Higher-order Beliefs in Simple Trading Models

Timothy Shields*
Assistant Professor
Argyros School of Business and Economics, Chapman University

Baohua Xin†
Assistant Professor
Rotman School of Management, University of Toronto

*Corresponding Author, Email: shields@chapman.edu
†Email: Baohua.Xin@Rotman.Utoronto.Ca

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Abstract

We examine the role of higher order beliefs in asset markets where coordination between a buyer and seller can lead to gains to trade. The scenarios are modeled such that trader's strategies do not only depend upon their beliefs of underlying economic phenomena, but also upon the others' beliefs regarding the beliefs of themselves. Under certain parameters the breakdown of coordination is predicted–even when both traders are certain the underlying phenomena dictates trade is advantageous. We demonstrate the equilibrium predictions can be constructed via a small number of iterated thought exercises. The experimental design allows us to control for various behavioral phenomena and examine subjects' decisions across different accounting regimes as to tease out strategic uncertainty due solely to information asymmetry. In this setting we find evidence supporting higher order beliefs. An implication is that the lack of uniformity leads to lack of common knowledge of the beliefs of others, which in turn leads to the spreading of inefficient outcomes.

Keywords: information asymmetry; experiment; strategic uncertainty; higher-order beliefs; iterative reasoning.

Data Availability: Experimental data available upon request.

INTRODUCTION

Business decisions generally require disparate parties such as managers and employees, buyers and sellers, shareholders and creditors, to coordinate their efforts to capture gains to trade and specialization. In such cases, people face both fundamental and strategic uncertainty, where fundamental uncertainty refers to beliefs about the exogenous states of nature, and strategic uncertainty refers to beliefs about others' beliefs. The strategic interplay between the two types of uncertainty gives rise to Keynes' analogue of capital asset pricing to the "beauty contests" that highlight the importance of higher order beliefs in capital markets when investors 1) have different beliefs about the value of the risky asset, and 2) are uncertain about the beliefs of other investors (Keynes 1936). As such, an understanding of capital markets requires an understanding of not only market participants' beliefs of the underlying state of the asset, but also their beliefs of other participants' beliefs, and their beliefs of other participants' beliefs of their beliefs, and so on. This is especially true in asset pricing when market participants have short horizons. In such a scenario, what really matters in the buy and sell decisions is not market participants' own beliefs, but the average beliefs of other participants about the fundamental (or liquidation) value of the asset, which determines the intermediate price of the asset that buyers and sellers trade at.

Although intuitively appealing, formally developing a framework of analysis that accommodates higher order beliefs in asset pricing has only appeared in the recent decade or so. In Allen et al. (2006)'s overlapping generations model, investors care about the short-run price movements, and are thus motivated to second- and third-guess other investors. Allen et al. show that price deviates systematically from the market consensus of the expected fundamental value of the asset. In a dynamic "differences of opinions model, Banerjee et al. (2009) conclude that common knowledge or disagreement only about first order beliefs is not enough for prices to exhibit drifts. Higher-order disagreement is necessary for heterogeneous beliefs to generate price drift. Other work relating higher order beliefs to asset pricing, directly or indirectly, includes Bacchetta & Van Wincoop (2006), Bacchetta & Van Wincoop (2008), Abreu & Brunnermeier (2003), and Gao (2008).

The higher order belief thinking in asset pricing has important implications on accounting standards. The primary objective of accounting is to communicate value relevant information about the underlying phenomenon among interested parties to facilitate decision-making. Communication demands common understanding. As such, accounting needs to have the ability to coordinate behavior within a framework of shared understanding. Unlike the communication channels in other fields such as finance, organization, or marketing, accounting disclosures are highly regulated and standards play a dominant role in defining the way financial information is disclosed through accounting. Accounting systems summarize, classify, and report transactional information. Both external and internal users view summarized results. Different entities may have different rules for classification and reporting (i.e., cost-flow assumptions, revenue recognition, allowance for doubtful accounts, etc.), resulting in non-uniformity. Within this framework we study the presence of higher-order beliefs due to the non-uniformity of accounting rules.

The objective of this study is two-fold. First, we experimentally examine whether subjects apply

the iterative thinking in asset pricing when both fundamental and strategic uncertainties exist in part due non-uniformity of accounting rules. Second, we investigate the implication of subjects' iterative thinking, if applicable, on the desirability of uniformity in accounting standards. We utilize a setting where the dispersion in subjects' beliefs about the value of the risky asset in question comes solely from the differential measurement rules resultant from the use of different accounting measurements. We build a parsimonious model to derive predictions underlying higher-order beliefs thinking, and test experimentally the model using a design that allows for non-modeled differences in preferences, so that the only differences between same subject measures are due to strategic uncertainty.

We find evidence that beliefs of others do economically matter, and that the observed behavior is consistent with the iterative process underlying analytical predictions of higher order belief models. However, the observed iterative process falls short of prediction, which in itself is consistent with prior research (Nagel 1995; Costa-Gomes et al. 2001). We also find that under our parameter values, the disagreement between subjects' beliefs about the value of the risky asset (the fundamental uncertainty), together with subjects' beliefs about the beliefs of other subjects (strategic uncertainty) demonstrably reduce trade and efficiency. As such non-uniformity in accounting standards are value destroying.

Our paper contributes to our understanding of the role of beliefs in exchange markets. The extensive theoretical literature on voluntary and mandatory disclosure offers great insight into how fundamental uncertainty is priced in capital markets (e.g., Dye & Sridhar 2008, Verrecchia 2001, and Kanodia 2007 provide a series of comprehensive review of papers in this line of research that use various modeling approaches). Empirical accounting research, whether it be archival research examining management conference calls, studies of financial markets reaction to analysts' forecasts and guidance, experimental research examining the impact of categorizing a transaction as a component of net income or comprehensive income, or event studies of the reaction to income statement expenses reported below or above the line, provides prima fascia evidence that beliefs do matter in asset pricing.[1] However, these papers generally leave the higher order beliefs out of picture.

The analytical body of work examining the iterative nature of beliefs posits that small disagreement in the beliefs about the fundamental uncertainty can have pronounced economic consequences. At an extreme, even with nearly common information agents respond to others as a possibly detrimental event occurred, even though both agents know the event could not have possibly occurred. Why? While the agent also knows that others also know it could not have occurred, she does not necessarily know that the others know that she knows it has not occurred.

[1]For example, Aboody (1996) studies the oil and gas industry and finds that investors value recognized information differently from disclosed information; Espahbodi et al. (2002) document differential value relevance of recognition versus disclosure in the case of employee stock options, and Libby et al. (2006) propose a possible explanation by providing experimental evidence that auditors have a higher tolerance level towards misstatements in disclosed amounts; the results from Elliott et al. (2012) suggest that the form of management forecasts have a significant influence on investors' interpretation of information contained in earnings announcement (reducing earnings fixation); Elliott & Hanna (1996) and Bradshaw & Sloan (2002) find that investors appear to put different weights on individual line revenues and expenses depending on how close these items are to core sales, and managers seem to be acutely aware of this and use the classification shifting as an earnings management tool when needed (McVay 2006).

As a result, coordination fails and potential trading gains are foregone. Work by economists Stephen Morris, Hyun Shin, and others (Rubinstein 1989; Shin 1996; Allen et al. 2006; Morris & Shin 2012) analytically model rational agents behavior. However empirically examining how higher order beliefs affect exchange markets has been rare.[2] We hope our study can shed light on this important issue. We find that higher order beliefs do factor in exchange market, albeit not to the level as predicted.

Allen et al. (2006) demonstrate that public information has dual roles in asset pricing as a result of investors higher order beliefs: the informational role and the commonality role. Gao (2008) explicitly explores the endogenous dynamics of the two roles of public information and shows that public information always drives stock prices closer to the fundamental value and enhances market efficiency. Our results suggest that not only the precision of public information, but also the shared understanding, matter. When agents agree to disagree on the information they have with regard to the fundamental value of the underlying risky asset, even with precise information, trade can completely breakdown, reducing market efficiency.

