PROPOSAL

UNCERTAINTY, IDENTIFICATION, AND PRIVACY: EXPERIMENTS IN INDIVIDUAL DECISION-MAKING

by

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ABSTRACT

The alleged privacy paradox states that individuals report high values for personal privacy, while at the same time report behavior that contradicts a high privacy value. This is a misconception. Reported privacy behaviors can be explained by asymmetric subjective beliefs. Beliefs may or may not be uncertain, and non-neutral attitudes towards uncertainty are not necessary to explain behavior. The major objective of the research proposed here is to identify attitudes towards uncertainty and replicate reported privacy behaviors in a controlled laboratory environment. This research would be conducted in three related parts.

Part One proposes two experiments in individual decision making. The first seeks to identify attitudes towards uncertainty using an experimental replication of Ellsberg's canonical 2-color choice problem. The second proposes to test Smith's conjecture that Ellsberg's hypothesized preferences are observable when an ambiguous lottery is replaced by a compound objective lottery. The literature has presented evidence that tends to support both Ellsberg's and Smith's claims. However, without verification of symmetry of beliefs, previous research is subject to the Duhem-Quine thesis. These experiments address this concern by eliciting beliefs and estimating a structural model of choice to test the symmetry assumption.

The second part of this dissertation proposal extends the concept of uncertainty to commodities where "quality" and accuracy of a "quality report" are ambiguous. In the tradition of Ellsberg, a family of hypothesis tests is proposed to identify attitudes towards uncertainty. These tests control risk attitudes by eliciting beliefs using a quadratic scoring rule which pays in lottery tickets instead of cash. This design generalizes well-known results in experimental economics from risk attitudes alone to include attitudes towards both risk and uncertainty. This experiment contributes to our understanding of behavior under uncertainty by using the proposed family of tests to identify different attitudes towards uncertainties which originate from different processes.

Finally, Part Three integrates a public-goods game with punishment opportunities with the Becker-DeGroot-Marschak mechanism to elicit privacy values, and replicate reported behaviors. The procedures developed in Part Two would then be used to elicit punishment beliefs in the context of individual privacy decisions. This final experiment contributes to the literature in various ways. First, by using cash rewards as a mechanism to map actions to consequences, the study would eliminate hypothetical biases as confounding behavioral factors. Second, if reported privacy behavior is robust to laboratory control, the roles of asymmetric beliefs and attitudes towards uncertainty in privacy decisions would be identified. A third contribution is a partial test to determine which uncertain process, loss of privacy or the resolution of consequences, is of primary importance to individual decision-makers.

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1. INTRODUCTION

As a field, experimental and behavioral economics is familiar with the value of individual anonymity in laboratory interactions. What is less understood, however, is how individuals value their own personal privacy, anonymity, and the consequences of privacy loss. What factors influence individual decisions to voluntarily give-up or protect personal privacy? Using the laboratory to simulate real-world exchanges of personal privacy, this thesis seeks to obtain a deeper understanding of how individuals value privacy (confidentiality) in bilateral bargaining situations, and how these expected values may be conditioned on existing states of privacy.

If values of privacy have been understood for centuries (Westin 1967, 2003), why then do individual privacy decisions appear to exhibit what some have called paradoxical behaviors? Acquisti and Grossklags (2005a) reports survey responses for 119 subjects, between 19 and 55 years of age. A majority of responses (89.2%) indicate that subjects are highly concerned about privacy.[1,2] However, 87.5% of those same respondents have signed up for loyalty shopping cards, *possibly* placing themselves in privacy-sensitive situations. For example, the marketing firm HMI Communications, hired by Microsoft to handle a promotional "give-away" of Visual Studio.net, inadvertently allowed personal information such as address, email, and telephone number for thousands of applicants to be made public (Orlowski 2002). Did these individuals consider the likelihood of their identifiable information becoming public, did they consider the likelihood of fraud, conditional on such a release, and how do the benefits of receiving a free copy of Visual Studio.net compare to the potential loss due to an increased risk of fraud? Similar questions can be asked of subscriber to AOL internet service (Barbaro and Zellner 2006). When AOL released 20 million web searches made from the AOL search engine, numerous individuals self-identified themselves through their web searches.

The claim of paradoxical behavior rests on a misconception. Privacy behavior is easily explained as a tradeoff between expected benefits and expected costs. Conditional subjective beliefs account for the behavior reported in Acquisti and Grossklags (2005a). This thesis studies the role risk and uncertainty in privacy decision making. To accomplish this goal, research will be conducted in three parts. Part one will use the canonical choice problem described by Ellsberg (1961, p. 650) and the role of uncertainty aversion in violations of Savage's (1954) subjective expected utility theory. Part two will extend the concept of uncertainty aversion to field commodities with more than one source of uncertainty. The experimental design of Heath and Tversky (1991) is adapted to partially identify if subjects differentiate between uncertainties from different sources. And, finally, part three expands on the methods developed in parts one and two to study privacy decision-making and the role of uncertainty aversion.

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[1] The term high concern is a self-reported qualitative ranking of how concerned survey respondents are about their privacy.

[2] Norberg, Horne, and Horne (2007) observe similar self-reported behaviors.

1.1 The Alleged Privacy Paradox

Individuals report high values for personal privacy, while at the same time report behaviors that would seem to contradict having high privacy values. These reports are self-reports from hypothetical surveys in which there are no real consequences from reporting truthfully or falsely. This statement on the alleged privacy paradox describes the canonical “loyalty card” example discussed in Acquisti and Grossklags (2005a).

Existing explanations for the paradox hypothesis include: psychological distortions, bounded rationality, risk/uncertainty aversion[3], and trust (Acquisti and Grossklags 2004, 2005a, 2005b; Chellappa and Sin 2002; Norberg, Horne, and Horne 2007; Syverson 2003). Syverson (2003) and Rifon, LaRose, and Lewis (2007) argue that there is no paradox. Self reported privacy behavior is attributable to either subject heterogeneity (Spiekermann, Grossklags, and Berendt 2002), or recognition that the alleged paradox assumes that stated attitudes map directly into consistent behavior (Syverson 2003; Rifon, LaRose, and Lewis 2007). While there is therefore some recognition of the fallacious assumption that attitudes map into behavior, no study jointly recognizes more basic experimental issues of biases induced by the hypothetical nature of most privacy studies, and saliency of rewards.

For instance, Acquisti and Grossklags (2005b) elicited open-ended hypothetical values for 13 data categories such as name, SSN, favorite online alias, home address, phone number, email address, sexual fantasies, etc.[4] Willingness-to-accept measures were elicited under a simple open-ended valuation, framed as either an exchange of information for money, or a discount on the purchase of a “good” with an assumed value. Some would use these results as providing “useful dollar values” for privacy valuations (Wathieu and Friedman 2007, sec. 1). However, we cannot overlook the experimental literature on the existence of hypothetical bias in value elicitation mechanisms.

Harrison and Rutström (1999) survey a large literature which shows that when exposed to hypothetical scenarios, subjects routinely over (under) state willingness-to-accept (willingness-to-pay) values for market *and* non-market goods. Even after correcting for potential hypothetical biases (List and Shogren 2002), the existing privacy literature does not provide for mechanisms that map actions to consequences. Even if the experiments were conducted with an incentive compatible design (Huberman, Adar, and Fine 2005; and Grossklags and Acquists 2007) uncertainty, ambiguity, and beliefs external to the laboratory environment, were not experimentally controlled.[5]

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[3] It should be noted that neither risk nor uncertainty aversion are necessary conditions to explain allegedly paradoxical privacy behavior.

[4] Acquisti and Grossklags (2005a) and (2005b) use the same subject pool.

[5] Huberman, Adar, and Fine (2005) conducted both an incentive compatible sealed bid real reverse Vickrey auctions, and a hypothetical reverse Vickrey auction. Real auctions consisted of selling verifiable personal information, such as weight and age for 127 individuals. Hypothetical auctions were carried out for “unverifiable” information, such as credit rating, income, and savings. The average demand prices for age and weight were $57.56 and $74.06, respectively.

Furthermore, the results presented in Acquists and Grossklags (2005b) do not allow for a test of the effects of uncertainty (ambiguity) on individual privacy decisions. The experimental design varied the framing of benefits as either a payment or discount on a purchase, not with uncertainty. Treating all subjects with both (open-ended contingent-valuation) *frames* without controlling for potential order effects, their design subjects their conclusions to the Duhem-Quine thesis[6], which is also a major confound factor for the conclusions drawn in Norberg, Horne, and Horne (2007).

In Norberg et al. (2007) an attempt was made to control for both uncertainty and trust through framing of a hypothetical survey instrument designed to simulate a marketer's request for personal information. Their results offer little, if any, support for paradoxical privacy behavior. Violation of the *ceteris paribus* condition, as well as deceitful experimental practices, explained below, confounds their experiment.

The initial experimental treatment in Norberg et al. (2007) was conducted under a hypothetical scenario, asking subjects to behave *as if* they were responding to an information request by a bank. Subjects were instructed that they were taking part in a focus group to aid in the design of a bank's survey instrument. The second treatment removed the *as if* condition but a level of trust (i.e., a bank representative[7]) was added. Treatment two of the "experiment" used dishonest practices. There was in fact no bank, and the bank representative was a fraud designed to cajole subjects into freely revealing personal information.

Deceitful practices question the validity of subject responses, even under the most pristine experimental conditions. Do the subjects in Norberg et al. (2007) have previous experiences with deceitful practices? If so, are they responding truthfully, or are they trying to exhibit behavior that they think the researchers want to see? Or, are they languid with respect to the experimental task, simply reporting systematic responses in an attempt to extract resources (e.g., money or grades) from the experimenter? Hertwig and Ortmann (2001, p. 396-399) offer a detailed survey of potential detriments to deceiving and using subjects whom have previously been deceived by such experimental designs.

The literature has recognized that individuals' stated intentions often contradict stated behavior in privacy sensitive decisions. At face value, these observations may seem compelling. However, privacy decisions entail subjective evaluations of risk, where the decision-maker may be uncertain about the "correctness" of his beliefs. Subjective expected utility (Savage 1954) and the uncertain priors model axiomatized independently by Neilson (1993, 2009) and Klibanoff, Marinacci, and Mukerji (2005) are capable of explaining the observed patterns of privacy behavior.

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[6] The Duhem-Quine thesis states that without proving the background assumptions it is impossible to prove or disprove a theory. Absence of order effects is an untested background assumption in Acquists and Grossklags (2005b).

[7] Phase two of the "experiment" presented in Norberg, Horne, and Horne (2007) used dishonest practices. There was no bank representative (ibid., 111, 115).

2. THEORY AND HYPOTHESES

The alleged privacy paradox says that decision-makers report high values for personal privacy, while at the same time these same decision-makers report behaviors that would seem to contradict having high privacy values. In the sequel I show how the pattern of observed privacy behaviors consistent with the alleged paradox are rationally explained by Savage's (1954) subjective expected utility (SEU) model, a special case of a preference function which allows the decision-maker to hold multiple uncertain prior beliefs for the risks associated with privacy behavior.

2.1 Subjective Expected Utility

Savage (1954) shows that if the decision-maker behaves according to a set of axioms he will behave *as if* maximizing a preference functional give by

$$V(\mathbf{z}) = \sum_{j \in J} p_j \cdot v(z_j), \tag{1}$$

where z_j are consequences of act Z, dependent on which state $j \in J$ occurs, p_j is a probability measure (subjectively) known to the decision-maker, and $v(\cdot)$ is the state independent utility function. To show how SUE preferences explain privacy behavior, consider the canonical "loyalty card" example discussed by Acquisti and Grossklags (2005a). A majority of survey respondents (89.2%) reported having a high concern for privacy. However, those same respondents admit to routinely placing themselves in privacy-sensitive situations. For example, 87.5% of respondents with a high concern for privacy have signed up for loyalty cards using real identifying information.

A high privacy concern is taken to be synonymous with a high dollar value of private information. Thus, the paradoxical privacy behavior is represented by the decision to not make a *direct sale* of information to someone who would potentially do harm, while at the same time make an *indirect sale* of the same personal information to someone who will not do direct harm but may reveal the information to the same person who would potentially do harm. Acquisti and Grossklags (2005a), among others, would claim this behavior represents a dichotomy between stated privacy concerns and stated behavior.

Consider this numerical example of the "loyalty card" problem. Assume the decision-maker has an initial wealth level given by w (e.g., $w = \$100$) and, in exchange for identifying information, he is offered some positive amount of money y (e.g., $y = \$20$). If the decision-maker is successfully defrauded, he will lose some portion of his wealth. For simplicity, assume he loses $1-\delta$ percent, retaining either δw or $\delta[w+y]$ following a successful fraud attempt. Specifically, let $\delta = 0.5$, $\delta w = \$50$ and

$\delta[w+y]=\$60$. Finally, let $J=(\text{cg},\text{cb},\text{ng},\text{nb})$ be the events (good (g) conditional of confidential (c), bad (d) conditional on confidentiality, etc.) considered by the decision.

For the direct sale the decision-maker compares the lottery between good and bad events conditional on confidentiality, against the alternative lottery for good and bad events conditional on non-confidentiality *and* payment for his identifying information. Assume these beliefs are given by $(p_{\text{g|c}}, p_{\text{b|c}}, p_{\text{g|n}}, p_{\text{b|n}})=(0.65, 0.35, 0.35, 0.65)$. When his identifying information is confidential, the decision-maker believes there is a lower risk of being defrauded.

Defining $v(x)=\sqrt{x}$, SEU preferences imply that if the decision-maker makes the direct sale he expects utility

$$V(\mathbf{z}|\text{direct sale})=0.35\cdot\sqrt{120}+0.65\cdot\sqrt{60}=8.869,$$

and if he does not make the direct sale he expects utility

$$V(\mathbf{z}|\text{no direct sale})=0.65\cdot\sqrt{100}+0.35\cdot\sqrt{50}=8.975.$$

The decision-maker decides not to make the direct sale. However, when confronted with the same offer of \$20 for an indirect sale, the decision-maker agrees to the transaction because he believes there is a 50 percent chance his personal information remains confidential. For the indirect sale, the decision-maker expects utilities

$$V(\mathbf{z}|\text{indirect sale})=0.5\cdot\left[0.35\cdot\sqrt{120}+0.65\cdot\sqrt{60}\right] +0.5\cdot\left[0.65\cdot\sqrt{100}+0.35\cdot\sqrt{50}\right]=9.350, \text{ and}$$

$$V(\mathbf{z}|\text{no indirect sale})=0.65\cdot\sqrt{100}+0.35\cdot\sqrt{50}=8.975=V(\mathbf{z}|\text{no direct sale}).$$

As this example demonstrates, uncertainty aversion and other exotic preference weighting functions are not necessary to explain privacy behaviors. However, for ambiguous events decision-makers tend to exhibit aversion to the inherent uncertainty (Camerer and Weber 1992). Halevy (2007) reports on an experiment where approximately 30% of subjects violate reduction of compound lotteries (p. 523), and are characterized by *ambiguity aversion*. Although unnecessary to rationalize privacy behavior, the uncertain priors (UP) model axiomatized separately by Neilson (1993, 2009) and Klibanoff, Marinacci, and Mukerji (2005), studied by Halvey (2007), Chakravarty and Roy (2008), and Andersen, Harrison, Fountain, and Rutström (2009) will be used to allow for uncertainty aversion in privacy decision-making. The canonical concept of uncertainty aversion is introduced with Ellsberg's (1961, p. 650) two urn problem. The same UP model also explains Ellsberg's three color problem and other extensions of his paradox.

2.2 Uncertainty Aversion: Ellsberg's Paradox

Consider the following Ellsberg (1961, p. 650) example. There are two urns, and each is filled with red and black balls. Urn 1 contains 100 balls, split evenly between red and black. Balls drawn from urn 1 are labeled "R" for red and "B" for black. Urn 2 also contains 100 balls. However, the mix of balls is unknown. Balls drawn from urn 2 are labeled "r" for red and "b" for black.

Table 1: Ellsberg's Two Urn Problem

Outcomes	L_1	L_2	L_3	L_4
Rr	\$100	\$0	\$100	\$0
Rb	\$100	\$100	\$0	\$0
Br	\$0	\$0	\$100	\$100
Bb	\$0	\$100	\$0	\$100

Table 1 shows four lotteries (L_1, L_2, L_3, and L_4), with prizes \$0 or \$100 defined over the unique outcomes from drawing one ball from urn 1, and then a second ball from urn 2. Ellsberg (1961) hypothesized that subjects would exhibit preference relations given by $L_1 \sim L_4$, $L_2 \sim L_3$, $L_1 \succ L_2$, and $L_4 \succ L_3$. These hypotheses are the result of a thought experiment by Ellsberg, in the sense defined by Harrison and List (2004). He did pose these choices hypothetically to several prominent economists, including Savage. But the key "empirical hypothesis" here derives from intuition, not observed choices in the sense that modern experimental economics would suggest. Indifference between L_2 and L_3 imply the formation of a belief that the balls in urn 2 (the uncertain urn) are split evenly, 50 red and 50 black. However, preferences for L_1 over L_2 and for L_4 over L_3 implies under subjective expected utility theory that subjects believe the likelihood of drawing red and black balls from urn 2 are less than $\frac{1}{2}$, hence the paradox. The UP model (Neilson 1993, 2009; and Klibanoff, Marinacci, and Mukerji 2005) rationalizes these preferences for second-order beliefs.

2.2.1 The Uncertain Priors Model

Using the terminology of Anscombe and Aumann (1963), let there be $j = 1,...,J$ (uncertain) horse lotteries and $k = 1,...,K$ (certain) roulette lotteries. The decision-maker holds $i = 1,...,I$ prior distributions over each horse's ability to win the race – the outcome of the uncertain process U. Denote the probability over these priors as $\boldsymbol{\rho} = (\rho_1,...,\rho_I)$. The set $(U_{i1},...,U_{iJ})$ is the set of uncertain processes with unknown probabilities for each of the J horses winning the race. Define a set $(C_1,...,C_K)$ as the set of certain processes with known probabilities over each of the K roulette lotteries.

Let $\left(\sigma_{ij1},...,\sigma_{ijK}\right)$ define the subjective conditional probabilities assigned to j^{th} horse winning and the k^{th} roulette lottery outcome under each prior i. The decision-maker's overall evaluation of his preference for the race is

$$W\left(\mathbf{z}\right)=\sum_{i=1}^{I}\rho_i u\left(\sum_{j=1}^{J}\sum_{k=1}^{K}\sigma_{ijk}v\left(z_{jk}\right)\right), \tag{2}$$

where $W\left(\mathbf{z}\right)$ is the evaluation of all I priors that the decision-maker holds, and $\sigma_{ijk}\equiv\pi_{ij}^{U}\pi_{k}^{C}$ with π_{ij}^{U} defined as the probabilistic belief of each horse j winning and π_{k}^{C} the known probability of the k^{th} certain event. The function $v(\cdot)$ measures utility over final payoffs z_{jk}, and $u(\cdot)$ is the evaluation of the decision-maker's subjective expected utility over final payoffs from the certain roulette lotteries. The curvature of $u(\cdot)$ measures uncertainty associated with the priors $i=1,...,I$. To illustrate how the UP model is able to account for the preferences depicted in Ellsberg's example, I recreate the numerical example found in Andersen, Harrison, Fountain, and Rutström (2009).

For some argument x, define $v(x)=\sqrt{x}$ and $u(x)=x^{0.9}$. Define balls drawn from urns 1 and 2 as belonging to the sets $k=\{\text{R},\text{B}\}$ and $j=\{\text{r},\text{b}\}$, respectively. Further assume the decision-maker holds three priors over the distribution of balls in urn 2. That is, $\left(\rho_1,\rho_2,\rho_3\right)=\left(0.6,0.2,0.2\right)$, with $\left(\pi_{1\text{r}}^{U},\pi_{1\text{b}}^{U}\right)=\left(0.5,0.5\right)$, $\left(\pi_{2\text{r}}^{U},\pi_{2\text{b}}^{U}\right)=\left(0.4,0.6\right)$, and $\left(\pi_{3\text{r}}^{U},\pi_{3\text{b}}^{U}\right)=\left(0.6,0.4\right)$. For each of these priors, the decision-maker evaluates $\sigma_{ijk}=\pi_{ij}^{U}\pi_{k}^{C}$ as $\left(\pi_{1\text{r}}^{U}\pi_{\text{R}}^{C},\pi_{1\text{b}}^{U}\pi_{\text{R}}^{C},\pi_{1\text{r}}^{U}\pi_{\text{B}}^{C},\pi_{1\text{b}}^{U}\pi_{\text{B}}^{C}\right)=\left(0.25,0.25,0.25,0.25\right)$ for his first prior set of probabilistic beliefs, $\left(\pi_{2\text{r}}^{U}\pi_{\text{R}}^{C},\pi_{2\text{b}}^{U}\pi_{\text{R}}^{C},\pi_{2\text{r}}^{U}\pi_{\text{B}}^{C},\pi_{2\text{b}}^{U}\pi_{\text{B}}^{C}\right)=\left(0.2,0.3,0.2,0.3\right)$ for his second set of prior beliefs, and finally for his third set of priors the decision-maker believes $\left(\pi_{3\text{r}}^{U}\pi_{\text{R}}^{C},\pi_{3\text{b}}^{U}\pi_{\text{R}}^{C},\pi_{3\text{r}}^{U}\pi_{\text{B}}^{C},\pi_{3\text{b}}^{U}\pi_{\text{B}}^{C}\right)=\left(0.3,0.2,0.3,0.2\right)$. For each of these priors, the evaluation of $\sum_{j=1}^{J}\sum_{k=1}^{K}\sigma_{ijk}v\left(z_{jk}\right)$ for lottery L_1 (see Table 1) is then given by

$$L_1: \qquad 0.25\cdot 10+0.25\cdot 10+0.25\cdot 0+0.25\cdot 0=5,$$

under prior 1,

$$L_1: \qquad 0.20\cdot 10+0.30\cdot 10+0.20\cdot 0+0.30\cdot 0=5,$$

under prior 2, and

$$L_1: \qquad 0.30\cdot 10+0.20\cdot 10+0.30\cdot 0+0.20\cdot 0=5,$$

under prior 3. Similar calculations are made for lotteries L_2, L_3, and L_4. Evaluating preferences for each lottery,

$$W(L_1) = 0.6 \cdot 5^{0.9} + 0.2 \cdot 5^{0.9} + 0.2 \cdot 5^{0.9} = 4.257,$$
$$W(L_2) = 0.6 \cdot 5^{0.9} + 0.2 \cdot 6^{0.9} + 0.2 \cdot 4^{0.9} = 4.254,$$
$$W(L_3) = 0.6 \cdot 5^{0.9} + 0.2 \cdot 4^{0.9} + 0.2 \cdot 6^{0.9} = 4.254,$$
$$W(L_4) = 0.6 \cdot 5^{0.9} + 0.2 \cdot 5^{0.9} + 0.2 \cdot 5^{0.9} = 4.257.$$

For this numerical example, $W(L_1) = W(L_4)$, $W(L_2) = W(L_3)$, $W(L_1) > W(L_2)$, and $W(L_4) > W(L_3)$, which explains the hypothesized pattern of preferences in Ellsberg's example. It is easy to see that, if there is no aversion to uncertainty, such that $u(x) = x$ apart from arbitrary normalizations, then $W(L_1) = W(L_2) = W(L_3) = W(L_4)$. This is the prediction of conventional subjective expected utility theory.

