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Magic Mirror on the Wall, Who Is the Smartest One of All?

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Abstract

In the leading model of bounded rationality in games, each player best-responds to their belief that the other players reason to some finite level. This paper investigates a novel behavior that could reveal if the player's belief lies outside the iterative reasoning model. This encompasses a situation where a player believes that their opponent can reason to a higher level than they do. We propose an identification strategy for such behavior, and evaluate it experimentally.

JEL Classification: C72, C92, D91.

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1 Introduction

The leading models of bounded rationality in games, as level-k and cognitive hierarchy, are iterative 'top-down' models of reasoning: a player with a finite level of reasoning believes others can reason to a strictly lower level and best responds to that belief. This restriction is critical in how the model is operationalized – it ensures that a player requires only a finite number of steps of reasoning to optimally respond to their belief. Importantly, a player who can do k steps of iterated reasoning (i.e., k steps of "I think, you think, I think, ...") can only model others as being capable of doing at most $k-1$ steps of iterated reasoning.[1] This ability to model the behavior of others is a key assumption in these models. This, however, leads to a natural and interesting question: what happens if a player believes others may reason to a higher level than they do? For example, how will a player respond if they believe that their opponent is more sophisticated than them?

We propose a behavior that reveals to an analyst that Ann, who is playing a game with Bob, is reasoning about Bob's behavior outside of the iterative 'top-down' model of reasoning. We then implement a novel experimental design that allows us to identify this behavior experimentally and evaluate its pervasiveness in the population. We also investigate whether Ann's behavior depends on Bob's observed characteristics that may be correlated with his sophistication.

Recall that in iterative 'top-down' reasoning models players' beliefs are anchored in the behavior of a specific non-rational L0 type, and types are heterogeneous in their level of reasoning. The L1 type performs one level of reasoning and best responds to the L0 type. In turn, the L2 type performs two levels of reasoning and best responds to some belief over L0 and L1 types, and so on with the Lk type best responding to some belief over L0, ..., L$(k-1)$ types. But how would Ann behave if she believed that Bob may be more sophisticated than her? Within the prism of the iterative 'top-down' model of reasoning, it implies that although she would believe that Bob is rational (since she is rational), she will not be able to model his behavior. Still, Ann's behavior would be consistent with 2-rationalizability, which allows all actions that are consistent with rationality and belief

[1] Any player who can reason about their opponent doing m steps must necessarily be able to do at least $m+1$ steps of reasoning themselves.

in others' rationality.

We design two diagnostic games that allow the analyst to identify this behavior. The first is a *dominance-solvable* game ("*DS*") in which Bob has a dominant strategy. This game permits the analyst to identify if Ann "believes that Bob is rational." Using the second game – which we refer to as the *iterative-reasoning* game ("*IR*") – the iterative 'top-down' model of reasoning *together* with belief in rationality makes the sharp prediction that Ann would value *IR* strictly more than *DS*. However, if Ann only believes that Bob is rational, but her reasoning process is not captured by the model (but is consistent with 2-rationalizability), she may value *DS* more than *IR*. Importantly, these inferences do not depend on Ann's risk or social preferences. This results in a conservative estimate of the proportion of participants who are inconsistent with the iterative 'top-down' model of reasoning.

Our identification strategy uses a more general anchor than the standard L0 type. We consider a rational, but non-strategic, L1 type to anchor the iterative 'top-down' model of reasoning. This player concentrates only on their own payoff, without making any strategic considerations. This increases the set of possible actions that are consistent with the L1 type, includes the "standard" L1 type (that best-responds to uniform play of the L0 type), and accommodates other focal behaviors.

Our test to identify if Ann's behavior is consistent with the prediction of a generalized iterative reasoning model may be extended to the case where Ann may not believe that Bob is rational, if the form of irrationality considered is a random choice of action by Bob (a uniform play by the L0 type, as is typical in many models). In this case, the ranking of *DS* and *IR* games is unaltered.

The novel experimental design we employ has four components. The first are the two diagnostic games: *IR* and *DS*. The second are two control games that rule out other confounding factors that can contribute to preferring *DS* over *IR*. Third, we investigate whether participants' reasoning process (iterative 'top-down' models of reasoning or 2-rationalizability) depends on their opponents' observed characteristics. To achieve this, we exogenously vary the participants' opponent type: they face either a Ph.D. student in Economics or an undergraduate student of any discipline. The fourth component is a preference-elicitation mechanism over the games. Rather than directly eliciting a choice between the two diagnostic games, participants first choose their actions in each game (and against each potential opponent), and then we elicit their respective *valuations*.[2,3] This allows the analyst to infer both participants' preferences between the two diagnostic games and participants' (confidence in their) beliefs about their opponents' behavior. Moreover, we can exploit the valuation data to isolate those participants who believe that their opponent is rational, as the predictions in our games are the starkest for this subset of participants.

We find that approximately half of the choices made by participants are inconsistent with the iterative 'top-down' model of reasoning, especially for those who believe that their opponents are rational – where the model's prediction are inconsistent with 64% of choices. Moreover, roughly 72% of participants exhibit a stable model of reasoning irrespective of the opponent's characteristics. Among the remainder, the results are split: roughly 12% make choices consistent with iterative 'top-down' reasoning against an undergraduate but not against a Ph.D. student, while roughly 16% exhibit the opposite pattern.

Pioneering scholarly contributions in the iterative 'top-down' reasoning literature include Nagel (1995), Stahl and Wilson (1994; 1995), Costa-Gomes, Crawford, and Broseta (2001), Camerer, Ho, and Chong (2004), and Costa-Gomes and Crawford (2006). For a survey of this literature, see Crawford, Costa-Gomes, and Iriberri (2013). By construction, these papers do not consider the questions we investigate here.

Arad and Rubinstein (2012a) and Kneeland (2015) developed novel experimental designs to identify levels of reasoning in an iterative model. Moreover, in the former design, the authors explicitly asked participants about their thought process when making their choices to gain a better understanding of participants' behavior. Arad (2012) proposed a new allocation game to study iterative reasoning and the performance of the level-k model, and showed that level-k thinking accounts for a smaller number of

[2]Heinemann, Nagel, and Ockenfels (2009), Coricelli and Nagel (2009), and Nagel, Brovelli, Heinemann, and Coricelli (2018) use a related strategy to elicit certainty equivalents in coordination games, however, in their context, the elicited valuations affect both the payoffs in the games and their value.

[3]To allow participants to recall their reasoning in the valuation stage, we encouraged them to write it down in a text box. We use this information to gather further qualitative evidence on their choice process.

choices made by participants than in other experiments. Further, Arad and Rubinstein (2012b) studied how participants reason iteratively on few dimensions, or features, in an allocation game (Colonel Blotto). Subsequently, Arad and Penczynski (2024) studied a few other environments of resource allocation with communication between participants, and confirmed that many participants engage, in fact, in multi-dimensional iterative reasoning.

Also related to our work is Agranov, Potamites, Schotter, and Tergiman (2012) who manipulated participants' beliefs about the cognitive levels of the players they are playing against; and Alaoui and Penta (2016) who studied a model of iterative reasoning where player's depth of reasoning is endogenously determined. More recently, Alaoui, Janezic, and Penta (2020) further developed an experimental design strategy to distinguish level-k behavior driven by participants' beliefs from their cognitive bounds, and found an interaction between participants' own cognitive bound and reasoning about the opponent's reasoning process. Gill and Prowse (2016) investigated how cognitive ability and character skills influence the evolution of play in repeated strategic interactions and estimate a structural model of learning based on level-k reasoning.

The paper proceeds as follows. Section 2 introduces the design and the set of diagnostic games as well as the two control games. It builds the theoretical background necessary for our experiment – discussed in Section 3 – and the identification strategy used in the analysis conducted in Section 4. Section 5 offers a more formal analysis. Finally, Section 6 concludes with a brief discussion of the results. The Appendix contains further analyses, details on participants' individual behavior, the experimental instructions, and screenshots of the experimental interface.

2 The Design

We employ both an iterative 'top-down' model of reasoning, based on level-k and cognitive hierarchy, and the solution concept of 2-rationalizability to guide our experimental design, identification strategy, and analysis. We provide a brief description of the model and the concept here and engage in a discussion on how these interact with our setup in the next subsection. A more formal and general analysis is provided in Section 5.

2.1 Building Intuition: Model and Solution Concept

Iterative 'top-down' model of reasoning In this model, players anchor their beliefs in a naïve model of others' behavior and adjust their beliefs by a finite number of iterated best-responses. To date, these models have been anchored in an "irrational" (L0) player-type who either plays each strategy with equal chance or chooses some salient action, depending on the application. Players of level-k ($k > 0$) are rational in the sense of best-responding to their beliefs, but players of different k differ in their beliefs over the action(s) played by their opponents.