Our paper also contributes to the ongoing debate over the desirability of uniformity in accounting standards setting. There has been a long debate over whether accounting standards, such as Generally Accepted Accounting Principles (GAAP), should be made more rigidly uniform or somewhat more flexible. On the one hand, imposing uniformity on accounting standards may suppress substantive variations among similar economic transactions conducted in various decision environments or by diversified entities. As a result the information contained in the financial reports based on the standards is compromised. Allowing non-uniformity in accounting can improve private information communication (Healy & Palepu 1993; Hann et al. 2007) and facilitate efficient contracting (Watts & Zimmerman 1986). On the other hand, non-uniform accounting standards offer management the opportunity to manipulate financial reports (Graham et al. 2005; Schipper 1989), resulting in damaged investor confidence (e.g., the passage of Sarbanes-Oxley Act 2002 as a remedy) and deadweight losses (Bloomfield 1996; Stein 1989). Traditionally the Financial Accounting Standards Board (FASB) has been leaning toward eliminating or reducing flexibility in accounting practices (FASB 1979), but this does not come without strong oppositions (Foster III & Vickrey 1978). Lev (1976) calls "there is undoubtedly an urgent need for research on the optimal balance between regulation and free market forces in the production of financial information."

Despite the importance of the research question, there have been few studies examining explicitly whether uniformity is more desirable in accounting standards setting. Horwitz & Kolodny (1980) evaluate the economic effects of the mandated rules of the FASB requiring a single, uniform method of accounting for research and development (R&D) expenditures. They document that the expense-only rule caused a significant reduction in the level of R&D investments for firms that had previously used the deferral method. Hann et al. (2007) examine the effects of discretion allowed under GAAP on the value relevance of the pension obligation and conclude that allowing flexibility in the choice of pension assumptions on average improves information communication through the projected benefit obligation.[3] Analytically Dye & Verrecchia (1995) model a setting

[2] An exception is Balakrishnan et al. (2011).

[3] There is also a rich literature on the effects of income smoothing or discretionary accruals on the informational efficiency of capital market prices, for example, Subramanyam (1996), and Tucker & Zarowin (2006). But the

where firm's current period activities create expenses that are not realized until future periods and there is a question as to how much of these future expenses should be recognized currently, in the presence of both an internal agency problem (problem between a firm's shareholders and their manager) and an external agency problem (problem between current and prospective shareholders). They show that discretionary GAAP is always preferred over uniform GAAP if the internal agency problem is the only concern, however, when both internal and external agency problems are present concurrently, discretionary GAAP can be inferior to uniform GAAP. Dye & Sridhar (2008) model uniformity versus flexibility in terms of whether the biases in the mapping form the underlying transactions to the accounting numbers are common across firms or firm specific. A central result is that firms prefer uniformity to flexibility when the measured transactions are more homogenous or when there is substantial variation in how transactions are measured for reasons unrelated to the economic value of the transactions.

The extant literature on uniformity seems to focus on the trade-off between the improved information communication and opportunistic manipulation by the management.[4] We examine uniformity of accounting standards in a setting where there is there is no room or need for any opportunistic manipulation of financial information. We abstract away from any internal and external agency problems, but focus exclusively on how higher order beliefs of participating agents affect the social welfare when the use of different accounting standards create disagreement between the transactional parties in their beliefs regarding the value of the underlying asset. Thus we identify a previously unexplored reason that non-uniformity in accounting standards may not be desirable.

The paper proceeds as follows: we first present a parsimonious model to provide conditions underlying higher-order beliefs thinking. We next discuss the experimental design and procedures. Thereafter we present the experimental results and analyze the date using log-likelihood models before concluding.

THE MODEL

We begin by describing a setting where both the buyer and seller have an accounting system using uniform standards. This results in symmetric information as to lower bounds of losses that may result from trade. Motivated by Morris & Shin (2012), we first construct a setting that allows us to discuss the decisions faced by the buyer and seller before examining a richer setting where there is information asymmetry due to non-uniform accounting systems. The introduction of differing accounting procedure leads to asymmetric information as to the lower bounds of losses that may result from trade, allowing us to introduce the role of higher-order beliefs. We start with a single hypothetical state of nature to illustrate the basic tensions due to private information before introducing multiple states and thereafter non-uniformity in accounting systems.

measurement error in the discretionary accruals proxy makes the results difficult to interpret (Bernard & Skinner 1996; Morris et al. 2006).

[4] Dye & Verrecchia (1995) point out that "whether expanding discretion in accounting choice is desirable appears to depend on whether the prospects for improved communication of the firm's financial condition are more than offset by the effects of managerial opportunism."

Uniform Accounting Regime

A seller with a durable good meets with a buyer. It is common knowledge that the value to the buyer exceeds the value to the seller. There exists a market price for the underlying durable good such that the expected gains to trade are shared equally between buyer and seller. The buyer will use the good in the future, and it is equally likely the future market value of the good will either be higher or lower than the current expected value.[5] In the 'lemon' outcome the market value drops so the seller benefits from selling today at the current market price. Alternatively, in the 'peach' outcome the market value rises so the buyer benefits from buying today at the current market price. Any benefit to one trader due to the rise or drop from the current market price is at the expense of the other trader. The buyer's net payoff is G for the peach outcome and L for the lemon outcome, where $G > L$. Symmetrically, the seller's net payoff is L and G for the peach and lemon outcomes, respectively. Net payoffs are common knowledge. Both the buyer and seller may have private information regarding the future market price. It is common knowledge that each trader is equally likely to be privy or ignorant of the lemon or peach outcome. As such both, neither, or only one trader might be privy to the realized payoffs. Both buyer and seller must jointly and simultaneously agree to trade and forgo opportunity with a payoff of E (where $G > E > L$ and $E > 0$) or trade does not occur. We assume $G + L > 2E$, so that gains to trade exceed foregone opportunity, and as such, trade is socially efficient.

For exposition we use the pronoun 'she' to refer to the decision maker, and 'he' to refer to the paired trading partner. Some observations regarding the simultaneous-move game:

1. Assuming strictly selfish preferences, if one sees her payoff is G, she will agree to trade. Symmetrically, if the payoff is L she will not trade.
2. Consequently, any scenario where there is trade is one where at least one trader is ignorant of the outcome.

Imagine one trader does not know the outcome, so from her perspective there are two possibilities: either the other trader is also ignorant, or is informed. Additionally, if the informed trader knows his outcome is L he will not agree to trade. So the ignorant trader might agree to trade if her expected payoffs are greater than the foregone opportunity, given by eq.(1).

$$\underbrace{\frac{1}{2}}_{\text{other informed}}\left[\underbrace{\frac{1}{2}L}_{\text{other agrees}} + \underbrace{\frac{1}{2}E}_{\text{other rejects}}\right] + \underbrace{\frac{1}{2}}_{\text{other ignorant}}\left[\underbrace{\frac{G+L}{2}}_{\text{average result}}\right] \geq E$$
$$\Rightarrow L \geq \frac{3E - G}{2} \tag{1}$$

If eq. (1) is true, then both parties will trade when ignorant if, and only if, they believe the other trader will do the same. However, if eq. (1) is false, then neither will trade when ignorant, and the equilibrium is one of no trade. We summarize these results in the following proposition.

[5] We model two outcomes for the sake of parsimony. The results of the model remain intact when allowing for a status-quo outcome where the current expected value equals the future market value.

Proposition 1. *Under the uniform accounting regime:*

(a) If a trader is informed, she trades when she knows the outcome is favorable and rejects when she knows the outcome is unfavorable;

(b) If a trader is ignorant and eq. (1) is false, then there is a unique equilibrium of no trade;

(c) If a trader is informed and eq. (1) is true, there is a non-unique equilibrium where ignorant parties agree to trade;

(d) As such, the maximum ex-ante probability of trade is one-half when eq. (1) is true and zero otherwise. The ex-ante welfare is equal to [probability of trade] $*[G + L - 2E]$.

