$ is indifferent to $(0.20,y; 0.80,0)$ as a percentage of x |
| Uncertainty Attitude | x/2 minus the value of a gamble to win x on the color of a ball drawn from an urn with an unknown number of red and black balls as a percentage of x/2 |
| Ambiguity Aversion | Difference between value of a gamble to win x on the color of a ball drawn from an urn with 20 red balls and 20 black balls, and one based on an urn with an unknown number of red and black balls as a percentage of x/2 |
| Compound Lottery Attitude | x/2 minus the value of a gamble to win x on the color of a ball drawn from an urn with a uniform probability of any number of red and black balls as a percentage of x/2 |
| Reduction Aversion | Difference between value of a gamble to win x on the color of a ball drawn from an urn with 20 red balls and 20 black balls and one based on an urn with a uniform probability of any number of red and black balls as a percentage of x/2 |
| Mixed Risk | x minus the value y that makes the lottery $(0.5,x; 0.5,-y)$ indifferent to 0 for sure |
| Loss Aversion | Ratio of parametrically estimated slopes of utility functions in the gain and loss domains |
| Buy Risk | x/2 minus the certainty equivalence measured as buying price of a lottery $(0.5,x; 0.5,0)$ as a percentage of x/2 |
| Endowment Effect | Difference between selling and buying price for a lottery as a percentage of its expected value |
| Trust:Sender | How much is sent as first mover in trust game |
| Trust:Returner | Average percent amount sent that is returned (elicited using strategy method) |
| Cognitive Ability | Number correct of 17 Raven's Matrix questions |
| Overconfidence | Predicted minus actual score for Raven's Matrix questions |
| Overplacement | Predicted own score minus predicted group mean for Raven's Matrix questions |
| Depression | Score on Beck's Depression Inventory |
| Anxiety | Score on Beck's Anxiety Inventory |

Present bias for each pair of questions is measured as the change in indifference points due to the shift to immediate sooner payment as a proportion of the later amount.[5] Note that standard exponential discounting implies that there should be no present bias.

It should be noted that, while we use the term 'Discount Rate', we mean this in a purely behavioral sense: it is the rate at which the subject is prepared to trade money at one point in time for money at another point in time. As we discuss below, there are many reasons why this may not be the same as (for example) the discount factor in the standard exponential model of time preference.

*Risk Aversion.* We measure risk aversion by eliciting the certainty equivalence of three 50/50 lotteries: between \$6 and \$0, \$8 and \$2 and \$10 and \$0. We report the difference between the expected value and certainty equivalence of the lottery as a proportion of the expected value.

*Violations of Expected Utility Under Risk: Common Ratio and Common Consequence Effects.* We measure two classic violations of expected utility under risk: the common ratio and common consequence effects, both forms of the Allais paradox.

To measure the common consequence effect, first we measure the value of $z$ that makes subjects indifferent between lotteries $A = \{100\%$ chance of $x\}$, and $B = \{89\%$ chance of $x$, 1% chance of \$0, 10% chance of $z\}$. We then elicit the $y$ that makes the agent indifferent between $A' = \{11\%$ chance of $x$ and 89% chance of \$0\} and $B' = \{10\%$ chance of $y$ and 90% chance of \$0\}. We do this for two values of $x$: \$4 and \$8. Expected utility implies $y = z$. The standard common consequence effect is that $z > y$, which is usually interpreted as implying that the subject needs more compensation in order to choose lottery $B$ over $A$ than to choose $B'$ over $A'$ because $A$ provides a prize with certainty. We estimate the size of the common consequence effect as $\frac{z-y}{x}$.

The common ratio effect is estimated similarly. We find the $z$ that makes the subject indifferent between $C = \{100\%$ chance of $x\}$ and $D = \{80\%$ chance of $z$ and 20% chance of \$0\} and the $y$ that makes her indifferent between $C' = \{25\%$ chance of $x$ and 75% chance of \$0\} and $D' = \{20\%$ chance of $y$ and 80% chance of \$0\}. Again, we use \$4 and \$8 as two values for $x$, and again, expected utility maximization implies that $y = z$. The standard common ratio effect finds that $z > y$. We measure the common ratio effect as $\frac{z-y}{x}$.

*Ambiguity Aversion and Compound Lottery Aversion.* In order to measure aversion to ambiguity and compound lotteries, we use a technique similar to that of Halevy [2007]: subjects are presented with bags filled with 40 poker chips that are either red or black. They can select a color to bet on, creating a gamble in which they will win a prize of value $x$ if the poker chip that is drawn is of their selected color, and \$0 otherwise. Their certainty equivalence of this gamble is then elicited. For each prize level $x$, the certainty equivalence is extracted for three different type of bags:

- <u>Risk</u>: subjects are told there are 20 red chips and 20 black chips.

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[5]For example, if a subject was indifferent between \$8 in 5 weeks and \$10 in 7 weeks, and \$7 in 0 weeks and \$10 in 2 weeks, their present bias would be measured as 10%. Indifference measured by the point at which they switch from earlier to later payment, as described above.

- Uncertainty: subjects are told nothing about the composition of the bag.[6]

- Compound: subjects are told the following "The number of red chips was determined as follows: a computer randomly chose a number between 0 and 40 with equal probabilities. The number chosen is the number of red chips in the bag. The remainder of the chips are black."

We refer to the negative of the difference between the certainty equivalence of the compound urn and expected value as 'compound attitude,' and the negative of the difference between the certainty equivalence of the uncertain earn and its 'expected value' (assuming an equal probability of red and black) as 'uncertainty attitude'. In both cases a higher number reflects a lower value placed on the gamble in question.

Note that a subject who reduces the uncertainty of compound lotteries in the standard way should treat the risk and compound lottery bags in the same way, while under subjective expected utility the gamble on the uncertain bag should be valued at least as highly as the gamble on the risky bag.[7] We therefore measure ambiguity aversion for each prize level as the certainty equivalence of the gamble on the risky bag minus the certainty equivalence of the gamble on the ambiguous bag, divided by the expected value of the gamble on the risky bag. Aversion to reducing compound lotteries ('reduction aversion') is measured in the same way, but using the value of the gamble on the compound lottery bag rather than that of the ambiguous bag. We measure each of these behaviors at three prize levels: $6, $8 and $10, using a different bag each time.

*Loss Aversion.* Loss aversion in risky choice is usually defined in the context of a specific model of decision making: the utility function in the loss domain has a steeper slope than in the gain domain. The behavioral implication of loss aversion is that risk aversion for lotteries that involve both gains and losses is higher than for those which involve only gains or only losses (see for example Thaler [1997]). As non-parametric ways of measuring loss aversion require a large number of choices to be observed (Wu and Gonzalez [1996]), we use the parametric methodology of Abdellaoui et al. [2008]. First, the answer to the questions on risky bets are used to estimate a constant relative risk aversion (CRRA) utility function for the gain domain. Next, the certainty equivalent of a mirror image set of lotteries in the loss domain is used to estimate a CRRA utility function for losses. Finally, we elicit the value of $y$ that makes the subject indifferent between $0 for sure and a 50/50 gamble between $x$ and -$y$, for $y$ equal to $6, $8 and $10 (a value we call 'Mixed Risk'). Loss aversion is estimated as the additional slope of the utility function in the loss domain relative to the gain domain that is necessary to match these choices, conditional on the slopes estimated separately in the two domains.[8]

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[6]Specifically, they are told "The bag contains 40 chips. The number or red and black chips is unknown. It could be any number between 0 red chips (and 40 black chips) and 40 red chips (and 0 black chips)."

[7]The reason is that in both cases the subject can choose which color to bet on. Since for any subjective belief $r$ about the probability of a red ball being drawn, $\max(r, (1 - r)) \geq 0.5$, then by choosing the right color the ambiguous bag has to have at least as high a probability of winning as the risky bag.

[8]That is, for each subject we estimate a Constant Relative Risk Aversion utility function in the gain domain and in the loss domain. The loss aversion parameter is then estimated as the value of $\lambda$ that best fits $0 = U_G(y) + \lambda U_L(x)$, where $U_G$ and $U_L$ are the estimated utility functions in the gain and loss domain

*The Endowment Effect.* The endowment effect refers to the phenomenon in which subjects tend to require more money to relinquish an item that they already have than they are prepared to pay for it when they do not own the item (the willingness to accept/willingness to pay gap). To measure it, we use the certainty equivalent of the lotteries used to elicit risk aversion (described above) as an estimate of the 'willingness to accept' for these lotteries.[9] The willingness to pay for the same lotteries is then extracted by endowing subjects with an additional $10, then telling them: "...you will be offered the opportunity to buy a lottery ticket. That is, you will be offered the opportunity to use some of this additional $10 in order to buy a lottery ticket. If you choose to do so (and that question is selected as one that will be rewarded), then you will pay the specified cost for the lottery, and you would keep the remaining amount of money and the lottery." We call risk aversion measured using this question 'Buy Risk'. The endowment effect for each lottery is measured as the willingness to accept minus the willingness to pay for that lottery, as a proportion of the lottery's expected value.[10]

*Sender and Receiver Behavior in the Trust Game.* The trust game is a standard tool in experimental economics used to estimate social preferences (see for example Berg et al. [1995]). Player 1 in the trust game is endowed with a certain amount of money ($5 in our experiment). They then have to decide how much of this to keep, and how much to send to Player 2.[11] Any amount they send is tripled by the experimenter. Player 2 then has to decide how much of this money to keep and how much to return to Player 1.