We consider a more general model of reasoning, with a different cognitive interpretation of L1. Our model is anchored in the behavior of a non-strategic L1 type who makes decisions based solely on their own-payoff information. To build intuition for this type, consider a decision maker who chooses an action to allow for the possibility of achieving the highest possible payoff in a given game, or, alternatively, chooses an action to maximize their average payoff. In both cases, the decision maker is non-strategic as they *never* form beliefs about their opponents' behavior. Nevertheless, their behavior may very well reflect their *own* payoff information and primary focus therein. If one views their choice of action independently of the strategic environment, L1-choices could be viewed as "rational." Since there are many possible criteria a decision maker could employ to determine their action choice, selecting an action in order to ensure the maximum or the average payoff being just two examples, we will use a partial-order approach to formalize this behavior.[4] Effectively, as long as an action is optimal under some own-payoff criteria, we would allow our non-strategic type (L1) to play it.[5]

Since we want to capture all reasonable own-payoff criteria that our decision maker could use, the only assumptions we impose are that the criteria must be non-strategic in nature, and respect the notion that higher payoffs are preferred, i.e., strict monotonicity.

[4]Text data collected indicates that "average" and "maximum" payoff are terms with relatively high Term Frequency-Inverse Document Frequency scores, a numerical statistic that is intended to reflect how important a word is to a comment in a collection.

[5]Coricelli and Nagel (2009) as well as Nagel, Brovelli, Heinemann, and Coricelli (2018) found that players who do not engage in high-level strategic thinking have similar brain activation to decision makers who make risky decisions in non-strategic environments, providing physical support to our typology of L1 as rational but non-strategic.

Consider two payoff vectors $\boldsymbol{x} = (x_1, \ldots, x_n)$ and $\boldsymbol{y} = (y_1, \ldots, y_n)$ such that $\boldsymbol{x}$ is greater than $\boldsymbol{y}$; that is, $x_i \geq y_i$ for all $i \in \{1, \ldots, n\}$ with strict inequality for at least one i. In this case, it seems clear that $\boldsymbol{x}$ should be preferred to $\boldsymbol{y}$ if our decision maker prefers higher payoffs. Further, since we are trying to capture the behavior of a non-strategic type, we should ignore any information contained in the ordering of the payoff vectors, as any concerns for ordering would reflect strategic considerations. Thus, we propose the following partial order $\succ_1$: $\boldsymbol{x}$ is preferred to $\boldsymbol{y}$ if there exists a permutation of $\boldsymbol{x}$ that is greater than $\boldsymbol{y}$. We then allow our non-strategic type to play any action that is undominated according to $\succ_1$.

Notice that the binary relation $\succ_1$ is not, in general, complete. For example, consider two payoff vectors $\boldsymbol{a} = (20, 0, 10)$ and $\boldsymbol{b} = (12, 8, 16)$. Here, neither $\boldsymbol{a}$ is preferred to $\boldsymbol{b}$ nor $\boldsymbol{b}$ is preferred to $\boldsymbol{a}$. This reflects the fact that strategy a might be optimal under one criteria (e.g., it has the highest payoff), yet strategy b might be optimal under another criteria (e.g., it has the highest arithmetic mean).[6] Alternatively, consider the two payoff vectors $\boldsymbol{c} = (20, 9, 14)$ and $\boldsymbol{d} = (12, 8, 16)$ that are comparable according to $\succ_1$; that is, $\boldsymbol{c}$ is preferred to $\boldsymbol{d}$.

In general, the partial order $\succ_1$ incorporates many potential own-payoff heuristics that seem both intuitive and reasonable. The set of actions an L1 type will choose from – the actions that are undominated through $\succ_1$ – must always contain an action that leads to the highest payoff, an action with the highest minimum payoff, as well as the action with the highest arithmetic mean.[7] Further, notice that the action with the highest arithmetic mean is equivalent to the action that maximizes a player's expected payoffs under the belief that others' play each action with equal probability. As such, our approach nests the standard level-k and cognitive hierarchy models as a special case as they typically assume that the L0 type plays uniformly random.[8]

The behavior of all higher types is then anchored in the behavior of the L1 type. A

[6]Note that probabilistic beliefs on the actions chosen by others, as is assumed in the literature to date, induces a complete ranking on the player's actions.

[7]All three of these own-payoff heuristics were shown to have explanatory value as part of a focal L0 type in Wright and Leyton-Brown (2014).

[8]Moreover, our approach also nests many special cases of non-strategic behavior proposed in the level-k literature to express notions of 'focal points' such as playing 20 in Arad and Rubinstein (2012a)'s 11-20 game. Hence, in the current setup, the L1 type will play that strategy but beyond relabelling of levels – nothing will change.

level-2 (L2) type assumes that all other players are the L1 type and chooses accordingly a strategy that maximizes their expected utility under some probability distribution over L1 strategies.[9] A level-3 (L3) type assumes that all other players are either L1 or L2 types and chooses a strategy that maximizes their expected utility under some probability distribution over both L1 and L2 strategies. This process continues for higher-level types *ad infinitum* and, more generally, with Lk types choosing a strategy that maximizes expected utility given some belief over the play of strictly lower types.

2-rationalizability This solution concept can be intuitively understood via its relationship with the notion of rationality and reasoning about rationality. A player is *rational* if they play a best-response – maximize expected utility – given their subjective belief about how the game is played. A player *believes in rationality* if they believe others are rational. That is, if they believe others are playing a best-response given their subjective beliefs about how the game is played. The solution concept of 2-rationalizable strategies incorporates both the assumption of rationality and belief in rationality.[10] The 2-rationalizable set is found by first finding the set of 1-rationalizable actions for each player. These are the actions played by a rational player: any action that maximizes a player's expected utility given some utility function and some belief about the play of others. The 2-rationalizable set comprises of all actions played by a rational player who believes others play actions in the 1-rationalizable set: any action that maximizes a player's expected utility given some utility function and some belief over the 1-rationalizable play of others. This solution concept is formally defined in Section 5.

Iterative 'top-down' model of reasoning and 2-rationalizability Below we highlight the relationship between the model and the solution concept introduced above. To start, notice that the iterative 'top-down' model of reasoning implicitly imposes assumptions about how types reason about rationality. We highlight three facts. First, all types with $k \geq 2$ are rational as they best respond to their beliefs about others' play. Second, even

[9]Most iterative reasoning applications assume that players are risk-neutral and hence maximize expected payoffs. Importantly, we allow instead for *any* expected-utility preferences.

[10]The relationship between reasoning about rationality and k-rationalizable strategies follows from standard results, e.g., Bernheim (1984), Brandenburger and Dekel (1987), and Tan and da Costa Werlang (1988) among others.

though the L1 type cannot be considered rational in the game-theoretic sense as they are non-strategic and do not form beliefs about others' strategies, they nevertheless do play actions that are consistent with rationality. That is, any action that is undominated by $\succ_1$ is also a best response to some belief about others' play under some expected utility preferences. Third, the behavior of any Lk type with $k \geq 2$ is consistent with the assumption of belief in rationality. This result follows naturally since any such type believes that the behavior of others is, in fact, consistent with rationality.[11]

Further notice that the iterative 'top-down' model of reasoning imposes an additional assumption *beyond* reasoning about rationality. It imposes the assumption that beliefs are anchored in non-strategic play. Put differently, the L2 type cannot hold arbitrary beliefs about the play of the game. Rather, they must hold beliefs consistent with L1 play. While we use a generous definition of L1 play here to allow for a broad notion of non-strategic behavior, in many games this set of actions may still be small, even a singleton set. As such, one can interpret the L2 type here as a type that can model the play of others. Naturally, the same holds true similarly for higher levels. The L3 type that believes others are either L1 or L2 types cannot hold arbitrary beliefs about others' rational play, but rather must hold beliefs that are consistent with L1 or L2 play, and so on. Therefore, one can interpret the iterative 'top-down' model of reasoning as assuming that players in fact *can* model the play of others.

This is in sharp contrast to the concept of 2-rationalizability. This approach is grounded in the assumption that players can hold *any* beliefs about the play of others, and only requires those beliefs to be consistent with the assumption that others are rational. The assumption of rationality is less stringent than that imposed by L1 play. In this sense, 2-rationalizability can be interpreted as relaxing the assumption that players possess the ability to model the play of others, in contrast to iterative 'top-down' models of reasoning.

Key design assumptions In what follows, we will assume that players are strategic. For the iterative 'top-down' model of reasoning, this means that we will focus on the behavior of Lk types for $k \geq 2$ and not the non-strategic L1 players. This restriction is motivated by

[11] Notice that the model can easily be generalized if one wishes to allow for uncertainty over others' rationality by simply introducing an additional non-strategic type that randomizes uniformly over the set of actions. We shall discuss this in more detail in Section 5.

our main research question – whether players can model the play of others. This question is not applicable to non-strategic players who, by definition, do not reason about the play of others. Moreover, players that are rational and believe in rationality will play a key role in our design. As we assume that players themselves are rational since our focus is on types with $k \geq 2$, and investigate if they believe that others may be more sophisticated than them, it is natural to at least require them to believe that others are rational – even if they cannot model their behavior. As such, our design will make stark predictions for those participants who are rational and believe in rationality of others.

2.2 The Games

In order to identify behavior that reflects the player's belief that other players may be rational, but their behavior cannot be modeled, we judiciously designed two diagnostic games. One where the ability to model the opponents' behavior is important for how the participant values the game, and the other where such an ability is less important.