Proof. (a), (b), and (c) are straightforward. For (d), the maximum ex-ante probability of trade is calculated as:

$$\underbrace{\frac{1}{2} \times \frac{1}{2}}_{\text{buyer informed of peach outcome}} \times \underbrace{\frac{1}{2}}_{\text{seller ignorant}} + \underbrace{\frac{1}{2} \times \frac{1}{2}}_{\text{both buyer and seller ignorant}} + \underbrace{\frac{1}{2} \times \frac{1}{2}}_{\text{seller informed of lemon outcome}} \times \underbrace{\frac{1}{2}}_{\text{buyer ignorant}} = \frac{1}{2}$$

□

Now that we have illustrated the tensions underlying trade, we depart from a single state of nature with two outcomes and examine three states of nature denoted as A, B, or C, each with two outcomes. For simplicity, we assume all three states of nature are equally likely, and in each state of nature, both the favorable outcome G and the opportunity costs E are identical [6] The unfavorable outcome, $L \in \{L_a, L_b, L_c\}$, differs over the three states so that $L_a > L_b > L_c$. One could think of state A as the least risky to conduct trade when ignorant, but state C as the most risky. We further assume that while trade increases welfare for all states, $G + L_i > 2E \ \forall i$, eq.(1) holds true for states A and B, but not for state C. Formally, $L_a > \frac{3E-G}{2}$, $L_b \geq \frac{3E-G}{2}$, but $L_c < \frac{3E-G}{2}$. Table 1 summarizes the net payoffs when both parties elect to trade.

Table 1: Net Payoffs if Trade

	Probability	Seller's Payoff		Buyer's Payoff	
State	of State	Lemon	Peach	Lemon	Peach
A	1/3	G	L_a	L_a	G
B	1/3	G	L_b	L_b	G
C	1/3	G	L_c	L_c	G

If a trader's accounting system was informative of the state, that is, it provided a definite lower bound on the potential loss, then by Proposition 1, there is trade only when the state is A or B. Fearing loss, an ignorant trader would not agree to trade when the state is C. Note that

[6] The relaxation of these assumptions do not change the nature of the analysis nor yield any additional insights.

despite uniformity of accounting system there is inefficiency. Trade requires the state is not C and that the buyer and/or seller is ignorant. As such, trade can happen at most one-third of the time.[7]

Non-uniform Accounting Regime

Consider an accounting regime where traders might have used different standards. For example, assume the seller uses a conservative standard that recognizes the state C perfectly and pools remaining states A and B, while the buyer has an aggressive standard that recognizes state A perfectly and pools states B and C. Before electing to trade, each trader receives a private signal of the state of nature from their accounting system in the form of a partition where the true state is one of the elements in the partition. The buyer's partition is $S_1 = \{\{A\}, \{B, C\}\}$ and the seller's partition is $S_2 = \{\{A, B\}, \{C\}\}$. For example, if that state is B, then buyer receives the accounting measurement $s_1 = \{B, C\}$ and the seller receives the accounting measurement $s_2 = \{A, B\}$. If the signal has one element, then the trader knows the state of nature with certainty. If the signal has two elements, then the trader knows the state of nature is equally likely to be either element of her signal. While the accounting measurements s_1 and s_2 are private, the measurement rules of each trader's accounting system, and thus the partition structure, is known by the other.

The Role of Higher-Order Beliefs

When a trader is informed of the outcome, it is straight-forward to show that Proposition 1 (a) applies for all three states. Here we focus on the more interesting case where the trader is ignorant of the outcome, but are unsure whether her partner is informed or ignorant. We show there are parameters such that trade is possible with uniform accounting systems, but when the accounting system is non-uniform, trade completely collapses due to higher-order beliefs.

Proposition 2. *Assume the opportunity cost satisfies eq. (3) such that it is not so large as to always discourage trade but not small so there is always an unique equilibrium of trade when ignorant. If accounting systems are not uniform, then higher-order beliefs reasoning dictates there exists a unique equilibrium where both parties choose not to trade regardless of the signals observed, when ignorant. Informed parties are indifferent to trade when the outcome is favorable, but will not trade when the outcome is unfavorable. As a result, there is never trade and social welfare is zero.*

Proof. As a benchmark, we start with no higher-order beliefs of any degree, i.e., all traders consider their own accounting information, and ignore other's potential accounting information and strategic behavior. It is easy to verify that in this benchmark case, there exists an equilibrium where an ignorant buyer agrees to trade when $\{A\}$ is observed, or when $\{B, C\}$ is observed and

[7] Under Proposition 1, the maximum ex-ante probability of trade is 1/2 for states A and B, and is zero for state C. Each state has equal chance of occurring, hence the overall probability is 1/3.

$L_b + L_c > 3E - G$, but does not agree to trade in all other cases. Likewise, an ignorant seller agree to trade when $\{A, B\}$ is observed but does not when $\{C\}$ is observed.

Alternatively, a trader might hold higher-order beliefs. We start with an ignorant seller observing $\{C\}$. If she decides not to trade, she can capture a payoff E. If she decides to trade, her expected payoff will depend on what the buyer will do. Since she observes $\{C\}$, she believes that he, if ignorant, must have observed $\{B, C\}$. If she believes that he accepts when $\{B, C\}$ is observed, her expected payoff will be $\frac{1}{2}\left[\frac{L_c+E}{2}\right] + \frac{1}{2}\left[\frac{L_c+G}{2}\right] = \frac{1}{2}L_c + \frac{1}{4}\left[E + G\right] < E$. On the other hand, if she believes the buyer will not trade when ignorant and $\{B, C\}$ is observed, her expected payoff is $\frac{1}{2}\left[\frac{L_c+E}{2}\right] + \frac{1}{2}E < E$. In either case it is optimal not trade when ignorant and the signal is $\{C\}$.

Suppose an ignorant buyer observes $\{B, C\}$. If she decides to trade, her expected payoff will depend on what the seller chooses to do given their signal. Given her partition, she knows the seller observes $\{A, B\}$ and $\{C\}$ with equal probability. She also believes an ignorant seller will not trade when observing $\{C\}$. If she believes the seller will not trade when observing $\{A, B\}$, her expected payoff is $\frac{1}{2}\left[\frac{1}{2}(\frac{L_b+L_c}{2}) + \frac{1}{2}E\right] + \frac{1}{2}E < E$. However, if she believes the seller will trade when observing $\{A, B\}$, her expected payoff is $\frac{1}{2}\left[\frac{1}{2}(\frac{L_b+L_c}{2}) + \frac{1}{2}E\right] + \frac{1}{2}\left[\frac{1}{2}(\frac{L_b+G}{2}) + \frac{1}{2}E\right] = \frac{1}{2}E + \frac{1}{8}(2L_b + L_c + G) < E$ if $E > \frac{1}{4}(2L_b + L_c + G)$. Combined with eq.(1), for eq. (2), an ignorant buyer observing $\{B, C\}$ elects not to trade.

$$\max\{\frac{1}{4}(2L_b + L_c + G), \frac{2}{3}L_c + \frac{1}{3}G\} < E \leq \frac{2}{3}L_b + \frac{1}{3}G \tag{2}$$

Suppose an ignorant seller observes $\{A, B\}$ and eq. (2) holds. If she decides not to trade, she can capture a payoff of E. If she decides to trade, her expected payoff will depend on what the buyer does when ignorant. Given her partition is $\{A, B\}$ she knows the buyer observes $\{A\}$ and $\{B, C\}$ will equal probability. She knows that if the buyer observes $\{B, C\}$ she will not elect to trade if ignorant. If the seller believes the buyer will not trade when observing $\{A\}$, her expected payoff is $\frac{1}{2}\left[\frac{1}{2}(\frac{L_a+L_b}{2}) + \frac{1}{2}E\right] + \frac{1}{2}E < E$. However, if she believes the seller will trade when observing $\{A\}$, her expected payoff is $\frac{1}{2}\left[\frac{1}{2}(\frac{L_a+L_b}{2}) + \frac{1}{2}E\right] + \frac{1}{2}\left[\frac{1}{2}(\frac{L_a+G}{2}) + \frac{1}{2}E\right] = \frac{1}{2}E + \frac{1}{8}(2L_a + L_b + G) < E$ if $E > \frac{1}{4}(2L_a + L_b + G)$. Combined with eq. (1), for eq. (3)–which implies eq. (2), an ignorant buyer observing $\{A, B\}$ elects not to trade.

$$\max\{\frac{1}{4}(2L_a + L_b + G), \frac{2}{3}L_c + \frac{1}{3}G\} < E \leq \frac{2}{3}L_b + \frac{1}{3}G \tag{3}$$

Last, consider an ignorant buyer observes $\{A\}$ and assume eq. (3). If the buyer decides to trade, her expected payoff depends on the what seller does when ignorant and observes $\{A, B\}$. Knowing the seller will not trade when ignorant, the buyer's expected payoff is $\frac{1}{2}(\frac{L_a+E}{2}) + \frac{E}{2} < E$, and therefore decides not to trade. As such there is no trade. $\square$

THE EXPERIMENT

Design

To test whether higher-order beliefs predict behavior under non-uniform accounting we design a three-part experiment:

- In the first part (Part I), subjects participate in uniform accounting regime where they know the state of nature (i.e., State A, B, or C). However, subjects do not have private information as to the outcome when deciding to trade (i.e., lemon or peach).
- In the second (Part II), subjects again have uniform accounting regime but also have a 1/2 chance of knowing the outcome before deciding to trade.
- In the third (Part III), subjects participate in an non-uniform accounting regime where sellers and buyers receive a partition as described in section . As in Part II there is a 1/2 chance of knowing the outcome before deciding to trade.