In our experiment, we use the strategy method to elicit each subject's play in each possible decision node in the game.[12] Subjects are asked to report how much they would send if they were Player 1, and how much they would return as Player 2, conditional on each possible received amount. If this question was selected as one to be actualized, then their responses were paired with those of another subject to determine payment.

The unique subgame perfect equilibrium of the extensive form of this game is that Player 1 sends nothing, and Player 2 never returns anything. Subjects often do not conform to this behavior. We measure sender behavior as the amount that they choose to send as Player 1, and returner behavior as the average fraction of the amount that Player 1 sends that they choose to return.

*Cognitive Ability, Overconfidence, Overplacement and Gender.* We measure cognitive ability using Raven's Matrices, a standard, non verbal measure of perceptual reasoning. We use a 12 question subset from Raven's Advanced Progressive Matrices test developed by Arthur

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respectively.

[9]These questions were phrased as follows: after a description of the lottery, the subjects were told "This lottery is yours to keep (if this is one of the questions that is selected at the end of the experiment). However, you will be offered the opportunity to exchange this lottery for certain amounts of money (for example $5)."

[10]While the endowment effect has typically been measured using the difference between the WTP and WTA of physical goods such as mugs, there are many studies that have used lotteries - see for example Isoni et al. [2011].

[11]Our subjects were constrained to choose from 50 cent increments.

[12]This approach is standard, although it may bias downward the subject's degree of trust (see Casari and Cason [2009]).

and Day [1994],[13] as well as a subset of 5 matrix questions from the set used by Putterman et al. [2011], giving 17 questions in total.

Experimental subjects are often found to exhibit 'overconfidence' in their abilities. In this study we use two methods to estimate this. First, after the task we ask subjects to report their expected performance in the cognitive test, i.e., how many of the 17 questions they think they got right. Following the classification in Moore and Healy [2008], we measure 'overestimation' as the difference between the predicted score and the actual score. We also ask them to estimate the average number of correct responses in the session. We then call 'overplacement' the difference between their own predicted score and their predicted average for the room. Finally, we asked subjects to self-report their gender.

*Anxiety and Depression.* We measure anxiety and depression in our subjects using the Beck Anxiety and Depression indices, tools commonly used to assess these traits. Each consists of 21 or 20[14] multiple choice questions designed to assess the subject's depression and anxiety. For anxiety, scores range from 0 to 63, with a score over 36 considered a sign of severe anxiety. Depression scores range from 0 to 60, with scores above 31 considered a sign of 'severe depression'.

## 2.2 Experimental Details

The experiment was performed on 190 subjects over 8 sessions in 2011. All subjects were recruited from Brown University. The experiment was administered via a specially written computer program.[15] In total, subjects answered approximately 50 questions to estimate their preferences, followed by the cognitive test, overconfidence measures, demographics and personality measures. On average subjects took about 40 minutes to complete the experiment. A copy of the instructions to subjects is included in the online Appendix.[16]

Economic questions were asked in 8 blocks (discounting and present bias, risk aversion, violations of expected utility, uncertainty and compound lottery attitude, risk aversion for losses, risk aversion for gains and losses, trust game, willingness to pay for lotteries), with specific instructions appearing before each block. For slightly less than half the subjects, the order of these blocks was reversed, allowing us to control for order effects.

At the end of the study, two questions of the 50 were selected at random for payment. For each of these, one line was then selected at random, and subjects would receive the option that they chose on that line.

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[13]Items 1, 4, 8, 11, 15, 18, 21, 23, 25, 30, 31 and 35.

[14]In consultation with the Institutional Review Board at Brown University, we dropped the question from the depression inventory related to suicide.

[15]Available from the authors upon request.

[16]Some sessions of the experiment included further questions which were not used in this study. Some subjects answered additional common ratio-type questions which were aimed at measuring the magnitude of this effect at different probability levels. Some subjects completed the NEO Five Factor Inventory, aimed at measuring the 'big five' personality traits. As with the Beck anxiety and depression inventories, these measures were not highly correlated with our behavioral measures. We also asked subjects to self-report their SAT scores. These measures were not used, as they appeared not to add much information to the results of the Raven's matrix questions while reducing the sample size, as several subjects did not self-report.

Table 2: Summary of Estimated Behaviors

| Variable | Obs | Mean | S.D. | Median | Prob | Stand. | Neut. | Non-Stand. | Incon. |
|---|---|---|---|---|---|---|---|---|---|
| Discount Rate | 174 | 294% | 453% | 75% | 0.000 | 39% | 61% | | |
| Present Bias | 167 | 3.6% | 8.0% | 0.0% | 0.000 | 35% | 49% | 8% | 8% |
| Risk Av. | 161 | 5.4% | 11.3% | 3.1% | 0.000 | 45% | 30% | 17% | 7% |
| Common Consequence | 173 | 8.7% | 30.4% | 0.0% | 0.000 | 45% | 35% | 12% | 8% |
| Common Ratio | 167 | 10.8% | 17.1% | 7.8% | 0.000 | 60% | 17% | 14% | 10% |
| Ambiguity Av. | 159 | 13.5% | 15.3% | 11.7% | 0.000 | 64% | 18% | 9% | 9% |
| Reduction Av. | 160 | 10.4% | 14.9% | 6.8% | 0.000 | 59% | 19% | 10% | 12% |
| Loss Av. | 140 | 1.29 | 0.49 | 1.17 | 0.000 | 49% | 42% | 9% | |
| Endowment Effect | 144 | 14.2% | 17.0% | 12.2% | 0.000 | 58% | 9% | 12% | 22% |
| Trust | 177 | 2.6 | 1.9 | 2.5 | 0.000 | 79% | 21% | | |
| Return | 180 | 26.7% | 20.3% | 28.6% | 0.000 | 81% | 19% | | |
| Ravens | 180 | 12.8 | 3.4 | 13.5 | | | | | |
| Overconfidence | 180 | -0.8 | 2.3 | -1.0 | 0.000 | 26% | 22% | 52% | |
| Overplacement | 180 | 0.9 | 2.4 | 1.0 | 0.000 | 60% | 15% | 25% | |
| Depression | 162 | 6.6 | 6.0 | 4.0 | | | | | |
| Anxiety | 151 | 6.6 | 6.5 | 5.0 | | | | | |

Prob: probability associated with the test of the null hypothesis that behavior is standard (i.e. equal to 1 for loss aversion, 0 for all other measures). 'Stand.' is the percentage of subjects who weakly exhibit the effect in the standard direction for all three measures (and strictly in at least one). 'Neut'. is the percentage of subjects who do not exhibit the effect. 'Non-Stand.' is the percentage of subjects who weakly exhibit the effect in the non-standard direction for all three measures (and strictly in at least one). 'Incon.' is the proportion of subjects that sometimes exhibit the effect in the standard direction and sometimes in the non-standard direction.

## 2.3 Summary of Estimated Behaviors

Table 2 summarizes our measures of each behavior across subjects. By and large, our estimated behaviors are similar to those reported in the literature. Almost all the phenomena of interest are exhibited and are statistically significant at the 0.1% level.[17] The only exception is that we do not observe overconfidence in our subjects: on average participants under-predict their performance in the Raven's Matrices task by almost 1 question. This is unsurprising given the difficult nature of the task, which often leads to underconfidence – see, for example, Moore and Healy [2008]. Subjects do, however, exhibit overplacement: on average, subjects expect to be above the mean in performance.

## 2.4 Comments

*2.4.1 Measurement Error and Regression Techniques* One potential cause of concern for our study is measurement error, which would lead to a downward bias in the magnitude of the estimated relationships between our variables. This would be particularly worrying if, as seems likely, some of our measures are more prone to measurement error than others. In order to address this problem we use the fact that we have multiple observations for almost all of our measures. In regression analysis we treat each observation as a noisy indicator of the underlying behavior: so, for example, the three questions in which subjects value lotter-

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[17]By which we mean, for example, that the hypothesis that the mean of the common consequence measure is zero can be rejected at the 0.1% level.

ies for gains are treated as noisy estimates of their true risk attitudes. Using the 'multiple indicators' approach,[18] we perform a two stage least squares regression, instrumenting one of these measures with the remaining two. So for example, the relationship between ambiguity aversion and risk aversion is estimated by regressing measured ambiguity aversion on the first of our risk aversion measures, using the other two risk aversion measures as instruments. Assuming that measurement error is uncorrelated across questions, this technique will provide consistent parameter estimates.[19]

*2.4.2 Incentives* A potential concern with our incentivization procedure is that, while the multiple price list method is incentive compatible for expected utility maximizers,[20] this is not necessarily the case for more general preferences over risk. As pointed out by Holt [1986], a subject who obeys the reduction of compound lotteries but violates the independence axiom may make different choices under a randomly incentivized elicitation procedure than they would make in each choice in isolation. On the other hand, if the decision maker treats compound lotteries by first assessing the certainty equivalents of all first stage lotteries, then plugging these numbers into a second stage lottery (in the manner of Segal [1987]) then this procedure is incentive compatible. Karni and Safra [1987] prove the non-existence of an incentive compatible mechanism for general non-EU preferences.