The strategic form of these games is depicted in Figure 1.

IR

Player 1 \ Player 2	*A*	*B*	*C*	*D*
a	12 0	14 12	12 13	8 11
b	0 4	0 14	16 0	4 6
c	16 10	5 0	0 11	0 12
d	7 13	11 8	10 6	12 0

DS

Player 1 \ Player 2	*A*	*B*	*C*
a	6 0	3 12	4 11
b	15 5	8 13	13 0
c	10 12	9 8	9 0

Figure 1: The Iterative-Reasoning Game (IR) and the Dominance-Solvable Game (DS). In every cell, Player 1's payoff is displayed in the lower left, and the payoff to Player 2 is on the upper right.

The iterative-reasoning game "IR" The iterative 'top-down' model of reasoning predicts that Player 1 chooses an action in $\{a, b\}$ and Player 2 chooses an action in $\{B, C\}$. To gain intuition, consider first the simple case where for all $k \geq 2$, Lk type believes others are L$(k-1)$. Recall that Player 1 of type L1 considers their own payoffs but is non-strategic.

This player chooses between the payoff vectors $\boldsymbol{a} = (0, 12, 13, 11)$, $\boldsymbol{b} = (4, 14, 0, 6)$, $\boldsymbol{c} = (10, 0, 11, 12)$, and $\boldsymbol{d} = (13, 8, 6, 0)$. Thus, the L1 type plays actions a or b, as actions c and d induce payoffs that are dominated by a permutation of a's payoffs. Either action a or b could be a natural focal action: action a is associated with the highest arithmetic mean while action b is associated with the highest payoff. Similarly, Player 2 of level-1 plays action C. This action dominates all other actions according to $\succ_1$: it contains the highest arithmetic mean and highest payoff, and is therefore a natural focal action.

Any new iteration ("the next level") is a best response to the opponent's behavior. For example, the L2 type of Player 1 plays a and the L2 type of Player 2 plays B or C. Then, the L3 type of Player 1 plays a or b and the L3 type of Player 2 plays B. This process continues *ad infinitum*. Player 1's best responses are always in $\{a, b\}$ and Player 2's best responses are always in $\{B, C\}$.

The iterative 'top-down' model of reasoning is a more general model than this simple model. It explicitly allows players to hold arbitrary risk preferences within expected utility. Moreover, players may hold *any* belief about the expected-utility preferences of other players as well as over lower types L1, ..., L($k - 1$) of other players. Even with these generalizations it is still true that players will play actions in $\{a, b\}$ and in $\{B, C\}$. For details, see Section 5. As all strategic types (Lk where $k \geq 2$, i.e., those types that are rational and believe in rationality) of Player 1 in the generalized iterative 'top-down' model of reasoning play an action in $\{a, b\}$ and expect Player 2 to choose an action in $\{B, C\}$, their expected payoff must be *strictly greater than 12*.[12]

The solution concept of 2-rationalizability does not restrict Player 1 to value the game IR above 12. First, note that all actions of Player 2 in IR are 1-rationalizable, since for any of their actions there exists some belief about Player 1's play such that the action is a best response.[13] Second, if Player 1 believes that Player 2 is rational, they must believe that Player 2 plays a 1-rationalizable action. Such a player may reasonably hold *any* belief over the distribution of $\{A, B, C, D\}$. For example, Player 1 who believes that Player 2 is

[12] Player 1 may value IR exactly at 12. This, however, can only occur with an extreme form of ambiguity aversion coupled with the player's set of priors including all degenerate priors. We elaborate on this point in Section 5 and document that it is not an empirical concern.

[13] Beyond B and C discussed above, A is a best-response to Player 1 playing c and D is a best response to Player 1 playing d.

rational and assigns equal probability to all actions of Player 2 will choose the action a, and their expected payoff will be less than 12.

The dominance-solvable game "DS" The second diagnostic game is dominance-solvable in a single iteration, as A is a strictly dominant strategy for Player 2. It obviously dominates B and C according to $\succ_1$, as strict domination does not require strategic reasoning. That is, the L1 type and any higher type of Player 2 will play action A, which is a natural focal point for Player 2.

Now consider Player 1's behavior. If they are of level-1, they choose between payoff vectors $\boldsymbol{a} = (0, 12, 11)$, $\boldsymbol{b} = (5, 13, 0)$, and $\boldsymbol{c} = (12, 8, 0)$. Notice that a permutation of $\boldsymbol{a}$ dominates $\boldsymbol{c}$, thus $\boldsymbol{a} \succ_1 \boldsymbol{c}$. However, neither $\boldsymbol{a} \succ_1 \boldsymbol{b}$ nor $\boldsymbol{b} \succ_1 \boldsymbol{a}$ is true. Either action a or b could be natural focal points for a Player 1 of type L1. Action a is associated with the highest arithmetic mean, while action b is associated with the highest payoff. Since Player 2 of type Lk ($k \geq 1$) plays A, it must be that any Player 1 of type Lk ($k \geq 2$), best responds by playing c. From the argument above, it follows that the expected payoff of a rational Player 1 who believes that Player 2 is rational (all types with $k \geq 2$) equals 12.

In contrast to the *IR* game, the solution concept of 2-rationalizability *does restrict* the valuation of the *DS* game. Any player who is rational and believes in rationality must still behave exactly the same as in the iterative 'top-down' model of reasoning. Thus, any such player chooses action c and has an expected payoff of *exactly 12* irrespective of being an iterative-reasoner or not.

Player 1's preferences over IR and DS All players who are rational and believe that their opponents are rational prefer playing *IR* over *DS* in the iterative 'top-down' model of reasoning. The expected payoff of 12 in *DS* is strictly lower than the expected payoff in *IR*. As a consequence, a 'top-down' iterative-reasoner should strictly prefer to play *IR* over *DS*. However, a player who is rational and believes in rationality, yet falls outside the iterative 'top-down' model of reasoning, may very well prefer to play *DS* over *IR*. This behavioral difference is the core of our identification strategy.

Up to this point, we have constrained beliefs of rationality somewhat tightly for our strategic types (types with $k \geq 2$). In our iterative 'top-down' model of reasoning, there is no way for such a type to be uncertain about rationality; that is, there is no sense in which a type could believe others are playing actions that are not consistent with rationality. However, we can easily account for that by introducing a second non-strategic type that plays randomly, which we refer to as "level-0" ("L0 type"). We now simply permit a strategic Lk type to hold *any* beliefs over lower types $\{L0, L1, \dots, L(k-1)\}$. Importantly, relaxing beliefs about rationality in such way does not alter the ranking of IR over DS. Put differently, any such strategic 'top-down' iterative-reasoner should still strictly prefer to play IR over DS.[14]

Lastly, the comparative statics also hold in Nash equilibrium.[15] IR has a Nash equilibrium in mixed strategies where the equilibrium actions coincide with the actions prescribed by the iterative 'top-down' model of reasoning. The equilibrium payoff is also strictly greater than 12 and strictly dominates the equilibrium payoff in DS, which is exactly 12. The Nash equilibrium of IR is $\big((8/9, 1/9, 0, 0), (0, 13/15, 2/15, 0)\big)$ with payoffs $\big(182/15, 112/9\big)$. DS has a Nash equilibrium in pure strategies: $\big((0, 0, 1), (1, 0, 0)\big)$ with payoffs $(12, 10)$.

The control games The two control games are designed to rule out other confounding factors that can potentially contribute to preferring DS over IR. Their strategic form is depicted in Figure 2. Notice that Player 1's potential payoffs in the two control games are identical to their payoffs in DS, so the only difference between the three games arises from varying Player 2's payoffs.

MS

Player 1 \ Player 2	A	B	C
a	6 0	10 12	8 11
b	16 5	3 13	10 0
c	9 12	8 8	10 0

NE

Player 1 \ Player 2	A	B	C
a	13 0	14 12	6 11
b	5 5	3 13	16 0
c	10 12	9 8	9 0

Figure 2: The controls – The Mixed-Strategy Game (MS) and the Nash-Equilibrium Game (NE)

[14] We elaborate on this in Section 5, where we present a more formal analysis.

[15] This is also true in logit Quantal Response Equilibrium. Details are available upon request.

Our controls serve two purposes. First, we want to control for the size of the game; that is, whether players prefer any smaller game over *IR per se*. To do so, we introduce *MS*, which is a 3×3 bimatrix game with the iterative 'top-down' model of reasoning prescribing to Player 1 actions $\in \{a, b, c\}$. *MS* has a Nash equilibrium in mixed strategies similar to *IR* where players mix over actions $\in \{a, b\}$ (but not c), and Player 1's equilibrium payoff is strictly lower than the equilibrium payoff in *IR*.[16]

Second, we want to control for the fact that *DS* has a unique Nash equilibrium in pure strategies. Thus, we consider *NE* – a game with a unique Nash equilibrium in pure strategies. In contrast to *DS*, however, this game is not dominance-solvable. Here too, the iterative 'top-down' model of reasoning prescribes player's action $\in \{a, b, c\}$. Once again, Player 1's equilibrium payoff in *NE* is strictly lower than the equilibrium payoff in *IR*. The Nash equilibrium in *NE* is $\big((0, 0, 1), (1, 0, 0)\big)$ with equilibrium payoffs $(12, 10)$, which coincide with the equilibrium payoffs in *DS*.