Via Parts I and II we capture subjects' attitudes towards lotteries, other-regarding behavior, and their beliefs as to others' strategies. We then examine Part III to ascertain how higher-order beliefs triggered by non-uniformity in the accounting systems may affect trade. The design allows us to examine within-subject behavior. Our design of measuring behavior in Part II allows us to create proxies for comparison to Part III behavior.

While in the manuscript we use the terms 'state', 'seller', 'buyer', 'lemon', 'peach', etc. . . , we strove to use neutral terms in the experimental materials as to minimize experimenter demands or unintended normative behavior. All sessions used the exact same instructions (see Appendix) and were conducted by the same experimenter. The parameters value in Table 2 were selected such that the lower payoffs $\overrightarrow{L}$ were positive and satisfy eq. (3).

Table 2: Experimental Parameters

	Opportunity	Seller's Net Payoff		Buyer's Net Payoff	
State	Costs	Lemon	Peach	Lemon	Peach
A	5	10	3.2	3.2	10
B	5	10	3	3	10
C	5	10	2	2	10

(a) Costs and Net Payoffs Used in Experiment

	Knowledge	Information Regarding State	
Part	Of Outcome	Buyer	Seller
I	No	A, B or C	A, B or C
II	1/2	A, B or C	A, B or C
III	1/2	$\{A\}$ or $\{B, C\}$	$\{A, B\}$ or $\{C\}$

(b) Information Structure

Procedures

The experiment was conducted at a North American university. Subjects were recruited from a standard subject pool consisting primarily of undergraduate students and randomly assigned into sessions. Subjects interacted with each other anonymously over a local computer network. The experiment was programmed and conducted using z-Tree (Fischbacher 2007). The computers were placed within individual cubicles in such a way that all subjects could only view their own computer screen.

The sessions each consisted of 24 subjects, lasted approximately sixty-five minutes, and were sequenced as follows. For Part I, an experimenter read the instructions aloud as each subject followed along with their own copy of the instructions. The instructions explained the experimental procedures and payoffs used in the experiment. During the instructions, subjects were given five minutes to write down their answers to several questions to ensure that they understood the instructions. Subjects' answers remained confidential. After subjects completed the quiz, the correct quiz solutions were projected overhead while the experimenter explained the solutions (projections available in Appendix). The experimenter privately answered any questions regarding the experimental procedures. Each subject was assigned a role of buyer or seller and remained in that role for the experiment. The subjects were randomly regrouped using the stranger's protocol for each round. The sequence of event was repeated for Part II and again for Part III. In Part I subjects played five rounds; in Part II subjects played ten rounds, and in Part III subjects played 20 rounds. Subjects were not told the number of rounds in each part.

After completing all parts subjects filled out an open-ended questionnaire asking them to explain how they came to their decisions. Each subject was paid a $US 7 participation fee and the payoffs after signing a receipt. Subjects were paid for one randomly selected round from each part.

Construction of Higher-Order Beliefs

While simple, the three-state game with nearly perfect information provides a setting where coordination can completely deteriorate, destroying the expected benefits of trade. The setting also allows us to construct a thought exercise that converges to equilibrium after two iterations from a base-level strategy. Non-uniformity in the accounting systems results in lack of common knowledge regarding the lower bound of unfavorable outcomes, which then implies contagious spreading of inefficient outcomes.

First, we construct a base level strategy. Using the left-hand side of eq. (1), where our trader conjectures the other will trade if he is uninformed as to the outcome, the payoffs are computed with the values reported in Table 2. The resulting expected payoff when uninformed is reported in the first row of Table 3. However, if the other decides he will not trade when uninformed, then the payoff is given by eq. (4):

$$\underbrace{\frac{1}{2}}_{\text{other informed}}\left[\underbrace{\frac{1}{2}L}_{\text{other accepts}} + \underbrace{\frac{1}{2}E}_{\text{other rejects}}\right] + \underbrace{\frac{1}{2}}_{\text{other ignorant}}\left[\underbrace{E}_{\text{other rejects}}\right] \tag{4}$$

Using the same values in Table 2, the expected payoffs of trading when uninformed are reported in the second row of Table 3.

Table 3: Expected Payoff Given State and Partner's Strategy

	State		
	A	B	C
If uniformed partner trades (eq. (1))	5.35	5.25	4.75
If uniformed partner does not trade (eq. (4))	4.60	4.50	4.25

The most efficient equilibrium is one where ignorant traders trade when the State is A or B when the expected value is greater than the foregone opportunity. They do not trade when the State is C. Since there is not common knowledge in regards to the state, each trader conjectures what the other may do conditional upon her information, and determines a best response. We start with a base-level where the decision maker disregards the signal the other trader may have received and simply considers the payoffs in Table 3 to construct a strategy. The buyer receives either signal $\{A\}$ or $\{B, C\}$. When she receives signal $\{A\}$, she knows the State is A, and decides to trade as the expected payoffs are greatest when trading (comparing net payoff to forgone opportunity). However, when the signal is $\{B, C\}$, the State is B or C with equal probability, and she must accept or reject both. When she accepts, the expected payoff (5.25 and 4.25 for State B and C, respectively) is less than the foregone payoff E, so she does not trade. The seller receives either signal $\{A, B\}$ or $\{C\}$. When she receives signal $\{A, B\}$, she knows the State is A or B with equal probability, and the expected payoff of trading (5.35 and 5.25 for State A and B, respectively) exceeds opportunity costs, so she trades. When she knows the State is C, she does not. This behavior is summarized in the first row of Table 4.

In the next iteration the decision considers the signal value the other trader might have received given her own signal, and constructs a best response. When the buyer receives the signal $\{A\}$ she knows the other received the signal $\{A, B\}$, and since he trades when uniformed, trade is a best response. When she receives the signal $\{B, C\}$, she knows the other received either $\{A, B\}$ and accepted or $\{C\}$ and rejected, and the expected payoffs are 5.25 and 4.25 for States B and C, respectively, so does not trade. In summary, the buyer's response does not change from the base level. However, the seller's response does change. When she receives the signal $\{A, B\}$, she knows the State is A and the other will trade, or the state is B and the other will not, and the expected payoffs are 5.35 and 4.50 for States A and B, respectively. So, on average the payoffs are less than the opportunity costs and she does not trade when ignorant. When she knows the State is C, she also does not trade. This is summarized in the second row of Table 4.

The last iteration considers what signal the other trader believes the decision maker received, and constructs a best response. Now when the buyer receives $\{A\}$, she knows the other player

received $\{A, B\}$. However, she also knows the seller reasons either she received $\{A\}$, and from the last iteration, trades, or she received $\{B, C\}$, and from the last iteration, does not trade. Recall the seller will not trade when receiving the signal $\{A, B\}$ as per the last iteration. The expected payoff of accepting is 4.60 and less than opportunity costs. So the buyer's best response to a signal of $\{A\}$ is to not trade when uninformed. This is last iteration of interest as all further iterations yield the same prediction of no trade for all signal values as shown in the last row of Table 4. Hence, when the seller sees $\{A\}$, she knows the bounds on unfavorable outcomes imply coordination is possible, and she knows the buyer also knows the bounds are conducive to trade. Nonetheless, no trade is predicted to occur as trade requires at least one ignorant trader, and we show that a trader will not choose to trade when ignorant.