Ours is not the first study to run into these issues, and there is significant methodological work examining the properties of the randomly incentivized elicitation procedures. In general, the results are encouraging. Beattie and Loomes [1997], Cubitt et al. [1998] and Hey and Lee [2005] all compare the behavior of subjects in randomly incentivized treatments to those that answer just one choice and find little difference. Even more encouragingly, Kurata et al. [2009] compare the behavior of subjects that do and do not violate expected utility in the Becker-DeGroot-Marschak procedure (which is strategically equivalent to our price list method) and find no difference. On the other hand, Freeman et al. [2015] find that subjects tend to choose the riskier lottery more often in choices from lists than in pairwise choices.

*2.4.3 Missing Data* In order to identify the indifference point on which we base our estimates, we require our subjects to make exactly one interior switch per question from the (constant) option on the left to the improving option on the right. Data from questions in which subjects do not make exactly one switch are discarded. Subjects who make multiple interior switches have behavior which is not compatible with monotonicity in money, while we cannot estimate an indifference point for subjects who have zero interior switches (such subjects would also have to have very extreme preferences or, more likely, not be paying attention to the question). This leaves us with the issue of how to deal with this missing data.

We exclude from our analysis entirely 10 subjects who failed to make a unique switch

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[18]See, for example, Wooldridge [2001] section 5.3.2.

[19]Naturally, any component of measurement error which is correlated across questions is indistinguishable from 'true' preferences.

[20]It is optimal for subjects to choose their preferred option in each case independent of their responses to other questions

on more than 15 questions, on the assumption that any remaining information from these subjects is likely to be of little use. For the remaining subjects the loss of data varies from 0% of observations for the trust game to 22% for the loss aversion measure (which is constructed using 9 separate choices, and thus is much more likely to have missing data). On average, we lose about 8% of the subjects for each measure, which is broadly in line with what is found in other studies (e.g., Holt and Laury [2002]).

Because the use of multiple measures in regressions and factor analysis compounds this problem, we interpolate using the data we have to estimate the missing data – so, for example, if we observed data for two of the three risk aversion questions for a subject, we estimate the response to the third question using the relationship between the answers to the questions estimated on subjects that answer all three. Doing so reduces the number of missing observations – for example it allows us to construct a loss aversion measure for all but 10% of our subjects. Importantly, this approach doesn't significantly alter our findings: similar results are obtained if we just disregard this data, albeit with a smaller sample size.

*2.4.4  Multiple Comparisons*   One potential issue with our study is the problem of multiple comparisons: because we report many correlations, we would expect some fraction to be significant even if all were, in fact, independent. As we are at least in part interested in the comparison between these correlations and those predicted by existing theories, the uncorrected significance levels we report are still of interest. An alternative approach would be to treat this as a purely statistical problem, in which case it would be appropriate to control for multiple comparisons using, for example, the Sidak correction.[21] We discuss the implication of such a correction in section 3.1 below.

# 3.   Results

We now describe the relationships between measured behaviors that we find in our data. In this section, we focus on describing the empirical results in a model-free way. In Section 4 we will discuss the implications of these findings for existing models that predict relationships between our variables of interest.

## 3.1   Overview

Table 3 shows the raw correlations between our measures of time preference, risk aversion, attitudes to compound lotteries and uncertainty, common ratio and common consequence effect, mixed risk and buy risk, sender and receiver behavior in the trust game and our various demographic measures, personality, and belief measures.[22] For simplicity, this table includes only 'raw' measures (such as uncertainty attitude), rather than those which are constructed from multiple questions (such as ambiguity aversion). This means that we do

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[21]For $n$ comparisons, a variable is significant at the 5% level after Sidak correction if it is significant at the $1 - 0.95^{\frac{1}{n}}$ level pre-correction.

[22]Multiple measures were aggregated into a single value by taking their principal component.

Table 3: Correlation Between Behaviors

| | Discount | Present Disc. | Risk Av. | C. Consequence | C. Ratio | Uncertainty | Compound | Mixed Risk | Buy Risk | Send | Return |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Discount | 1.00 | | | | | | | | | | |
| Present Disc. | 0.67 (0.00) | 1.00 | | | | | | | | | |
| Risk Av. | 0.15 (0.06) | 0.32 (0.00) | 1.00 | | | | | | | | |
| C. Consequence | 0.06 (0.46) | 0.14 (0.06) | 0.26 (0.00) | 1.00 | | | | | | | |
| C. Ratio | 0.00 (0.98) | -0.01 (0.91) | 0.20 (0.01) | 0.30 (0.00) | 1.00 | | | | | | |
| Uncertainty At. | 0.17 (0.03) | 0.18 (0.03) | 0.46 (0.00) | 0.16 (0.05) | 0.23 (0.00) | 1.00 | | | | | |
| Compound At. | 0.17 (0.03) | 0.18 (0.02) | 0.49 (0.00) | 0.20 (0.01) | 0.17 (0.03) | 0.83 (0.00) | 1.00 | | | | |
| Mixed Risk | 0.11 (0.21) | 0.25 (0.00) | 0.26 (0.00) | 0.17 (0.04) | 0.27 (0.00) | 0.15 (0.09) | 0.20 (0.02) | 1.00 | | | |
| Buy Risk | 0.08 (0.34) | 0.19 (0.02) | 0.33 (0.00) | 0.20 (0.01) | 0.17 (0.04) | 0.24 (0.00) | 0.35 (0.00) | 0.63 (0.00) | 1.00 | | |
| Trust - Send | -0.09 (0.23) | -0.02 (0.82) | -0.04 (0.63) | -0.09 (0.27) | 0.04 (0.61) | -0.04 (0.65) | -0.06 (0.41) | 0.11 (0.21) | 0.01 (0.86) | 1.00 | |
| Trust - Return | -0.04 (0.58) | 0.02 (0.84) | 0.07 (0.34) | 0.01 (0.85) | 0.04 (0.58) | 0.10 (0.20) | 0.02 (0.76) | 0.22 (0.01) | 0.17 (0.17) | 0.46 (0.00) | 1.00 |
| Intelligence | -0.23 (0.00) | -0.08 (0.29) | -0.06 (0.46) | 0.02 (0.84) | 0.03 (0.71) | -0.11 (0.15) | -0.07 (0.34) | -0.02 (0.83) | -0.19 (0.02) | 0.10 (0.17) | -0.01 (0.88) |
| Overconf. | -0.01 (0.95) | -0.02 (0.78) | 0.04 (0.59) | -0.07 (0.36) | -0.06 (0.40) | 0.05 (0.55) | 0.00 (0.97) | -0.14 (0.08) | 0.03 (0.68) | 0.06 (0.41) | 0.09 (0.26) |
| Overplace | -0.15 (0.05) | -0.08 (0.31) | -014 (0.08) | -0.15 (0.04) | -0.06 (0.41) | -0.19 (0.02) | -0.13 (0.09) | -0.28 (0.00) | -0.35 (0.00) | 0.01 (0.87) | -0.06 (0.42) |
| Gender | 0.11 (0.14) | 0.06 (0.47) | -0.07 (0.39) | 0.06 (0.41) | -0.01 (0.86) | -0.11 (0.15) | -0.06 (0.44) | 0.43 (0.00) | 0.34 (0.00) | -0.02 (0.83) | 0.08 (0.31) |
| Anxiety | -0.01 (0.88) | 0.09 (0.26) | 0.16 (0.06) | -0.15 (0.08) | -0.04 (0.65) | -0.01 (0.91) | 0.00 (1.00) | -0.03 (0.76) | -0.01 (0.87) | 0.00 (0.99) | 0.07 (0.40) |
| Depression | 0.12 (0.12) | 0.15 (0.05) | 0.03 (0.68) | -0.13 (0.12) | -0.01 (0.88) | -0.07 (0.36) | 0.04 (0.63) | 0.07 (0.43) | -0.02 (0.77) | -0.04 (0.62) | 0.00 (0.99) |

Cells shaded in yellow (lightest) are significant at the 0.05 level, those in green are significant at the 0.01 level, and those in red (darkest) are significant at the 0.001 level. Top pane shows correlation coefficient between row and column variable. Bottom pane shows probability associated with the null hypothesis of no correlation. Gender coded 0=male, 1=female.

not have to worry about spurious correlations caused by the same underlying question being used in the construction of multiple measures. The colors of the cells indicate the level of significance.

Several broad patterns are apparent:

1. There are significant pairwise correlations between almost all of our measures of attitudes to risk and uncertainty. However, the bilateral strength of these relationships varies greatly. The highest correlations are between (i) risk aversion and attitudes to uncertainty and compound lotteries and (ii) mixed risk (which is related to loss aversion) and buy risk (which is related to the endowment effect). Also notable are the correlations between (iii) risk aversion, common ratio and common consequence effect (iv) buy risk and compound lottery aversion and (v) risk and buy risk.