As we are solely interested in participants' behavior in the role of Player 1, all three 3×3 games (*DS*, *MS*, and *NE*, respectively) are chosen to share common features. As noted above, all payoffs for Player 1 are kept constant across these games to improve control and ease of comparison. We only altered the payoffs associated with actions $\in \{A, B, C\}$ for Player 2. Moreover, notice that in the control games, like the *IR* game, all actions are iteratively undominated. Thus, *DS* stands alone as being the unique game where reasoning about rationality alone is enough to predict the opponent's play.

3 The Experiment

3.1 Implementation

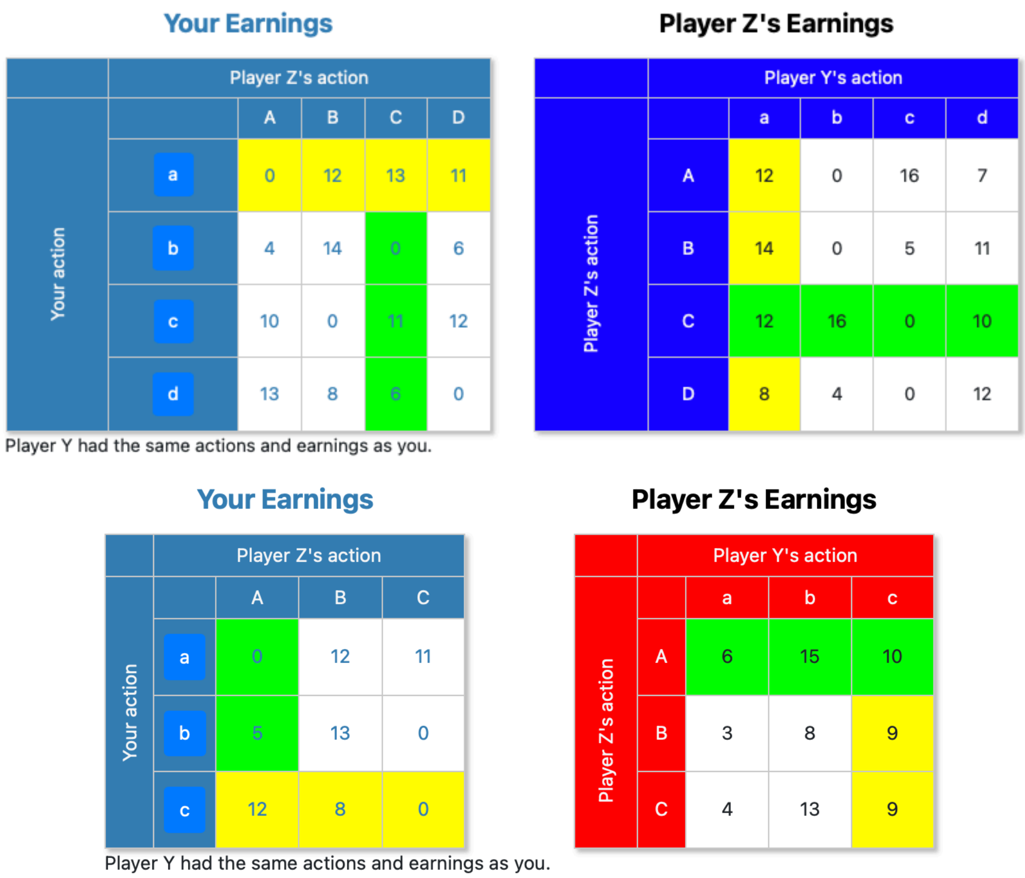
We divided the experiment into two parts. In each part, participants faced four decision-making problems in random order. We told participants that they would be randomly matched with another participant, who already made their choices in a previous auxiliary session. The purpose of this design feature was to collect all data in an individual decision-making setting, to ameliorate any form of social preferences when choosing

[16] The Nash equilibrium in *MS* is $\big((7/9, 2/9, 0), (0, 11/12, 1/12)\big)$ with payoffs $\big(143/12, 76/9\big)$.

actions and participants engaging in forward-induction considerations.

We told participants that this other participant, whom we called "Player Z," is either an undergraduate student from any year or discipline at the University of Toronto or a Ph.D. student in Economics who took several advanced courses that are highly relevant for this experiment. Participants would not learn their opponent type until the conclusion of the experiment. Therefore, participants made always two choices: one if Player Z was an undergraduate student from any year or discipline and another if they were a Ph.D. student in Economics.

Figure 3 visualizes the implementation of the two diagnostic games.



Your Earnings

Your action \ Player Z's action	A	B	C	D
a	0	12	13	11
b	4	14	0	6
c	10	0	11	12
d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action \ Player Y's action	a	b	c	d
A	12	0	16	7
B	14	0	5	11
C	12	16	0	10
D	8	4	0	12

Your Earnings

Your action \ Player Z's action	A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action \ Player Y's action	a	b	c
A	6	15	10
B	3	8	9
C	4	13	9

Figure 3: Game Implementation – *IR* (top) and *DS* (bottom)

The matrices on the left represent participants' payoffs in *IR* (top) and *DS* (bottom). The matrices on the right represent Player Z's payoffs in *IR* and *DS*, respectively. The opponent type was visualized via color (red = undergraduate and blue = Ph.D. student).

Our experimental implementation of the games makes it particularly salient for participants that Player Z has a strictly dominant strategy in DS. Moreover, in IR, it highlights the attractiveness of action C for the L1 type of Player Z, even though it is more nuanced compared to DS. As this type is non-strategic and does not take the other player's incentives into account, visualizing each player's payoffs in a separate matrix directs attention to the sequence of numbers or single entry that is the highest. Put differently, both our design and implementation make natural focal points for a non-strategic player in both games particularly salient.

To improve participants' experience and to assist in selecting an action, we implemented a highlighting tool that used two colors: yellow and light green. When a participant moved their mouse over a row in their matrix ("Your Earnings"), the action was highlighted in yellow color in both matrices: a row in their matrix, and a column in Player Z's matrix ("Player Z's Earnings"). By left clicking the mouse over a row it remained highlighted, and participants could unhighlight it by clicking their mouse again or clicking another row. Similarly, when participants moved their mouse over a row that corresponds to an action of Player Z in "Player Z's Earnings," the row was highlighted in light green and the corresponding column was highlighted in light green in "Your Earnings." Clicking the mouse over the row kept it highlighted, and clicking it again (or clicking another row) unhighlighted it.

We further told participants that Player Z participated in a previous auxiliary experimental session in which they were matched with another participant, called "Player Y," who participated in the same session and played their role. When Player Z was an undergraduate student from any year or discipline, so was Player Y; and when Player Z was a Ph.D. student in Economics, so was Player Y. We used Player Z's decisions from the auxiliary sessions to determine participants' earnings in the main experiment.

In addition, we gave participants the opportunity to write notes to their "future self." Below each decision problem, participants could write down the reasoning behind their choice of action in a text box. What they typed was displayed later on in the experiment. We told participants that these notes would help them when making choices in the second part of the experiment.

To account for possible order effects, we gave participants another opportunity to revisit their choices and confirm them.[17] We displayed their notes and participants were able to modify them. Afterwards, participants advanced to the next part of the experiment.