Although the hypothesis that individuals exhibit uncertainty aversion has been studied extensively (Camerer and Webber 1992), Ellsberg's (1961) seminal 2-color problem has yet to be tested using rigorous experimental designs. Prior investigations of the uncertainty aversion hypothesis failed to verify the background assumption that the decision-maker believes that the realization of events is equally likely for both the known and unknown urns. Given this gap in the existing literature, the first hypothesis to be tested is:

HYPOTHESIS 1: In Ellsberg's (1961) 2-color problem (p. 650), subjects behave *as if* the realization of each event is equally likely for both the known and unknown urn *and* bets on the known urn are preferred to bets on the unknown urn.

Smith (1969, p. 329) conjectured that Ellsberg's (1961) pattern of preferences would also be observable for bets where the distribution of balls in the ambiguous urn was determined by a uniform random integer 0-100. Since then, experimentalists (Sarin and Weber 1993; Harrison 2009 p. 19) have considered compound lotteries as attractive tools for inducing uncertainty in laboratory settings. Because Smith (1969) remains *untested*, the following two hypotheses emerge as important methodological inquiries:

HYPOTHESIS 2: The pattern of preferences for Smith's (1969) urns is similar to the pattern of preferences for Ellsberg's (1961) urns.

HYPOTHESIS 3: The distribution of attitudes towards uncertainty using Ellsberg's urns is similar to the distribution of attitudes using Smith's urns

The second proposed experiment extends this analysis to identify uncertainty aversion and estimate the parameters of the UP model using a field commodity, instead of cash rewards. The experimental design of Heath and Tversky (1991) which elicits preferences for probabilistically equivalent certain and uncertain lottery pairs is adapted to Harrsion, List, and Towe (2007) which elicits preferences for lotteries paying with a graded field commodity rather than cash. The primary hypothesis to be tested is:

HYPOTHESIS 4: Subjects are indifferent between probabilistically equivalent certain and uncertain lottery pairs paying on commodity grades.

Finally, I propose to apply the experimental methods used to test hypotheses 1 through 4 to identify uncertainty aversion in privacy decision. The remainder of this section presents the UP model in the context of privacy and extends the analysis to include two uncertain processes.

2.3 Explaining Privacy Behavior with The Uncertain Priors Model

The Ellsberg (1961) example(s) and the UP model (Neilson 1993, 2009; and Klibanoff, Marinacci, and Mukerji 2005) demonstrate how the uncertainty averse individual, will discount more heavily those processes which are described as "more uncertain." The utility spread for L_2 and L_3 are greater than that of L_1 and L_4. The remainder of this section uses a numerical example to present an UP model for privacy behavior. As before, the "loyalty card" problem is used as an illustration. However, the paradox can occur in any privacy decision making process. The acts of confession or being an "anonymous source" are other examples of the privacy paradox.

Redefine $k = \{\text{g}, \text{b}\}$ for the good and bad outcomes. Let the J uncertain events be given by $j = \{\text{c}, \text{n}\}$ for when the vendor has upheld the confidentiality of the decision-maker and when confidentiality was violated. The following example shows that the UP model with only one uncertain process explains the alleged privacy paradox when the objective probabilities of experiencing either a good or bad events are conditional on the decision-maker's state of confidentiality.

Assume the decision-maker has an initial wealth level given by w (e.g., $w = \$100$) and, in exchange for identifying information, he is offered some positive amount of money y (e.g., $y = \$20$). Unconditional on the decision to sell information, if the decision-maker is successfully defrauded, he will lose some portion of his wealth. For simplicity, assume he loses $1-\delta$ percent, retaining either δw or $\delta\left[w+y\right]$. Specifically, let $\delta = 0.5$, $\delta w = \$50$ and $\delta\left[w+y\right] = \$60$. Assume the decision-maker holds 2 priors $\boldsymbol{\rho} = (0.5, 0.5)$ for the uncertainty that the decision-maker's confidentiality is violated. For each of these priors, let the distribution of events $j = \{\text{c}, \text{n}\}$ be $\left(\pi_{1\text{c}}^{U}, \pi_{1\text{n}}^{U}\right) = (0.7, 0.3)$ and $\left(\pi_{2\text{c}}^{U}, \pi_{2\text{n}}^{U}\right) = (0.3, 0.7)$. These beliefs assume the decision-maker has joined the loyalty card program. If the decision-maker does not make an indirect sale, then he forms a set of degenerate beliefs $\left(\pi_{1\text{c}}^{U}, \pi_{1\text{n}}^{U}\right) = \left(\pi_{2\text{c}}^{U}, \pi_{2\text{n}}^{U}\right) = (0,1)$.

Let the objectively-known probabilities of a bad event conditional on a privacy breach be $\left(\pi^C_{\text{g|c}},\pi^C_{\text{b|c}}\right)=\left(0.65,0.35\right)$ and $\left(\pi^C_{\text{g|n}},\pi^C_{\text{b|n}}\right)=\left(0.35,0.65\right)$. For prior one the decision-maker holds subjective probabilistic belief given by $\left(\sigma_{\text{1cb}},\sigma_{\text{1nb}},\sigma_{\text{1cg}},\sigma_{\text{1ng}}\right)=\left(0.245,0.195,0.455,0.105\right)$, and for prior two his beliefs are given by $\left(\sigma_{\text{2cb}},\sigma_{\text{2nb}},\sigma_{\text{2cg}},\sigma_{\text{2ng}}\right)=\left(0.105,0.455,0.195,0.245\right)$. Defining $v\left(x\right)=\sqrt{x}$ and $u\left(x\right)=x^{0.7}$, equation (2) implies that if the decision-maker makes an indirect sale, he expects utility

$$W\left(\mathbf{z}|\text{indirect sale}\right)=0.5\cdot\left[0.245\cdot\sqrt{60}+0.195\cdot\sqrt{60}+0.455\cdot\sqrt{120}+0.105\cdot\sqrt{120}\right]^{0.7}$$
$$+0.5\cdot\left[0.105\cdot\sqrt{60}+0.455\cdot\sqrt{60}+0.195\cdot\sqrt{120}+0.245\cdot\sqrt{120}\right]^{0.7}=4.781.$$

If he does not make an indirect sale, the decision-maker's information remains confidential and he forms beliefs $\left(\pi^U_{1c},\pi^U_{1n}\right)=\left(\pi^U_{2c},\pi^U_{2n}\right)=\left(1,0\right)$, which imply that $\left(\sigma_{\text{2cb}},\sigma_{\text{2nb}},\sigma_{\text{2cg}},\sigma_{\text{2ng}}\right)=\left(\sigma_{\text{1cb}},\sigma_{\text{1nb}},\sigma_{\text{1cg}},\sigma_{\text{1ng}}\right)=\left(0.35,0,0.65,0\right)$, and

$$W(\mathbf{z}|\text{no indirect sale})=\left[0.35\cdot\sqrt{50}+0.65\cdot\sqrt{100}\right]^{0.7}=4.646<W\left(\mathbf{z}|\text{indirect sale}\right),$$

and the decision-maker decides to make the indirect sale because he expects a higher utility.

Calculating utilities for the direct sale part of the alleged paradox is similar to the first part of the example. The direct sale decision removes the uncertainty from the decision-maker's problem. He forms one of two degenerate beliefs, 100% or 0% confidentiality. By not directly selling his information, the decision-maker forms the degenerate belief $\left(\pi^U_{\text{1c}},\pi^U_{\text{1n}}\right)=\left(\pi^U_{\text{2c}},\pi^U_{\text{2n}}\right)=\left(1,0\right)$. Thus,

$$W(\mathbf{z}|\text{no direct sale})=\left[0.35\cdot\sqrt{50}+0.65\cdot\sqrt{100}\right]^{0.7}=W(\mathbf{z}|\text{no indirect sale}).$$

By directly selling his personal information, the decision-maker holds beliefs $\left(\pi^U_{\text{1c}},\pi^U_{\text{1n}}\right)=\left(\pi^U_{\text{2c}},\pi^U_{\text{2n}}\right)=\left(0,1\right)$, such that his beliefs are *objectively* given by $\left(\sigma_{\text{2cb}},\sigma_{\text{2nb}},\sigma_{\text{2cg}},\sigma_{\text{2ng}}\right)=\left(\sigma_{\text{1cb}},\sigma_{\text{1nb}},\sigma_{\text{1cg}},\sigma_{\text{1ng}}\right)=\left(0,0.65,0,0.35\right)$, and so

$$W(\mathbf{z}|\text{direct sale})=\left[0.65\cdot\sqrt{60}+0.35\cdot\sqrt{120}\right]^{0.7}=4.608<W(\mathbf{z}|\text{no direct sale}).$$

When the objective probabilities of either a bad or good event occurring are conditional on the decision-maker's state of confidentiality, then the UP model with one uncertain process can directly explain reported privacy behavior. Extending the UP model to include two uncertain processes also yields preferences that account for the observed patters of the first privacy behavior. While this extension to two uncertain processes is mathematically unnecessary to account for the alleged incidence of a privacy paradox, objectively known probabilities of fraud are unrealistic.

2.4 Explaining the Privacy Paradox with Two Uncertain Processes

Extending the UP model to account for subjective belies for both a privacy breach and a bad event is a conceptually straightforward exercise, although it does impose some notational burden. Consider the preference function

$$W(\mathbf{z}) = \sum_{i^1=1^1}^{2^1} \sum_{i^2=1^2}^{2^2} \rho_{i^1} \theta_{i^2} u\left(\sum_{j^1=\{\mathrm{c},\mathrm{n}\}} \sum_{j^2=\{\mathrm{g},\mathrm{b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right) \right). \quad (3)$$

In addition to his first I^1 priors for his identifying information remaining confidential, the decision-maker has now formed the additional I^2 prior probabilistic beliefs of a bad event, conditioned on the $j^1 = \{\mathrm{c},\mathrm{n}\}$ events. This formulation of the UP model assumes ROCL applies between the two uncertain processes. Beliefs represented by $\pi^2_{j^1 i^2 j^2}$, and $\sigma_{i^1 i^2 j^1 j^2} \equiv \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2}$ are the decision-maker's beliefs of realizing the events $j^1 = \{\mathrm{c},\mathrm{n}\}$ *and* $j^2 = \{\mathrm{g},\mathrm{b}\}$. Finally, θ_{i^2} are the probabilities over the I^2 priors.

In equation (3), curvature of $u(x)$ at the point x measures the decision-maker's aversion to his $I^1 \times I^2$ uncertain beliefs of the $J^1 \times J^2$ events. To show how equation (3) explains privacy behavior, use the same payoffs and functions before. Denote the subjective beliefs of good or bad events by $\left(\pi^2_{1^2\,\mathrm{g}|\mathrm{c}}, \pi^2_{1^2\,\mathrm{b}|\mathrm{c}}, \pi^2_{1^2\,\mathrm{g}|\mathrm{n}}, \pi^2_{1^2\,\mathrm{b}|\mathrm{n}}\right) = (0.7, 0.3, 0.3, 0.7)$ and $\left(\pi^2_{2^2\,\mathrm{g}|\mathrm{c}}, \pi^2_{2^2\,\mathrm{b}|\mathrm{c}}, \pi^2_{2^2\,\mathrm{g}|\mathrm{n}}, \pi^2_{2^2\,\mathrm{b}|\mathrm{n}}\right) = (0.6, 0.4, 0.4, 0.6)$ which are his beliefs of bad and good events under each prior, conditional on his state of confidentiality.

Define $SEU_{i^1 i^2} \equiv \sum_{j^1=\{\mathrm{c},\mathrm{n}\}} \sum_{j^2=\{\mathrm{g},\mathrm{b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right)$ as the decision-maker's prior subjective expected utilities over the final outcomes g *or* b, conditioned on c *or* n. Beliefs of having his identifying information remain confidential after engaging in an indirect sale are given by $\left(\pi^1_{1^1\,\mathrm{c}}, \pi^1_{1^1\,\mathrm{n}}, \pi^1_{2^1\,\mathrm{c}}, \pi^1_{2^1\,\mathrm{n}}\right) = (0.7, 0.3, 0.3, 0.7)$

If the decision-maker indirectly sells his information

$$SEU_{1^1 1^2} = 0.58\sqrt{120} + 0.42\sqrt{60} = 9.607\,,$$

$$SEU_{1^1 2^2} = 0.42\sqrt{120} + 0.58\sqrt{60} = 9.094\,,$$

$$SEU_{2^1 1^2} = 0.54\sqrt{120} + 0.46\sqrt{60} = 9.479 \text{, and}$$

$$SEU_{1^1 2^2} = 0.46\sqrt{120} + 0.54\sqrt{60} = 9.222 .$$

The decision-maker expects *final* utility

$$W(\mathbf{z} \mid \text{indirect sale}) = 0.25 \cdot [9.607]^{0.7} + 0.25 \cdot [9.094]^{0.7} + 0.25 \cdot [9.479]^{0.7} + 0.25 \cdot [9.222]^{0.7} = 4.781 .$$

If the decision-maker decides not to make the indirect sale, then he recognizes that he will be in a confidential state with certainty, and he forms the degenerate prior conditional probability distributions $\boldsymbol{\pi}^1 = \left(\pi^1_{1^1 \text{c}}, \pi^1_{1^1 \text{n}}, \pi^1_{2^1 \text{c}}, \pi^1_{2^1 \text{n}}\right) = (1,0,1,0)$, which implies

$$SEU_{1^1 1^2} = SEU_{1^1 2^2} = 0.70\sqrt{100} + 0.30\sqrt{50} = 9.992 \text{, and}$$

$$SEU_{2^1 1^2} = SEU_{1^1 2^2} = 0.60\sqrt{100} + 0.40\sqrt{50} = 9.671 .$$

By deciding not to make the indirect sale, the decision-maker expects final utility

$$W(\mathbf{z} \mid \text{no indirect sale}) = 0.5 \cdot [9.992]^{0.7} + 0.5 \cdot [9.671]^{0.7} = 4.646 < W(\mathbf{z} \mid \text{indirect sale}).$$

The decision-maker will make the indirect sale because he expects to be better-off.

Not making a direct sale is equivalent to not making an indirect sale of identifying information. Thus, $W(\mathbf{z} \mid \text{no direct sale}) = W(\mathbf{z} \mid \text{no indirect sale}) = 4.646$. Making the direct sale, the decision-maker forms the degenerate beliefs $\boldsymbol{\pi}^1 = \left(\pi^1_{1^1 \text{c}}, \pi^1_{1^1 \text{n}}, \pi^1_{2^1 \text{c}}, \pi^1_{2^1 \text{n}}\right) = (0,1,0,1)$ by recognizing that he will be in a non-confidential state. Hence,

$$SEU_{1^1 1^2} = SEU_{1^1 2^2} = 0.30\sqrt{100} + 0.70\sqrt{50} = 8.709 \text{, and}$$

$$SEU_{2^1 1^2} = SEU_{1^1 2^2} = 0.40\sqrt{100} + 0.60\sqrt{50} = 9.029 .$$

By deciding not to make the direct sale, the decision-maker expects final utility

$$W(\mathbf{z} \mid \text{direct sale}) = 0.5 \cdot [8.709]^{0.7} + 0.5 \cdot [9.029]^{0.7} = 4.607 < W(\mathbf{z} \mid \text{no direct sale}),$$

and the decision-maker decides not to sell his information.

These numerical examples have shown how reported privacy behavior is explained by allowing for the uncertainty of the bad outcome to be subjectively determined and depend on the state of confidentiality – which may also be a subjective belief.

The two-process UP model specified by equation (3) has two alternative interpretations. First, the decision-maker cognitively differentiates between the probabilities he assigns to his I^1 and I^2 priors (Kramer and Budescu 2002), and his preferences are given by

$$W(\mathbf{z}) = \sum_{i^1=1^1}^{2^1} \rho_{i^1} u^1 \left(\sum_{i^2=1^2}^{2^2} \theta_{i^2} u^2 \left(\sum_{j^1=\{\mathrm{c,n}\}} \sum_{j^2=\{\mathrm{g,b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right) \right) \right), \tag{4}$$

which is consistent with the interpretation that the decision-maker believes the uncertain confidentiality process determines the determines fraud process, which finally determines his payoff (Nielson's 1993, 2009). The second (re)interpretation says the resolution of the fraud event determines the uncertain confidentiality process which determines confidentiality, and preference are given by

$$W(\mathbf{z}) = \sum_{i^2=1^2}^{2^2} \theta_{i^2} u^2 \left(\sum_{i^1=1^1}^{2^1} \rho_{i^1} u^1 \left(\sum_{j^1=\{\mathrm{c,n}\}} \sum_{j^2=\{\mathrm{g,b}\}} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 j^2} v\left(z_{j^2}\right) \right) \right). \tag{5}$$

Each of these last two models reduces to equation (3) when the decision-maker's attitudes are neutral towards the uncertainty of his priors over confidentiality or fraud, respectively. Section 3.3.1.3 presents an almost complete test to identify the uncertainty aversion for two uncertain processes.

My primary thesis, offers the first true test for uncertainty aversion in privacy decisions. It extends the analysis of uncertainty and identification to include the concealment of identifying information. The main hypotheses to be tested are:

HYPOTHESIS 5: Subjects are indifferent between probabilistically equivalent certain and uncertain lottery pairs for confidentiality.

HYPOTHESIS 6: Subjects are indifferent between probabilistically equivalent certain and uncertain lottery pairs for a good event.

Combining hypothesis 5 and hypothesis 6 allows for a partial test that subjects have separate attitudes towards separate uncertain processes. Finally, FIML techniques will be used to estimates the structural parameters of the SEU and UP models which were presented in the preceding discussion.

3. PROPOSED EXPERIMENTS

3.1 Ellsberg's Paradox and Smith's Hypothesis

This chapter presents a two part study of uncertainty aversion in decision-making. The first is a methodological inquiry to replicate Ellsberg's (1961) 2-color thought experiment using real monetary rewards in a controlled laboratory environment. Although experimental evidence has been offered suggesting uncertainty aversion is a good normative theory of human decision-making (Becker and Brownson 1964; Yates and Zukowski 1976; Chow and Sarin 2002; Halevy 2007), verification of symmetric beliefs for both the known and unknown urns, which imply uncertainty aversion, have not been verified. Ellsberg's (1961, p. 653) 3-color problem has been replicated by Ford and Ghose (1998), Schmidt and Neugebauer (2003).

The 3-color problems, as well as supporting arguments for the 2-color problem (Ellsberg's 1961, p. 651 fn. 1) offer inappropriate support for uncertainty aversion. This argument has been previously recognized by Wakker (2001, p. 1040) and supported by Tversky and Kahneman (1992, §1.3). Like the Allais paradox, multi-color and 1-urn problems are also explained without reference to attitudes uncertainty aversion. As a result, single urn problems do not isolate uncertainty aversion, a violation of simple ordering[8], from violations of independence or the sure-thing principle.[9] Neilson (1993, 2009) and Klibanoff, Marinacci, and Mukerji (2005), as well as other multiple prior models (e.g., maxmin EU of Gilboa and Schmeidler (1989) and anticipated utility of Segal (1987)), capture the essence of UA, as describing attitudes towards expectations of utility.

The closest replication of the 2-color problem was offered by Chow and Sarin (2002).[10] In their experiments, an unopened bag of M&Ms was used to simulate Ellsberg's unknown urn. Chow and Sarin (1976, p. 135) report that "…there was virtually no difference in the mean prices…" for bets on red, blue, or orange and bets on green, brown, or yellow. The M&Ms test reveals the most compelling evidence in favor of uncertainty aversion. However, lacking statistical verification of symmetric probabilistic beliefs, reported certainty equivalents in Chow and Sarin (2002) are consistent with both aversion to acts with uncertain or ambiguous probabilities, and the formation of asymmetric beliefs. These criticisms point to the need to control for subjective beliefs in order to properly identify attitudes towards uncertainty.