2. There are significant relationships between many of our measures of risk/uncertainty attitude and measured discount rates, particularly between risk aversion and discounting to the present.

3. While sender and receiver behavior in the trust game are strongly related to each other, there is no evidence of a systematic relationship between these variables and risk attitude.

4. Demographic variables are only weakly predictive of behavior. The exception is our measure of overplacement - which is significantly and negatively correlated with many variables - and gender - which shows that females dislike mixed risk and buy risk significantly more than males.

As discussed above, it is possible to control for the problem of multiple comparisons using, for example, the Sidak correction. We note that such a correction in this case is extremely demanding: significance at the 5% level corrected would require significance of about 0.05% before correction. Broadly speaking, the relationships that survive correction are those labeled as significant at the 0.1% level in Table 3.

Table 3 is designed to provide only a general overview of the data (although the four patterns above will survive more rigorous analysis, as we will see below). It does not correct for measurement error (as discussed in section 2.4.1). It also does not include controls that may be deemed relevant in some cases. We address these issues using regression analysis for relationships of particular interest in the next 4 subsections. We focus on the relationships between: (i) different facets of choice under risk and uncertainty; (ii) risk/uncertainty preferences and time preferences; (iii) risk/uncertainty preferences and trust game behavior; (iv) all our behaviors and demographic/personality measures.

For ease of interpretation, we renormalize our data to have a mean of zero and a standard deviation of one for the regression analysis in the following sections.

## 3.2 Attitudes to Risk and Uncertainty

We begin by examining in more detail the relationship between various aspects of preference for risk and uncertainty. We look at the relationship between risk aversion and the common consequence and common ratio effect, between attitudes to uncertainty and compound lotteries and other aspects of behavior towards risk, and between the endowment effect and other aspects of risk and uncertainty preferences. We conclude with a principal component analysis meant to summarize the key relationships between various aspects of preferences under risk.

Table 4: Risk Aversion, Common Consequence and Common Ratio

|  | (1) Common Ratio | (2) Risk Aversion | (3) Risk Aversion |
|---|---|---|---|
| Common Consequence | 1.701*** | | 1.764*** |
|  | (0.554) | | (0.673) |
| Common Ratio | | 0.335** | |
|  | | (0.150) | |
| Constant | 0.0868 | -0.0390 | 0.129 |
|  | (0.203) | (0.108) | (0.205) |
| Observations | 166 | 166 | 174 |

2SLS regression. Controls included for gender, order, and intelligence.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

*3.2.1 Risk Aversion, Common Ratio and Common Consequence* We first examine the relationship between the common consequence and common ratio effects and risk aversion (as measured by the certainty equivalent of a 50/50 lottery). Table 4 shows the relevant regression results. In each case, the dependent variable is the normalized average of the relevant questions (common ratio effect for column 1, risk aversion for columns 2 and 3). As discussed in section 2.4.1, we use 2SLS regression to mitigate the effects of measurement error. We control for intelligence, gender, and the order in which the questions were asked.

Table 4 shows that there is a strong relationship between risk aversion, the common ratio effect and the common consequence effect, as indicated in Table 3.

*3.2.2 Attitudes to Risk, Uncertainty, and Compound Lotteries* We next examine the relationship between violations of expected utility in the domains of risk and uncertainty. Table 5 shows that, in our experiment, subjects who violate expected utility in one domain are more likely to violate it in another. The first panel of Table 5 divides subjects into those who are ambiguity averse, ambiguity neutral or ambiguity loving. For each of these groups, it then shows the proportion of subjects who (i) exhibit the common ratio effect in the standard direction, exhibit it in the non-standard direction, and do not exhibit it at all; (ii) exhibit

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the common consequence effect in the standard direction, exhibit it in the non-standard direction, and do not exhibit it at all; and (iii) are reduction averse, neutral and loving. The second panel repeats parts (i) and (ii) for subjects who are reduction averse, neutral, and loving.

Table 5: Violations of Independence under Risk and Uncertainty

|  | Common Ratio | p=0.001 | | Common Conseq. | p=0.005 | | Reduction | p=0.000 | |
|  | Stand | Neut | NonStand | Stand | Neut | NonStand | Averse | Neut | Loving |
|---|---|---|---|---|---|---|---|---|---|
| Ambiguity Averse | 70% | 13% | 16% | 54% | 26% | 20% | 90% | 2% | 8% |
|  | 74 | 14 | 17 | 57 | 28 | 21 | 91 | 2 | 8 |
| Ambiguity Neutral | 30% | 44% | 26% | 33% | 67% | 4% | 4% | 96% | 0% |
|  | 8 | 12 | 7 | 9 | 18 | 1 | 1 | 27 | 0 |
| Ambiguity Loving | 70% | 10% | 20% | 45% | 40% | 20% | 16% | 5% | 79% |
|  | 14 | 2 | 4 | 9 | 8 | 4 | 3 | 1 | 15 |

|  | Common Ratio | p=0.005 | | Common Conseq. | p=0.015 | |
|  | Stand | Neut | NonStand | Stand | Neut | NonStand |
|---|---|---|---|---|---|---|
| Reduction Averse | 70% | 12% | 18% | 56% | 28% | 16% |
|  | 68 | 12 | 17 | 56 | 28 | 16 |
| Reduction Neutral | 34% | 41% | 24% | 31% | 66% | 7% |
|  | 10 | 12 | 7 | 9 | 19 | 2 |
| Reduction Loving | 67% | 17% | 17% | 46% | 38% | 17% |
|  | 16 | 4 | 4 | 11 | 9 | 4 |

For each row, each block reports the fraction of subject of that type who fall into the different categories. For example, 70% of ambiguity averse subjects exhibited the common ratio effect in the standard direction, 13% exhibited no common ratio effect and 16% exhibited the common ratio effect in the non-standard direction. The equivalent number for ambiguity neutral subjects was 30%, 44% and 26% respectively. p is the probability of the associated Fisher's exact test

Subjects who are ambiguity averse are 86 percentage points (pp.) more likely to be reduction averse, 40pp. more likely to exhibit the common ratio effect and 21pp. more likely to exhibit the common consequence effect than those who are ambiguity neutral. Those that are reduction averse are also more likely to exhibit the common ratio effect (by 36pp.) and the common consequence effect (by 25pp.) than those that are neutral with respect to compound lotteries. As shown in the table, these differences are significant according to a Fisher's exact test.

Table 6 reports the results of regressing attitudes to uncertainty and compound lotteries on various aspects of attitudes to risk. It shows that, while Table 5 indicates that there is a relationship between the propensity to violate independence in the risk and uncertain domains, there is no strong link between the degree to which a subject exhibits ambiguity aversion or reduction aversion and the degree to which they exhibit the common ratio and common consequence effects. Column 1 shows the results of a 2SLS regression of uncertainty attitude on risk aversion, common ratio and common consequence effects, the endowment effect and loss aversion, as well as controls for intelligence, gender and order.[23] It shows an extremely strong relationship between uncertainty attitude and measured risk aversion, as well as a significant positive relationship with the endowment effect. There is no significant

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[23]All measures are instrumented as discussed in section 2.4.1 apart from loss aversion, for which we have only a single measure.

Table 6: Attitudes to Uncertainty and Compound Lotteries

| | (1) Uncertainty Av | (2) Ambiguity Av | (3) Compound Av | (4) Reduction Av | (5) Ambiguity Av |
|---|---|---|---|---|---|
| Risk Aversion | 0.929**** | 0.398** | 0.880**** | 0.321* | -0.139 |
| | (0.203) | (0.200) | (0.190) | (0.189) | (0.198) |
| Common Ratio | -0.0147 | 0.0611 | 0.0739 | 0.107 | -0.00827 |
| | (0.202) | (0.198) | (0.175) | (0.174) | (0.152) |
| Common Conseq. | -0.316 | -0.214 | -0.212 | 0.0598 | 0.0146 |
| | (0.354) | (0.348) | (0.315) | (0.313) | (0.253) |
| Endowment Effect | 0.334** | 0.360** | 0.403** | 0.439*** | 0.180 |
| | (0.169) | (0.166) | (0.159) | (0.158) | (0.140) |
| Loss Aversion | 0.0499 | 0.123 | -0.0570 | 0.0291 | 0.128 |
| | (0.122) | (0.120) | (0.107) | (0.106) | (0.0949) |
| Compound Av. | | | | | 0.598**** |
| | | | | | (0.121) |
| Constant | 0.166 | 0.190 | 0.0987 | 0.122 | 0.101 |
| | (0.141) | (0.139) | (0.129) | (0.128) | (0.117) |
| Observations | 150 | 150 | 149 | 149 | 149 |
| Prob CR & CC Insig | 0.628 | 0.821 | 0.767 | 0.783 | 0.997 |

2SLS regression. Controls included for gender, order, and intelligence.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

relationship with either the common ratio or common consequence effect (the final row of the table shows that the joint hypothesis that the coefficient on both variables is zero cannot be rejected). The coefficient on the common ratio effect is in fact large and *negative,* though imprecisely estimated.