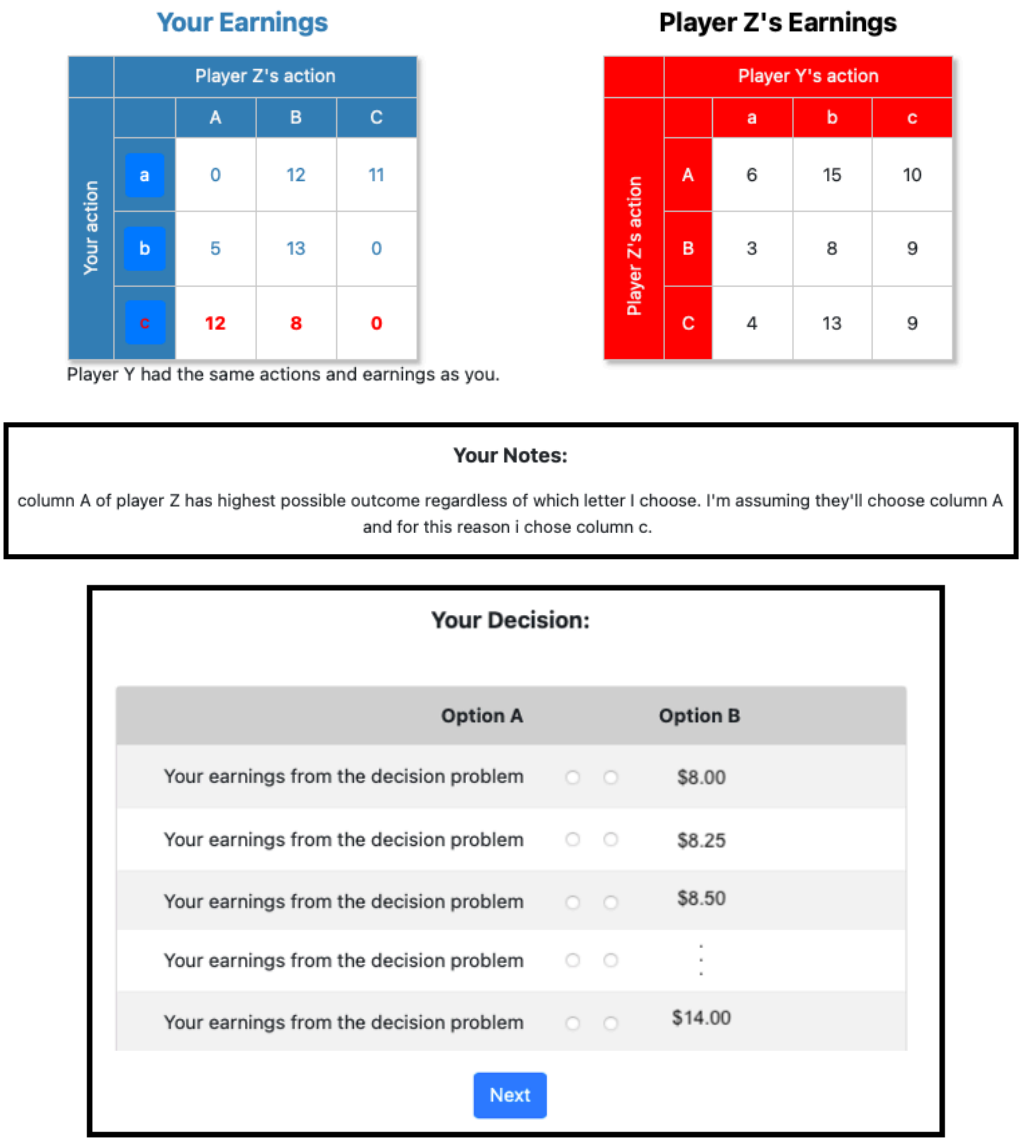


Figure 4: The Valuation Task

In the second part of the experiment, we elicited participants' approximate valuations via choice lists. We asked them to make a series of choices between playing the four decision problems against both Player Z types with their action choices from the first part of the experiment and sure amounts. For example, suppose that in the first part of

[17] We find no evidence of order effects, using both parametric and non-parametric tests.

the experiment a participant chose action c in any given 3×3 game, as highlighted in Figure 4. The payoff from the decision problem depends on the action chosen by Player Z and is either \$12, \$8, or \$0 if Player Z chose A, B, or C, respectively.

The choice problems were organized in four pairs ($4 \times 2 = 8$ lists), where Option A changed across lists and represented participants' payoffs from each of the four decision problems against both opponent types from the first part of the experiment. Option B paid with certainty and started at \$8 in the decision of the choice list, and increased by \$0.25 as the participant moved from one line to the next until \$14. For each decision problem, we showed participants their notes from the first part of the experiment to remind them of their reasoning behind their action choices.

Finally, one of the choice problems in one of the choice lists was randomly selected, and the participants' choice in that choice problem determined their payment. If a participant chose the sure amount in Option B, then they received the payment specified in Option B in that choice problem. If a participant opted for Option A, then their payment depended on the action chosen in the decision problem in the first part of the experiment, if their Player Z was an undergraduate student or a Ph.D. student, and on the action chosen by Player Z.[18]

3.2 Participants and Procedure

We conducted the experiment in April 2020 with students enrolled at the University of Toronto. Participants were recruited from Toronto Experimental Economics Laboratory's (TEEL) subject pool using ORSEE (Greiner 2015). No one participated in more than one session. Participants signed up ahead of time for a particular day, either the 4^{th} or 5^{th} of April 2020 for the auxiliary part of the experiment; or the 11^{th}, 13^{th}, and 15^{th} to 20^{th} of April 2020 for the main experiment. On the day of the experiment, we sent participants an electronic link at 8 AM EDT, and they had to complete the tasks by 8 PM EDT. During this time window, participants could contact an experimenter anytime via cell phone or Skype for assistance. After reading the instructions, participants had to correctly answer nine incentivized comprehension questions before starting the

[18] The timeline of the experiment and the key features are visualized in the Online Appendix.

first task, and further five incentivized comprehension questions before starting the second task. We paid \$0.25 for answering each question correctly on their first attempt. If participants made a mistake, no payment was made for that question, but they had to answer it correctly in order to proceed to the next question. The experiment was programmed in oTree (Chen, Schonger, and Wickens 2016). We recruited a total of 244 (9 for the auxiliary sessions and 235 for the main experiment) participants and all payments were made via Interac e-transfer, a commonly used payment method by Canadian banks that only requires an e-mail address and a bank account. The average participant earned approximately \$18 (maximum payment was \$22.50 and minimum payment was \$5.50), including a show-up payment of \$5. All payments were in Canadian dollars. The instructions and experimental interface are reproduced in the Online Appendix.[19]

3.3 Discussion of the Implementation and Procedure

The core idea of this paper is to identify a novel behavior that reflects whether reasoning is outside the iterative 'top-down' model of reasoning. Thus far, we developed an identification strategy for such behavior and before presenting the results of the evaluation of its pervasiveness, we briefly discuss some aspects of the experimental implementation and its procedure. We collected Player Z's decisions on action choices in the four games in two separate auxiliary sessions. This has the following advantages: First, we were able to match participants (Player Y and Player Z) with the same level of sophistication. Second, we could collect all decisions in the main experiment in an "individual decision-making" framework. As we collected the data during the lockdown in the COVID-19 pandemic, we could not run any experiment sessions in the laboratory. Instead, undergraduate students enrolled at the University of Toronto eagerly participated remotely. Thus, we were able to avoid any coordination issues stemming from simultaneous strategic decision-making in an online context. Lastly, as choices and payments in the auxiliary sessions had materialized already, this design can eliminate concerns that choices made by participants in the main experiment were motivated by social preferences or forward induction considerations. To avoid quick heuristic-based decision-making, we forced participants

[19] A live version with all dynamic elements displayed to participants can be accessed upon request.

to spent at least 10 minutes on each set of instructions and at least 3 minutes on each of the four games against either opponent type before buttons were activated. Further, we presented all four games in random order to avoid any order effects, and, in addition, gave participants the opportunity to revise their decisions after they were exposed to all four games and had selected an action choice. Remaining conscious of possible order effects, we also reversed the opponent order between the two parts of the experiment. That is, if participants faced always an undergraduate student before a Ph.D. student in Economics when choosing an action, then they always faced a Ph.D. student in Economics before an undergraduate student in the valuation task and *vice versa*.

4 Results

We break the analysis into four sections. After a brief coherence examination of the valuation data, we begin our main analysis by presenting the experimental results focusing first on preferences between IR and DS, and then explore the valuation data across all four games. Next, we focus on behavior conditional on the opponent's identity; that is, whether Player Z was an undergraduate student of any year or discipline or a Ph.D. student in Economics. Lastly, we delve into the non-choice data embedded in the participants' notes.

4.1 Coherence of Elicited Valuations

Before turning to choice behavior and the ranking of IR and DS, we first present the empirical valuation data from some of the games to illustrate both that participants exhibit reasonable valuations and that there are powerful insights to be gained for an outside observer by eliciting participants' certainty equivalent for each game.

In total, we collected data from $N = 235$ participants. The only exclusion restriction for valuations that we impose is *consistency with rationality*. That is, we exclude behavior characterized by valuations that exceed the maximum possible payoff given their action choice, for example, playing action b with a valuation $v = 14$ in DS, MS, or NE, respectively. Figure 5 displays several empirical value distributions.