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[8] Cox and Epstein (1989) found that preference reversals were the result of violations of the completeness axiom, rather than violations the sure-thing principle.

[9] It must also be recognized that direct replication of the 3-color problem as in the case of Ford and Ghose (1998) omits the possibility of indifference which allows for an explanation of the preference reversal as (possibly) the result of a systematic resolution of indifference. Those decision-maker's choices should not be considered significant (Savage 1954, p. 17).

[10] Halvey (2007, p. 516, footnote 14) does make note of the background assumption that subjective beliefs for the composition of the unknown urn needs to be 50-50 for either color. However, they offer no test of the assumption.

Heath and Tversky (1991) addressed control of beliefs by eliciting probabilistic reports for the occurrence of a series of uncertain events. Reports were then used to present subjects with paired lottery choices between the status quo uncertain prospect and an equivalent objective lottery with probabilities equal to subjects' reports. The crux of the problem with this design is that unless reports are honest in the sense of Myerson (1981), arguments in favor or against the presence of uncertainty aversion are unjustified. It is well known that reports elicited without properly aligned incentives are biased by attitudes towards risk and/or uncertainty. Or, maybe, because it was costless to do so, subjects simply felt like misrepresenting their true belief.

Symmetry of beliefs can be controlled using an incentive compatible mechanism such as proper scoring rules or, to a certain extent**,** paired lotteries and direct elicitation of indifference as I propose for these experiments. A design using paired lotteries is capable of alleviating the criticisms of previous experimental designs. While the use of paired lottery choices may have low statistical power or pattern recognition in the sense of Ellsberg's choices, it does not reduce the power of structural estimation of the UP model's parameters and the identification of attitudes towards uncertainty. By replicating Ellsberg's 2-color problem with an incentive compatible mechanism I isolate attitudes towards uncertainty as explanations of choice behavior when probabilities are not well formed. The 2-color problem using compound objective lotteries will also be replicated to test Smith's (1969) hypothesis that behavior would be similar to that of Ellsberg (1961).

3.1.2 Experimental Design

In this section, I present the general design of the experiments to test for uncertainty aversion and the statistical validity of Smith's (1969) hypothesis that similar choice patterns from Ellsberg's 2-color problem are observed when the unknown urn is replaced with an objective compound lottery. A detailed selection of proposed instructions for these experiments is located in Appendix B.

Ellsberg's (1961) 2-color problem will be replicated using a within-subject design with real monetary rewards.[11] Subjects will be confronted with two bingo cages that are used in place of Ellsberg's urns. One of these cages will remain covered until a ball is drawn from it at the end of the experiment. The covered cage represents the unknown urn. Each cage will be filled with either, 2, 10, or 100 uniformly distributed orange and white balls. One subject chosen at random will publicly count and verify that there are

[11]To the best of my knowledge, there are no presentations of individual decisions that support the hypothesis that subjects believe the draw of red or black from the Ellsberg's unknown urn is 50-50. Becker and Brownson (1964, p. 66) claim "…subjects given a choice of colors … are typically indifferent…", however, no statistical evidence to support the 50-50 background assumption is presented. Chow and Sarin (1988 p. 134) acknowledge subjects having 50-50 beliefs for the colors of M&M candies in a bag (their unknown urn), yet they offer no test statistics. The background assumption of 50-50 beliefs for the distribution of balls in Ellsberg's uncertain urn is a necessary condition for any Ellsberg test. Ellsberg (1961) was aware of this fundamental issue. However, Kadane (1992) shows that Ellsberg's pattern of preferences is possible without 50-50 beliefs provided the subjects distrust the experimenter. Kadane's model is nearly untestable hypothesis tantamount to a faith based argument.

indeed either 1, 5, or 50 balls of each color. Prior to drawing one ball from each cage and making payments accordingly, subjects complete two tasks: a choice task replicating Ellsberg's problem, and a belief elicitation task used to identify and estimate subjective beliefs.

Smith's (1969) hypothesis is tested using an almost identical design as that of the Ellsberg test. The difference being a third cage was filled with balls numbered 0 to 2, 0 to 10, or 0 to 100. The ball drawn form this third cage determines the number of orange balls that are placed in the unknown cage. Subjects make their choices in both tasks prior to the resolution of how many balls of each color are placed in the unknown cage.

3.1.2.1 Preference Elicitation Task

The two bingo cages used to represent Ellsberg's urns are labeled "Cage I" and "Cage II." Cage I represents the known urn with a verified number and distribution of orange and white balls, while Cage II will remain covered and represent the unknown urn. The decision sheet decision sheet presented to subjects is recreated in Table 2. To avoid potential contamination from portfolio effects, randomization devices (i.e., dice) will be used to randomly select one row from each subject's decision sheet to be played for real rewards.

Because expressions of preference for either option A or option B are weak order preferences, option C randomly selects option A or B and pays a small premium to induce truthful reporting for subjects with indifferent preferences between each Ellsberg bet (A and B). When choosing the magnitude of the premium to be paid for reporting indifference, consideration must be made that the premium not only incentivizes honest reporting of indifference, but also increases the likelihood that subjects with strict preference report indifference (i.e., type II error). As an example the premium listed in Table 2 shows a 50¢ premium.

Table 2 Decision Sheet for Ellsberg Task

Option A	Option B	Option C	Decision		
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C

After subjects state their preferences for bets on the color ball to be drawn from Ellsberg's urns, they will be given the choice to keep their lottery or trade and participate in a belief elicitation task with the chance to win a much larger amount of money. Following the belief elicitation task, one ball will be chosen from each urn and subjects will be paid according to either their stated preference and reported belief, whichever decision they choose to bind.

In the Smith treatment, the composition of balls in Cage II will be determined by an objective lottery that would be played after subjects' preferences are elicited. To facilitate this second-order probability, additional ping-pong balls will be assigned unique numbers between 0 to 2, 0 to 10, or 0 to 100. To ensure saliency, one subject will be chosen at random to inspect each ball and place them in the third bingo-cage (Cage III). Once each subject has expressed a preference for the lotteries in the above price list, one ball will be randomly selected and played for real rewards

One subject will be randomly selected to draw a single numbered ball out of Cage III. The number on the chosen ball will determine the composition of balls in Cage II. Finally, a different subject will be randomly selected to draw one ball from Cage I and Cage II, and subjects will be paid accordingly.

3.1.2.2 Belief Elicitation

Beliefs will be elicited using a linear scoring rule. To avoid possible wealth effects, subjects will be required to give up their Ellsberg or Smith lotteries to participate in this task. This will be their choice to make.

Belief elicitation will be facilitated using paper, pencil, and a price list format. An example of the decision sheet is as follows:

Decision	Ball Drawn from Cage II is Orange	Ball Drawn from Cage II is White
1	\$0	\$100
2	\$1	\$99
⋮	⋮	⋮
51	\$50	\$50
⋮	⋮	⋮
100	\$99	\$1
101	\$100	\$0

The second and third columns indicate the payoff for each event if the subject were to choose the corresponding decision number in row one. As a subject becomes more confident that Cage II is filled entirely with black (red) balls, he should choose a lower (higher) numbered decision row. The subject who believes either color is equally likely would select decision 51.

3.2 Field Commodities, Identification, and Uncertainty

In the previous section, I developed and discussed the implementation of an experimental design replicating the choice patterns observed in the Ellsberg (1961) classic 2-color problem and verifying Smith's (1969) conjecture that the same pattern of preferences would be observed by replacing Ellsberg's ambiguous urn with a compound objective lottery. Building upon those methods, the present section presents an experimental design to identify uncertainty aversion with respect to portfolio choices in a market-type setting.

To facilitate the identification of uncertainty aversion, subjects will complete a series of binary choices using a multiple price list (MPL) format (Holt and Laury 2002) which pays in a *graded* commodity where information possessed by the decision-maker is noisy. Harrison, List, and Towe (2007) employed the same design and found that background risk in commodities identification (e.g., uncertain quality) bias estimates of risk attitudes which diminish their applicability to policy analysis. By using a field commodity as the payment method, the experiment proposed here accomplishes two objectives. First, it would demonstrate that biases caused by the presence of background risk are robust. Second, by eliciting beliefs regarding both commodity grade and accuracy of available information, the design of Heath and Tversky (1991) allows me to determine if subjects differentiate between different uncertainties in meaningful ways.

Consider the UE for an objective bet on receiving either commodity A or D, with *known* (certified) grades $g', g'' \in G$ where $g' \succ g''$ and the known unconditional chances of winning either commodity A or D are given by $\Pr(\mathrm{A})$ and $\Pr(\mathrm{D})$.

$$EU(\mathrm{A},\mathrm{D}) = \Pr(\mathrm{A})v(\mathrm{A}_{g'}) + \Pr(\mathrm{D})v(\mathrm{D}_{g''}), \tag{6}$$

This is the model that Harrison et al. (2007) estimate. When the commodities have *unknown* (uncertified) grades, UP preferences for the same objective bet on receiving each commodity would be given by

$$UP(\mathrm{A},\mathrm{D}) = \sum_{i\in I} \rho_i u\left(\sum_{g\in G} \pi_{\mathrm{A}ig} \Pr(\mathrm{A})v(\mathrm{A}_g) + \pi_{\mathrm{B}ig} \Pr(\mathrm{D})v(\mathrm{D}_g)\right), \tag{7}$$

where $\pi_{\mathrm{A}ig}$ and $\pi_{\mathrm{B}ig}$ are the subjective beliefs for each commodities possible grade, and ρ_i are the weights the decision-maker applies to each of his I priors. For commodities which are not independently certified or when the decision-maker does not believe a given grade is accurate, equations (6) and (7) combine to form the preference

$$\begin{aligned} UP(\mathrm{A},\mathrm{D}) = \sum_{\substack{i\in I\\ j\in J}} \rho_i \theta_j u\Big(\pi_{j\mathrm{w}}\Big[\sum_{g\in G} \pi_{\mathrm{A}ig} \Pr(\mathrm{A})v(\mathrm{A}_g) + \pi_{\mathrm{B}ig} \Pr(\mathrm{D})v(\mathrm{D}_g)\Big] \\ + \big[1-\pi_{j\mathrm{w}}\big]\big[\Pr(\mathrm{A})v(\mathrm{A}_{g'}) + \Pr(\mathrm{D})v(\mathrm{D}_{g''})\big]\Big), \end{aligned} \tag{8}$$

where π_{jw} is the belief that the commodity is graded wrong under prior j. These UP preferences are analogous to the preferences given by equation (3) with alternative specifications similar to equations (4) and (5).

$$UP(\mathrm{A},\mathrm{D}) = \sum_{j\in J}\theta_j u^1\Big(\sum_{i\in I}\rho_i u^2\Big(\pi_{jw}\Big[\sum_{g\in G}\pi_{\mathrm{A}ig}\Pr(\mathrm{A})v(\mathrm{A}_g)+\pi_{\mathrm{B}ig}\Pr(\mathrm{D})v(\mathrm{D}_g)\Big] + \big[1-\pi_{jw}\big]\big[\Pr(\mathrm{A})v(\mathrm{A}_{g'})+\Pr(\mathrm{D})v(\mathrm{D}_{g''})\big]\Big)\Big), \text{ and} \quad (9)$$

$$UP(\mathrm{A},\mathrm{D}) = \sum_{i\in I}\rho_i u^2\Big(\sum_{j\in J}\theta_j u^1\Big(\pi_{jw}\Big[\sum_{g\in G}\pi_{\mathrm{A}ig}\Pr(\mathrm{A})v(\mathrm{A}_g)+\pi_{\mathrm{B}ig}\Pr(\mathrm{D})v(\mathrm{D}_g)\Big] + \big[1-\pi_{jw}\big]\big[\Pr(\mathrm{A})v(\mathrm{A}_{g'})+\Pr(\mathrm{D})v(\mathrm{D}_{g''})\big]\Big)\Big). \quad (10)$$

Identification of multiple priors (i.e., the existence of $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$) and uncertainty aversion (i.e., non-linearity in $u^1(\cdot)$ and $u^2(\cdot)$) required the elicitation of honest beliefs from the experimental subjects. A quadratic lottery scoring rule (QLSR) and computer interface facilitate the elicitation of beliefs. The quadratic scoring rule is chosen for its theoretical truth telling properties, provided the reports are made by an uncertainty neutral subject. Risk neutrality is induced by paying subjects in lottery tickets defined over final prizes, instead of cash. As a result, deviations from truthful reporting are determined by uncertainty aversion alone. This design generalizes well-known results in experimental economics (e.g., Berg, Daley, Dickhaut, and O'Brien (1986)) from risk attitudes alone to include attitudes towards both risk and uncertainty. The risk neutral and uncertainty neutral subject will report:

- The belief that the commodities in the chosen option was incorrectly graded ($\sum_{j\in J}\theta_j\pi_{jw}$), and
- The beliefs that each commodity in the chosen option is grade g ($\sum_{i\in I}\rho_i\pi_{\mathrm{A}ig}$, $\sum_{i\in I}\rho_i\pi_{\mathrm{B}ig}$, $\sum_{i\in I}\rho_i\pi_{\mathrm{C}ig}$, and $\sum_{i\in I}\rho_i\pi_{\mathrm{D}ig}$).

To identify uncertainty aversion and determine the appropriate form of preferences (i.e., equations (8), (9), or (10)) the QLSR is adapted to the design of Heath and Tversky (1991), where symmetric objective bets are constructed using reported beliefs as probabilities. Preferences will be elicited for either this new objective bet or the uncertain process already held by each subject. Patterns of elicited preferences may be used to empirically test hypothesis 4 that subjects are indifferent between probabilistically equivalent certain and uncertain lottery pairs. Indifference will be tested for both the believed correctness of "labeled" grades and the beliefs for the actual grade of the commodity, which are each discussed in turn.

Consider subjects in the treatment where grades are labeled, but not certified. These subjects would report their belief that the commodities are incorrectly graded. If these subjects are uncertainty neutral for both processes then their optimal report is $r_{\mathrm{W}}^{*}=\sum_{j\in J}\theta_{j}\pi_{j\mathrm{w}}$ and they would be indifferent between keeping their lottery tickets $R\left(r_{\mathrm{W}}^{*}\right)$ or $R\left(1-r_{\mathrm{W}}^{*}\right)$, depending on the commodities being graded correctly, and trading for the objective lottery which pays with $r_{\mathrm{W}}^{*}R\left(r_{\mathrm{W}}^{*}\right)$ or $\left[1-r_{\mathrm{W}}^{*}\right]R\left(1-r_{\mathrm{W}}^{*}\right)$ probability. Indifference would indicate subjects are either uncertainty neutral or their preferences are described by equation (10) with $u^{1}\left(x\right)\equiv x$. The appropriate hypothesis to test is:

H4a$_0$: ROCL applies: subjects are indifferent between keeping their uncertain lottery which pays with probability $R\left(1-r_{\mathrm{W}}^{*}\right)$ if the commodities are graded correctly and $R\left(r_{\mathrm{W}}^{*}\right)$ otherwise, or trading for an equivalent objective $1-r_{\mathrm{W}}^{*}$ chance that the lottery pays with probability $R\left(1-r_{\mathrm{W}}^{*}\right)$ and an r_{W}^{*} chance the lottery pays with probability $R\left(r_{\mathrm{W}}^{*}\right)$.

H4a$_A$: ROCL does not apply: subjects strictly prefer one lottery over the other.

Rejection of the null H4a $_0$ is evidence that ROCL does not apply and subjects treat uncertainty different from risk. At most, hypothesis one allows for the discrimination of preferences as not being SEU consistent. Hypothesis one would be used to complete the first objective of the part two of my thesis. It would allow for identifying aversion to uncertain commodity identification using a commodity with field context.

Subjects in the not certified and not graded treatment would report their probabilistic beliefs that each commodity in their chosen option is grade $\mathbf{g}\in G$. For commodity A the uncertainty neutral subject would report $r_{\mathrm{Ag}}^{*}=\sum_{i\in I}\rho_{i}\pi_{\mathrm{A}ig}$ for each possible grade. He would also be indifferent between keeping the lottery tickets $R\left(\mathbf{r}_{\mathrm{Ag}}^{*}\right)$ conditional on the true grade of commodity A or trading for the objective lottery which pays with probability $\mathbf{r}_{\mathrm{Ag}}^{*}R\left(\mathbf{r}_{\mathrm{Ag}}^{*}\right)$ unconditional of the true grade of commodity A. Indifference would indicate subjects are either uncertainty neutral, or their preferences are described by equation (9) with $u^{2}\left(x\right)\equiv x$. The hypothesis to test for the order in which subjects nest these uncertainties is:

H4b$_0$: ROCL applies: subjects are indifferent between keeping their lottery tickets $R\left(\mathbf{r}_{\cdot\mathrm{g}}^{*}\right)$ conditional on the revelation of the true grade and trading for an equivalent (certain) $\mathbf{r}_{\cdot\mathrm{g}}^{*}$ chance of receiving a lottery with $R\left(\mathbf{r}_{\cdot\mathrm{g}}^{*}\right)$ probability of winning.

H4b$_A$: ROCL does not apply: subjects strictly prefer one lottery over the other.

These hypotheses allow the following inferences[12] to be drawn:

- If $H4a_0$ is not rejected *and* $H4b_0$ is not rejected there is evidence of SEU preferences.

- If $H4a_0$ is not rejected *and* $H4b_0$ is rejected there is evidence that equation (10) describes preferences. Subjects have neutral attitudes towards uncertainty that commodities are graded correctly ($u^1(x) \equiv x$) and non-neutral attitudes towards uncertainty over prior beliefs for the commodity's correct grades.

- If $H4a_0$ is rejected *and* $H4b_0$ not rejected there is evidence that equation (9) describes preferences. Subjects have neutral attitudes towards uncertain prior beliefs for the commodity's correct grades ($u^2(x) \equiv x$) and non-neutral attitudes towards uncertainty that commodities are graded correctly.

- If $H4a_0$ is rejected *and* $H4b_0$ is rejected then there is evidence that preferences are *not* SEU. However, there is insufficient evidence to distinguish between equations (8), (9) or (10).

This family of tests completes the second objective of part two of my thesis. Choices made by these subjects allow for a partial identification of different attitudes towards different uncertain processes.

3.2.2 Experimental Design

This section summarizes the experimental design tat would be used to identify uncertainty aversion with respect to portfolio choices. Appendix C contains detailed experimental instructions for one the planned treatment combinations.

3.2.2.1 Eliciting Preferences

Testing uncertainty aversion and ROCL for graded commodities will be undertaken using a multiple price list format. The first stage of the experiment will elicit preferences for a commodity that is *graded and certified*, *not certified and not graded*, and *not certified but graded*. To control utility rankings, the same commodity would be used for each treatment. The decision sheet would appear as:

Option I	Option II	Decision	
5/100 of C, 95/100 of B	5/100 of D, 95/100 of A	I	II
10/100 of C, 90/100 of B	10/100 of D, 90/100 of A	I	II
15/100 of C, 85/100 of B	15/100 of D, 85/100 of A	I	II
⋮	⋮	⋮	⋮

[12] To jointly test $H4a_0$*and* $H2_0$, corrections must be made to the critical values for both hypothesis test $H1_0$ *and* $H4b_0$. A *Bonferroni* corrected critical value for each test is $\alpha_{H1_0} = \alpha_{H2_0} = 1 - \sqrt{0.95}$.

A second treatment will control for *anchoring effects* by varying the differences in probabilities between rows. Probabilities of the first row will be held fixed at 5-95, and probabilities of the last row will be fixed at 100-0.

3.2.2.2 Inferring Attitudes towards Uncertainty

Subjects' attitudes towards uncertainty will be inferred by preferences for lotteries that are consistent with $H4a_0$ and $H4b_0$. Testing these hypotheses require the use of a computer interface to facilitate the use of the quadratic scoring rule. Details of this experimental design are located in Appendix C. To remove wealth effects subjects participating in the belief elicitation tasks will be required to give-up their previous decisions. This choice will be theirs to make.

Subjects who participate in this stage of the experiment will have reported either their belief that each commodity in their chosen option is graded correctly, r_W^*, or the probabilistic belief that each of their commodities is each possible grade, $\mathbf{r}_g^*$.

Those subjects who reported their belief that each commodity is accurately graded will be asked whether they would like to keep the lottery which pays \$100 with probability $R\left(1-r_{\mathrm{W}}^*\right)$ if the commodity is graded correctly and \$100 with probability $R\left(r_{\mathrm{W}}^*\right)$ other wise, or if they would like to trade for an equivalent objective lottery which pays \$100 with probability $\left[1-r_{\mathrm{W}}^*\right]R\left(1-r_{\mathrm{W}}^*\right)$ and \$100 with probability $r_{\mathrm{W}}^* R\left(r_{\mathrm{W}}^*\right)$.

Similar to above, assume a subject reports his beliefs $\mathbf{r}_g^*$ that *each* commodity in his chosen option are grade $\boldsymbol{g}$. The QLRS says, conditional on the commodity won, he receives a lottery paying \$100 with probability $R\left(\mathbf{r}_g^*\right)$, where $R\left(\mathbf{r}_g^*\right)$ is the score for the report $\mathbf{r}_g^*$ of the commodity that he won. The subject is then given the option to keep this lottery, or, if he would like, to trade for an objective lottery paying \$100 with probability $\mathbf{r}_g^* R\left(\mathbf{r}_g^*\right)$.