Table 4: Iterations to Equilibrium Prediction

	Accounting Signal Received			
	$\{A\}$	$\{B, C\}$	$\{A, B\}$	$\{C\}$
Base level	Trade	Do Not Trade	Trade	Do Not Trade
One iteration	Trade	Do Not Trade	Do Not Trade	Do Not Trade
Two iterations	Do Not Trade	Do Not Trade	Do Not Trade	Do Not Trade

RESULTS

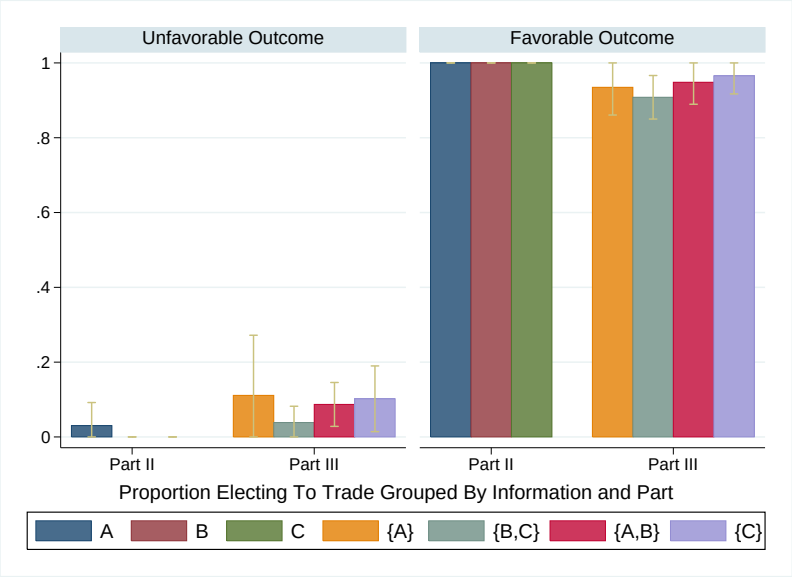
Descriptive Statistics

We do not find any unusual differences between sessions and report the combined results. Note that when traders have knowledge of the outcome, the behavior shown in Figure 1a mirrors Proposition 1 (a). When the outcome is known to be favorable subjects chose to trade and when outcome is known to be unfavorable chose not to. The fundamental assumptions underlying the behavior of uninformed subjects inherent in the first portion of eq. (1) are observed. Hereafter we focus upon behavior when subjects are not informed.

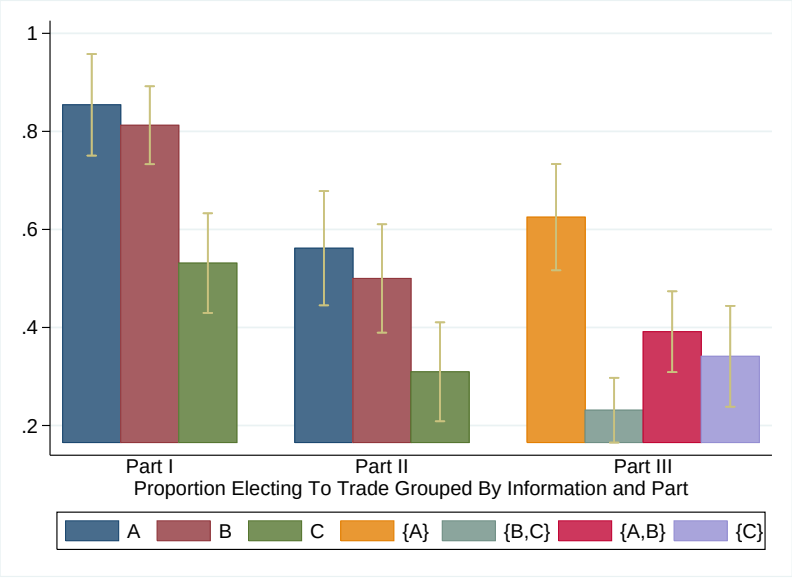
Lacking knowledge of the outcome we find, on average, subjects in Part I are hesitant to trade when the state is C, suggesting risk aversion hinders trade at the state where the expected payoff is lowest (see Figure 1b). In Part II where subjects use uniform accounting systems trade occurs most frequently when the state is A, and least when the state is C. In Part III, where subjects use non-uniform accounting systems, we find that only for signal $\{A\}$ does the number of decisions to trade exceed those to not trade.

Subject Level Analysis

We confine our analysis to observations where the subject was not informed of the 'peach' or 'lemon' outcome. We analyze behavior within subject by comparing using the average trading



(a) Subjects Informed of Outcome



(b) Subjects Uninformed of Outcome

Figure 1: Observed Trade when Subjects Informed or Uninformed of Outcome
Mean and Standard Error Shown

decision by subject for each part.[8] Unless stated otherwise statistical results of the Wilcoxon matched-pairs signed-ranks test are reported. The mean of the average subject trading rate are reported in Table 5. In Part I, we find behavior consistent with risk aversion. A risk-neutral subject will trade in all states. While we observe trade indistinguishable between states A and B (p-value $= 0.34$) we find trade lowest when the state was C (p-value < 0.01 compared to state B). Consistent with the statistical analysis, an examination of the post-experiment questionnaire reveals subjects cite risk as a reason not to trade.

Recall there is not a unique equilibrium: given parameters such that uninformed parties might trade, trade is nonetheless contingent upon the other is using the same strategy. Subjects trade less so in Part II than in Part I as expected given the non-uniqueness (p-value < 0.01 for states A and B; p-value < 0.05 for state C). We cannot ascertain whether the difference is due to strategic uncertainty of what the other subject may due, or based on other-regarding preferences. However, as in Part I we find trade lowest when the state was C (p-value < 0.05).

To compare trading rates in Part III, where accounting systems are not uniform, we compute a benchmark rate using Part II data for each subject. To illustrate, using Part II trades we compute mean of the subject's average trading rate when the state was A, again when the state was B, and take the average of these means. We compare this construct with trading rate in Part III when the signal is $\{A, B\}$ (and the state is equally likely to be A or B). A similar construct was computed for the signal $\{B, C\}$. For the two-element partition signals, we had four incidences where a benchmark could not be constructed as a uniformed trading decision was not observed for A or B as private knowledge of the outcome was stochastic.

Recall that buyer received the $\{A\}$ and $\{B, C\}$ partitions from her accounting system. The means of the average subject trading rates are reported in Panel B of Table 5. The average rate is greater for the $\{A\}$ (0.57 for $\{A\}$ and 0.24 for $\{B, C\}$ with p-value < 0.01). We do not find trading differs significantly from the appropriate Part II benchmarks (p-values of 0.18 and 0.22 for $\{A\}$ and $\{B, C\}$, respectively). If higher-order beliefs predictions held at highest level of iteration in our thought-exercise, neither signal should yield trade, yet the trading rate is greater than fifty percent for $\{A\}$, albeit less than twenty-five percent for $\{B, C\}$. As shown in Table 4, no difference between the Part II construct and Part III behavior suggests either no or one iterations by the buyer, but rules out two iterations.

Examination of the seller's behavior allows us to determine if there is any evidence of higher-order beliefs. The average seller response to the accounting signals $\{A, B\}$ and $\{C\}$ are also shown in Table 5. While the average acceptance is smaller for $\{C\}$, the difference is not statistically significant (0.38 for $\{A, B\}$ and 0.31 for $\{C\}$ with a p-value of 0.60). We find similar average trade for signal $\{C\}$ to Part II (p-value of 0.24). However, comparing trade for signal $\{A, B\}$ to the aforementioned Part II benchmark, we find trade significantly decreases (0.52 for the Part II benchmark versus 0.38 for Part III with p-value < 0.01). As shown in Table 4, a difference between the Part II construct and Part III behavior suggests either one to two iterations by the seller, but rules out no iterations.

[8] We use each subject's average behavior over all rounds within a part as an observation. We find no visual suggestion of behavior changing over time, nor do we find statistical evidence via panel data robust regressions by subject that include a time as independent variable, or by running time-series regression. Results are available from authors upon request.

Notice a decrease in trade results from seeing $\{A, B\}$, but not for $\{A\}$ is consistent with one iteration. This suggests subjects are pondering what the other might be thinking, but not to the extent posited by our thought-exercise. Nonetheless, since there is diminished trade when seeing $\{A, B\}$ there is a reduction in the probability of trade to approximately six percent when the state is A or B. Trade and welfare decrease, consistent with prediction, but not the level of zero trade.