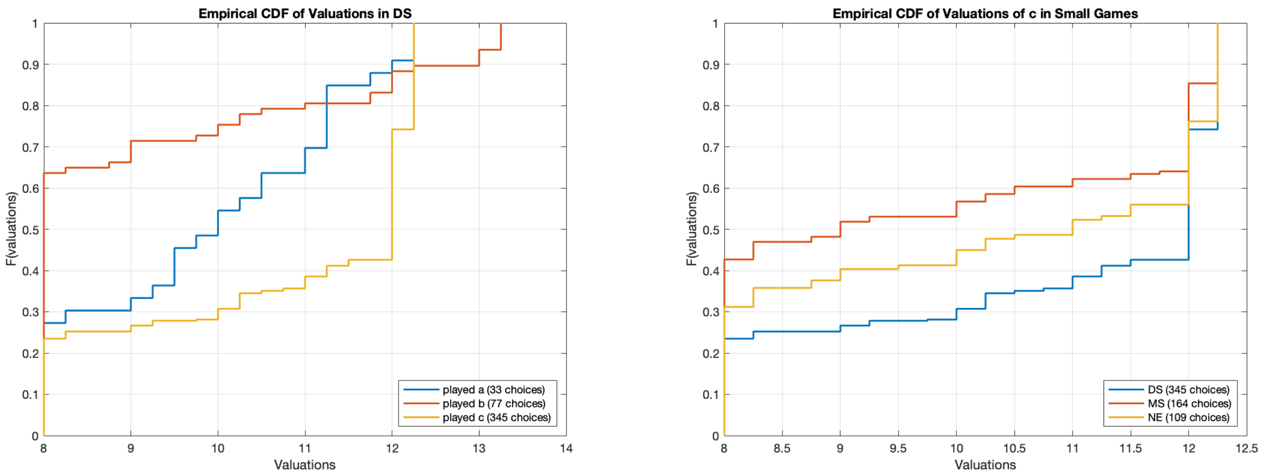


Figure 5: Empirical Value Distributions of *DS* by action choice; and Empirical Value Distributions of *DS MS*, and *NE* conditional on Playing Action *c* in *DS*

First, we show the empirical value distributions in *DS* by action for $n = 455$ choices; namely, all choices with consistent valuations irrespective of opponent type. Roughly 76% of choices fall on action *c*, 17% play action *b* and the remaining 7% choose action *a*. Participants who play *c* tend to value playing *DS* more than participants who chose *a* or *b*. Recall that *c* is dominated by *a* according to $\succ_1$, and that the highest payoff in *b* (13) is higher than the highest payoff in *c* (12). This suggests that those who played *c* have done so due to strategic reasons.

Second, we highlight the empirical value distributions in *DS* and both control games conditional on playing action *c* irrespective of opponent type, which leaves us with $n = 618$ choices in total. Recall that participants face the exact same payoffs in these three games, so different choices and valuations in these games must arise from the different strategic structures. The frequency of action-*c* play in *DS* is approximately $2 - 3$ times higher compared to those in the two control games, *MS* and *NE*, respectively. Further, the empirical value distribution for *DS* first-order stochastically dominates those for *NE* and *MS*, suggesting that opponent behavior in *DS* is easier to predict relative to *NE* and *MS*.

4.2 *IR* and *DS* Valuations

We impose one additional exclusion restriction for the *IR* and *DS* choices in our main analysis. That is, in addition to imposing consistency of rationality, we focus on observed choices where only action *c* is played in *DS*. Restricting attention to action *c* in *DS* allows us to isolate the choices made by strategic participants, as the L1 non-strategic type only plays actions *a* or *b* in *DS* and never plays action *c*. Thus, we restrict attention to $n = 343$ choices. That is, we focus on 179 participants facing an undergraduate student and 164 participants facing a Ph.D. student in Economics.[20] To give a first overview, we present aggregate results of action choices in the diagnostic games. Table 1 offers a synopsis of the frequency of action choices in *IR*.

Table 1: Frequency of Action Choices in the *IR* Game

Action	*IR*
a	242/343
b	37/343
c	37/343
d	27/343

All choices made irrespective of opponent type.

Approximately 71% of choices in *IR* are concentrated on action *a*, and the remainder is roughly equally distributed among actions *b*, *c*, and *d*, respectively.

As a first pass, we summarize choice behavior and the ranking of *IR* and *DS* irrespective of the opponent type. Table 2 lists these results.

Table 2: Preferences between *IR* and *DS*

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	154/343	189/343
Percentage	44.9%	55.1%

All choices made irrespective of opponent type.
IRM ≡ Iterative 'top-down' model of reasoning.

The observed choices are clearly at odds with the predictions of the iterative 'top-down' model of reasoning (or Nash equilibrium). While players are predicted to strictly

[20] All analyses reported in the main text are replicated for all participants and choices in our sample. These results are reported in the Online Appendix.

prefer IR over DS, less than half of all observed choices are in line with the prediction. This is the first evidence at the aggregate choice-level suggesting that participants' reasoning may fall outside the iterative 'top-down' model of reasoning.

Introducing controls As a next step, we include the two control games in our aggregate-choice analysis. We are interested in those participants who weakly prefer DS over IR, and not those who may have a preference for smaller games or Nash equilibrium in pure strategies *per se*.

Table 3: Controlling for Best-Response Consistency in All Games and Equal Valuations of All Small Games

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Control #1	135/291	156/291
B-R Consistency	46.4%	53.6%
Control #2	138/268	130/268
NE Preference	51.5%	48.5%
Control #3	107/213	106/213
Equal Valuations	50.2%	49.8%

All choices made irrespective of opponent type excluding all choices that are inconsistent with best-responding ("C#1"); preference for Nash equilibrium in pure strategies ("C#2"); and value DS, MS, and NE equally ("C#3"). $IRM \equiv$ Iterative 'top-down' model of reasoning.

To do so, we require that participants make choices consistent with best-responding in both MS and NE games.[21] As a result, we are now focussing on 153 participants facing an undergraduate student and 138 participants facing a Ph.D. student in Economics, respectively. Table 3, Control #1 lists these results of $n = 291$ observed choices irrespective of opponent type. As is evident, controlling for best-response consistency at the aggregate choice level does not make a substantial dent on participants' overall ranking of IR and DS.

Next, we exploit the Nash equilibrium in pure strategies that characterizes both DS and NE. Here, we exclude those choices that play action c in both games *and* value NE

[21] In this step, we remove participants' choices of a with a valuation $v > 12$, and further exclude those whose valuations that exceed the maximum possible payoff given their action choice in either of the two control games.

weakly above IR. This allows us to control for those that may feature an intrinsic preference for Nash equilibrium in pure strategies *per se*. By doing so, we focus on 147 participants playing against an undergraduate student and 78 participants playing against a Ph.D. student in Economics, respectively. The summary statistics for this control are listed as Control #2 in Table 3. Similar to the previous control, this control does not alter the overall ranking of the diagnostic games either.

Last, we leverage MS and NE and, in this step, exclude those choices that value all small games equally; i.e., $v_{DS} = v_{MS} = v_{NE}$. This allows us to control for those participants who have high valuations in DS relative to IR because of an intrinsic preference for smaller games or Nash equilibrium in pure strategies. This results in concentrating on 113 participants playing against an undergraduate student and 100 participants playing against a Ph.D. student in Economics. These results are reported in Table 3, Control #3. Though this control slightly reduces the proportion of participants preferring the DS game over the IR game, still about half of the participants make choice and valuation decisions inconsistent with the iterative reasoning model. Overall, the inclusion of the controls does not alter the results. While the ratio of those who weakly prefer DS over IR somewhat decreases, the big picture still suggests that participants' reasoning may fall outside of the iterative 'top-down' model of reasoning.[22]

Belief that opponent is rational Here, we consider those participants that believe that their opponents are rational and are confident that Player Z is rational. Recall that our design makes the sharpest predictions for these types – unambiguously predicting that participants using the iterative 'top-down' model of reasoning would strictly prefer to play IR over DS. Our design allows us to identify these participants by exploiting the valuation data collected in the second part of our experiment. In particular, we now include an additional exclusion restriction by requiring valuations of $12 \leq v \leq 12.25$ in

[22] A potential concern may arise because we used choice lists to elicit participants' approximate valuation for each game. As these lists are discrete we could potentially misclassify participants. Those participants who valued both IR and DS *exactly* at $v = 12.25$ could be classified as ranking DS weakly above IR even though being consistent with the iterative 'top-down' model of reasoning. Of the $n = 343$ choices presented in Table 2, only 29 choices value both games exactly at $v = 12.25$. For the controls, this reduces further to 10/291 in Control #1 and 7/213 in Control #3, respectively.

DS.[23] Table 4 summarizes the choice behavior by the ranking of IR and *DS* irrespective of the opponent type but conditional on believing in the opponent's rationality.

Table 4: Belief that Opponent Is Rational

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	72/197	125/197
Percentage	36.5%	63.5%

All choices made irrespective of opponent type conditional on believing in opponent's rationality.
$IRM \equiv$ Iterative 'top-down' model of reasoning.

When requiring that players be confident that their opponent is rational (valuation of c in *DS* is 12, indicating that Player 1 is confident that Player 2 will play the dominant action), close to two-thirds of $n = 197$ choices rank *DS* above IR. This behavior reflects reasoning that falls outside the iterative 'top-down' model of reasoning.

4.3 Opponent Type

We now turn to choices at the subject-level and discuss differences in behavior by opponent type. We maintain all our exclusion restrictions discussed above but as we are interested in participants that satisfy these exclusion restrictions against *both* opponent types – the intersection – we thus concentrate now on $n = 144$ participants. Thus far, we have established that approximately half of the choices fall outside the iterative 'top-down' model of reasoning. Recall that this turns out to be true especially if they believe that their opponents are rational. Among this subset of choices, approximately two-thirds of choices fall outside the model.

Table 5 shows the comparative statics of the ranking over the set of diagnostic games conditional on the opponent's identity; that is, whether participants played against an undergraduate student of any year or discipline or a Ph.D. student in Economics.

These numbers are not overly sensitive to the opponent's type: 71.5% of participants exhibit a stable model of reasoning irrespective of the opponent's characteristics. That is, the majority of participants respond similarly to both undergraduate students and

[23] This results in concentrating on 106 (91) participants playing against an undergraduate student (a Ph.D. student in Economics).