Ambiguity aversion is also related to risk aversion and the endowment effect as shown by column 2. The coefficient on risk aversion falls, but remains significant. The coefficient on the endowment effect is largely unchanged.

Columns 3 and 4 show similar patterns when compound lottery attitude and reduction aversion are the dependent variables.

Table 6 also demonstrates that reduction aversion and ambiguity aversion are extremely strongly related. The final column adds compound attitude as an explanatory variable to regression (2).[24] Not only is the associated coefficient highly significant, it explains so much of the variance that all other coefficients become insignificant.

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[24]We use compound attitude (the value of the compound lottery) rather than reduction aversion (the difference between the value of the compound lottery and its non-compounded equivalent) because the evaluation of the risky urn appears in both the ambiguity aversion and reduction aversion measure, leading to the possibility of spurious correlation.

Table 7: The Endowment Effect

| | (1) Buy Risk | (2) Endowment Effect |
|---|---|---|
| Risk Aversion | 0.631**** | |
| | (0.184) | |
| Common Ratio | -0.0985 | -0.126 |
| | (0.181) | (0.155) |
| Common Consequence | 0.193 | 0.254 |
| | (0.327) | (0.312) |
| Loss Aversion | 0.405**** | 0.392**** |
| | (0.0989) | (0.0826) |
| Risk Aversion (Alt) | | -0.187** |
| | | (0.0926) |
| Constant | -0.431**** | -0.303*** |
| | (0.120) | (0.105) |
| Observations | 150 | 150 |

2SLS regression. Controls included for gender, order, and intelligence.
Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

*3.2.3  Loss aversion and the Endowment Effect*  Table 7 examines the relationship between the endowment effect and other elements of risk attitude. It shows that the endowment effect is strongly related to loss aversion in risky choice. The first column has as the dependent variable risk aversion measured by the buying price of the lottery. This is regressed on loss aversion, as well as risk aversion, the common ratio and common consequence effect, and the usual controls.[25] The results show an extremely significant coefficient on the loss aversion variable (as well as on risk aversion). The common ratio and common consequence effects have insignificant coefficients. The second column repeats the analysis using as the dependent variable the endowment effect (the difference between the selling and buying price of the lottery). In order to avoid spurious correlations we use an alternative measure of risk in this regression, based on the attitude to the 'risky urn' in the ambiguity aversion section. Again, we find loss aversion to be extremely strongly correlated with the endowment effect, even after controlling for risk aversion. This supports the observation in Table 3 that mixed risk (related to loss aversion) and buy risk (the endowment effect) are strongly correlated.

*3.2.4  Summary for Risk Preferences*  The results above suggest that attitudes to risky and uncertain prospects are governed by three distinct factors - one related to the common ratio and common consequence effect, one related to loss aversion, and a third that governs attitudes towards ambiguous and compound prospects. We use a principal component analysis

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[25]As mentioned above, because of the way we construct loss aversion, we do not have multiple measures, and so cannot use the multiple indicators approach for this measure. If anything this could mean that the coefficient on loss aversion is biased downwards by measurement error.

to summarize these relationships. This is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components and therefore a way of summarizing the linear relationships present in our data. Table 8 reports the results of a principle component analysis on risk aversion, common consequence, common ratio, uncertainty attitude, compound attitude, mixed risk and buy risk.

A key question for the use of principal component analysis is how many components should be used to summarize the data. One standard approach is the Kaiser criterion, which keeps factors for which the associated eigenvector of the covariance matrix is above 1 (this being the eigenvalue equal to the information accounted for by an average single item). For our data, this criterion selects 3 components, which between them explain 74% of the variance of the data. Following orthogonal rotation, the first of these factors is most strongly associated with attitudes towards uncertain and compound prospects, the second with mixed and buy risk and the third with the common consequence and common ratio effect. Risk aversion is associated mostly with the first factor.

Table 8: A principal Component Analysis

|  | Factor 1 | Factor 2 | Factor 3 | Uniqueness |
|---|---|---|---|---|
| Risk Aversion | 0.648 | 0.127 | 0.262 | 0.496 |
| Common Ratio | -0.017 | 0.150 | 0.827 | 0.294 |
| Common Consequence | 0.234 | 0.071 | 0.750 | 0.378 |
| Uncertainty Aversion | 0.909 | 0.064 | 0.035 | 0.169 |
| Compound Aversion | 0.913 | 0.144 | 0.057 | 0.143 |
| Mixed Risk | 0.059 | 0.880 | 0.224 | 0.173 |
| Buy Risk | 0.161 | 0.901 | -0.018 | 0.163 |

Factor 1-Factor 3 report the factor loadings for each variable of the first three principle component factors following orthogonal rotation. Uniqueness reports the proportion of the common variance of the variable not associated with the factors.

Ideally, principal component analysis would show a sharp fall in the proportion of variance explained by additional factors around the cutoff, or equivalently in the eigenvalues associated with each factor. In our data, the eigenvalues associated with the first four factors are 2.7, 1.4, 1.1 and 0.7 respectively. Including a fourth component in the analysis leads to two distinct factors associated with the common ratio and common consequence effects.

## 3.3 Time Preferences and Risk/Uncertainty Attitudes

We now examine the relationship between time preferences and attitudes to risk and uncertainty. Table 9 reports the results of regressing time preferences on risk/uncertainty measures. The first column shows the results of a 2SLS regression of the measured discount rate on our various measures of risk preferences. The second column repeats the analysis for the present discount rate and the third for present bias.

We find that risk aversion is weakly related to the discount rate, strongly related to

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Table 9: Time Preferences and Attitudes to Risk and Uncertainty

|  | (1) Discount | (2) Present Discount | (3) Present Bias |
|---|---|---|---|
| Risk Aversion | 0.373* | 0.760**** | 0.584*** |
|  | (0.201) | (0.227) | (0.210) |
| Common Ratio | -0.0217 | -0.240 | -0.0732 |
|  | (0.200) | (0.226) | (0.209) |
| Common Consequence | 0.140 | -0.215 | -0.399 |
|  | (0.337) | (0.381) | (0.352) |
| Ambiguity Aversion | 0.229* | 0.219 | 0.130 |
|  | (0.132) | (0.149) | (0.138) |
| Endowment Effect | -0.216 | -0.0120 | 0.0978 |
|  | (0.173) | (0.195) | (0.181) |
| Loss Aversion | 0.158 | 0.105 | -0.0156 |
|  | (0.127) | (0.144) | (0.133) |
| Constant | -0.0421 | -0.0796 | -0.109 |
|  | (0.146) | (0.165) | (0.152) |
| Observations | 150 | 150 | 150 |
| Prob CR and CC Insig | 0.918 | 0.394 | 0.427 |

2SLS regression. Controls included for gender, order, and intelligence.

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

the present discount rate, and therefore significantly related to present bias. The other measures of risk and uncertainty attitudes have little additional explanatory power, although ambiguity aversion is positively correlated with discounting at the 10% level. The common ratio and common consequence effect are not significantly related to time preferences, either individually or jointly. Note also that the point estimate of the relationship between these two behaviors and present bias is negative.

## 3.4 Trust Game Behavior and Risk Preferences

We next turn to the relationship between risk/uncertainty preferences and sender and receiver behavior in the trust game. Sending money in the first stage of the game is an uncertain prospect, while keeping the money is not. Thus it is possible that play in the trust game is related to risk/uncertainty preferences. One of the advantages of the approach taken in this paper is we can test simultaneously for the relationship between trust game behavior and various different components of risk preferences.

Table 10 suggests there is no such relationship. Column 1 shows that only loss aversion

Table 10: Trust Game Behavior and Attitudes to Risk and Uncertainty

| | (1) Trust | (2) Return | (3) Trust |
|---|---|---|---|
| Risk Aversion | 0.107 | 0.252 | -0.0191 |
| | (0.189) | (0.200) | (0.167) |
| Common Ratio | -0.0426 | -0.153 | 0.0412 |
| | (0.184) | (0.199) | (0.158) |
| Common Consequence | -0.0253 | 0.304 | -0.143 |
| | (0.309) | (0.336) | (0.262) |
| Ambiguity Aversion | 0.0380 | 0.0577 | 0.000503 |
| | (0.123) | (0.131) | (0.108) |
| Endowment Effect | 0.0272 | 0.168 | -0.0354 |
| | (0.160) | (0.172) | (0.140) |
| Loss Aversion | 0.261** | 0.189 | 0.165 |
| | (0.117) | (0.127) | (0.102) |
| Return | | | 0.454**** |
| | | | (0.0760) |
| Constant | 0.114 | 0.00589 | 0.126 |
| | (0.139) | (0.146) | (0.121) |
| Observations | 147 | 150 | 147 |
| Prob CR and CC Insig | 0.966 | 0.566 | 0.845 |

2SLS regression. Controls included for gender, order, and intelligence.
Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

is related to sender behavior, with subjects who are *more* loss averse sending more - a surprising result given that sending money in the trust game represents a gamble with both gains and losses. Column 2 shows no relation between risk preferences and return behavior, while column 3 suggests a strong relationship between sender and receiver behavior. Such a link could occur either because those who return money in the trust game have different beliefs about the behavior of others, or because subjects who have stronger other-regarding preferences both send and return more in the trust game.