Table 5: Mean Average Trading Rates When Uninformed of Outcome

		State		
		A	B	C
Part I	Mean	0.85	0.85	0.53
	Error of the Mean	(0.05)	(0.04)	(0.06)
	Observations	*48*	*48*	*48*
Part II	Mean	0.57	0.48	0.32
	Error of the Mean	(0.07)	(0.07)	(0.06)
	Observations	*43*	*46*	*44*

(a) Uniform Accounting Regime

		Signal			
		$\{A\}$	$\{B, C\}$	$\{A, B\}$	$\{C\}$
Part III	Mean	0.57	0.24	0.38	0.31
	Error of the Mean	(0.10)	(0.08)	(0.07)	(0.08)
	Observations	*24*	*24*	*24*	*22*

(b) Non-uniform Accounting Regime

Log-likelihood Fit

To provide further evidence of subjects' use of higher-order thinking, we examine log-likelihood models of the data. This allows us to examine risk preferences in the presence and absence of common knowledge and to fit different log-likelihood models of subjects' beliefs. Specifically, we fit the data to three models by incorporating no, one, or two levels of iteration in the aforementioned thought-exercise.

We model subjects' utility of payoff as $U(y) = (y^{1-\rho}-1)/(1-\rho)$ where ρ captures risk preferences and y represents monetary payoff. Notice her utility function exhibits constant relative risk aversion. The expected utility is a function of the subject's information (state, private signal and outcome), as well as the assumed strategy of the other (denoted as 'he'). Note the models yield different predictions only for Part III:

Model 0 The subject behaves as in Part II for the expected states. As such she disregards her partner's possible signal from his accounting system. Instead she considers only what she believes the state could be as per her accounting system.

Model 1 Behavior is rooted in Part II except now the subject considers her trading partner's possible signals from his accounting system, conditional on her own signal from her own accounting system. The trader partner's strategy is specified by Model 0. There is one level of iteration: she considers what her partner believes the state could be and takes into account his resulting strategy when forming her own strategy.

Model 2 The decision maker takes into account that her trading partner also takes into account her conjectured signals for each of his possible signals from his accounting system, conditional on her own signal from her own accounting system. Her partner's strategy is specified by Model 1. There are two levels of iteration: she considers what her partner might believe her beliefs of the state and takes into account his resulting strategy when forming her own strategy.

The probability that a subject elects to trade is $P_k(I, \lambda, \rho)$, where I is the information set (i.e., outcome if known, state or signal value), and λ is a precision parameter. Following Wilcox (2011), we use a logit-type probability function scaled by the maximum obtainable utility value less the minimum possible utility value of the possible states given her private information. Use of the scalar, designated as $U_s^* = U(G) - U(L_s)$ where $s \in \{a, b, c\}$, results in the probability function for model $k \in \{0, 1, 2\}$ as:

$$P_k(I, \lambda_k, \rho) = \frac{1}{1 + \exp\left[-\frac{\lambda_k}{U_s^*}\left(EU(I) - U(E)\right)\right]} \tag{5}$$

In calculating the subject's expected utility, when beliefs of others' are applicable (Models 1 and 2), we construct her beliefs of her partner's strategy as $P_{k-1}(I, \lambda, \rho)$. Note this function is at the prior level of iteration, $k - 1$, and furthermore we let $\lambda_{k-1} \to \infty$, and thus our traders are modeled with a belief the partner is using pure strategies.[9] The log-likelihood of a subject i's choice probabilities over the 35 round experiment, X_i, is given by:

$$LL_k(\rho, \lambda | X_i) = \sum_{n=1}^{35} \ln\Big(x_n^i P_k(I_n, \lambda, \rho) + (1 - x_n^i)(1 - P_k(I_n, \lambda, \rho))\Big) \tag{6}$$

where x_n^i equals one if subject i in round n chose to trade and zero otherwise.

The estimation results of log-likelihood function given by eq. (6) summed over all subjects are shown in Table 7. The results are supportive of the intuition of the prior section: subjects' trading is consistent with iterated beliefs of others' strategies but not to the level of iteration predicted. The values of ρ given by the models are not significantly different from each other.

Comparing the three models, we find Model 1 yields the best fit and highest precision. Compared to the data, Model 0 predicts too much trade from the sellers with signals $\{A, B\}$, while Model 2 predicts too little trade for the buyers with signals $\{A\}$. Of course not all subjects may iterate to the same level, nor may all subjects use the same level of iteration for all decisions. So we also

[9] To illustrate the resulting value of the probability function, consider the function $P_k(I, \lambda, \rho)$ for Part I when the State is A. Using a risk parameter of $\rho = 1/2$ and precision $\lambda = 10$ the function yields 0.97. When $\lambda \to \infty$, then $P_k(I, \lambda, 1/2) \to 1$ resulting in a pure strategy.

examine a mixture model (Model M), where some fraction of the choices, π_k, are made using a particular model. The log-likelihood of a subject's choice probabilities over the experiment, X_i, is given by:

$$LL(\pi, \rho, \lambda_k | X_i) = \sum_{n=1}^{35} \ln \sum_{k=0}^{2} \pi_k \Big(x_n^i P_k(I_n, \lambda_k, \rho) + (1 - x_n^i)(1 - P_k(I_n, \lambda_k, \rho)) \Big) \tag{7}$$

As we found no statically significant difference between the risk parameters generated for Models 1 - 3, we construct Model M using a single risk parameter. The estimation results of the Model M log-likelihood function given by eq. (7) and summed over all subjects are shown in Table 6. The results show that the majority of decisions display behavior consistent with one or more iterations and a minority is consistent with to iterations. While Model M has the highest fitted value and lowest value of the Akaike information criterion (AIC), Model M also has a higher Bayesian information criterion (BIC) value than Model 1. Furthermore, while we can reject that Model M is different from Model 0 or Model 2 at a ten-percent level using a Chi-square test (p-value < 0.07 with 3 d.f.), we fail to reject a difference between Model M and Model 1 (p-value $= 0.17$). As such, despite having a worst LL value than Model M, both Model 1 and Model M are valid candidates for predicting behavior.

Table 6: Log-Likelihood Results

	Model 0	Model 1	Model 2	Model M
Minimized Value of LL	-806	-804	-872	-799
Precision Parameter λ_k	8.17	10.23	9.63	*See below*
Risk Parameter ρ	0.48	0.45	0.45	0.47
AIC	1,614	1,611	1,747	1,608
BIC	1,618	1,614	1,751	1,617
Parameters for Model M:				
Proportion π_k	0.42	0.55	0.03	
Precision Parameter λ_k	9.55	9.43	7.27	

(a) Fitted Parameters for the Log-Likelihood Models

	Model 0	Model 1	Model 2	Observed
$\{A\}$	0.51	0.53	0.32	0.62
$\{B, C\}$	0.37	0.32	0.25	0.23
$\{A, B\}$	0.49	0.40	0.41	0.39
$\{C\}$	0.28	0.24	0.25	0.34

(b) Probability $P_k(I, \lambda_k, \rho)$ in Part III Given Signal

DISCUSSION

Our results are consistent with the subjects' use of higher-order beliefs and the resultant contagious spreading of inefficient outcomes. Experimental behavior was consistent with theory, where a uniform accounting system would result in higher trade and social welfare than a non-uniform accounting system. We argue the decrease is not due to decreased information content. For example, if both traders have the accounting system consisting of partition $\{\{A, B\}, \{C\}\}$, then theoretically welfare is identical to the case when the partition $\{\{A\}, \{B\}, \{C\}\}$ is used. Why? Because a trader is assured the state is or is not C, assured the other knows this to be true, and last, assured the other trader knows she knows this to be true. As such the second-best solution is achieved. At the same time partitioning matters, as when traders have the partition $\{\{A\}, \{B, C\}\}$, then there is less trade, but as in the prior example, there is no role for higher-order beliefs. Given how partitioning can destroy welfare, even when accounting systems are uniform, a natural extension is to examine the optimal accounting system when the values of lower payments or opportunity costs are stochastic rather than static.