Table 5: Ranking of IR and DS by Opponent Type

			Undergraduate $IR \succ DS$	*Undergraduate* $IR \precsim DS$
Ph.D.	$IR \succ DS$	IRM Prediction	*all*	*nil*
		Ratio	46/144	23/144
		Percentage	31.9%	16.0%
	$IR \precsim DS$	IRM Prediction	*nil*	*nil*
		Ratio	18/144	57/144
		Percentage	12.5%	39.6%

$IRM \equiv$ Iterative 'top-down' model of reasoning.

Ph.D. students in Economics. Specifically, about 32% of the participants' choices are consistent with the iterative 'top-down' model of reasoning against both undergraduate students and Ph.D. students in Economics in IR and about 40% are inconsistent against both.[24] Among the remainder, of those who respond to the opponent's type, the results are split. 12.5% are consistent with the iterative 'top-down' model of reasoning against undergraduate students and not Ph.D. students in Economics, while 16% are consistent with the iterative reasoning model against Ph.D. students in Economics but not undergraduate students.

4.4 Non-Choice Data

Recall that we gave participants the opportunity to write notes to their "future-self." Below each of the two diagnostic games as well as two control games against either opponent type, participants could write down the reasoning behind their choice of action in a text box. If participants decided to type anything in these text boxes, then it was displayed later on again in the experiment: the first time when participants were prompted to confirm their choice of action and a second time when facing the valuation task. We did not force participants to write anything in these text boxes, however, we told them that these notes would help them when making choices in the second part of the experiment. As expected, not all participants made use of this opportunity. Those who

[24] These 57 participants value the DS game (weakly) more than the IR game. Moreover, the valuation data reveal that for these participants the IR game becomes relatively more valuable than the DS game when playing against a Ph.D. student rather than an undergraduate student.

did, however, give us the opportunity to use their notes as "the window of the strategic soul."[25] Using both action choice and valuation data, we documented evidence at the aggregate choice-level that suggests that participants may value the predictability of their opponents' behavior. Moreover, we showed that this observation is even starker if participants believe that their opponents are rational with 63.5% of choices ranking *DS* above IR. Among this subset of participants, we are curious to see whether there is any suggestive evidence of participants indicating that the opponents' actions are predictable in *DS* and IR, and if there is any difference by the ranking of IR and *DS*. We have established that 197 choices are consistent with holding the belief that their opponent is rational, meaning that the player is confident that Player Z is rational. In 105 (113) of these choices, participants took notes in IR (*DS*). Table 6 provides summary statistics for this subset of choices by the ranking of the set of diagnostic games.

Table 6: Notes – Belief that Opponent Is Rational

Indication that Player Z's Action Is Predictable

		IR		*DS*	
		yes	*no*	*yes*	*no*
$IR \succ DS$	Ratio	22/52	14/53	18/60	25/53
	Percentage	42.3%	26.4%	30.0%	47.2%
$IR \precsim DS$	Ratio	30/52	39/53	42/60	28/53
	Percentage	57.7%	73.6%	70.0%	52.8%

If a participant indicated that the opponent's choice is predictable in one of the games, it increased the likelihood they would prefer that game. For example, out of the 105 participants who took notes in the IR game, 52 participants noted that Player Z's action is predictable. The likelihood of preferring IR to *DS* increased from 26.4% to 42.3% (an increase of approximately 60%). Similarly, out of 113 participants who took notes in *DS*, 60 wrote that Player Z's action was predictable. The likelihood of preferring the IR game to the *DS* game among them was 30%, compared to 47.2% among participants who took notes but did not mention the predictability of Player Z's action in *DS* (a decrease of more than 36.4%).

We complement this qualitative analysis with natural language processing tools to

[25] Vincent Crawford coined this term in Crawford (2008).

gain additional insights on participants' thought process. In line with the choice behavior presented in Section 4, participants who rank one diagnostic game above the other also express their reasoning in more detail, use more complexity-related keywords to express more sophisticated reasoning, are more positive and optimistic, and feature more determination and certainty in their preferred game compared to the other diagnostic game. Moreover, differences in the ranking of games is associated with different topics and clusters that can be recovered using natural language models.[26] This lends further qualitative support for the idea that the $DS \succsim IR$ group and the $DS \prec IR$ group treat the two diagnostic games systematically differently and employ fundamentally different reasoning processes.

5 Theoretical Analysis

In Section 2, we provided intuitive explanations for our identification strategy. In this section, we elaborate and present a formal analysis.

5.1 Theory

Let $G = (S_1, S_2, u_1, u_2)$ be a finite 2-player game where S_i is player i's strategy set and $\pi_i : S_1 \times S_2 \to \mathbb{R}$ is player i's pecuniary payoff function, which depends on player i and the other player's $(-i)$ strategies. We allow for general expected-utility preferences over monetary payoffs. Let $\mathcal{U}$ be the set of von Neumann-Morgenstern utility functions, which are strictly increasing functions mapping $\mathbb{R}$ to $\mathbb{R}$. For any $u_i \in \mathcal{U}$, the function $u_i \circ \pi_i : S_i \times S_{-i} \to \mathbb{R}$ represents the utility of player i. Denote by $\mu_{-i} \in \Delta(S_{-i})$ player i's beliefs over player $-i$'s strategies. Extend $u_i(\pi_i(S_i, S_{-i}))$ to $u_i(\pi_i(S_i, \mu_{-i}))$ in the usual way to represent player i's expected utility.

Let $\mathbb{BR}_i$ be the best response set for each player i. This set specifies the strategies that are a best response for player i given both player i's preferences, $u_i \in \mathcal{U}$, and the belief

[26] We elaborate on this in detail in the Online Appendix.

they hold about the play of the other player, μ_{-i}. Formally, for $u_i \in \mathcal{U}$ and $\mu_{-i} \in \Delta(S_{-i})$,

$$\mathbb{BR}_i[u_i, \mu_{-i}] := \{s_i \in S_i : u_i(\pi_i(s_i, \mu_{-i})) \geq u_i(\pi_i(r_i, \mu_{-i})), \text{ for each } r_i \in S_i\}.$$

We will be interested in two solution concepts. First, the iterative 'top-down' model of reasoning, which intuitively captures how players reason when they can model the behavior of others. Second, the concept of 2-rationalizable strategies, which incorporates the assumption that player i is rational and believes player $-i$ is rational and nothing more. Intuitively, this solution concept captures how players reason when they cannot model the behavior of others. We define both below.

Iterative 'top-down' model of reasoning This model is anchored by the non-strategic L1 behavior characterized by $\succ_1$. Let $L_i^1 = \{s_i \in S_i | \nexists\ s_i{}' \in S_i \text{ where } s_i{}' \succ_1 s_i\}$ be the set of actions that can be played by the L1 type. This is the set of actions that are undominated according to $\succ_1$.

In Section 2, we discussed the possibility of extending the model to allow for uncertainty over others' rationality. We do this by defining an L0 type that is non-strategic and plays all actions – even strictly dominated actions – with positive probability. Specifically, we impose the restriction that the L0 type plays uniformly random: $\mu_i^0(s) = \frac{1}{|S_i|}$ for all $s \in S_i$. Strategic types that place positive probability on facing the L0 type will then be uncertain about the rational play of others.

The behavior of all Lk types can be defined recursively, anchored on the behavior of the L0 and L1 types. Denote by L_i^k the set of actions consistent with k iterations of reasoning by player i. Then, for $k \geq 2$, the set L_i^k is the set of strategies s_i in $\mathbb{BR}_i[u_i, \mu_{-i}]$ such that there exists some $u_i \in \mathcal{U}$ and $\mu_{-i} \in \Delta(S_{-i})$ that satisfies the following two conditions. First, beliefs over the play of others must take the following form: $\mu_{-i} = p \cdot \mu_{-i}^0 + (1-p) \cdot \eta_{-i}$ for some $p \in [0, 1)$ and $\eta_{-i} \in \Delta(S_{-i})$ with $\eta_{-i}(\cup_{j=1}^{k-1} L_{-i}^j) = 1$. This ensures that player i's beliefs about player $-i$'s behavior are consistent with the assumption that players' reasoning is organized in a 'top-down' fashion. Put differently, player i can only assign positive probability to actions played by types with levels strictly less than k. Second, $s_i \in \mathbb{BR}_i[u_i, \mu_{-i}]$. This condition ensures that player i's strategy s_i maximizes their expected utility given player i's preferences u_i, and the belief that player $-i$ plays according to μ_{-i}. We will refer to any action a_i in L_i^k as *an action played by the Lk type* for player i.