## 3.5   Demographics, Personality Measures and Overconfidence

Finally, we analyze the relationship between our measured behavioral phenomena and intelligence, gender, and personality measures (overconfidence, depression and anxiety). Table 3 shows the raw correlations between these variables, while Table S1 in the appendix shows the relevant regressions.[26]

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[26]These regressions are OLS rather than 2SLS because we do not have multiple measures of demographic and personality variables. All variables are normalized to mean zero and standard deviation one apart from

We find little evidence of any relationship between intelligence and any of our behaviors. Table 3 suggests a weak relationship with intelligence and both time preferences and buy risk, but Table S1 shows that this does not extend to present bias or the endowment effect. This is in contrast to recent papers (Burks et al. [2009a], Dohmen et al. [2010], Benjamin et al. [2013]) that find strong relationships between intelligence and risk and time attitudes. One possible explanation for this difference is that our sample, consisting of students at a very selective university, has much less relevant variance in intelligence.

In contrast, we find overplacement to be strongly related to many of our behaviors. Table 3 and Table S1 suggest that higher overplacement is related to lower discounting, risk aversion, common consequence effect, ambiguity and reduction aversion, mixed risk and buy risk (although the last two relationships disappear when controlling for gender - see below). The relationship between overplacement and ambiguity aversion is particularly intriguing: the more overconfident, the more a subject may find it less likely that she has been 'outsmarted' by the environment and thus may exhibit lower ambiguity aversion. Overconfidence, as measured by the difference between the subject's predicted and actual scores are not related to any of our measures.

We find some gender effects in our data, though fewer than in previous studies. This again may be due to the selective nature of our sample. One extremely robust finding is that females exhibit more loss aversion than males, both in risky choice and via the endowment effect.

Finally, we find little evidence of a link between economic behaviors and measured depression or anxiety.

# 4. Implications For Existing Theories

We now discuss the implications of our findings for existing models that make predictions about the relationships between our measured behaviors. We begin with a summary of the EPT model, which offers the possibility of explaining many of the behaviors we study by adding only two extra parameters. We then discuss what our data implies for this and other models.

## 4.1 Extended Prospect Theory

Cumulative prospect theory (CPT) was introduced by Tversky and Kahneman [1992], initially as a description of choice under risk. It augments the standard expected utility model with two features. The first is probability weighting, in line with the Rank Dependent Expected Utility model of Quiggin [1982], which deviates from Expected Utility by allowing the decision maker to overweight or underweight probabilities when assessing choices. This is modeled by a function that maps objective probabilities to decision weights in a rank-dependent manner. A simple single parameter probability weighting function was provided

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gender

by Prelec [1998].

The second innovation of prospect theory is loss aversion, that captures the degree to which 'losses loom larger than gains' for decision makers. This is operationalized by the assumption of a reference dependent utility function for which the positive utility of gaining amount $x$ is smaller than the magnitude of the negative utility associated with losing $x$. This is captured by a difference in slopes of the utility function between gains and losses measured by the parameter $\lambda$.

The addition of probability weighting makes CPT compatible with violations of Expected Utility for objective risk such as the common ratio and common consequence effects. Most commonly used weighting functions will give rise to both, with more extreme probability weighting associated with more extreme expressions of each.[27] Probability weighting will also affect risk aversion measured through certainty equivalence: for most common parameterizations, the measured risk premium will increase if probability weighting increases. Thus the CPT model implies a correlation between the common ratio and common consequence effects and risk aversion.

Extensions of CPT can then generate other behavioral phenomena. Segal [1990] shows that probability weighting can lead to reduction aversion by using a model in which compound lotteries are evaluated in two stages. First, the certainty equivalence of each second-stage lottery is calculated as in CPT. Second, the first-stage lottery is rewritten as a single-stage lottery, with each second-stage lottery replaced with its certainty equivalent. Third, CPT is applied again to calculate the value of the first-stage lottery. If there is no probability weighting, this procedure will lead compound lotteries to be treated exactly the same as their reduced form equivalents. However, if there is probability weighting, then the two values can differ. Segal [1990] shows that probability weighting leads to reduction aversion as long as the weighting function is convex and has nondecreasing elasticity. These are, respectively, the conditions associated with the common consequence and common ratio effect. This model therefore predicts a relationship between reduction aversion and the common ratio and common consequence effects.

Segal [1987] further links probability weighting with ambiguity aversion by suggesting that decision makers view ambiguous prospects as compound lotteries: they form a belief over the various different ways that the ambiguous urn could be filled, each of which implies a second-stage lottery. Thus, ambiguity aversion should be correlated both with reduction aversion and with the common ratio and common consequence effects.

CPT can also be extended to predict a relationship between loss aversion in risky choice and the endowment effect, despite the fact that these are, on the face of it, very different phenomena.[28] This link is discussed in Tversky and Kahneman [1991] and Koszegi and Rabin [2007]. The first article considers the case in which subjects who are offered the chance to buy a lottery treat doing so as a gain, while those that are offered to sell it see doing so as a loss, generating a link between the WTP/WTA gap and loss aversion. The second

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[27]Although the two effects are in principle independent - see Diecidue et al. [2009].

[28]The former is estimated directly as $\lambda$ and manifests itself as an increase in risk aversion for lotteries that contain both gains and losses, while the latter is a difference between the selling price and buying price for the same lottery.

article shows that if those that own the lottery see it as a stochastic reference point, then loss aversion will lead to an endowment effect for risk.

Finally, Halevy [2008] shows that probability weighting can also lead to present bias (see also Saito [2012]) if subjects see immediate payments as certain and future payments as risky - for example if they perceive a risk of not receiving the payment in the future. In this case intertemporal prospects can be seen as lotteries to which CPT can be applied. Halevy [2008] and Saito [2012] show that this implies a tight link between non-Expected Utility attitudes towards risk and present bias: with a constant hazard of non-payment, a subject should exhibit present bias only if she exhibits probability weighting. In particular, the type of probability weighting required for present bias is the same as that required for the common ratio effect. Thus, the model predicts that the common ratio effect should be correlated with present bias.

The approach described above could be seen as an Extended Prospect Theory model which explains many of the behaviors studied in this paper while adding only two additional parameters (loss aversion and probability weighting) to the standard model. Andreoni and Sprenger [2010] and Epper and Fehr-Duda [2012] discuss further the possibility of using extension of cumulative prospect theory to explain a number of observed anomalies.

## 4.2   Implications for Models of Risk and Uncertainty

Our results provide mixed support for the EPT model as a description of choice under risk and uncertainty. On the one hand, as predicted by the model we find a strong relation between loss aversion in risky choice and the endowment effect, in line with the hypothesis that both phenomena are driven by the same underlying notion of loss aversion. We also document a link between small stakes risk aversion and violations of Expected Utility for objective risk (common ratio and consequence effects), in line with the prediction that probability weighting is a contributory factor to small stakes risk aversion. On the other hand there is little evidence that bigger violations of Expected Utility for objective risk are related with stronger ambiguity and compound lottery aversion: if, as suggested by the EPT model, all three phenomena are caused by the same probability weighting function we would expect to find such a correlation. Instead, it seems that there is a third factor to individual preferences that relates to attitudes towards ambiguity and reduction. The factor analysis reported in section 3.2.4 supports this conclusion.

Beyond EPT, there are of course many models that consider ambiguity attitudes as a distinct notion from probability weighting (for example Schmeidler [1989], Gilboa and Schmeidler [1989], Ghirardato et al. [2003]). These models would generally predict the relation between the certainty equivalence of risky, compound and uncertain prospects that we find in our data, as all are affected by the curvature of the utility function. For example, as the utility function becomes more concave, both risky and uncertain prospects become less attractive with respect to fixed amounts. Notice that this does not however imply a relation between risk and ambiguity aversion – these are independent traits in these models.

However, most of models of ambiguity aversion also assume that subjects satisfy Expected

Utility for objective risk (embodied in the properties of certainty independence, weak c-independence, etc.), which is not compatible with the fact that in our data the subjects that exhibit ambiguity aversion also tend to violate independence in the risk domain (i.e., exhibit the common ratio and common consequences effect). One exception is Dean and Ortoleva [2016] which characterizes a 'Multiple Priors Multiple Weighting' (MPMW) model that embodies a generalized notion of a preference for hedging which generates both Ellsberg-like and Allais-like behavior.