Higher-order belief models predict behavior in settings that depend upon economic fundamentals, but also upon a person's beliefs regarding the beliefs of others. The models hold insight into phenomena regularly cited as evidence of inefficient markets or limited rationality. That is, observed behavior may not necessarily depart from rationality, but from strategic uncertainty.

We experimentally examine a setting where the predictions of rational strategies can be constructed via iterations of a thought exercise, and the number of iterations to equilibrium is, in a crude sense, feasible. The design allows us to set aside various behavioral phenomena and examine decisions across different regimes as to tease out the effects of strategic uncertainty in simple, albeit novel, setting. We find evidence supporting the models' underlying feature of the breakdown of coordination, and thus welfare, due to asymmetric belief of others' belief of the lower bound due to non-uniformity in the accounting systems. Similar to Camerer et al. (2004), we find a limited number of iterations predicts overall behavior, but at the same time, the majority of decisions display some level of iteration. In our setting uniform accounting procedures enable higher levels of coordination and thus higher efficiency and social welfare.

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APPENDIX

Instructions

The Experiment

The participants in todays experiment will be randomly assigned into two-person groups. In addition to the group assignment each participant will also be randomly assigned to a specific **type** in the group, designated as **Person H** or **Person T**. There are three parts of the experiment and several periods in each part. Each period consists of one decision. In each period of a part you will be randomly assigned into a new group so that you will never be in a group with another participant more than one time within a part.

In all three parts of the experiment you and the other person in your group will make a choice that will in part determine your payoffs. The payoffs you earn depend upon:

- A coin flip (with an equal chance of coin landing heads or tails),
- The payoff table used (where there is an equal chance the payoff table will be A, B, or C),
- Your and the other persons choice (each person can decide in or out).

	Table A		Table B		Table C	
	Heads	Tails	Heads	Tails	Heads	Tails
Person H if both in	10	3.2	10	3	10	2
Person T if both in	3.2	10	3	10	2	10
Both Person H and Person T if either out	5	5	5	5	5	5

Each period we will ask you if you choose in or out.

Part I In part I of the experiment, you and the other person are told which payoff table is being used before you choose in or out.

Part II In part II of the experiment, in addition to knowing which payoff table is being used, there is 50% chance you will know whether the coin landed heads or tails before you choose in or out.

Part III In the last part of the experiment, there is 50% chance you will know whether the coin landed heads or tails before you choose in or out. Further, you will receive a separate clue about which payoff table is being used. Sometimes you will know precisely whether the Payoff Table is A or C. Other times you will know only that it is not A (so has to be B or C), or you will know it is not C (so has to be A or B).

At the end of the experiment we will pay you for three randomly selected periods, one from each part. On the white board are three pieces of paper. Behind each piece of paper is the number of a period you will be paid in. To further illustrate the experiment we describe a series of examples.

Part I - When Both Persons Do Not Know the Coin Flip

Each period you are asked to choose to be in or out. While you cannot know if the flip was heads or tails, you can determine the payoff on average. This requires you to guess what the other persons chose to do. Imagine you are Person T.

First, imagine the payoff table is A and the other person chooses out. There is 50% chance the coin is heads and your payoff is 5 and a 50% chance the coin is tails and your payoff is also 5. So on average your payoff is 50% *5 + 50% *5 = 5. Notice that this is the case whether you chose in or out.

Alternatively imagine the payoff table is A and the other person chooses in. If you decide out, your average payoff is 5 as above. But if you decide in, there is 5% chance the coin is heads and your payoff is 3.2 and a 50% chance the coin is tails and your payoff is 10. So on average your payoff is 5% *3.2 + 50% *10 = 6.6.

We want you to answer some questions regarding the experiment to be sure you understand what will follow. Please answer the following questions. We will review the answers in a few minutes.

Questions

	Table A	Table B	Table C
1. Imagine you are Person H, do not know the flip, and decide in. Imagine that Person T decides out. On average what is your payoff?			
2. Imagine you are Person H, do not know the flip, and decide in. Imagine that Person T decides in. On average what is your payoff?			
3. Imagine you are Person H, do not know the flip, and decide out. Imagine that Person T decides in. On average what is your payoff?			

Do you have questions before continuing? If so raise your hand and an experimenter will come answer your questions privately.

This part of the experiment will last 5 periods. You will be Person H or Person T for all of Part I. Each period you will be matched with a new person whom you have not been paired with before. You will be asked to choose in or out. When the experiment starts, you will see a screen like that shown below.

At the end of every period you know what the flip was, the other persons choice of in or out, and your payoff. Please denote your payoff on your Personal Payoff Sheet with the pencil provided. After you have done so, please click the button 'proceed'. *The experiment cannot continue until everyone has pressed the button.*

Do you have questions before Part I starts? If so raise your hand and an experimenter will come answer your questions privately.

Figure 1: Screen shot of Part I

Part II - You May or May Not Know the Coin-flip

Each period there is 50% chance you know the outcome of the coin-flip. There is also a 50% chance the other person in your group knows the coin flip. As such 25% of the time neither person knows the flip, 25% of the time both know the flip, 25% of the time you know the flip and the other does not, and 25% of the time you do not know the flip but the other does.

	Person T knows	Person T does not know
Person H knows	25%	25%
Person H does not know	25%	25%

When You Know the Coin Flip

Imagine you are Person T, you see the coin flip, and you know the payoff table is C. If the other person decides out, so it does not matter if you decide in or out, your payoff is 5.

However, if the other person chooses in, then your payoff depends upon your action. Imagine the coin flip was tails. If you chose in, your payoff is 10. If you chose out, your payoff is 5. Now imagine the flip was heads. If you chose in, your payoff is 2. If you chose out, your payoff is 5.

We want you to answer some questions regarding the experiment to be sure you understand what will follow. Please answer the following questions.

Questions

	Table A	Table B	Table C
4. Imagine you are Person T and chose out, what is your payoff?			
5. Imagine you are Person T, the coin is tails, and you and the other person decide in. How much more is your payoff than in question (4)?			
6. Imagine you are Person T, the coin is heads, and you and the other person decide in. How much smaller is your payoff than in question (4)?			

Do you have questions before continuing? If so raise your hand and an experimenter will come answer your questions privately.

When You Do Not Know the Coin Flip But the Other Person Does Know

You will not know what the other person will choose when you choose. The other person may choose in or out depending on the outcome of the coin flip. For example, imagine that Person T decides in when seeing tails, and out when seeing heads. Notice that from questions (4)-(6), this choice yields highest possible payoff to Person T.

Imagine you are Person H and the payoff table is A. What is the payoff, on average, if you decide in when Person T knows the flip? There is a 50% chance the coin is tails, and imagine that when Person T knows the coin is tails he chose in, so your payoff is 3.2. There is also a 50% chance the coin is heads, and imagine that when Person T knows the coin is heads he chose out, so your payoff is 5. So on average your payoff is 50% *3.2 + 50% *5 = 4.1.

Questions

	Table A	Table B	Table C
7. Imagine you are Person H and do not know the flip, but that Person T does. Imagine that Person T always chooses out. On average what is your payoff if you chose in?			
8. Imagine you are Person H and do not know the flip, but that Person T does Imagine that Person T always chooses in. On average what is your payoff if you chose in?			
9. Imagine you are Person H and do not know the flip, but that Person T does. Imagine that Person T chooses in when the flip is tails and chooses out when the flip is heads. On average what is your payoff if you chose in?			

Do you have questions before continuing? If so raise your hand and an experimenter will come answer your questions privately.

Putting It All Together

In the prior two examples we calculated average payoffs when the other person knew the coin flip and he did not. There is equal chance of both. Half the time the other person will not know the coin flip so the average payoffs depends upon whether the other person chooses in or out. We calculated these payoffs in questions (1) and (2). Half the time the other person will know the coin flip so the average payment depends upon whether the other person chooses out, always chooses in, or chooses based upon the outcome of flip. We calculated these payoffs in questions (7) - (9).

Questions

	Table A	Table B	Table C
10. Imagine you are Person H and do not know the coin flip. On average, what is your payoff when you choose in, imagining that Person T chooses out when he does not know the coin flip (as in question 1), but chooses in when he knew the flip is tails and chooses out when he knew the flip is heads (as in question 9)?			
11. Imagine you are Person H and do not know the coin flip. On average, what is your payoff when you choose in, imagining that Person T chooses in when he does not know the coin flip (as in question 2), but chooses in when he knew the flip is tails and chooses out when he knew the flip is heads (as in question 9)?			
12. Imagine you are Person H and do not know the coin flip. What is your payoff if you choose out?			