For example, assume that, for the randomly selected row, the subject preferred option II. Prior to playing out option II, the subject reports his probabilistic beliefs that commodities A and D are grades $\mathbf{g} \in G$. The lottery is then played and he wins commodity D. Prior to revealing the true grade and playing the lottery $R\left(\mathbf{r}_{\mathrm{D}g}^*\right)$ for commodity D, the subject has the option to either keep $R\left(\mathbf{r}_{\mathrm{D}g}^*\right)$ or trade for the objective lottery $\mathbf{r}_{\mathrm{D}g}^* R\left(\mathbf{r}_{\mathrm{D}g}^*\right)$, where $\mathbf{r}_{\mathrm{D}g}^*$ is his reported probabilistic belief that D is grade $\boldsymbol{g}$. The uncertainty averse subject should prefer the certain lottery $\mathbf{r}_{\mathrm{D}g}^* R\left(\mathbf{r}_{\mathrm{D}g}^*\right)$ to the uncertain lottery $R\left(\mathbf{r}_{\mathrm{D}g}^*\right)$ conditional on the true grade of the commodity.

As discussed above, the pattern of responses to each of these questions allows for a between-subject indication of both attitudes towards uncertainty as well as differentiation between different uncertain processes.

3.3 Privacy, Identification, and Uncertainty

3.3.1 Experimental Design

This section discusses and presents an incentive compatible experimental design to elicit and estimate the parameters of the UP model in the context of privacy. In order for any experiment to claim that it is able to characterize the effects of privacy loss, privacy must be salient to the experiment. There must be a link between subject A's chosen strategy and subject B's valuation of the knowledge of A's strategy. Furthermore, confounds represented by uncontrolled strategies outside of the lab must be controlled.

Table 3 lists games and tasks that generate private information, which human subjects may value. These include:

- *Social Dilemma Games*, where the payoff to each individual is higher from defecting behavior than those from cooperative behaviors, and all individuals are worse off when cooperation is not unanimous,
- *Bargaining Games*, where common knowledge of otherwise private information is known to change the solution concept (Roth and Malouf 1979),
- *Joy-of-Destruction*, a new game designed to measure "nastiness" towards others, and
- *Lottery Choice Tasks*.

Excluding the Joy-of-Destruction game, introduced by Abbink and Sadrieh (2008) and simple lottery choice tasks, anonymity loss may alter the way subjects play these games (Gächter and Fehr 1999). Anonymity loss may engender other-regarding preferences such as social approval, possibilities for reciprocal actions outside the lab, exhibitionism, and plain old nastiness.

Multiple mechanisms and institutions generate different pieces of information for each subject. Histories of play (actions) are the most salient types of information generated in the games listed in Table 3. Knowing Player A's payoff indirectly informs Player B of Player A's history of play, and vice versa. The qualifying criterion for a candidate experimental design is that actions by Player A map into the payoffs and strategies of Player B, such that Player B's payoffs are partly determined by Player A's chosen strategy. Player A's effect on Player B's payoff, coupled with an appropriate mechanism for reciprocal action would lead Player A to value keeping his history private from Player B.

Consider the joy-of-destruction game. Each player (A or B) can either earn their endowment, or be assigned one at random. Abbink and Sadrieh (2008) used an earnings based mechanism to avoid house *money effects*[13] in their experimental analysis of anonymity and/or players' willingness to impose financial damage on others. The analysis of Abbink and Sadrieh (2008) focuses on changes to Player A's (the dictator) actions, not his belief regarding possible repercussions, such as the possibility of reciprocal actions from Player B (the victim) knowing Player A's identity. Confounds represented by uncontrolled opportunities for reciprocity that may exist outside the lab makes this particular design inappropriate, since beliefs and utilities would not be uniquely identified or controlled.

Furthermore, Rutström and Williams (2000) concluded that irrespective of the way in which endowments were earned subject behavior may be best described as self-interested. Poorer subjects prefer distributions that increase own payoffs, while richer subjects prefer distributions that leave their payoffs intact. These results suggest that Player A "knowing" Player B's potential payoff would not alter Player A's chosen strategy in the joy-of-destruction in any meaningful way. Player A would rather be nasty, destroying Player B's wealth to maximize the likelihood that he earns at least as much as Player B. In the experimental design of Abbink and Sadrieh (2008), Player B's beliefs for the occurrence of a bad outcome will be unchanged by a loss of privacy over wealth. Player B would have little incentive to be willing to pay to maintain privacy.

Burnham (1997) reported on a series of dictator games where, in one treatment, Player A would receive Player B's photo prior to deciding whether or not to split a $10 endowment between himself and Player B. Burnham (1997) found that receiving player B's photo does not change the likelihood that Player A chooses to keep the entire $10. However, conditional on Player A already giving Player B a portion of the $10, losing anonymity increases Player A's giving. These results suggest that the classic dictator game is also an inappropriate design to elicit values of privacy. Both the dictator game and joy-of-destruction game lack mechanisms that would induce dictators to behave in a more self-interested way following the recipients' loss of confidentiality.

In a series of related experiments, Fehr and Fischbacher (2004), Goette, Huffman, and Meire (2006), Bernhard, Fehr, and Fischbacher (2006), and Chen and Xin Li (2009) measure the effects of induced group identities and real group identities. Using prisoner's dilemma and dictator games, each analysis measured punishment levels associated with deviations from social norms. Within-group and between-group designs were employed in each experiment. In-group members were robustly found to punish deviation more severely than out-group members, and this finding was statistically significat.

Supporting the saliency of laboratory induced (group) identities to explain the privacy behavior, Fehr and Fischbacher (2004, Fig. 1 and 2) show that subjects form expectations of punishment that increase with violations of social norms. Their results suggest that a

[13] Thaler and Johnson (1990, p. 643-644) define the house money effect as when "… under some circumstances a prior gain can increase subjects' willingness to accept gambles." Contemporary experimental economics uses the term house money effect to describe behavioral differences between those subjects who earn money in the lab as consequences to choices made and those subjects who are "given" money by the experimenter.

dictator game, coupled with the formation of identities and opportunities for reciprocal punishment, may allow subjects to form values of identifying information that are endogenous to the experiment.

The joy-of-destruction and dictator games using *real* subject identities have therefore been eliminated as potential institutions that allow subjective values of privacy to emerge as a result of salient consequences from strategies chosen in the laboratory. Fortunately, integrating (repeated) prisoner's dilemma games with punishment opportunities would allow for experimental control of previously identified confounds.

Public goods and common pool resource games with punishment accomplish this task. Consider the simple linear public goods game, where each players' payoff is the sum of the social composition function and the part of their endowment not contributed to the public good. Although full cooperation is the socially optimal decision, resulting in each player receiving higher payoffs, as long as the marginal return from own contributions to the public good is less than unity, Players A, B, and any other subject will completely free-ride. Although the free-rider hypothesis[14] tends to fail one-shot tests, under repeated play behavior tends toward complete free-riding by each player (Camerer 2002, p. 46; Fehr and Gächter 2000). When punishment opportunities are then introduced to the game, behavior converges towards full cooperation within a relatively short period of time (Fehr and Gächter 2000; Ostrom, Walker, and Gardner 2001).[15]

Observations that punishment opportunities increase contributions to the public good are explainable by a simple subjective expected utility model. Player A evaluates the probability that other players punish him for each possible contribution level. He then chooses the contribution level that maximizes his subjective expected utility. This contribution level would minimize his expected punishment. As punishments are realized, Player A updates his beliefs, and contributions continue to increase towards full cooperation.

Players presented with a non-anonymous public goods game with punishment should have a willingness to pay for anonymity that is no more than the amount of money that dissipates all gains from anonymous play. Subjects form beliefs about the likelihood *and* severity of punishment without anonymity, and then compare these beliefs to their expected utility from anonymous play. This is essentially the same evaluation process that individuals make when evaluating privacy decision similar to the privacy paradox.

From the games discussed above and decision tasks presented in Table 3, public goods games, common pool resource games, and other appropriately designed repeated interaction social dilemma problems appear as natural institutions that may be used to generate individualized histories of play that allow subjects to endogenously value keeping their histories of play private.

[14] The free-rider hypothesis tells us that nonexcludability imparts, on each individual, an incentive to contribute less than his marginal value to the cost of providing a public good.

[15] Ostrom, Walker and Gardner (2001) found that sanctions need not be financial. "Cheap talks" communication is sufficient to substantially reduce over use of the resource.

Table 3: Candidate Games/Tasks with Private Information

Games/Tasks	Information Generating Process	Stake Holder of Privacy and Payoffs	Saliency of Keeping Privacy
<u>Public Goods</u> Non-rivalrous and non-excludable goods and services.	1) Contributions a) Amount of free-riding behavior. 2) Endowment a) Earned / Random	1) Contributors a) loose money 2) Free-riders gain money	1) Free-riders reduce payoffs to contributors 2) Controlled punishment opportunities *inside* of the lab.
<u>Common Pool Resource</u> Rivalrous and (usually) non-excludable goods, such as grazing lands in the tragedy of the commons.	1) Consumption a) Amount of resource use. 2) Endowment a) Earned / Random	1) Over-users a) Increase payoffs 2) Everyone else a) Relatively lower payoffs	1) Over-users reduce payoffs to all others. 2) Controlled punishment opportunities *inside* the lab.
<u>Dictator Games</u> One person divides a pie between himself and another.	1) Endowment a) Earned / Random 2) Allocation	1) Dictator a) Unilaterally allocates payoffs 2) Receiver a) No laboratory Identity	1) Uncontrolled punishment opportunities *outside* of the lab. 2) Controlled punishment opportunities *inside* of the lab.
<u>Ultimatum Games</u> One person makes an offer to another. The second person may reject the offer, leaving both with zero.	1) Endowment a) Earned / Random 2) Proposal 3) Acceptance / Rejection	1) Proposer a) Offers a payoff 2) Receiver a) Accepts or rejects payoff.	1) Controlled punishment opportunities *inside* of the lab. 2) Uncontrolled punishment opportunities *outside* of the lab.
<u>Prisoner's Dilemma</u> Each player must choose whether to obtain security, to the detriment of the common good.	1) Defection(s) a) One-shot play b) Iterated play	1) Cooperators a) Loose money 2) Defectors a) Gain money	1) Controlled punishment opportunities *inside* of the lab. 2) Uncontrolled punishment opportunities *outside* of the lab.
<u>Joy-of-Destruction</u> Players can mutually destroy each others wealth.	1) Endowment a) Earned / Random	1) Victim looses money. 2) Nasty player gains no money	1) Privacy (hidden-action) would tend to reduce social distance, increasing players' nastiness to one another.
<u>Lottery Choice tasks</u> Lotteries are randomly presented to subjects, who then state preference for the same lotteries.	1) Randomly determined lottery pairs 2) Randomly determined prizes	1) No laboratory identities	1) Prize differences are random 2) Uncontrolled punishment opportunities *outside* of the lab.

An experimental design that elicits values for privacy *must* accomplish at least two things. First, it should allow values for privacy to emerge endogenously as a result of actual choices made by subjects in the lab. Second, it should elicit these values with an incentive compatible mechanism. A four stage experimental design is sufficient to satisfy these two criteria. In the first stage, subjects play a public goods game. The second stage consists of a bargaining situation, where subjects sell information pertaining to their identity that is induced in the lab, as well as their history of play in the first stage. The third stage elicits belief and presents a pretest to which preferences: SEU of UP describe subject's decisions. Finally, Stage 4 introduces punishment choices for those subjects assigned to the roles of *buyer* and/or *receiver*.

3.3.1.1 Stage 1: The Public Goods Game

In the first stage of the experiment, subjects play an absolute-strangers version of the public goods game. Stage 1 will be played for 10 rounds, a sufficient length of time for subjects to learn that complete free-riding is in their best interest (Isaac, Walker, and Thomas 1984; Isaac, McCue, and Plott 1985).

All parameters that determine each subject's pecuniary payoffs, ϑ_t, will be identical for each pairing. The social composition functions will be linear and the marginal return from own contributions, c_t, will be defined such that purely self-interested subjects should completely free-ride.[16] Pecuniary payoffs for each subject would be given by

$$\vartheta_t = e_t - c_t + \kappa \sum_{k=\{1,2\}} c_k \ ,$$

where e_t is the subject's endowment, $0 < \kappa < 1 < 2\kappa$ ensures that the myopic subject is always better off by free-riding, and that full contributions maximize group welfare.

At the end of the first stage, subjects will be informed of their own pecuniary payoffs that result from their own contributions as well as the contributions of others they were paired with. Subjects will not be given any information regarding contributions for their partners. Next, subjects will have the chance to sell their histories, knowing the punishment choices available to those subjects assigned to the roles of *buyer* and/or *receiver* of that information. There will be a third belief elicitation stage that subjects will learn about following Stage 2.

3.3.1.2 Stage 2: Eliciting Privacy Values

The bargaining stage of the experiment would randomly assign subjects to the roles of seller, buyer/punisher, buyer/sender, and receiver/punisher. With group sizes of

[16] It is possible to define public goods games with interior Nash Equilibria – for example, see Harrison and Hirshleifer (1987).

25 subjects, each group will consist of ten sellers, five buyer/punishers, five buyer/senders, and five receiver/punishers. Figure 1 illustrates these bargaining punishment pairings. It is recognized that the public goods game reverses the "good guy" and "bad guy" roles from the loyalty card example.[17] The difference between the public goods game and the loyalty card example is that in the later the person responsible for conferring the bad event on the seller wants to defraud the seller in an attempt to better themselves, while in the former the person conferring the bad event on the seller wants to punish the seller for free-riding. The bargaining and punishment pairings in Figure 1 preserve the kernel of reported privacy behavior. Sellers have private information, which if released may incentivize the receiver of that information to harm the initial seller. The rates at which the buyer/punishers and receiver/punishers confer bad events on the sellers are expected to be proportional to the sellers' wealth.

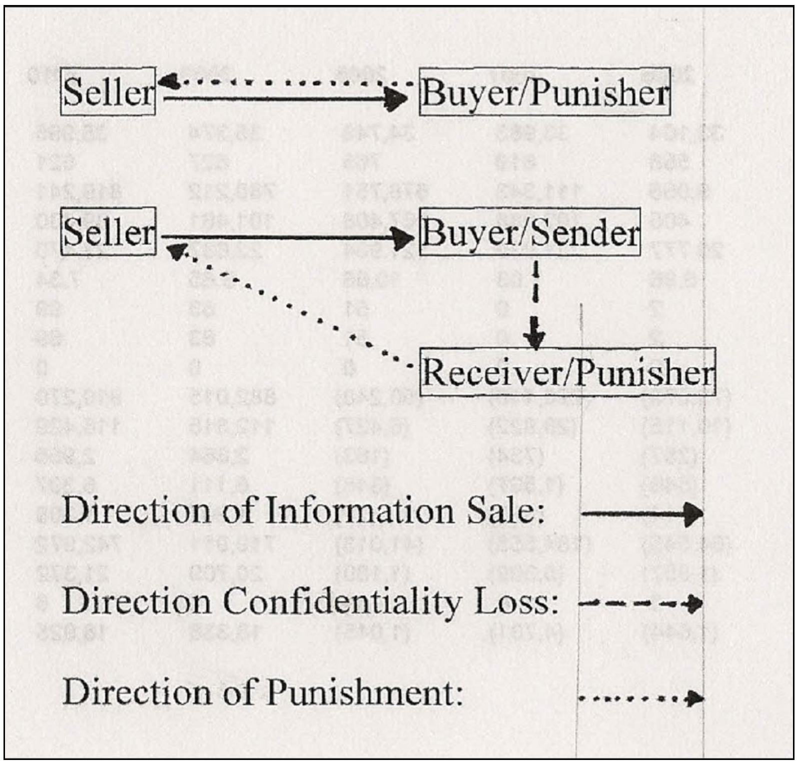

Figure 1: Bargaining and Punishment Pairs

Figure 1 should be read as follows. Five of those subjects that are assigned the role of seller may choose to sell their history of play to their buyer/punisher counterpart. In turn, the buyer/punishers will decide whether or not they will punish the seller. The remaining subjects assigned to the role of seller may choose to sell their history of play to their buyer/sender counterpart. In turn, the buyer/senders may or may not violate confidentiality by giving the sellers' information to their receiver/punisher counterpart. Finally, the receiver/punishers may or may not decide to punish the initial seller.

[17]The loyalty card example is the name given to the privacy decision discussed above in Section 2.

Sale of information will be facilitated by a (reverse) random price mechanism, similar to the Becker, DeGroot, and Marschak (1964) mechanism. Subjects assigned to the role of seller will be instructed to state their minimum willingness-to-sell their history of play, the payment necessary such that the seller is indifferent between keeping his history private or not.[18] This value will then be compared to a randomly determined bid price. If the seller's asking price is less than or equal to the randomly determined bid, the transaction will take place. The seller will receive the randomly determined bid, and the buyer will receive the seller's identifying information and history of play. If the asking price is greater than the random bid, then no transaction takes place. The seller's identifying information remains private. Consider the following example, which illustrates the truth telling properties of the transaction mechanism.

Assume Player A is assigned to the role of seller, and let WTA be his actual willingness-to-accept a privacy loss. With random bid b, his payoff will be $b - WTA \geq 0$ if $WTA \leq b$ and 0 otherwise. Reporting truthfully is a dominant strategy. If Player A reports $WTA^r > WTA > b$, then he is equally well off with either a true or false report. If he reports $WTA^r > b > WTA$, then he loses $b - WTA > 0$ and would have been better off by reporting truthfully. Over-reporting is dominated by reporting honestly. Similarly, if Player A reports $WTA > WTA^r > b$, then he receives 0 with either a true or false report. However, by reporting $WTA > b > WTA^r$, Player A loses $b - WTA < 0$ and would have been better off by reporting truthfully. Under-reporting is dominated by truthful reporting.

Following the resolution of whether a transaction is facilitated (i.e., $WTA^r \leq b$) or not (i.e., $WTA^r > b$), subjects assigned the role of buyer will be informed of the bid price. If a sale takes place, the buyer will receive both the seller's history and a statement of the bid price. If a sale does not take place, the buyer will only receive information pertaining to the randomly determined bid price. Supplying the buyer with the random bid price, irrespective of a transaction taking place, ensures that buyers and sellers possess the same information that they would have in a real-world bargaining situations. This part of the mechanism increases the validity of the transaction mechanism.

<u>3.3.1.3 Stage 3: Belief Elicitation</u>

Beliefs will be elicited using QLSR. Reports made by each subject will be used as a pretest to identify attitudes towards uncertainty of having a confidentiality loss and bad events. These reports would then be used to estimate the UP model (equations (3), (4), and (5)). Technical features of the punishment phase will be discussed in greater detail below. For now it is useful to note that the punishment opportunities presented to the punisher counterpart will be binary decisions, and that the punishment amount is a fixed proportion of the seller's wealth.

Subjects in the direct sale treatment will be asked to state their beliefs that they will not be punished. These beliefs will be conditioned on whether or not they sold their

[18] Players will be given sufficient practice to learn that truthful reporting is a dominant strategy.

history to their buyer/punisher counterpart. As such, uncertainty neutral subject's optimal reports are

$$\omega^*_{\mathrm{g|c}} = \sum_{i^2=1^2}^{2^2} \theta_{i^2} \pi^2_{\mathrm{c}i^2\mathrm{g}} \text{ , and}$$

$$\omega^*_{\mathrm{g|n}} = \sum_{i^2=1^2}^{2^2} \theta_{i^2} \pi^2_{\mathrm{n}i^2\mathrm{g}} \text{ .}$$

Subjects in the indirect sale treatment will be asked to report one of two beliefs: their belief of a confidentiality loss, ω^*_{c}, *or* their belief they will not be punished, ω^*_{g}. The belief these subjects are asked to report will be determined at random. The uncertainty neutral subjects would optimally report

$$\omega^*_{\mathrm{g}} = \sum_{i^1=1^1}^{2^1} \sum_{i^2=1^2}^{2^2} \sum_{j^1=\{\mathrm{c,n}\}} \rho_{i^1} \theta_{i^2} \pi^1_{i^1 j^1} \pi^2_{j^1 i^2 \mathrm{g}} \text{ , and}$$

$$\omega^*_{\mathrm{c}} = \sum_{i^1=1^1}^{2^1} \rho_{i^1} \pi^1_{i^1\mathrm{c}} \text{ .}$$

As sellers become more risk averse and/or uncertainty averse, optimal reports tend to 50%.

The design from Section 3.2.2.2 will be used to identify attitudes towards these uncertainties and uncertain process. Prior to punishment, but after the belief elicitation stage, subjects will be given the option to keep their status quo uncertain punishment process or trade for a bet where the uncertain process has been replaced by an objective probability equal to their report for that event.