An additional issue is the need to explain the relation between ambiguity and compound lottery aversion – a very strong pattern in our data. This empirical relation has often been viewed as evidence for the hypothesis that ambiguous urns are treated as compound lotteries (as in Segal [1990], or EPT). At the same time, there is a possible alternative interpretation, one that we deem more realistic, that views this relation in the opposite way: we can argue that for some subjects compound lotteries are 'ambiguous.' The intuition is that a compound lottery is an object which is quite 'foreign' to the decision maker, and it is natural to expect that she might fear that she does not fully understand it – it is, in the end, a rather complicated object. And if the agent fears that she does not fully understand it, then a compound lottery is ambiguous for her, and she may therefore approach it as she approaches other ambiguous bets. This explanation of how agents see compound lotteries could lead to the patterns we find in our data. Probabilistically sophisticated agents 'see through' the compound lottery, and also do not fall for the common consequence or common ratio effects. Probabilistically naive agents see the compound lottery as ambiguous, and also tend to exhibit the common ratio and common consequence effects.

A final point to note is the relationship we identify between ambiguity aversion and the endowment effect. While not predicted by EPT, a variety of other models in the literature relate the endowment effect to status quo bias, or inertia, and indirectly to incomplete preferences: see Bewley [1986], Masatlioglu and Ok [2006, 2013], Ortoleva [2010]. In turn, Ortoleva [2010] links also ambiguity aversion with status quo bias, thus implying a connection between ambiguity aversion and the endowment effect, as seen in our data.

### 4.3  Implications for Models of Risk and Time Preferences

We have seen that the EPT model links present bias and probability distortions. However, such a relationship is not present in our data: in contrast to the prediction of the model, neither the common ratio nor the common consequence effect are significantly related to our measures of time preference.

At the same time, we do find that risk aversion, measured using certainty equivalence, is strongly correlated with both discounting and present bias. On the one hand, this connection can be seen as unsurprising as it is implied by most 'standard' models of time preferences via the curvature of the utility function. To see why, consider a quasi-hyperbolic discounting model (Phelps and Pollak [1968], Laibson [1997]), under which income in one period is discounted by $\beta\delta$, and in two periods by $\beta\delta^2$. The amount $c_1$ received today that will make

the subject indifferent to \$10 in one period is given by

$$u(I + c_1) + \beta\delta u(I) = u(I) + \beta\delta u(I + 10),$$

while the amount $c_2$ received in one period which is indifferent to \$10 in two periods is given by

$$u(I + c_2) + \delta u(I) = u(I) + \delta u(I + 10).$$

Rearranging these two equations implies that

$$
\begin{aligned}
u(I + c_1) &= (1 - \beta\delta)u(I) + \beta\delta u(I + 10) \\
u(I + c_2) &= (1 - \delta)u(I) + \delta u(I + 10).
\end{aligned}
$$

It is clear from these expressions that there should be a positive link between the curvature of the utility function and both discounting to the present and to the future: the higher the curvature of the utility function the steeper discounting in both cases. The curvature of the utility function could also be either positively or negatively related to present bias (measured by $\frac{c_2 - c_1}{10}$): If $\delta$ is large present bias will increase as the curvature of the utility function increases, if it is small then it will decrease.[29] Our evidence is consistent with the latter case.

On the other hand, while implied by standard models, the relationship between estimated risk aversion and time preferences is somewhat surprising in the light of the finding of Andreoni and Sprenger [2012], who document violations of interchangeability, which they interpret as evidence for different utility functions for risky and risk-free prospects (see also Abdellaoui et al. [2013]). This should imply that the curvature of the utility function we find in risky choice should be different from that which governs intertemporal choice for risk-free prospects. Moreover, Andreoni and Sprenger [2012] report finding almost linear utility for intertemporal choices between certain prospects in the aggregate. There are a number of possible explanations that can reconcile these findings. One is that, because we use certainty equivalence to identify risk aversion, our measures are a mixture of the parameters of the 'certain' utility and the 'uncertain' utility. Another is that, while there may still be separate utility functions for risky and risk free choices, these may be related – more curvature of one can be linked with more curvature of the other.[30]

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[29]For any two utility functions $u^1$ and $u^2$ we can normalize $u^1(I) = u^2(I) = 0$ and $u^1(I+10) = u^2(I+10) = 1$. This implies that

$$
\begin{aligned}
u^1(I + c_1^1) &= u^2(I + c_1^1) = \beta\delta \\
u^1(I + c_2^1) &= u^2(I + c_2^1) = \delta
\end{aligned}
$$

So present bias is measured by the extra money on top of $c_1^j$ necessary to compensate for the increase in the right hand side of $(1 - \beta)\delta$. If $u^1$ exhibits more risk aversion than $u^2$, and so is more concave, then, for low $x$, $u^{1'}(x) > u^{2'}(x)$, while for high $x$ $u^{1'}(x) < u^{2'}(x)$. In the former case, the increase in money necessary to offset the increase of $(1 - \beta)\delta$ is smaller for $u^1$ than for $u^2$, meaning that present bias is negatively related to the curvature of the utility function. In the latter case there are two offsetting effects: on the one hand, at any given $x$, $u^2$ is steeper than $u^1$, on the other hand, $c_1^1 < c_2^2$, meaning that both functions are steeper at $I + c_1^1$ than they are at $I + c_1^1$. In general, as $\delta$ gets small, the former effect dominates the latter, meaning that curvature is positively related to present bias.

[30]Of course neither of these explanations are sufficient if the utility at certainty is linear at the individual

# 5.  Relationship to the Existing Literature

There currently exists a small but significant literature that examines the empirical relationship between different behavioral measures. Contemporary to our work is that of Stango et al. [2016], which measures a broad set of economic behaviors in a quasi-representative panel. While our work is interested in measuring the correlations between behavioral patterns, they focus mainly on the prevalence of each of them and on the construction of measures of deviation from the standard model and their relation to economic outcomes. We thus view their work as complementary to ours. Explicitly following our paper and building on it for different populations are Gillen et al. [2015].

Other papers that are close in spirit to ours are Burks et al. [2009a] and Anderson et al. [2011]. These two papers make use of a large scale experiment carried out on a group of newly recruited truck drivers. The authors use parametric methods to measure risk aversion, short term and long term discounting (though a beta-delta model) and behavior in a sequential two-person prisoner's dilemma (similar to our trust game).[31] These papers find a statistically significant (though quantitatively small) relationship between risk attitude, patience, and sender behavior in the prisoner's dilemma: more patient people tended to be less risk averse and send more in the prisoner's dilemma. The authors also document a strong relationship between cognitive and non-cognitive personality traits and economic behaviors, and find that non-cognitive skills have strong predictive power for 'real life' economic outcomes. Two other papers that document the relationship between cognitive skills and behavioral traits are Dohmen et al. [2010] and Benjamin et al. [2013]. Both papers report that higher cognitive skills relate to less risk aversion and more patience. Similar results have been reported in a variety of studies in psychology, as documented in a meta-study by Shamosh and Gray [2008]. As noted in the text, the fact that we do not find such a relationship may be due to the fact that our sample has less variance in terms of intelligence.[32]

A second set of literature looks at the relationship between attitudes towards risk and uncertainty. These include Cohen et al. [1987], Lauriola and Levin [2001], Chakravarty and Roy [2009] and Cohen et al. [2011]. By and large, these studies find either no relationship or only a weak relationship between risk attitudes and ambiguity attitudes. However, these studies do not look at the relationship between ambiguity aversion and the common consequence and common ratio effect. Halevy [2007] reports a strong link between compound lottery aversion and ambiguity aversion, as we find (though recent work by Abdellaoui et al. [2015a] finds a weaker relationship). Ahn et al. [2014] conduct an experiment which allows them to parametrically estimate risk, ambiguity and loss aversion. Subjects are faced with a series of portfolio-choice problems, in which the assets are Arrow securities corresponding to three states of nature, where the probability of one state is known and the remaining two are ambiguous. They use this data to estimate a model with three parameters relating

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level. However, this is not implied by the observation of Andreoni and Sprenger [2012] that it is linear at the aggregate level, as this may mask individual differences in curvature. A further possible explanations is that subsequent research has managed to replicate the findings of Andreoni and Sprenger [2012] with convex time budgets, but not with multiple price lists (see Cheung [2012]).

[31] Anderson et al. [2011] also provide a measure of ambiguity aversion and the 'Big 5' personality measures.

[32] Li et al. [2013] look at the relationship between economic behaviors and age.

to risk, ambiguity and loss aversion. They report finding a correlation between risk and ambiguity aversion, but not ambiguity and loss aversion. Von Gaudecker et al. [2011] looks at the distribution of preference parameters governing risky choice in a broad population.

A third set of papers theoretically and empirically considers the relationship between risk and time preferences, noting the implicit link between the two forged by the curvature of the utility function. Andersen et al. [2008] find that taking into account risk attitudes reduces estimated discount rates, implying a relationship between risk attitudes and discount rates calculated under the assumption of risk neutrality (as we do in this paper). Andreoni and Sprenger [2012] find evidence for a failure of 'interchangeability': intertemporal preferences vary depending on whether the objects of choice are lotteries or certain payments, which they interpret as evidence for different utility functions for risky and risk-free prospects, as we discuss above. Finally, Epper et al. [2011] find a significant relationship between decreasing impatience and probability weighting in an experiment that links the two behaviors. Unlike our experiment, they estimate probability weighting parametrically from choices over lotteries, rather than using questions explicitly designed to identify the existence of probability weighting. Tanaka et al. [2010] examine the correlations between measured risk and time preferences with socioeconomic variables. They find some variables to be related jointly to risk attitude and patience (for example mean village income) while others, such as household income, are related to patience but not risk.