Do you have questions before continuing? If so raise your hand and an experimenter will come answer your questions privately.

This part of the experiment will last 10 periods. You will be Person H or Person T for all of Part II. Each period you will be matched with a new person whom you have not been paired with before. When the experiment starts, you will see a screen like that shown below.

At the end of every period you will told what the flip was, the other person's choice of in or out, and your payoff. Please denote your payoff on your Personal Payoff Sheet with the pencil provided. After you have done so, please click the button 'proceed'. The experiment cannot continue until everyone has pressed the button.

Do you have questions before Part II starts? If so raise your hand and an experimenter will come answer your questions privately.

Part III - You May or May Not Know the Coin-flip or Table

Clues About Which Payoff Table

Before the start of every period, each payoff table is equally likely to be used. At the start of each period, each person will receive a clue regarding which payoff table will be used for that period. If the

Figure 2: Screen shot of Part II

table is A, then Person H will know the table is A, but Person T will only know the table is either A or B. When the table is B, then Person H will know the table is either B or C, but Person T will know the table is either A or B. Last, when the table is C, then Person H will know the table is either B or C, but Person T will know the table is C. In summary, the clue depends upon the table being used:

If the Table is	Table A	Table B	Table C
Person H knows	*A*	*B,C*	*B,C*
Person T knows	*A,B*	*A,B*	*C*

Questions

13. If the payoff table is A, what clue will Person H and Person T receive?

14. If Person H sees the clue *B,C*, what payoff tables are possible?

15. If Person T sees the clue *A,B*, what clues might Person H receive?

Do you have questions before continuing? If so raise you hand and a experimenter will come answer your questions privately.

This part of the experiment will last 20 periods. You will be Person H or Person T for all of Part III. Each period you will be matched with a new person whom you have not been paired with before. When the experiment starts, you will see a screen like that shown below.

At the end of every period you will told what the flip was, the table used, the other person's choice of in or out, and your payoff. Please denote the payoff on your Personal Payoff Sheet with the pencil provided. After you have done so, please click the button 'proceed'. The experiment cannot continue until everyone has pressed the button.

Figure 3: Screen shot of Part III

Personal Payoff Sheet

Period	Payoff	Period	Payoff
Part I		*Part III*	
1		1	
2		2	
3		3	
4		4	
5		5	
Part II		6	
1		7	
2		8	
3		9	
4		10	
5		11	
6		12	
7		13	
8		14	
9		15	
10		16	
		17	
		18	
		19	
		20	

Overheads

Introduction

This is an experiment in the economics of decision-making. Various research agencies have provided funds for this research. The currency used in the experiment is US dollars. At the end of the experiment your earnings will be paid to you in private and in cash.

It is very important that you remain silent and do not look at other's work. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you. If you talk, laugh, exclaim out loud, etc… you will be asked to leave and you will not be paid.

We expect, and appreciate, you adhering to these policies.

(a) Slide 1

	Table A		Table B		Table C	
	Heads	Tails	Heads	Tails	Heads	Tails
Person H if both in	10	3.2	10	3	10	2
Person T if both in	3.2	10	3	10	2	10
Both Persons if either out	5	5	5	5	5	5

	Table A	Table B	Table C
1. Imagine you are Person H, do not know the flip, and decide in. Imagine that Person T decides out. On average what is your payoff?	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5
2. Imagine you are Person H, do not know the flip, and decide in. Imagine that Person T decides in. On average what is your payoff?	50% of $10 + 50% of $3.2 = $6.6	50% of $10 + 50% of $3 = $6.5	50% of $10 + 50% of $2 = $6
3. Imagine you are Person H, do not know the flip, and decide out. Imagine that Person T decides in. On average what is your payoff?	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5

(b) Slide 2

Part I

- Make your choice of in or out each period
- Denote your payoff on your sheet and press `proceed'

(c) Slide 3

	Table A		Table B		Table C	
	Heads	Tails	Heads	Tails	Heads	Tails
Person H if both in	10	3.2	10	3	10	2
Person T if both in	3.2	10	3	10	2	10
Both Persons if either out	5	5	5	5	5	5

	Table A	Table B	Table C
4. Imagine you are Person T and chose out, what is your payoff?	$5	$5	$5
5. Imagine you are Person T, the coin is tails, and you and the other person decide in. How much more is your payoff than in question (4)?	$10 - $5 = $5	$10 - $5 = $5	$10 - $5 = $5
6. Imagine you are Person T, the coin is heads, and you and the other person decide in. How much smaller is your payoff than in question (4)?	$3.2 - $5 = -$1.8	$3 - $5 = -$2	$2 - $5 = -$3

(d) Slide 4

Figure 4: Slides 1through 4

	Table A		Table B		Table C	
	Heads	Tails	Heads	Tails	Heads	Tails
Person H if both in	10	3.2	10	3	10	2
Person T if both in	3.2	10	3	10	2	10
Both Persons if either out	5	5	5	5	5	5

	Table A	Table B	Table C
7. Imagine you are Person H and do not know the flip, but that Person T does. Imagine that Person T always chooses out. On average what is your payoff if you chose in?	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5	50% of $5 + 50% of $5 = $5
8. Imagine you are Person H and do not know the flip, but that Person T does. Imagine that Person T always chooses in. On average what is your payoff if you chose in?	50% of $10 + 50% of $3.2 = $6.6	50% of $10 + 50% of $3 = $6.5	50% of $10 + 50% of $2 = $6
9. Imagine you are Person H and do not know the flip, but that Person T does. Imagine that Person T chooses in when the flip is tails and chooses out when the flip is heads. On average what is your payoff if you chose in?	50% of $5 + 50% of $3.2 = $4.1	50% of $5 + 50% of $3 = $4	50% of $5 + 50% of $2 = $3.5

(a) Slide 5

	Table A		Table B		Table C	
	Heads	Tails	Heads	Tails	Heads	Tails
Person H if both in	10	3.2	10	3	10	2
Person T if both in	3.2	10	3	10	2	10
Both Persons if either out	5	5	5	5	5	5

	Table A	Table B	Table C
10. Imagine you are Person H and do not know the coin flip. On average, your payoff when you choose in imagining that Person T chooses out when he does not know the coin flip (as in #1), but chooses in when he knew the flip is tails and chooses out when he knew the flip is heads (as in #9)?	50% of $5 + 50% of $4.1 = $4.55	50% of $5 + 50% of $4 = $4.5	50% of $5 + 50% of $3.5 = $4.25
11. Imagine you are Person H and do not know the coin flip. On average, your payoff when you choose in imagining that Person T chooses in when he does not know the coin flip (as in #2), but chooses in when he knew the flip is tails and chooses out when he knew the flip is heads (as in #9)?	50% of $6.6+ 50% of $4.1 = $5.35	50% of $6.5 + 50% of $4 = $5.25	50% of $6 + 50% of $3.5 = $4.75
12. Imagine you are Person H and do not know the coin flip. What is your payoff if you choose out?	$5	$5	$5

(b) Slide 6

=:

Part II

- Make your choice of in or out each period
- Denote your payoff on your sheet and press `proceed'

(c) Slide 7

If Table is:	Table A	Table B	Table C
Person H know	*A*	*B,C*	*B,C*
Person T knows	*A,B*	*A,B*	*C*

13. If the payoff table is A, what clue will Person H and Person T receive?
    Person H will see the clue `*A*', and know the table is A.
    Person T will see the clue `*A,B*' and know the table is A or B.

14. If Person H sees the clue `*B,C*', what payoff tables are possible?
    It is equally possible the table is B or C.

15. If Person T sees the clue `*A,B*', what clues might Person H receive?
    Person T knows the table A or B is equally possible. If the table is A, then Person H sees the clue `*A*' and knows the table is A. If the Table is B, then Person H sees the clue `*B,C*' and knows the table B or C is equally possible.

(d) Slide 8

Figure 5: Slides 5 through 8

Part III

- Make your choice of in or out each period
- Denote your payoff on your sheet and press `proceed'

(a) Slide 9

Figure 6: Slide 9

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