Subjects who report either their belief confidentiality is kept or a good event happens will receive the lottery which pays \$100 with $R\left(\omega^*_{\mathrm{c}}\right)$ probability if confidentiality is kept and $R\left(1-\omega^*_{\mathrm{c}}\right)$ probability otherwise (or with $R\left(\omega^*_{\mathrm{g}}\right)$ probability if a good event happens and $R\left(1-\omega^*_{\mathrm{g}}\right)$ probability for a bad event). The subjects would be given the choice to keep these uncertain lotteries or trade for equivalent objective lotteries, paying \$100 with $\omega^*_{\mathrm{c}} R\left(\omega^*_{\mathrm{c}}\right)$ probability is confidentiality is kept and $\left[1-\omega^*_{\mathrm{c}}\right] R\left(1-\omega^*_{\mathrm{c}}\right)$ probability otherwise (or with $\omega^*_{\mathrm{g}} R\left(\omega^*_{\mathrm{g}}\right)$ probability if a good event happens and $\left[1-\omega^*_{\mathrm{g}}\right] R\left(1-\omega^*_{\mathrm{g}}\right)$ probability for a bad event). If subjects that made an indirect sale are indifference between keeping their sale and trading for their objective probability of confidentiality loss (or a good event) then ROCL applies and there is evidence that preferences are described by SEU. Otherwise, there is evidence that model (3), (4), and (5) applies. The appropriate hypothesis to test is:

$H5_0$: ROCL applies: subjects who sold their information in the indirect sale treatment are indifferent between keeping their uncertain lottery which pays with $R\left(\omega_{\mathrm{c}}^{*}\right)$ ($R\left(\omega_{\mathrm{g}}^{*}\right)$) probability if confidentiality is kept (a good event happens) and $R\left(1-\omega_{\mathrm{c}}^{*}\right)$ ($R\left(1-\omega_{\mathrm{g}}^{*}\right)$) otherwise, or trading for the equivalent ω_{g}^{*} ($\left[1-\omega_{\mathrm{g}}^{*}\right]$) chance that the lottery pays with $R\left(\omega_{\mathrm{c}}^{*}\right)$ ($R\left(\omega_{\mathrm{g}}^{*}\right)$) probability.

$H5_A$: ROCL does not apply: subjects in the indirect sale treatment strictly prefer either the certain or uncertain lottery.

Rejection of the null hypothesis $H5_0$ is evidence that subjects treat uncertainty different from risk.

Subjects in both the direct sale and indirect sale treatments would report their probabilistic beliefs of a good event, ω_{g}^{*}, a good event conditional on confidentiality, $\omega_{\mathrm{g|c}}^{*}$, or a good event conditional on non-confidentiality $\omega_{\mathrm{g|n}}^{*}$. For those subjects reporting their beliefs conditional on a state of confidentiality, if a good event happens they will receive the lottery which pays \$100 with $R\left(\omega_{\mathrm{g|c}}^{*}\right)$ ($R\left(\omega_{\mathrm{g|n}}^{*}\right)$) probability conditional on confidentiality (non-confidentiality), and $R\left(1-\omega_{\mathrm{g|c}}^{*}\right)$ ($R\left(1-\omega_{\mathrm{g|n}}^{*}\right)$) probability otherwise. These subjects would be given the choice to trade for the equivalent objective lotteries paying \$100 with probability $\omega_{\mathrm{g|c}}^{*}R\left(\omega_{\mathrm{g|c}}^{*}\right)$ when confidentiality is kept or $\omega_{\mathrm{g|n}}^{*}R\left(\omega_{\mathrm{g|n}}^{*}\right)$ for a loss of confidentiality, and $\left[1-\omega_{\mathrm{g|c}}^{*}\right]R\left(1-\omega_{\mathrm{g|c}}^{*}\right)$ or $\left[1-\omega_{\mathrm{g|n}}^{*}\right]R\left(1-\omega_{\mathrm{g|n}}^{*}\right)$ otherwise.

Indifference between retaining their uncertain punishment process and trading for a lottery with an objective chances suggests that preferences are either SEU or preferences are described by equation (4) with $u^{2}\left(x\right)\equiv x$. The hypothesis to test for the order in which subjects nest these uncertainties is:

$H6_0$: ROCL applies: subjects in the direct sale treatment are indifferent between keeping their sale decision and trading for an equivalent objective lottery.

$H6_A$: ROCL does not apply: subjects in the direct sale treatment strictly prefer either the certain or uncertain lottery.

The following inferences can then be drawn from this family of tests:

- If $H5_0$ is not rejected *and* $H6_0$ is not rejected there is evidence of SEU preferences.

- If $H5_0$ is not rejected *and* $H6_0$ is rejected there is evidence that equation (5) describes preferences. The subjects have neutral attitudes towards uncertainty that confidentiality is violated ($u^1(x) \equiv x$) and non-neutral attitudes towards uncertainty over prior beliefs for a bad even conditional on confidentiality.

- If $H5_0$ is rejected *and* $H6_0$ not rejected there is evidence that equation (4) describes preferences. Subjects have neutral attitudes towards uncertain prior beliefs for a bad even conditional on confidentiality ($u^2(x) \equiv x$) and non-neutral attitudes towards uncertainty that confidentiality is violated.

- If $H5_0$ is rejected *and* $H6_0$ is rejected then there is evidence that preferences are *not* SEU. However, there is insufficient evidence to distinguish between equations (3), (4) or (5).

Reported beliefs serve two purposes. First, they allow me to test for evidence of uncertainty aversion in privacy decisions. Second, they serve as a pretest to identify subject heterogeneity with respect to their underlying preferences (i.e., SEU versus UP).

3.3.1.4 Stage 4: Punishment

Punishment will be determined by a binary yes/no (punish/don't punish) choice made by those subjects assigned to the roles of either buyer/punisher of receiver/punisher. Punishment will result in a fixed percentage loss of earning from the public goods game. Proportional punishment is chosen so that all sellers are guaranteed non-negative earnings from the punishment phase of the design. It is important maintain positive earnings to eliminate the need for house money because its effects have been shown to confound identification of "risky" behavior (Thaler and Johnson 1990).

All earnings from the belief elicitation tasks (Stage 3) will be retained by *sellers*, regardless of the resolution of punishment. This will have been made clear to subjects prior to the elicitation of their beliefs.

4. ECONOMETRIC AND NUMERICAL METHODS

From the numerical example above, the model requires the identification of eight parameters from two sets of beliefs and two sets of priors, in addition to the parameters of $v(\cdot)$ and $u(\cdot)$. Identification of the parameters from this UP model (equation (3)) is facilitated by making a set of *reasonable* identifying assumptions. These assumptions will be presented as they become necessary. The full information maximum likelihood (FIML) method that would be used to jointly estimate beliefs, risk and uncertainty attitudes, and prior weights is presented below.

4.1 Econometric Model

4.1.1 Controlling for Risk Attitudes

Risk attitudes, the parameters of $v(\cdot)$, may be identified using tradition lottery choice tasks. Assume an expo-power utility function[19] of the form

$$v(x) = \left[1 - \exp\left(-\kappa x^{1-\phi}\right)\right] \Big/ \kappa , \tag{11}$$

where $\kappa \neq 0$ and ϕ are parameters to be estimated, and x is income from observed lottery choices. The Arrow-Pratt measure of relative risk aversion is given by $\phi + \kappa[1-\phi]x^{1-\phi}$, which is increasing (decreasing) as $\kappa > 0$ ($\kappa < 0$). Furthermore, constant absolute risk aversion and constant relative risk aversion are nested special cases of this expo-power form as $\phi \to 0$ and $\kappa \to 0$, respectively.

With observed lottery choices, the utility function given by equation (11) can be estimated using traditional maximum likelihood techniques, assuming some latent structural model of choice such as EUT. Assuming the *link function* between choices and the maximum likelihood procedure is represented by logistic distribution, the decision-maker chooses either lottery depending on the index function

$$\nabla EU = \frac{\exp\left(EU_1 / \mu^0\right)}{\exp\left(EU_1 / \mu^0\right) + \exp\left(EU_2 / \mu^0\right)} , \tag{12}$$

where EU_1 is the expected utility of the lottery 1, EU_2 is the expected utility from choosing lottery 2, assuming the decision-maker has only two lotteries to choose from, and μ^0 is a noise parameter which is proportional to the standard deviation of the decision-maker's perceptual (or computational) error, conditional on the assumed logistic

[19] The two parameter expo-power form is chosen due to its empirical consistency over a wide range of real payoffs (Holt and Laury 2001).

link function. As $\mu^0 \to 0$ subject responses become more precise and the probability of choosing the utility maximizing choice converges to one. For noisier responses, as $\mu^0 \to 0$ choice probabilities are random and not explained by utility differences.

Ignoring indifference, the log-likelihood to be maximized is given by

$$\ln L(\phi; y, \mathbf{X}) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla EU + [1 - y_t] \ln [1 - \nabla EU] \right\}, \tag{13}$$

where $y_t = 1(-1)$ indicates the t^{th} decision-maker's choice of lottery 1(2), and $\mathbf{X}$ is data pertaining to the choice tasks and/or subject characteristics.

4.1.2 Estimating Beliefs and Uncertainty Aversion

Given estimates of $\hat{v}(x) = \left[1 - \exp\left(-\hat{\kappa} x^{1-\hat{\phi}}\right)\right] \big/ \hat{\kappa}$, the decision-makers' responses to the direct sale treatments coupled with reported beliefs $\omega^*_{\mathrm{g|c}}$ and $\omega^*_{\mathrm{g|n}}$ provide information to identify beliefs $\pi^2_{\mathrm{c1^2g}}$, $\pi^2_{\mathrm{c2^2g}}$, $\pi^2_{\mathrm{n1^2g}}$, and $\pi^2_{\mathrm{n2^2g}}$ conditional on the identifying assumption $\boldsymbol{\rho} = \bar{\boldsymbol{\rho}}$.

For decision-makers assigned the role of sellers in the direct sale portion of the experiment, let

$$W^2\left(\mathbf{z} + WTA^r \mid \mathrm{n}\right) = \sum_{i^2=1^2}^{2^2} \theta_{i^2} u\left(\sum_{j^2=\{\mathrm{g,b}\}} \pi^2_{\mathrm{n}i^2 j^2} v\left(z_{j^2} + WTA^r\right)\right), \tag{14}$$

define the expectation utility given that a sale of information has taken place, with a stated minimum selling price defined by WTA^r. Similarly, let

$$W^2\left(\mathbf{z} \mid \mathrm{c}\right) = \sum_{i^2=1^2}^{2^2} \theta_{i^2} u\left(\sum_{j^2=\{\mathrm{g,b}\}} \pi^2_{\mathrm{c}i^2 j^2} v\left(z_{j^2}\right)\right), \tag{15}$$

define a sellers expectation of utility conditional on a direct sale not taking place. These decision-maker states WTA^r such that $W^2\left(\mathbf{z} + WTA^r \mid \mathrm{n}\right) = W^2\left(\mathbf{z} \mid \mathrm{c}\right)$. Assuming an appropriate error structure, such as an error in reporting ε, then WTA^r solves

$$W^2\left(\mathbf{z} + WTA^r + \varepsilon \mid \mathrm{n}\right) = W^2\left(\mathbf{z} \mid \mathrm{c}\right), \tag{16}$$

If beliefs were known then all that would remain is to assume some functional form for $u(\cdot)$ and estimate the parameters of equations (11) and (16) via FIML methods.

For the remainder of this discussion assume a constant relative uncertainty aversion specification

$$u(x) = x^{1-\gamma} \big/ [1-\gamma]. \tag{17}$$

In the absence of known beliefs, responses to the belief elicitation stage of the experiment can be used to identify the unknown conditional beliefs of fraud. For sellers whose information remains confidential a report ω means they receive

$$\bar{W}^2\left(\cdot \mid \mathrm{c}, \omega^*_{\mathrm{g|c}}\right) = \sum_{i^2=1^2}^{2^2} \theta_{i^2} u\left(\sum_{j^2=\{\mathrm{g},\mathrm{b}\}} \pi^2_{\mathrm{c}i^2 j^2} v\left(z_{j^2} + S\left(\omega^*_{\mathrm{g|c}} \mid j^2\right)\right)\right), \tag{18}$$

and an appropriate likelihood function would be the multinomial logit

$$\nabla W^2_{\mathrm{g|c}} = \frac{\exp\left(\bar{W}^2\left(\cdot \mid \mathrm{c}, \omega^*_{\mathrm{g|c}}\right) \big/ \mu^{\mathrm{gc}}\right)}{\sum_{\varpi \in \Omega} \exp\left(\bar{W}^2\left(\cdot \mid \mathrm{c}, \varpi\right) \big/ \mu^{\mathrm{gc}}\right)}, \tag{19}$$

with error component μ^{gc}. For sellers whose histories do not remain confidential

$$\nabla W^2_{\mathrm{g|n}} = \frac{\exp\left(\bar{W}^2\left(\cdot \mid \mathrm{n}, \omega^*_{\mathrm{g|n}}\right) \big/ \mu^{\mathrm{gn}}\right)}{\sum_{\varpi \in \Omega} \exp\left(\bar{W}^2\left(\cdot \mid \mathrm{n}, \varpi\right) \big/ \mu^{\mathrm{gn}}\right)}, \tag{20}$$

with error component μ^{gn}.The appropriate likelihood functions to be jointly maximized with equation (13) are

$$\ln L\left(\phi, \gamma, \mu^{\mathrm{gc}}, \pi^2_{\mathrm{c}1^2\mathrm{g}}, \pi^2_{\mathrm{c}2^2\mathrm{g}}; y, \mathbf{X}, \bar{\boldsymbol{\rho}}\right) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla W^2_{\mathrm{g|c}} + [1-y_t] \ln\left[1 - \nabla W^2_{\mathrm{g|c}}\right]\right\}, \tag{21}$$

$$\ln L\left(\phi, \gamma, \mu^{\mathrm{gn}}, \pi^2_{\mathrm{n}1^2\mathrm{g}}, \pi^2_{\mathrm{n}2^2\mathrm{g}}; y, \mathbf{X}, \bar{\boldsymbol{\rho}}\right) = \sum_{t=1}^{T} \left\{ y_t \ln \nabla W^2_{\mathrm{g|n}} + [1-y_t] \ln\left[1 - \nabla W^2_{\mathrm{g|n}}\right]\right\}, \tag{22}$$

$$\ln L\left(\phi, \gamma, \pi^2_{\mathrm{c}1^2\mathrm{g}}, \pi^2_{\mathrm{c}2^2\mathrm{g}}, \pi^2_{\mathrm{n}1^2\mathrm{g}}, \pi^2_{\mathrm{n}2^2\mathrm{g}}; y, \mathbf{X}, \bar{\boldsymbol{\rho}}\right) = \sum_{t=1}^{T} \ln f\left(\varepsilon_t\right), \tag{23}$$

where $f(\cdot)$ is the assumed distribution of reporting errors, and equations (21), (22), and (23) are conditioned on the assumptions $\boldsymbol{\rho} = \bar{\boldsymbol{\rho}}$.

Beliefs $\pi^1_{1^1 c}$, are identified using the same techniques. Sellers in the indirect sale treatment report WTA^r such that $W\left(\mathbf{z}+WTA^r\right)=W^2\left(\mathbf{z}\,|\,\mathrm{c}\right)$. Assuming the decision-maker makes errors in reporting η, then WTA^r solves

$$W\left(\mathbf{z}+WTA^r+\eta\right)=W^2\left(\mathbf{z}\,|\,\mathrm{c}\right), \tag{24}$$

where $W^2\left(\mathbf{z}\,|\,\mathrm{c}\right)$ is defined by equation (15).

With reporting error measured by μ^{c} and μ^{g}, the likelihood of these sellers reported beliefs ω^*_{c} or ω^*_{g} is given by

$$\nabla W^2_{\mathrm{c}}=\frac{\exp\left(W^2\left(\cdot\,|\,\omega^*_{\mathrm{c}}\right)/\mu^{\mathrm{c}}\right)}{\sum_{\varpi\in\Omega}\exp\left(W^2\left(\cdot\,|\,\varpi\right)/\mu^{\mathrm{c}}\right)}, \text{ and} \tag{25}$$

$$\nabla W^2_{\mathrm{g}}=\frac{\exp\left(W^2\left(\cdot\,|\,\omega^*_{\mathrm{g}}\right)/\mu^{\mathrm{g}}\right)}{\sum_{\varpi\in\Omega}\exp\left(W^2\left(\cdot\,|\,\varpi\right)/\mu^{\mathrm{g}}\right)}. \tag{26}$$

Conditional on a second identifying assumption $\boldsymbol{\theta}=\overline{\boldsymbol{\theta}}$,

$$\ln L\left(\phi,\gamma,\mu^{\mathrm{c}},\pi^1_{1^1\mathrm{c}},\pi^1_{2^1\mathrm{c}};y,\mathbf{X},\overline{\boldsymbol{\rho}},\overline{\boldsymbol{\theta}}\right)=\sum_{t=1}^{T}\left\{y_t\ln\nabla W_{\mathrm{c}}+\left[1-y_t\right]\ln\left[1-\nabla W\right]\right\}, \tag{27}$$

$$\begin{aligned}\ln L\left(\phi,\gamma,\mu^{\mathrm{g}},\pi^1_{1^1\mathrm{c}},\pi^1_{2^1\mathrm{c}},\pi^2_{\mathrm{c}1^2\mathrm{g}},\pi^2_{\mathrm{c}2^2\mathrm{g}},\pi^2_{\mathrm{n}1^2\mathrm{g}},\pi^2_{\mathrm{n}2^2\mathrm{g}};y,\mathbf{X},\overline{\boldsymbol{\rho}},\overline{\boldsymbol{\theta}}\right)=\sum_{t=1}^{T}\Big\{&y_t\ln\nabla W_{\mathrm{g}}\\ &+\left[1-y_t\right]\ln\left[1-\nabla W_{\mathrm{g}}\right]\Big\},\end{aligned} \tag{28}$$

$$\ln L\left(\phi,\gamma,\pi^1_{1^1\mathrm{c}},\pi^1_{2^1\mathrm{c}},\pi^2_{\mathrm{c}1^2\mathrm{g}},\pi^2_{\mathrm{c}2^2\mathrm{g}},\pi^2_{\mathrm{n}1^2\mathrm{g}},\pi^2_{\mathrm{n}2^2\mathrm{g}};y,\mathbf{X},\overline{\boldsymbol{\rho}},\overline{\boldsymbol{\theta}}\right)=\sum_{t=1}^{T}\ln f\left(\eta_t\right), \tag{29}$$

are maximized in conjunction with equations (13), (21), (22), and (23) to jointly estimate beliefs as well as risk aversion and uncertainty aversion parameters.

The validity of these estimates is conditional on the correctness of the assumptions $\boldsymbol{\rho}=\overline{\boldsymbol{\rho}}$ and $\boldsymbol{\theta}=\overline{\boldsymbol{\theta}}$. In this discussion, $\boldsymbol{\rho}=\overline{\boldsymbol{\rho}}$ and $\boldsymbol{\theta}=\overline{\boldsymbol{\theta}}$ has implicitly implied the assumption of a discrete two-point distribution with mass at each prior probability. An alternative estimation procedure would be to assume some tractable parametric form of the densities of $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$, and in conjunction with maximum simulated likelihood (MSL) methods, estimate the parameters of equations (13), (21), (22), (23), (27), (28), and (29).[20] Below, a new method of maximum *maximized* likelihood is proposed to obtain point estimates of $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$.

4.2 Numerical Methods

Estimates obtained from the FIML estimation of equations (13), (21), (22), (23), (27), (28), and (29) are correct only if the assumptions $\bar{\boldsymbol{\rho}}$ and $\bar{\boldsymbol{\theta}}$ are correct. Absent additional information, the odds of making correct assumptions are zero. This section proposes a method of maximum *maximized* likelihood to identify $\boldsymbol{\rho}^*$ and $\boldsymbol{\theta}^*$.

For the constraint $\bar{\boldsymbol{\Theta}} = \left(\bar{\boldsymbol{\theta}}, \bar{\boldsymbol{\rho}}\right)$, let $G^*\left(\boldsymbol{\pi}^*\left(\bar{\boldsymbol{\Theta}}\right), \phi^*\left(\bar{\boldsymbol{\Theta}}\right), \gamma^*\left(\bar{\boldsymbol{\Theta}}\right), \lambda^*\left(\bar{\boldsymbol{\Theta}}\right); \bar{\boldsymbol{\Theta}}\right)$ be the conditional maximized grand likelihood function from the FIML estimation. For $G^*(\cdot)$ sufficiently smooth, identification of

$$\bar{\boldsymbol{\Theta}}^* \stackrel{\text{def}}{=} \arg\max_{\bar{\boldsymbol{\Theta}}} \left\{ \max_{\boldsymbol{\pi}, \phi, \gamma, \boldsymbol{\mu}} G^*\left(\boldsymbol{\pi}, \phi, \gamma, \boldsymbol{\mu}; \bar{\boldsymbol{\Theta}}\right) \right\}$$

yields the best estimates of beliefs, priors, and attitudes towards uncertainty and risk. Given identification of $\bar{\boldsymbol{\Theta}}^*$, the maximum *maximized* grand likelihood is equivalent to

$$V\left(\bar{\boldsymbol{\Theta}}^*\right) = G^{**}\left(\boldsymbol{\pi}^*\left(\bar{\boldsymbol{\Theta}}^*\right), \phi^*\left(\bar{\boldsymbol{\Theta}}^*\right), \gamma^*\left(\bar{\boldsymbol{\Theta}}^*\right), \boldsymbol{\mu}^*\left(\bar{\boldsymbol{\Theta}}^*\right); \bar{\boldsymbol{\Theta}}^*\right).$$

By the envelope theorem,

$$\frac{\partial V\left(\bar{\boldsymbol{\Theta}}^*\right)}{\partial \bar{\boldsymbol{\Theta}}} = \frac{\partial G^{**}\left(\cdot; \bar{\boldsymbol{\Theta}}^*\right)}{\partial \bar{\boldsymbol{\Theta}}},$$

and the gradient $\nabla G \equiv \left(\partial G^{**}/\partial \boldsymbol{\pi}, \partial G^{**}/\partial \phi, \partial G^{**}/\partial \gamma, \partial G^{**}/\partial \boldsymbol{\mu}, \partial V/\partial \boldsymbol{\Theta}\right)$ can be used to approximate the information matrix at $\bar{\boldsymbol{\Theta}}^*$ and perform a standard battery of statistical tests on *all* parameters of interest including $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$.[21]

[20] MSL methods are sometimes referred to as maximum-likelihood expectation-maximization (ML-EM) methods (Train 2003). Computationally cumbersome, the intuition of the method is straightforward. Define the parameter of interest as ξ, with a density function $h(\xi|\psi)$. Thus, conditional on a randomly brawn ξ from $h(\xi|\psi)$, the maximized conditional likelihood is evaluated with Baye's Theorem to infer the unconditional probabilities for each observation. The new posterior likelihood is approximated using Monte Carlo methods, and the hyper parameters $\boldsymbol{\psi}$ are found by maximization of the unweighted expectation over each replication of the maximized posterior likelihoods. This approach is sometimes referred to in the literature as Maximum Maximum Likelihood.