Gachter et al. [2007] study the relationship between loss aversion in risky choice and the endowment effect. They also find a significant relationship. However, their measure of loss aversion in risky choice is simply the degree of risk aversion in a choice involving losses and gains, and is therefore not distinguishable from risk aversion itself.

Another set of literature related to our current study looks at the relationship between risk attitudes and behavior in trust games (Eckel and Wilson [2004], Schechter [2007]), noting that choosing to send money in trust games is an inherently risky decision. These studies provide somewhat contradictory findings, but generally report at least some relationship between attitude towards risk and sender behavior in trust games. We know of one study that looks at the relationship between ambiguity aversion and overconfidence, (Brenner et al. [2011]), finding a significant, positive relationship.

Finally, our work is related to the literature in psychology that studies the empirical relationship between different kinds of violations of rationality. See, among many, Stanovich [2010]. While there is overlap with our work, this literature tends to focus on a different set of behaviors, including specific violations of reasoning, such as base rate neglect and syllogistic reasoning. We focus more specifically on violations of the classic model of economic choice, such as loss aversion and ambiguity aversion. Arguably these behaviors may represent preferences that are different from those assumed by the classic economic model, rather than violations of rationality.

# 6. Conclusions

In this paper we have studied the joint distribution of 11 different behavioral phenomena. Our main aim was to provide empirical guidance in the construction of a unified, parsimonious model of economic behavior.

Our work provides evidence in support of some proposed attempts at unification but not others. We find strong evidence that loss aversion, measured in risky choice, is predictive of the endowment effect. We also find evidence of a link between attitudes to risky, uncertain and compound prospects, and between these and discounting. This is consistent with the curvature of the utility function being related to all four behaviors. Finally, we find evidence for a consistent notion of probability weighting which is also related to small stakes risk aversion. We also find a robust relationship between ambiguity aversion and the endowment effect.

However, we also find evidence against other proposed unifications: we do not find any evidence that violations of Expected Utility are related to present bias, nor to ambiguity aversion - these seem to be distinct phenomena. We also do not find risk/uncertainty attitudes to be predictive of play in the trust game.

We see the empirical work in this paper as having two main benefits. First, for the development and the testing of unified theories of economic behavior. Our data set allows us to test the existing theories that make predictions on the joint distribution of behavioral phenomena, and provides a starting point for the development of new theories based on underlying connections between these behaviors – there are many intuitively plausible stories that could lead to relations between behavioral phenomena, and our data set helps to determine which of these are most promising for future study. We see one contribution of our paper as a step towards the development of parsimonious 'workhorse' models of economic decision making, which are capable of capturing a variety of important behavioral phenomena while using a parsimonious number of parameters. We believe that the development of such generalized models is of paramount importance. One potential barrier that may prevent the wider profession from taking into account behavioral phenomena is that there are simply too many of them to consider. In the absence of a parsimonious, general model, one is left with either choosing to focus on a subset of these phenomena (with the risk of cherry-picking some but excluding others of potential importance) or considering them all (with no clear prediction of their potential interactions, and with an often-unacceptable number of additional degrees of freedom). Understanding the relationships between behavioral phenomena could instead either help us develop such a parsimonious general model of behavior, or clarify the limitations that such model is bound to have - it could help us understand where attempts at theoretical unification are likely to succeed and where they are not.

The second contribution is that there are direct, practical benefits in understanding the correlation between multiple behaviors even independently of any modeling analysis: understanding the joint distribution of these behaviors could help the empirical analysis that allows for multiple behavioral phenomena. The identification of the main factors of economic decision making could help in the design of efficient tests of a person's 'economic makeup,' much in the same way that personality research has allowed psychologists to come up with

efficient tests that characterize a person's personality.

As mentioned in the introduction, two limitations of our current approach are that it focuses on a typical and yet special sample, highly selected undergraduate students, and that we don't link the constructs we measure to economic variables of interest such as financial choices. In ongoing work we are collecting data designed to address both of these issues.

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# 7. Appendix: Table S1: Regressions of Economic Behaviors on Demographics and Personality Measures

Table S1: Demographics

|  | (1) Discount | (2) Present Discount | (3) Present Bias | (4) Risk Av. |
|---|---|---|---|---|
| Intelligence | -0.112 | 0.0251 | 0.129 | 0.0535 |
|  | (0.0833) | (0.0970) | (0.104) | (0.0941) |
| Overconfidence | -0.0668 | -0.0158 | 0.0168 | 0.0216 |
|  | (0.0729) | (0.0849) | (0.0913) | (0.0821) |
| Overplacement | -0.0104 | -0.0745 | -0.0819 | -0.212** |
|  | (0.0858) | (0.0999) | (0.107) | (0.0972) |
| Gender | 0.119 | 0.106 | 0.0375 | -0.239 |
|  | (0.143) | (0.166) | (0.179) | (0.161) |
| Anxiety | -0.109 | 0.0800 | 0.119 | 0.166* |
|  | (0.0787) | (0.0917) | (0.0986) | (0.0932) |
| Depression | 0.187** | 0.0784 | -0.0495 | -0.0582 |
|  | (0.0784) | (0.0914) | (0.0983) | (0.0913) |
| Constant | -0.143 | -0.0951 | -0.0209 | 0.0589 |
|  | (0.0924) | (0.108) | (0.116) | (0.103) |
| Observations | 153 | 153 | 153 | 150 |
| $R^2$ | 0.080 | 0.035 | 0.021 | 0.057 |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

|                | (1)           | (2)       | (3)           | (4)           |
|----------------|---------------|-----------|---------------|---------------|
|                | C. Consequence | C. Ratio | Ambiguity Av. | Reduction Av. |
| Intelligence   | 0.0863        | 0.109     | 0.0358        | 0.175*        |
|                | (0.0957)      | (0.111)   | (0.103)       | (0.100)       |
|                |               |           |               |               |
| Overconfidence | -0.0440       | -0.0188   | -0.0373       | -0.00406      |
|                | (0.0841)      | (0.0959)  | (0.0897)      | (0.0890)      |
|                |               |           |               |               |
| Overplacement  | -0.175*       | -0.0783   | -0.242**      | -0.262**      |
|                | (0.0994)      | (0.119)   | (0.105)       | (0.103)       |
|                |               |           |               |               |
| Gender         | 0.0563        | -0.0226   | -0.148        | -0.00493      |
|                | (0.164)       | (0.191)   | (0.174)       | (0.171)       |
|                |               |           |               |               |
| Anxiety        | -0.103        | -0.0480   | -0.0669       | -0.0498       |
|                | (0.0901)      | (0.110)   | (0.101)       | (0.0987)      |
|                |               |           |               |               |
| Depression     | -0.143        | -0.0199   | -0.0353       | 0.000235      |
|                | (0.0900)      | (0.107)   | (0.0957)      | (0.0925)      |
|                |               |           |               |               |
| Constant       | -0.104        | -0.00367  | 0.0254        | -0.0743       |
|                | (0.106)       | (0.121)   | (0.113)       | (0.109)       |
| Observations   | 151           | 143       | 151           | 149           |
| $R^2$          | 0.074         | 0.012     | 0.057         | 0.061         |

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, **** $p < 0.001$

|  | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
|  | Loss Av. | Endowment Effect | Trust-Send | Trust-Return |
| Intelligence | 0.0932 | -0.126 | 0.129 | -0.0190 |
|  | (0.119) | (0.106) | (0.102) | (0.105) |
|  |  |  |  |  |
| Overconfidence | 0.0843 | 0.0987 | 0.177$^*$ | 0.133 |
|  | (0.104) | (0.0889) | (0.0897) | (0.0916) |
|  |  |  |  |  |
| Overplacement | -0.143 | -0.0757 | -0.0641 | -0.0766 |
|  | (0.120) | (0.105) | (0.106) | (0.108) |
|  |  |  |  |  |
| Gender | 0.438$^{**}$ | 0.648$^{****}$ | 0.0607 | -0.000153 |
|  | (0.197) | (0.173) | (0.176) | (0.180) |
|  |  |  |  |  |
| Anxiety | -0.219$^*$ | -0.173$^*$ | 0.0104 | 0.0834 |
|  | (0.123) | (0.0993) | (0.0968) | (0.0990) |
|  |  |  |  |  |
| Depression | 0.0882 | 0.00387 | -0.0438 | -0.0398 |
|  | (0.110) | (0.0980) | (0.0963) | (0.0987) |
|  |  |  |  |  |
| Constant | -0.177 | -0.255$^{**}$ | -0.00505 | 0.0114 |
|  | (0.124) | (0.111) | (0.115) | (0.116) |
| Observations | 121 | 146 | 150 | 153 |
| $R^2$ | 0.097 | 0.174 | 0.032 | 0.027 |

Standard errors in parentheses

$^*$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$, $^{****}$ $p < 0.001$