[21] Direct numerical evaluation of the elements of the information matrix contains possibly non-zero weighted averages of the marginal effects of $\boldsymbol{\rho}$ and $\boldsymbol{\theta}$ on the other parameters of interest, where weights are the block off-diagonal elements of it. The method of maximum *maximized* likelihood requires using the outer product of gradients to approximate the information matrix.

Efficient estimation of $\bar{\mathbf{\Theta}}^*$ can be accomplished by a Newton-like optimization method. The following Newton algorithm illustrates the desired optimization.

Initialization: Use a coarse grid search over $\bar{\boldsymbol{\rho}}$ and $\bar{\boldsymbol{\theta}}$ to pick an initial guess $\bar{\mathbf{\Theta}}^0$. Also choose stopping parameters μ and ξ.

Step 1: Solve $\max_{\boldsymbol{\pi},\phi,\gamma,\boldsymbol{\mu}} G^*\left(\boldsymbol{\pi},\phi,\gamma,\boldsymbol{\mu};\bar{\mathbf{\Theta}}^k\right)$.

Step 2: Numerically estimate $\nabla G^*\left(\bar{\mathbf{\Theta}}^k\right)$ and the hessian of G^*, $H^*\left(\bar{\mathbf{\Theta}}^k\right)$, at $\bar{\mathbf{\Theta}}^k$.

Step 3: Solve $H^*\left(\bar{\mathbf{\Theta}}^k\right)d^k = -\left(\nabla G^*\left(\bar{\mathbf{\Theta}}^k\right)\right)^{\mathrm{T}}$ for step size d^k.

Step 4: Choose new guess $\bar{\mathbf{\Theta}}^{k+1} = \bar{\mathbf{\Theta}}^k + d^k$.

Step 5: If the Euclidean norm $\left\|-d^k\right\| < \mu\left[1+\left\|\bar{\mathbf{\Theta}}^k\right\|\right]$, proceed to step 6. Otherwise go back to step 1.

Step 6: If $\left\|\nabla G^*\left(\bar{\mathbf{\Theta}}^k\right)\right\| < \xi\left[1+\left\|G^*\left(\bar{\mathbf{\Theta}}^k\right)\right\|\right]$, stop and report an optimal solution. Otherwise stop and report that a nonoptimal solution has been obtained.

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APPENDIX A: SOURCE-DEPENDANCE AS A SPECIAL CASE OF UNCERTAINTY AVERSION

Nau (2006, Model II, Theorem 2, p. 143) presents an axiomatic proof of the source-dependant risk aversion (SDRA) model capable of explaining the behavior in Ellsberg's example. The SDRA model may formally be represented as a special case of the UP model, and is interpreted as assuming that the decision-maker only considers uncertain processes where the ambiguous urns contains either all red or all black balls (Nau 2007).

From equation (1), if the decision-maker forms priors equal in number to the set of possible uncertain events, let $I = J$ and rewrite π_{ij}^{U} as π_{i}^{U}. Then, by making the further assumption that each prior i is degenerate, so that $\pi_{i}^{U} = \{1, 0\}$, the UP model becomes

$$W(\mathbf{z}) = \sum_{i=1}^{I} \rho_i u\left(\sum_{k=1}^{K} \pi_k^C v(z_{ik})\right), \tag{A1}$$

which is the SDRA model, where by definition $i = \{\text{r}, \text{b}\}$ and $k = \{\text{R}, \text{B}\}$.

In equation (2), the decision-maker can be viewed as if he evaluates $v(\cdot)$ first, then he evaluates $u(\cdot)$ at the expectation of $v(\cdot)$, taken over $k = \{\text{R}, \text{B}\}$. Finally, preferences for the lotteries in Table 1 are determined by the evaluation of the expectation of $u(\cdot)$, taken over $i = \{\text{r}, \text{b}\}$. In this case, the decision-maker simply behaves *as if* the uncertain urn contains either all red balls or all black balls.

For both lotteries L_2 and L_3 his expectation of utility over certain event k is $5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$. Table 2 shows the decision-maker's expectation of $v(\cdot)$ for each lottery, under these assumptions.

Table 4: Expected EU Assuming SDRA Model

U events	L_1	L_2	L_3	L_4
U_r	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$	$0 = \frac{1}{2} \cdot 0 + \frac{1}{2} \cdot 0$	$10 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 10$	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$
U_b	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$	$10 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 10$	$0 = \frac{1}{2} \cdot 0 + \frac{1}{2} \cdot 0$	$5 = \frac{1}{2} \cdot 10 + \frac{1}{2} \cdot 0$

From these calculations, it is easy to see how the SDRA model can also explain the pattern of preferences assumed in Ellsberg's example. The decision-maker will have final utility for L_2 equal to that of L_3, and utility from L_1 will equal L_4. However, if the decision-maker believes that "r" is less likely than "b" and $u(\cdot)$ is sufficiently concave, then it is easy to see how he could have the preference relations described above. Lotteries L_1 and L_4 hedge the uncertainty surrounding which color ball will be drawn from urn 2.

APPENDIX B: EXPERIMENTAL INSTRUCTIONS FOR ELLSBERG'S PARADOX AND SMITH'S HYPOTHESIS

This experiment has four treatments: *A*, *B*, *C* and *D*. Treatments: *A*, *B*, and *C* each have two levels. Treatment *D* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Ellsberg (0) or Smith (1) treatments
C	0,1	Anchoring effects: skewed low (0) or high (1)
D	0,1,2	Refinement: 2 balls (0), 10 balls (1), or 100 balls (2) in each urn

The instructions shown below are for the *abd*: 002 combination. These instructions are easily extended to the 000, 010, 001, 011, and 012 combinations.

[The remainder of this page intentionally left blank]

Experimenter Instructions

Welcome. This is an experiment in individual decision making. You can earn cash based on the choices you make today. Money you earn today will be paid to you in cash at the end of the experiment. You will be paid $5 for participating in the experiment today. We expect the experiment to last up to **Z** hours. Please make sure that you can stay until the end. In addition to the participation fee, you could earn additional money based partly on chance and partly on the choices you make today. The instructions are simple and you will benefit from following them carefully.

There is an instruction book in front of each of you. Please open it and follow along as I read the instructions out loud.

[Insert *Individual Decision Making* Instructions]

Before I spin Cage #1 and Cage #2, each of you have the chance to make another choice, with much higher potential payoffs. Our research assistants are passing around the decision sheets for this task. If you choose to participate in this task, we will not pay you for the decision that you just made. You have the choice which decision we will pay you for.

As seen on the decision book, earnings from this next choice may be very large, they may also be small. If you decide not to participate in this task, please use the red pen on your desk to cross out the title of your new book: *DECISION TASK II*. This is your decision to make. If you decide to participate, please circle the title of the decision book and cross out the title of your old book: *INDIVIDUAL DECISION MAKING*. Remember, while some of the payoffs are large, there is no catch. We will pay you today for all money earned in this task. Are there any questions?

[Insert *Decision Task II* Instructions]

Now that we know which one of your decisions is binding, I will uncover Cage #1. As you can see, Cage #1 is filled with orange and white balls. I would like to ask for one final volunteer to count and verify that there are exactly 100 balls in Cage #1.

I will now spin each cage. You will be paid according to the choices you have made and the color ball chosen from each cage.

Individual Choice

This experiment has four treatments: *A*, *B*, *C* and *D*. Treatments: *A*, *B*, and *C* each have two levels. Treatment *D* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Ellsberg (0) or Smith (1) treatments
C	0,1	Anchoring effects: skewed low (0) or high (1)
D	0,1,2	Refinement: 2 balls (0), 10 balls (1), or 100 balls (2) in each urn

The subject instruction books shown below are for the *bd*: 02 combinations. These instructions are easily extended to the 00, 10, 01, and 11 combinations.

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The decisions you will make are not designed to trick you. What we want to know is what choices you would make in them. The only right answer is what you really would choose. That is why the problems give you the chance of winning real money.

In the front of the room there are two bingo cages, labeled #1 and #2. Cage #1 is covered and contains 100 balls. Each ball is either orange or white. You do not know how many balls are orange or white. Additionally, there are 50 orange balls and 50 white balls in front of Cage #2. Before we start I would like to ask one person to come up here and inspect Cage #2. The volunteer will verify that there are 50 orange and 50 white balls. If you would like to volunteer please raise your hand.

On the last page of this booklet there is a record sheet with four paired choices between “Option A” and “Option B.” These four decisions are reprinted here.

Option A	Option B	Option C	Decision		
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C

In each row you will be asked to circle one of the three decisions shown in the right-hand column.

Before you circle your decisions, let me explain how these decisions affect your potential earnings. Only one of the four decisions you make will end up affecting your earnings, but you will not know in advance which decision will be used. Your earnings from this decision will depend on the outcome of a spin of each of the bingo cages in the front the room.

Please refer to decision 1, at the top of the table. Option A will pay $10 if the marble drawn from Cage #1 is orange *and* the marble drawn from Cage #2 is either orange or white. Option B will pay $10 if the marble drawn from Cage #1 is white *and* the marble drawn from Cage #2 is either orange or white. The other decisions are similar. For the last row, Option A will pay $10 if the marble drawn from Cage #1 is either orange or white *and* the marble drawn from Cage #2 is orange. Option B will pay $10 if the marble drawn from Cage #1 is either orange or white *and* the marble drawn from Cage #2 is white.

In the column labeled “Decision,” there are three choices for each row. For each row, please circle the letter of the option that you prefer. If you do not care whether you receive Option A or Option B, circle “C.”

After making each of you four decisions, please raise your hand and wait for assistance. A research assistant will bring you a 6-sided die that you will roll to determine which row from the record sheet you will be paid from. If you roll a 1, 2, 3, or 4 then you will be paid according to that row. If a 5 or 6 are rolled, you will roll the die again until you roll between 1 and 4. If you choose Don’t Care in the decision that we play out, you will roll a 10-sided die, where the numbers 1-5 correspond to Option A and 6-10 correspond to Option B.

After we know which decision is binding, we will uncover Cage #1 then spin both bingo cages to see if you receive the higher amount or the lower amount for the choice that you made. If you choose Option A, you would be paid the appropriate amount in Option A. If you choose Option B, you would be paid the appropriate amount in Option B.

Are there any questions?

You may now mark your decisions for each row of the decision sheet. When you are satisfied the decisions that you have made, please raise your hand and wait for a research assistant to bring the dice to determine which row you will be paid from.

Record Sheet

Option A	Option B	Option C	Decision		
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw red from urn I and draw either red or black from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw black from urn I and draw either red or black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C
Win $10 if draw either red or black from urn I and draw red from urn II	Win $10 if draw either red or black from urn I and draw black from urn II	50/100 Option A plus 50¢, 50/100 Option B plus 50¢	A	B	C

To be completed by Staff:

Row Number Selected: ___________ Option Selected: ___________

Ball Chosen from Cage #1: ___________ Ball Chosen from Cage #2: ___________

Earnings: ___________

Belief Elicitation

This experiment has four treatments: *A*, *B*, *C* and *D*. Treatments: *A*, *B*, and *C* each have two levels. Treatment *D* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Ellsberg (0) or Smith (1) treatments
C	0,1	Anchoring effects: skewed low (0) or high (1)
D	0,1,2	Refinement: 2 balls (0), 10 balls (1), or 100 balls (2) in each urn

The experimenter instructions shown below are for the *c*: 0 combinations.

[The remainder of this page intentionally left blank]

Before I spin Cage #1 and Cage #2 you will make one decision which will be used to determine how much money you make. Your decision sheet for this task is on the following page. Before you make your choice, lets discuss the decision sheet.

You will be paid based on the row you choose and the color ball drawn from Cage #1. For example, Choice 1 pays $0 if the ball chosen from Cage #1 is orange and $100 if the ball chosen from Cage #1 is white. If you believe that Cage #2 is filled entirely with white balls then you should select Choice 1. Similarly, Choice 51 pays $100 if the ball chosen from Cage #1 is orange and $0 if ball chosen from Cage #1 is white. If you believe that Cage #2 is filled entirely with orange balls then you should select Choice 51. Choices with low numbers pay more if a white marble is drawn from Cage #1, and less if an orange ball is drawn. Choices with high numbers pay more if an orange ball is drawn from Cage #1, and less if a white ball is drawn.

Are there any questions?

Choice	Payment if Ball Drawn from Cage #1 is Orange	Payment if Ball Drawn from Cage #1 is White
1	$0.00	$100.00
2	$4.17	$95.83
3	$8.33	$91.67
4	$12.50	$87.50
5	$16.67	$83.33
6	$20.83	$79.17
7	$25.00	$75.00
8	$29.17	$70.83
9	$33.33	$66.67
10	$37.50	$62.50
11	$41.67	$58.33
12	$45.83	$54.17
13	$50.00	$50.00
14	$51.32	$48.68
15	$52.63	$47.37
16	$53.95	$46.05
17	$55.26	$44.74
18	$56.58	$43.42
19	$57.89	$42.11
20	$59.21	$40.79
21	$60.53	$39.47
22	$61.84	$38.16
23	$63.16	$36.84
24	$64.47	$35.53
25	$65.79	$34.21
26	$67.11	$32.89
27	$68.42	$31.58
28	$69.74	$30.26
29	$71.05	$28.95
30	$72.37	$27.63
31	$73.68	$26.32
32	$75.00	$25.00
33	$76.32	$23.68
34	$77.63	$22.37
35	$78.95	$21.05
36	$80.26	$19.74
37	$81.58	$18.42
38	$82.89	$17.11
39	$84.21	$15.79
40	$85.53	$14.47
41	$86.84	$13.16
42	$88.16	$11.84
43	$89.47	$10.53
44	$90.79	$9.21
45	$92.11	$7.89
46	$93.42	$6.58
47	$94.74	$5.26
48	$96.05	$3.95
49	$97.37	$2.63
50	$98.68	$1.32
51	$100.00	$0.00

Row Choice: __________

To be completed by Staff:

Marble Drawn from Cage #1: ________ Earnings: __________

APPENDIX C: EXPERIMENTAL INSTRUCTIONS FOR FIELD COMMODITIES, IDENTIFICATION, AND UNCERTAINTY

This experiment has four treatments: *A*, *B*, and *C*. Treatments: *A* and *B* have two levels. Treatment *C* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Preference anchoring effects: skewed low (0) or high (1)
C	0,1	Beliefs: graded correctly (0) or **X**'s correct grade (1)
D	0,1,2	Information: graded & certified (0), graded & not certified (1), or not graded and not certified (2)

The experimenter instructions shown below are for the *ad*: 01 combination. It is assumed that those subjects with certified **X**s will <u>believe</u> the certification.

[The remainder of this page intentionally left blank]

Experimenter Instructions

Welcome. This is an experiment in individual decision making. You will be paid $5 for participating in the experiment today. We expect the experiment to last up to **Z** hours. Please make sure that you can stay until the end. In addition to the participation fee, you could earn additional money based partly on chance and partly on the choices you make today. The instructions are simple and you will benefit from following them carefully.

The decisions you will make are not designed to trick you. What we want to know is what choices you would make in them. The only right answer is what you really would choose. That is why the problems give you the chance of winning a real **X**.

There are 4 **X** on the table in front of you. Each **X** has been assigned grades “G1,” “G2,” “G3,” and “G4.” These grades are indicated on the card in front of each **X**. You will have the chance to win one of these **X** today. Your winnings today will be paid to you at the end of the experiment. There is an instruction book in front of each of you. Please open it and follow along as I read the instructions out loud.

[Insert *Individual Decision Making* Instructions]

Before you play your selected option, each of you have the chance to make another choice, with much higher potential payoffs. Research assistants are passing around the decisions book for the choice that you would make. If you choose to participate in this task, we will not pay you for the decision that you just made. You have the choice which decision we will pay you for.

Earnings from this next choice may be very large, they may also be small. If you decide not to participate in this task, please use the red pen on your desk to cross out the title of your new book: *DECISION TASK II*. This is your decision to make. If you decide to participate, please circle the title of the new decision book and cross out the title of your old book: *INDIVIDUAL DECISION MAKING*. Remember, while some of the payoffs are large, there is no catch. We will pay you today for all money earned in this task. Are there any questions?

[Insert *Decision Task II* Instructions]

By now everyone should have placed their bets. If you have not finished please raise your hand. Before you play your selected option, each of you has the choice to replace the revelation of the correct **X** grades with the roll of dice. A research assistant will bring you two 10-sided dice and if the number you roll is less than or equal to your report (71 for the example), you receive 916 out of 1,000 chances to win $100, and 496 out of 1,000 chances to win $100 if the number you roll is more than 71.

If you decide to replace the chance that the grades of the **X**s are correct with the condition that the roll of two 10-sided die is less than or equal to you reported belief, please use the red pen on your desk to cross out the last page of you decision book. Research assistants are passing around new decision sheets that will replace these.

Now that we know which one of your decisions is binding, a research assistant will come and reveal the correct **Y**-certified grades for each **X**. After each grade is revealed, an assistant will come by and you will play-out your binding decision.

Are there any questions?

Individual Choice

This experiment has four treatments: *A*, *B*, and *C*. Treatments: *A* and *B* have two levels. Treatment *C* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Preference anchoring effects: skewed low (0) or high (1)
C	0,1	Beliefs: graded correctly (0) or **X**'s correct grade (1)
D	0,1,2	Information: graded & certified (0), graded & not certified (1), or not graded and not certified (2)

The experimenter instructions shown below are for the *b*: 0 combinations.

[The remainder of this page intentionally left blank]

On the last page of this booklet there is a decision sheet with twenty paired choices between "Option I" and "Option II." In each row you will be asked to circle one of the three decisions shown in the right-hand column. Before you circle your decisions, let me explain how these decisions affect your potential earnings. Although you will make twenty decisions, only one choice will affect your earnings. You do not know in advance which decision you make will end up affecting your earnings. Your earnings from this decision will depend on the choices you make and the roll of a 100-sided die.

Please refer to row 1, at the top of the table. Option I pays **C** if the die shows a number between 1 and 5. It pays **B** if the die shows a number between 6 and 100. Option II pays **D** if the die shows a number between 1 and 5. It pays **A** if the die shows a number between 6 and 100. The other choices are similar.

In the column labeled "Decision," there are three choices for each row. For each row, please circle the letter of the option that you prefer. If you do not care whether you receive Option A or Option B, circle "Don't Care."

After making each of you four decisions, please raise your hand and wait for assistance. A research assistant will bring you a 20-sided die that you will roll to determine which row from the record sheet you will be paid from. The number that you roll will determine which row you are paid from. For example: If you roll a 17 then you will be paid according to row 17 of your decision sheet. If you choose Don't Care in the decision that we play out, you will pick one using a 10-sided die, where the numbers 1-5 correspond to Option A and 6-10 correspond to Option B.

After we know which decision is binding, you will roll two 10-sided die to determine which **X** you win. If you choose Option I, you will receive the appropriate **X** in Option I. If you choose Option II, you will receive the appropriate **X** in Option II.

Are there any questions?

You may now mark you decisions for each row of the decision sheet. When you are satisfied the decisions that you have made, please raise you hand and wait for a research assistant to bring the 20-sided dice to determine which row you will be paid from.

Row	Option I	Option II	Decision	
1	5/100 of C and 95/100 of B	95/100 of D and 5/100 of A	**I**	**II**
2	16/100 of C and 84/100 of B	84/100 of D and 16/100 of A	**I**	**II**
3	28/100 of C and 72/100 of B	72/100 of D and 28/100 of A	**I**	**II**
4	39/100 of C and 61/100 of B	61/100 of D and 39/100 of A	**I**	**II**
5	50/100 of C and 50/100 of B	50/100 of D and 50/100 of A	**I**	**II**
6	53/100 of C and 47/100 of B	47/100 of D and 53/100 of A	**I**	**II**
7	57/100 of C and 43/100 of B	43/100 of D and 57/100 of A	**I**	**II**
8	60/100 of C and 40/100 of B	40/100 of D and 60/100 of A	**I**	**II**
9	63/100 of C and 37/100 of B	37/100 of D and 63/100 of A	**I**	**II**
10	67/100 of C and 33/100 of B	33/100 of D and 67/100 of A	**I**	**II**
11	70/100 of C and 30/100 of B	30/100 of D and 70/100 of A	**I**	**II**
12	73/100 of C and 27/100 of B	27/100 of D and 73/100 of A	**I**	**II**
13	77/100 of C and 23/100 of B	23/100 of D and 77/100 of A	**I**	**II**
14	80/100 of C and 20/100 of B	20/100 of D and 80/100 of A	**I**	**II**
15	83/100 of C and 17/100 of B	17/100 of D and 83/100 of A	**I**	**II**
16	87/100 of C and 13/100 of B	13/100 of D and 87/100 of A	**I**	**II**
17	90/100 of C and 10/100 of B	10/100 of D and 90/100 of A	**I**	**II**
18	93/100 of C and 7/100 of B	7/100 of D and 93/100 of A	**I**	**II**
19	97/100 of C and 3/100 of B	3/100 of D and 97/100 of A	**I**	**II**
20	100/100 of C and 0/100 of B	0/100 of D and 100/100 of A	**I**	**II**

To be completed by Staff:

Row Number Selected: ___________ Option Selected: ___________
Roll of 100-Sided Die: ___________ Prize Won: ___________

Belief Elicitation

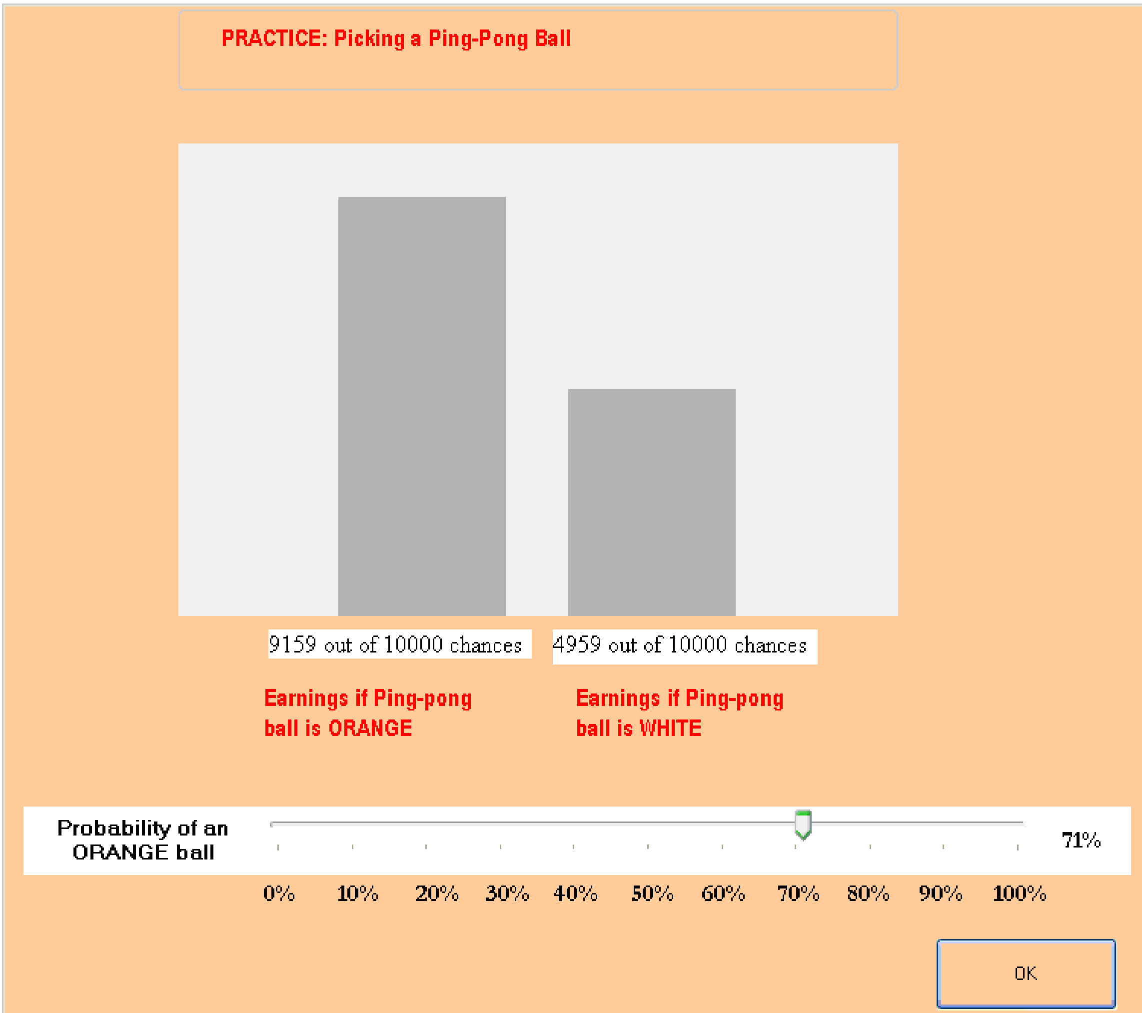
This experiment has four treatments: *A*, *B*, and *C*. Treatments: *A* and *B* have two levels. Treatment *C* has three levels. The table below summarizes these treatments.

Treatment	Levels	Description
A	0,1	Preference elicitation first (0) or second (1)
B	0,1	Preference anchoring effects: skewed low (0) or high (1)
C	0,1	Beliefs: graded correctly (0) or **X**'s correct grade (1)
D	0,1,2	Information: graded & certified (0), graded & not certified (1), or not graded and not certified (2)

The experimenter instructions shown below are for the *c*: 0 combination.

[The remainder of this page intentionally left blank]

In this stage we will give you a task where you will place a bet that both **X** in your chosen option are graded correctly. A correct grade is determined by the certification given by **Y**. You have more chances to make money the more accurately you can identify correctly graded **X**s. You place these bets on a screen like the one below. In a moment we will let you practice with this screen on your computer. Remember, any betting you do today is with our money, not your money.



You place your bets by sliding the bar at the bottom of the screen until you are happy with your choice of a probability report. The computer will start at some point on this bar at random: in the above screen it started at 71%, but you are free to change this as much as you like. In fact, you should slide this bar and see the effects on earnings, until you are happy to confirm your choice. Please wait while a research assist comes by and logs you on to the hypothetical practice example.

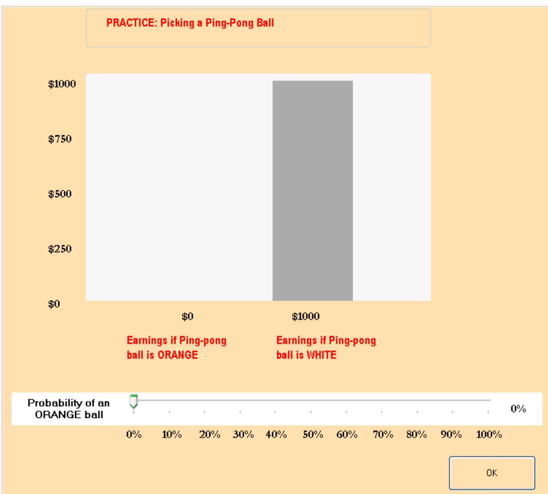
In this hypothetical example the maximum payoff you can earn is $1,000. In the actual tasks the maximum payoff will be lower than that. But the layout of the screen will be the same.

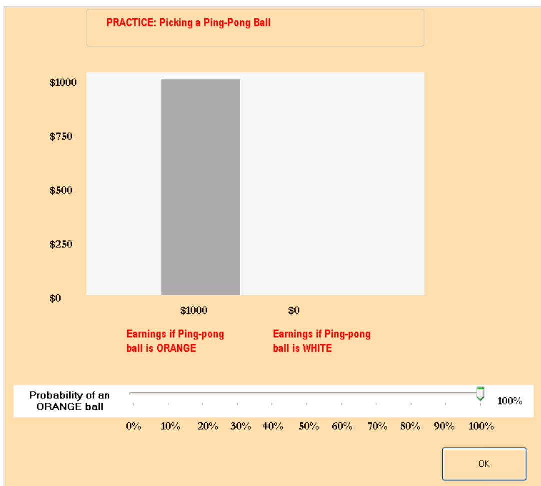
In this demonstration, the event you are betting on is whether a Ping Pong ball drawn from a bingo cage will be Orange or White. We have a bingo cage here, and we have 20 ping-pong balls. 15 of the balls are white, and 5 of the balls are orange. We will give the cage a few turns to scramble them up, and then select one ball at random.

What we want you to do is place a bet on which color will be picked. At the top of your screen we tell you what the event is: in this case, it is **Picking a Ping-Pong Ball**, and you need to bet on whether you think it will be **Orange or White**.

Your possible earnings are displayed in the two bars in the main part of the screen, and also in numbers at the bottom of each bar. For example, if you choose to report 71% you can see that you would earn 916 out of 1,000 chances to win $1,000 if the Ping Pong Ball was **orange**, and 496 out of 1,000 chances if the Ping Pong Ball was **white**.

Lets see what happens if you make different reports. If you chose to report 0% or 100% here is what you would see, and earn:





THESE SCRENES NEED TO BE CHANGED TO SAY TICKETS NOT DOLLARS

These screens are a little small, but you can see that these two reports lead to extreme payoffs. The "good news" is the possible $1,000 payoff, but the "bad news" is the possible $0 payoff. In between the reports of 0% and 100% you will have some positive payoff no matter what happens, but it will vary, as you can see from the report of 71%.

Summarizing, then, there are two important points for you to keep in mind when placing your bets:

1. **Your belief about the chances of each outcome is a personal judgment that depends on information you have about the different events.** In this practice example, the information you have consists of the total number of Orange balls and White balls.

2. **Your choices might also depend on your willingness to take risks or to gamble.** There is no right choice for everyone. For example, in a horse race you might want to bet on the longshot since it will bring you more money if it wins. On the other hand, you might want to bet on the favorite since it is more likely to win something.

For this task, your choice will depend on two things: your judgment about how likely it is that each outcome will occur, and how much you like to gamble or take risks.

You will now make your report in this practice round. When you have chosen the report, confirm your bet by clicking on the OK tab.

After you click OK, a special box will come up which causes the program to pause. We will tell you what the password is when we are all ready to proceed. There is plenty of time, so there is no need to rush.

When everyone has placed their bets we will pick the ball and you will see how many chances you would have to win $1,000. A research assistant will then come by and you will roll 4 10-sided die to determine if you would have won the $1,000.

For example, if the Ping Pong Ball was **orange** and the 4 numbers that your roll are less than 916, then you would have won $1,000. If the Ping Pong Ball was **white** and the 4 numbers that your roll are less than 496 then you would have won $1,000. If the 4 numbers that you roll are greater than the chances you have, then you win $0.

After the practice round we will go on with the bets for which you can earn real money.

Does anyone have any questions?

You may now place you bets. Please raise your hand when you finish.

Now that everyone has placed their bets we will pick the ball and you will see how many chances you would have to win $1,000. A research assistant will then come by and you will roll five 10-sided die to determine if you would have won the $1,000.

Now that everyone has had practice using the computer, we want you to place a bet that both of the **X**’s in your chosen option are graded correctly. The official grade certified by **Y** will be used to determine **X**’s correct grade.

You will now make your report. This report is binding and will be played for real. When you have chosen the report, confirm your bet by clicking on the OK tab.

Please go ahead now and place your bets for this event, unless you have any questions.

RECORD SHEET

Practice Round:

Chances of winning $1,000 if Ball is Orange: ___________

Chances of winning $1,000 if Ball is White: ____________

Circle color ball drawn from cage: Orange White

Chances to win $1,000: ____________

1st Die Roll	2nd Die Roll	3rd Die Roll	4th Die Roll

Earnings: _____________

Real Round:

Chances of winning $100 if grades shown for **X**s are correct: ___________

Chances of winning $100 if grades shown for **X**s are incorrect: __________

Circle color ball drawn from cage: correct incorrect

Chances to win $100: ____________

1st Die Roll	2nd Die Roll	3rd Die Roll	4th Die Roll

Earnings: _____________

RECORD SHEET

<u>Real Round</u>:

Reported belief: _____

Chances of winning $100 if roll of dice is less than or equal to the reported belief: _____

Chances of winning $100 if roll of dice is greater than the reported belief: _____

Roll of two 10-sided die: _____

Chances to win $100: ____________

1^{st} Die Roll	2^{nd} Die Roll	3^{rd} Die Roll	4^{th} Die Roll

Earnings: _____________

APPENDIX D: EXPERIMENTAL INSTRUCTIONS FOR PRIVACY, IDENTIFICATION, AND UNCERTAINTY

This appendix contains a detailed example of the instructions for part three of this thesis. Some of these instructions are incomplete. If that is the case, the parts that need to be completed will be indicated in red capital letters.

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P3-Experimenter Script

This document outlines the experimenter instruction that would be used to execute each session of part three of my thesis. Parameters that the experimenter has control over include: endowment for the public goods game, the social return on investment, and punishment a parameter.

Treatment	Levels	Description
A	0,1	Endowment: 20 tokens (0) or 30 tokens (1)
B	0,1	Social return: 0.6 (0) or 0.8 (1)
C	0,1	Punishment parameter: 0.4 (0) or 0.6 (1)

There are four stages to this experiment:
1) Linear public goods game
2) Value elicitation with BDM procedure
3) Belief elicitation with QLSR
4) Zero cost punishment

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Experimenter Instructions

The experiment you are about to take part in consists of several tasks. Instructions for each task will be given in a moment and you will have a chance to practice each task and ask questions before performing it for money. All earnings will be paid at the end of the experiment in cash. We expect the experiment to last up to **Z** hours. Please make sure that you can stay until the end. In addition to your earnings, you will also receive our standard $5 participation fee. This fee is guaranteed independent of the outcome of the experiment.

The instructions which we have distributed to you are solely for your private information. **You may not communicate with the other participants during the session**. Should you have any questions, please raise your hand and we will come to your desk and help you out in private.

[Insert Public Goods Instructions]

Now that everyone has finished this task, I would like to introduce the next decision task. Our research assistants are handing out the decision books for this task.

[Insert Directions for Value Task]

Before we record you earnings from the sale of your record sheet and play out the punishment phase of this experiment, each of you have the chance to make another choice, with much higher potential payoffs. Research assistants are passing around the decisions book for the choice that you would make. If you choose to participate in this task, we will not pay you for the decisions that you just made **and** you will not be able to be punished. You have the choice which decision we will pay you for.

[Insert Directions for Belief Elicitation Task]

By now everyone should have placed their bets. If you have not finished please raise your hand.

Before you play your selected option, each of you who participated in this third task has the choice to replace the resolution of punishment with the roll of dice. For the example we have been using, a research assistant would bring you two 10-sided die and if the number you roll is less than or equal to 71, you receive 916 out of 1,000 chances to win $100, and 496 out of 1,000 chances to win $100 if the number you roll is more than 71. If you decide **not** to replace the resolution of punishment with the roll of dice, your punishment will be played-out and then you will play the appropriate lottery.

If you decide to replace the chance that the grades of the resolution of punishment with the condition that the roll of two 10-sided die is less than or equal to you reported belief, please use the red pen on your desk to cross out the last page of you decision book. Research assistants are passing around new decision sheets that will replace these.

Before we play out the final phase of this experiment, our research assistants are going to come around and check to see that everyone has completed their decision books.

Now that everyone has completed their decision books, we will play out the final phase of the experiment.

ADD DIRECTIONS FOR PUNISHMENT AND THEN RESOLUTION OF EACH POSSIBLE PAYMENT.

Public Goods Game Instructions

This document outlines the experimenter instruction that would be used to execute each session of part three of my thesis. Parameters that the experimenter has control over include: endowment for the public goods game, the social return on investment, and punishment a parameter.

Treatment	Levels	Description
A	0,1	Endowment: 20 tokens (0) or 30 tokens (1)
B	0,1	Social return: 0.6 (0) or 0.8 (1)
C	0,1	Punishment parameter: 0.4 (0) or 0.6 (1)

There are four stages to this experiment:

1) Linear public goods game
2) Value elicitation with BDM procedure
3) Belief elicitation with QLSR
4) Zero cost punishment

The experimental instructions below are for the *ab*: 00 treatment combinations.

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During the session your earnings will be calculated in tokens. At the end of the session the total amount of tokens you have earned will be converted to dollars at the following rate:

1 token = 5¢

We will now go over the instructions for the first task.

The task that will be described to you next will be repeated 10 times. Each repetition will be referred to as a period. In each period you will be matched with a new person in the room. You will not know who this person is, nor will they know when and if they are matched with you. All matchings are done anonymously. You will only meet a person one time.

In order to make sure that each person is matched up with another person only one time, we have used a computer algorithm. We have created the table below so that you can verify for yourself that it is possible to make sure that people are only meeting once.

PARTICIPANT	PERIOD 1	2	3	4	5	6	7	8	9	10
A	B	C	D	E	F	G	H	I	J	K
B	A	D	F	H	J	L	N	P	R	T
C	Z	A	E	G	I	K	M	O	Q	S
D	Y	B	A	F	H	J	L	N	P	R
E	X	Z	C	A	G	I	K	M	O	Q
F	W	Y	B	D	A	H	J	L	N	P
G	V	X	Z	C	E	A	I	K	M	O
H	U	W	Y	B	D	F	A	J	L	N
I	T	V	X	Z	C	E	G	A	K	M
J	S	U	W	Y	B	D	F	H	A	L
K	R	T	V	X	Z	C	E	G	I	A
L	Q	S	U	W	Y	B	D	F	H	J
M	P	R	T	V	X	Z	C	E	G	I
N	O	Q	S	U	W	Y	B	D	F	H
O	N	P	R	T	V	X	Z	C	E	G
P	M	O	Q	S	U	W	Y	B	D	F
Q	L	N	P	R	T	V	X	Z	C	E
R	K	M	O	Q	S	U	W	Y	B	D
S	J	L	N	P	R	T	V	X	Z	C
T	I	K	M	O	Q	S	U	W	Y	B
U	H	J	L	N	P	R	T	V	X	Z
V	G	I	K	M	O	Q	S	U	W	Y
W	F	H	J	L	N	P	R	T	V	X
X	E	G	I	K	M	O	Q	S	U	W
Y	D	F	H	J	L	N	P	R	T	V
Z	C	E	G	I	K	M	O	Q	S	U

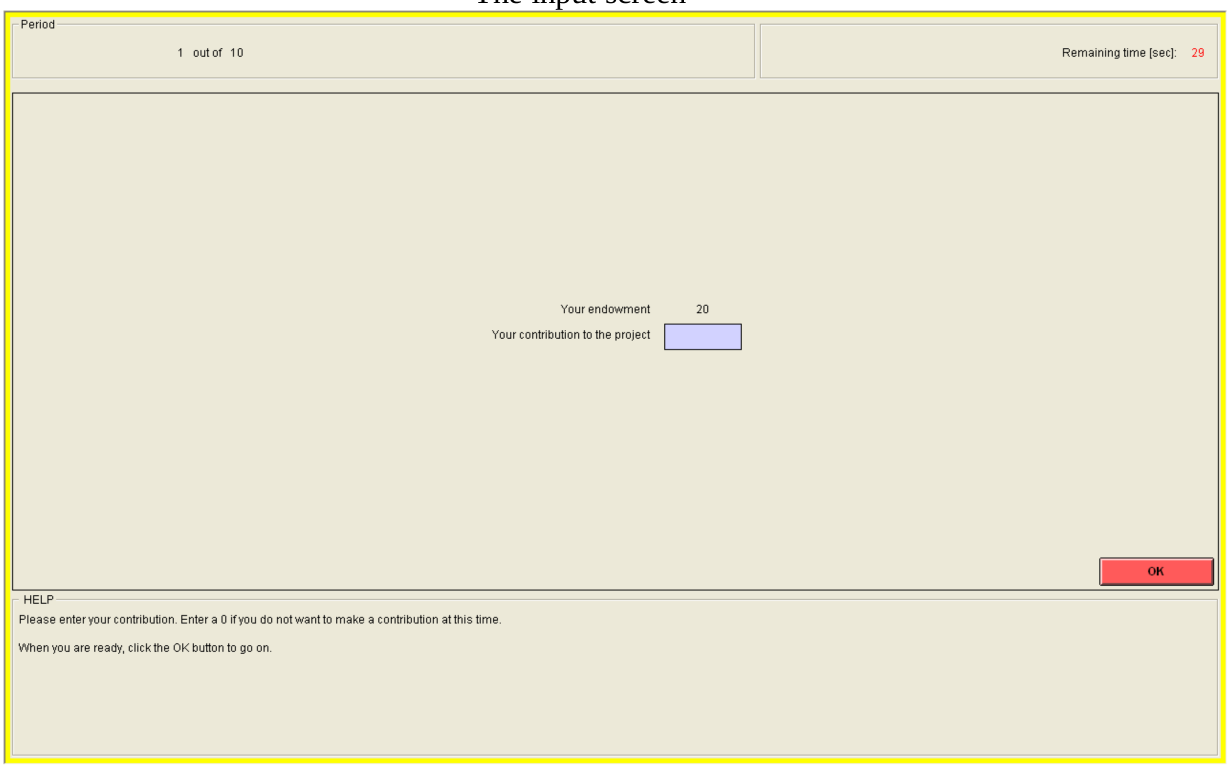
In this table, there are as many rows as there are people in the room, and it has 10 columns, one for each period. Each row is labeled with a letter. Each letter represents a computer in this room, and therefore a person sitting at that computer. By reading a row across the columns from left to right you can see that a person, as represented by the letter, is matched with a different person in each period. Nobody meets the same person twice. Please watch the display of the table at the front of the lab and we will look at a couple of examples.

All matchings are done anonymously so you will not know which person you are matched with. The same thing is true in reverse – nobody else will know when and if they are being matched with you either.

At the beginning of each period each participant receives 20 tokens. We call this your endowment. Your task is to decide how to use your endowment. You have to decide how many of the 20 tokens you want to contribute to a project and how many of the 20 tokens to keep for yourself. The consequences of your decision are explained in detail below.

At the beginning of each period the following input-screen will appear:

The input screen

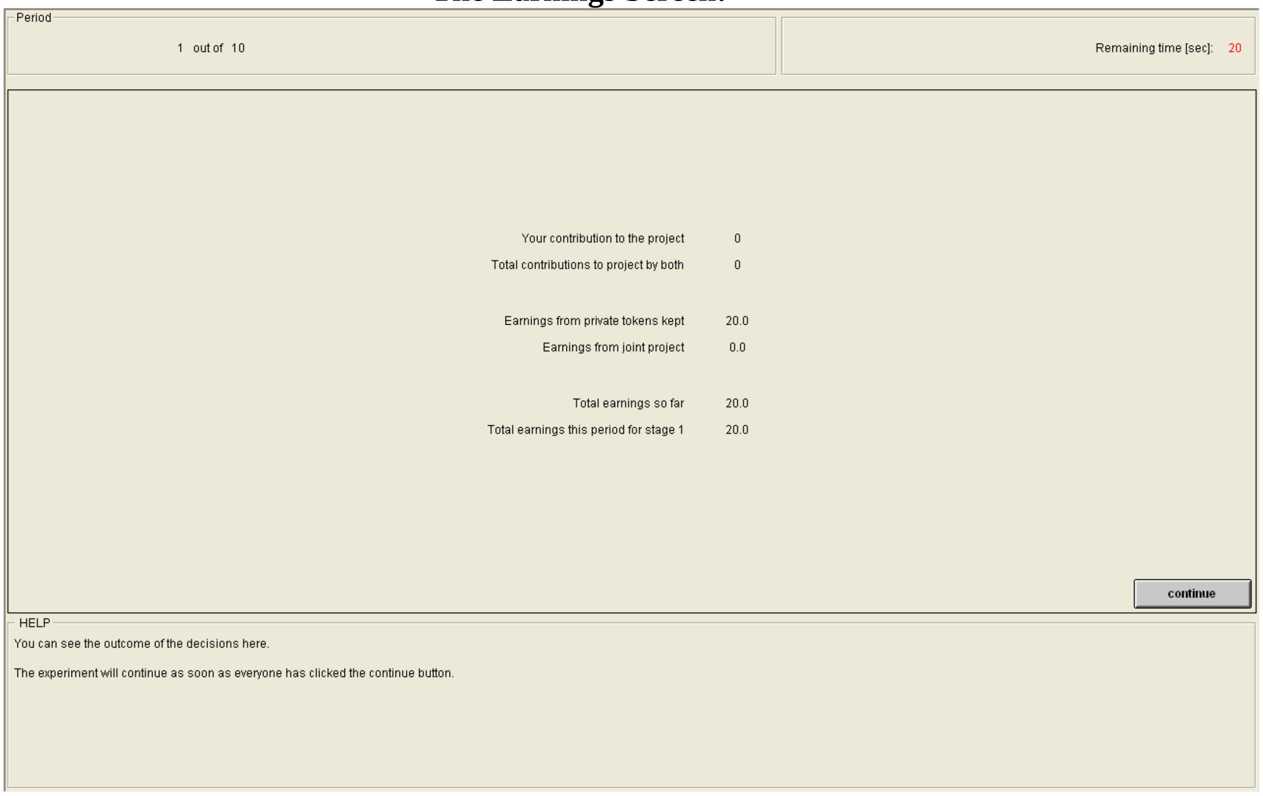


The number of the period appears in the top left corner of the screen. In the top right corner you can see how many more **seconds** remain for you to make your decision. Your decision must be made before the time displayed reaches 0 seconds.

Your endowment in each period is 20 tokens. You have to decide how many tokens you want to contribute to the project by typing a number between 0 and 20 in the input field. This field can be reached by clicking it with the mouse. As soon as you have decided how many tokens to contribute to the project, you have also decided how many tokens you keep for yourself, this is: **20 tokens minus your contribution**. After entering your contribution you must press the O.K. button with the mouse. Once you have done this, your decision can no longer be revised.

After both you and the person you are matched with have made your decisions the following earnings screen will show you the total amount of tokens contributed to the project by the two of you. This screen also shows you how many tokens you have earned during the period.

The Earnings Screen:



Your earnings in consist of two portions:

1) The tokens which you have kept for yourself ("Earnings from private tokens kept")
2) The "earnings from joint project". This is calculated as follows:
Your earnings from the project = 0.6 x the sum of the contributions of the two of you who are matched up this period.

Your earnings in tokens for each period are therefore:

(20 - your contribution to the project) + 0.6 x (sum of the contributions to the project)

The earnings **from the project** to each of the two of you is calculated in the same way, which means that each group member receives the same earnings from the project. Suppose the sum of the contributions is 30 tokens. In this case each of you receives earnings from the project of: 0.6 x 30 = 18 tokens. If the total contribution to the project is 3 tokens, then each member of the group receives earnings of 0.6 x 3 = 1.8 tokens **from the project**.

Each token which you keep for yourself is **added to your earnings**. Suppose you contributed this token to the project instead, then your earnings **from the project** would rise **by 0.6 x 1=0.6 tokens**. However the earnings of the other person would also rise by 0.6 tokens, so that your combined earnings from the project would rise by 1.2 tokens. Your contribution to the project therefore also raises the earnings of the other person. On the other hand you also get earnings for each token contributed by the other member to the project. For each token contributed by the other member you earn 0.6 x 1=0.6 tokens.

To summarize: For each token you contribute to the project, your earnings are reduced by the token you contribute and increased by the project earnings of 0.6 tokens. In addition, your earnings are increased by 0.6 tokens for each token contributed by the other group member. You have 20 seconds to view the earnings screen. If you are finished before the time is up, please press the continue button by using the mouse.

Before we start the actual experiment you will have a chance to practice this task for two periods, against a computer simulated player.

Record Sheet

Participant: __<write participant letter (A-Z) here>__

Total Tokens Earned: ______________

Record Sheet

Participant: __<write participant letter (A-Z) here>__

Total Tokens Earned: ______________

Value Elicitation Instructions

This document outlines the experimenter instruction that would be used to execute each session of part three of my thesis. Parameters that the experimenter has control over include: endowment for the public goods game, the social return on investment, and punishment a parameter.

Treatment	Levels	Description
A	0,1	Endowment: 20 tokens (0) or 30 tokens (1)
B	0,1	Social return: 0.6 (0) or 0.8 (1)
C	0,1	Punishment parameter: 0.4 (0) or 0.6 (1)

There are four stages to this experiment:
1) Linear public goods game
2) Value elicitation with BDM procedure
3) Belief elicitation with QLSR
4) Zero cost punishment

Information values are elicited using a BDM procedure. Only one set of instructions are used for all subjects in all sessions.

Treatment shown: *c*: 0.4 punishment parameter (0).

[The remainder of this page intentionally left blank]

In this task you have been randomly matched with another person in this room. You may or may not have been paired with that person during the game you just played. Every person in this room has one of four roles. Your role is indicated in the left hand column of the following table. Your partner's role is indicated on the right hand side. We have taken great care to ensure that none of you are seated next to your partner.

Your Role		**Partner's Role**
Seller		Buyer/Punisher

Sellers have the chance to sell a copy of their **record sheet** to **us**, and we would then **give** your record sheet to the person you are paired with. You are not required to sell your **information**. The decision is entirely up to the **Sellers**.

Buyer/Punishers may receive a copy of the other person's record sheet. Regardless of whether or not the other person sells his **information**, if you are assigned the roll of **Buyer/Punisher** you can then decide whether or not to reduce the Seller's earnings from the task just completed **and any money made from selling his record sheet** by 40 percent. This decision is entirely up to the **Buyer/Punishers.**

If you have been assigned the roll of **Buyer/Sender**, then you may still receive a copy of the other person's record sheet. However, the only decision **Buyer/Senders** will have is to either **give** this sheet to **someone else** who has the option to punish the **seller** or keep the record sheet secret.

People assigned the roll of **Receiver/Punisher** may receive a copy of a Seller's record sheet. **Receiver/Punishers** also then must decide whether or not to reduce the Seller's earnings from the task just completed **and any money made from selling his record sheet** by 40 percent. This decision is entirely up to the **Receiver/Punishers.**

Before we proceed, if you have any questions please raise your hand.

Now that everyone has had a chance to ask questions and understands their rolls, we will explain how those of you assigned to the roll of **seller** can sell a copy of your record sheet from the first task. On the last page of this decision book is an offer sheet. It reads as follows:

"I will sell record sheet for $______."

In order to provide you with an incentive to be as accurate as possible, we will do the following. We will randomly choose a price between $0.00 and $20.99 to pay for your record sheet. We will not pay more than $20.99. Before you write your offer in the blank space provided, let me explain how the sale will work.

After you write your price in the blank provided on the last page of this booklet, a research assistant will bring you one 20-sided die and two 10-sided dice. Your will roll each of these dice to determine how much money we will pay for you record sheet. Numbers on the 20-sided die will represent dollars. The numbers rolled with the two 10-sided dice will represent cents. Consider the following examples.

<u>Example 1</u>: "John Doe" is willing to sell his record sheet for $7.78 then he would write 7.78 on the last page of his booklet. If he then rolls a 5 on the 20-sided die and a 65 with the two 10-sided dice, then we are only willing to pay $5.65 for "John Doe's" record sheet. Because we are not willing to pay the price that "John Doe" has asked, no sale takes place and "John Doe" keeps his record sheet private.

<u>Example 2</u>: "Jane Doe" is willing to sell her record sheet for $4.33 then she would write 4.33 on the last page of her booklet. If she then rolls a 4 on the 20-sided die and a 73 with the two 10-sided dice, then we are only willing to pay $4.73 for "Jane Doe's" record sheet. Because we are willing to pay more than the price that "Jane Doe" has asked, a sale takes place and in exchange for a copy of her record sheet "Jane Doe" will receive $4.73.

Notice that your best interest is served by being accurate in representing your value. If the price you state is too high or too low, then you are passing up opportunities that you prefer.

- For example, suppose you would be willing to sell the bet for $12 but you marked $15. If the amount of money drawn at random is anything between the two (for example $13.50), you would keep you record sheet and loose the $13.50 that you would have been willing to make the trade for.

- Suppose you would be willing to sell for $15 but you marked $12. If the amount of money drawn at random is between the two (for example $13.50) then you would be forced to sell the record sheet even though at that price you prefer to play the record sheet.

Those of you assigned to the rolls of **Buyer/Punisher**, **Buyer/Sender**, and **Receiver/Punisher** have a page similar to the Seller's at the end of this booklet. While Seller's are writing their asking prices, we would like you to write how much money you would be willing to spend to acquire the Seller's information. **Buyer/Punisher**, **Buyer/Senders**, and **Receiver/Punishers** **<u>will not be paid for this task.</u>**

You may now mark your decision on the decision sheet.

RECORD SHEET

I am willing to sell my history for $__________

20-sided Roll	1st 10-sided Die Roll	2nd 10-sided Die Roll

Did sale take place? Yes No

If yes, amount paid $___________

Belief Elicitation Instructions

This document outlines the belief elicitation instruction that would be used to execute each session of part three of my thesis. Parameters that the experimenter has control over include: endowment for the public goods game, the social return on investment, and punishment a parameter.

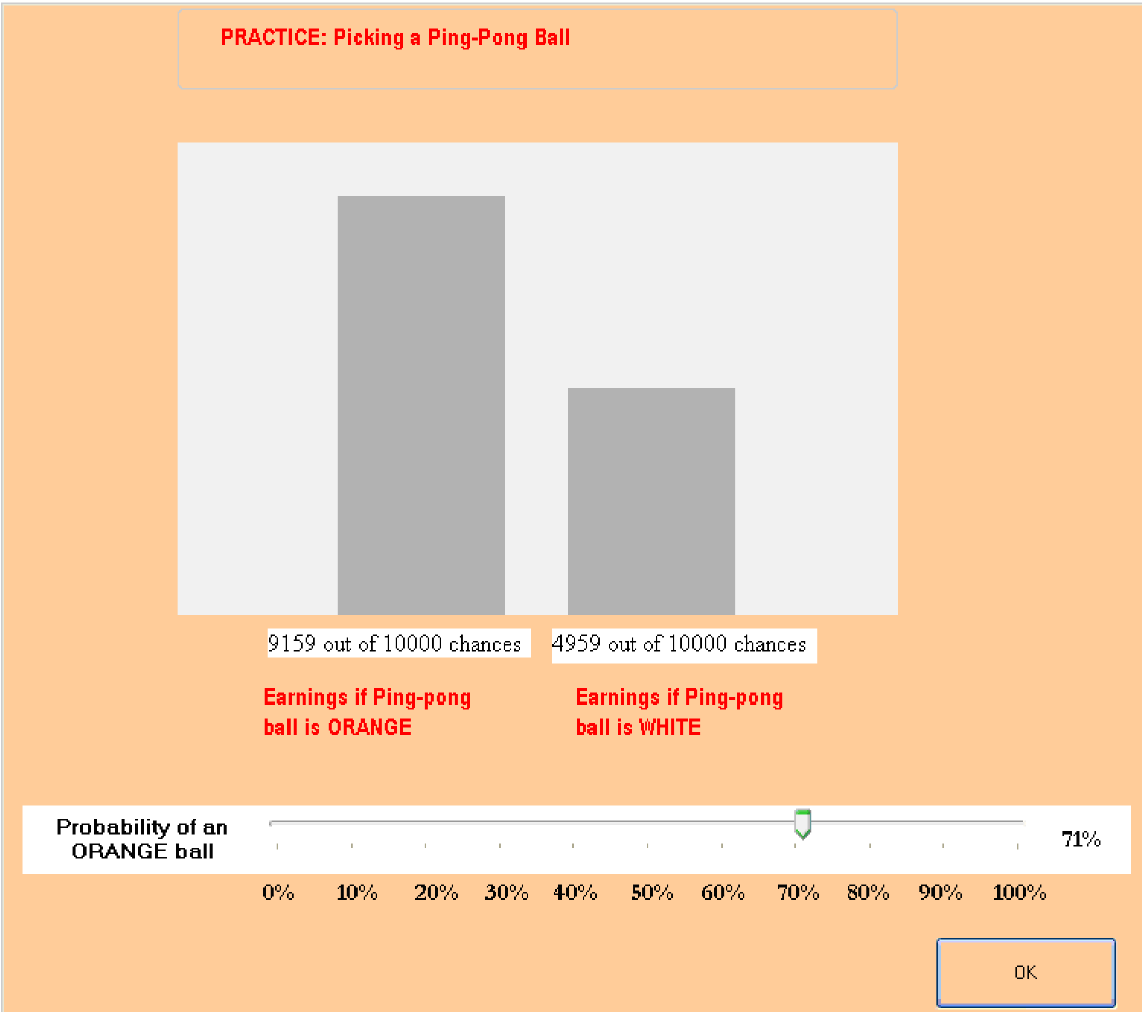
Treatment	Levels	Description
A	0,1	Endowment: 20 tokens (0) or 30 tokens (1)
B	0,1	Social return: 0.6 (0) or 0.8 (1)
C	0,1	Punishment parameter: 0.4 (0) or 0.6 (1)

There are four stages to this experiment:
1) Linear public goods game
2) Value elicitation with BDM procedure
3) Belief elicitation with QLSR
4) Zero cost punishment

The instructions shown below are for the punishment belief elicitation.

[The remainder of this page intentionally left blank]

In this stage we will give you a task where you will place a bet that you will be punished. You have more chances to make money the more accurately you predict if you will be punished. You place these bets on a screen like the one below. In a moment we will let you practice with this screen on your computer. Remember, any betting you do today is with our money, not your money.



You place your bets by sliding the bar at the bottom of the screen until you are happy with your choice of a probability report. The computer will start at some point on this bar at random: in the above screen it started at 71%, but you are free to change this as much as you like. In fact, you should slide this bar and see the effects on earnings, until you are happy to confirm your choice. Please wait while a research assist comes by and logs you on to the hypothetical practice example.

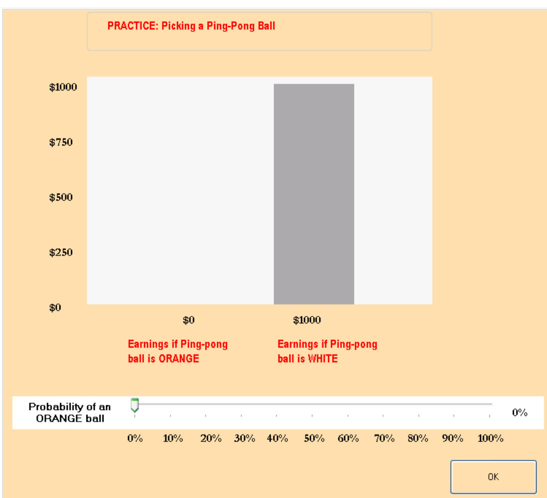
In this hypothetical example the maximum payoff you can earn is $1,000. In the actual tasks the maximum payoff will be lower than that. But the layout of the screen will be the same.

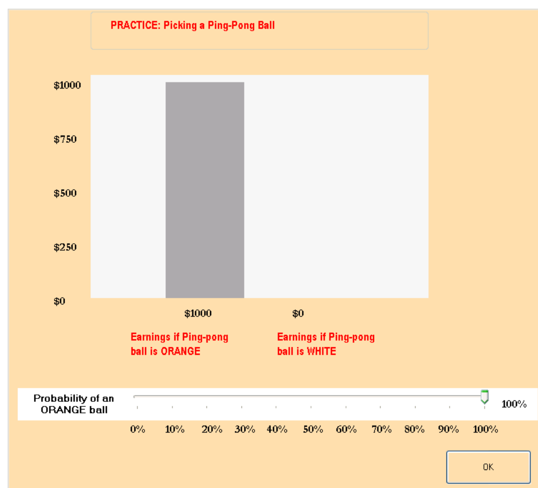
In this demonstration, the event you are betting on is whether a Ping Pong ball drawn from a bingo cage will be Orange or White. We have a bingo cage here, and we have 20 ping-pong balls. 15 of the balls are white, and 5 of the balls are orange. We will give the cage a few turns to scramble them up, and then select one ball at random.

What we want you to do is place a bet on which color will be picked. At the top of your screen we tell you what the event is: in this case, it is **Picking a Ping-Pong Ball**, and you need to bet on whether you think it will be **Orange or White**.

Your possible earnings are displayed in the two bars in the main part of the screen, and also in numbers at the bottom of each bar. For example, if you choose to report 71% you can see that you would earn 916 out of 1,000 chances to win $1,000 if the Ping Pong Ball was **orange**, and 496 out of 1,000 chances if the Ping Pong Ball was **white**.

Lets see what happens if you make different reports. If you chose to report 0% or 100% here is what you would see, and earn:





THESE SCRENES NEED TO BE CHANGED TO SAY TICKETS NOT DOLLARS

These screens are a little small, but you can see that these two reports lead to extreme payoffs. The "good news" is the possible $1,000 payoff, but the "bad news" is the possible $0 payoff. In between the reports of 0% and 100% you will have some positive payoff no matter what happens, but it will vary, as you can see from the report of 71%.

Summarizing, then, there are two important points for you to keep in mind when placing your bets:

1. **Your belief about the chances of each outcome is a personal judgment that depends on information you have about the different events.** In this practice example, the information you have consists of the total number of Orange balls and White balls.

2. **Your choices might also depend on your willingness to take risks or to gamble.** There is no right choice for everyone. For example, in a horse race you might want to bet on the longshot since it will bring you more money if it wins. On the other hand, you might want to bet on the favorite since it is more likely to win something.

For this task, your choice will depend on two things: your judgment about how likely it is that each outcome will occur, and how much you like to gamble or take risks.

You will now make your report in this practice round. When you have chosen the report, confirm your bet by clicking on the OK tab.

After you click OK, a special box will come up which causes the program to pause. We will tell you what the password is when we are all ready to proceed. There is plenty of time, so there is no need to rush.

When everyone has placed their bets we will pick the ball and you will see how many chances you would have to win $1,000. A research assistant will then come by and you will roll 5 10-sided die to determine if you would have won the $1,000.

For example, if the Ping Pong Ball was **orange** and the 5 numbers that your roll are less than 916, then you would have won $1,000. If the Ping Pong Ball was **white** and the 5 numbers that your roll are less than 469 then you would have won $1,000. If the 5 numbers that you roll are greater than the chances you have, then you win $0.

After that we will go on with the bets for which you can earn real money.

Does anyone have any questions?

You may now place you bets. Please raise your hand when you finish.

Now that everyone has placed their bets we will pick the ball and you will see how many chances you would have to win $1,000. A research assistant will then come by and you will roll five 10-sided die to determine if you would have won the $1,000.

Now that everyone has had practice using the computer, we want you to place a bet you will be punished.

You will now make your report. This report is binding and will be played for real. When you have chosen the report, confirm your bet by clicking on the OK tab.

Please go ahead now and place your bets for this event, unless you have any questions.

RECORD SHEET

Practice Round:

Chances of winning $1,000 if Ball is Orange: ___________

Chances of winning $1,000 if Ball is White: ____________

Circle color ball drawn from cage: Orange White

Chances to win $1,000: ____________

1st Die Roll	2nd Die Roll	3rd Die Roll	4th Die Roll

Earnings: _____________

Real Round:

Chances of winning $100 if punished: ___________

Chances of winning $100 if not punished: __________

Circle applicable bet: punished not punished

Chances to win $100: ____________

1st Die Roll	2nd Die Roll	3rd Die Roll	4th Die Roll

Earnings: _____________

RECORD SHEET

<u>Real Round</u>:

Reported belief: _____

Chances of winning $100 if roll of dice is less than or equal to the reported belief: _____

Chances of winning $100 if roll of dice is greater than the reported belief: _____

Roll of two 10-sided die: _____

Chances to win $100: ____________

1st Die Roll	2nd Die Roll	3rd Die Roll	4th Die Roll

Earnings: _____________

Punishment Stage Instructions

THE INSTRUCTIONS FOR THE PUNISHMENT PHASE ARE STILL BEING DEVELOPED.