2-rationalizability The solution concept of 2-rationalizable strategies incorporates both the assumption of rationality and belief in rationality. Let S_i^1 be the set of strategies s_i such that there exists some $u_i \in \mathcal{U}$ and $\mu_{-i} \in \Delta(S_{-i})$ with $s_i \in \mathbb{BR}_i[u_i, \mu_{-i}]$. The set S_i^1 includes all rational strategies for player i. These are a best response for player i given their preference u_i and beliefs μ_{-i} about player $-i$'s play. We refer to any action a_i in S_i^1 as a 1-*rationalizable strategy*. Given this, we can define S_i^2 as the set of strategies s_i so that there exists some $u_i \in \mathcal{U}$ and $\mu_{-i} \in \Delta(S_{-i})$ that satisfies the following conditions. First, $s_i \in \mathbb{BR}_i[u_i, \mu_{-i}]$, which ensures that s_i maximizes player i's expected utility given the belief that player $-i$ behaves according to μ_{-i}. Second, $\mu_{-i}(S_{-i}^1) = 1$. This ensures that player i can only place positive probability on 1-rationalizable strategies, which are the strategies consistent with the assumption that player $-i$ is rational. We will refer to any action s_i in S_i^2 as a 2-*rationalizable strategy*.[27]

5.2 Revisiting the Diagnostic Games

The iterative-reasoning game "IR" First, note that we can denote any probability measure $p \in \Delta(S_1)$ (and $p \in \Delta(S_2)$, respectively) as a 4-tuple (p_1, p_2, p_3, p_4). This represents the probabilities over $\{a, b, c, d\}$ (and $\{A, B, C, D\}$, respectively). Then in this game, L0 behavior is given by $\mu^0 = (1/4, 1/4, 1/4, 1/4)$ for both players. Further, recall from Section 2 that $L_1^1 = \{a, b\}$ and $L_2^1 = \{C\}$.

The L_i^k sets can then be calculated recursively given the anchoring L0 and L1 behavior. Let $k \geq 2$. For Player 1, the Lk type can hold any belief about Player 2's behavior that is a mixture between μ^0 and the two degenerate beliefs: $(0, 1, 0, 0)$ and $(0, 0, 1, 0)$. In other words, beliefs take the form $\mu_2 = \left(p_0/4, p_0/4 + p_B, p_0/4 + p_C, p_0/4\right)$ for some $p_0, p_B, p_C \in [0, 1]$ with $p_0 + p_B + p_C = 1$. A strategy s_i is in L_1^k if there exists some $u \in \mathcal{U}$ such that

[27] In order for the solution concept to be free of assumptions about risk preferences we explicitly allow players to hold any expected utility preferences. The same result could be achieved by specifying a single preference specification for each player with preferences characterized by extreme risk aversion. This follows from Battigalli, Cerreia-Vioglio, Maccheroni, and Marinacci (2016) and Weinstein (2016) who show that risk aversion expands the set of k-rationalizable actions (while risk loving contracts the set).

$s_i \in \mathbb{BR}_1[u, \mu_2]$. Clearly, actions a and b are in L_1^k as they maximizes the expected payoff under the player's belief when $p_C = 1$ and $p_B = 1$, respectively. Importantly, we also need to ensure that a and b are the only choices that maximize expected utility for every utility function u.[28] We begin with the observation that a strategy $s_i \in S_1$ induces a lottery through the belief $p \in \Delta(S_2)$, which we denote $s_{i,p}$. For example, the action a induces the lottery $a_{\mu_2} = (13, {}^{p_0}/_4; 12, {}^{p_0}/_4 + p_B; 11, {}^{p_0}/_4 + p_C; 0, {}^{p_0}/_4)$. This lottery first-order stochastically dominates the lotteries c_{μ_2} and d_{μ_2}. It follows that actions c and d cannot maximize the player's expected utility for any utility function u. Thus, we conclude that $L_1^k = \{a, b\}$.

For Player 2, the Lk type can hold any belief about Player 1's behavior that is a mixture between μ^0 and the two degenerate beliefs: $(1, 0, 0, 0)$ and $(0, 1, 0, 0)$. In other words, beliefs take the form $\mu_1 = \left({}^{p_0}/_4 + p_a, {}^{p_0}/_4 + p_b, {}^{p_0}/_4, {}^{p_0}/_4\right)$ for some $p_0, p_a, p_b \in [0, 1]$ with $p_0 + p_a + p_b = 1$ and $p_0 < 1$. Consider the case where $p_a \neq 1$, then the lottery C_{μ_1} first-order stochastically dominates the lotteries A_{μ_1} and D_{μ_1}. Next, consider the case where $p_a = 1$, then the lottery B_{μ_1} first-order stochastically dominates the lottery x_{μ_1} for $x \in \{A, C, D\}$. Thus, we conclude that $L_2^k = \{B, C\}$.

$$L_1^k = \{a, b\} \text{ if } k \geq 1 \qquad\qquad L_2^k = \begin{cases} \{C\} & \text{if } k = 1 \\ \{B, C\} & \text{if } k \geq 2 \end{cases}$$

We now turn to characterize the 2-rationalizable set for Player 1, which captures the case of a player who is rational and believes that Player 2 is rational. Here, Player 1 believes that Player 2 plays a 1-rationalizable strategy. The 2-rationalizable set for Player 1 and the 1-rationalizable set for Player 2 are:

$$S_1^2 = \{a, b, c, d\} \qquad\qquad S_2^1 = \{A, B, C, D\}$$

It is straightforward to see that all actions for Player 2 are 1-rationalizable. This is the case as each action maximizes expected payoffs under some degenerate belief about the

[28] For this we will rely on the following equivalence: a lottery p first-order stochastically dominates lottery q if and only if p is preferred to q for all $u \in \mathcal{U}$.

play of Player 1. It follows that all actions are 2-rationalizable for Player 1 as each action for Player 1 maximizes expected payoffs under some degenerate belief about Player 2's behavior.

Lastly, we elicited participants' valuation for each game, i.e., their certainty equivalent. Since a player's utility function is monotone, the analyst can infer their ranking over the games. Moreover, the valuations reveal important information about participants' beliefs.

In the iterative 'top-down' model of reasoning, restricting attention to types that are rational and believe that their opponent is rational confines attention to types that assign zero weight on others being the L0 type. The expected payoff in IR must be *strictly greater than 12* for these types. It is straightforward to confirm this claim by setting $p_0 = 0$ in the above arguments. This means that any type holds a belief that is a mixture of $(0,1,0,0)$ and $(0,0,1,0)$. For any such belief $\mu_2 = p(0,1,0,0) + (1-p)(0,0,1,0)$, the certainty equivalent of the lottery $a_{\mu_2} = \big(12, p; 13, (1-p)\big)$ is above 12 whenever $p \neq 1$, and the certainty equivalent of the lottery $b_{\mu_2} = \big(14, p; 0(1-p)\big)$ is 14 whenever $p = 1$. To summarize, players who are rational and hold the belief that their opponents are rational believe that they can guarantee themselves a payoff that is strictly greater than 12. It follows that the certainty equivalent of IR for any expected utility player who believes that their opponent is rational is strictly above 12.

Caution is potentially warranted if Player 1 is ambiguity averse as they may value IR at 12. This, however, can only occur under an extreme form of ambiguity aversion coupled with the player holding degenerate beliefs. More precisely, it requires Player 1 to play the "safe" action a, to have maxmin expected-utility preferences *and* their set of priors must include beliefs that Player 2 plays B with certainty and a prior that assigns a probability strictly less than $6/7$ that Player 2 plays B.[29]

Moving to payoffs when applying the concept of 2-rationalizability. A player that believes others are rational can hold any belief over Player 2 choosing a 1-rationalizable

[29] Whether this is an important concern is an empirical question. We can exploit participants' actions and valuations in the control games to evaluate if ambiguity aversion governs participants' valuations. If we allow for maxmin expected utility preferences, and allow that the set of priors of a player of level $(k+1)$ includes all degenerate priors consistent with the strategies in L_2^k in the control games, then (for any action in) both MS and NE have to be valued at 8. In our data, of all choices, only 1 choice exhibits such extreme form of ambiguity aversion.

action. This means that in IR Player 1 can hold any belief about the play of Player 2. In this case, such players may *not* believe that they can guarantee themselves any certain payoff. Moreover, one might reasonably conjecture the certainty equivalents of these actions to be less than 12.

The dominance-solvable game "DS" In this game, the L0 behavior is given by the 3-tuple $\mu^0 = (1/3, 1/3, 1/3)$ for both players. Further, recall from Section 2 that $L_1^1 = \{a, b\}$ and $L_2^1 = \{A\}$.

The L_i^k sets can then be calculated recursively given the anchoring L0 and L1 behavior. Let $k \geq 2$. For Player 1, the Lk type can hold any belief about Player 2's behavior that is a mixture between μ^0 and the degenerate belief: $(1, 0, 0)$. In other words, beliefs take the form $\mu_2 = \left(p_0/3 + p_A, p_0/3, p_0/3\right)$ for some $p_0, p_A \in [0, 1]$ with $p_0 + p_A = 1$. A strategy s_i is in L_i^k if there exists some $u_i \in \mathcal{U}$ such that $s_i \in \mathbb{BR}_i[u_i, \mu_{-i}]$. Clearly, action a and c are in L_1^k as they maximizes the expected payoff under the player's belief when $p_0 = 1$ and $p_A = 1$ respectively. Further, notice that the lottery b_{μ_2} is not first-order stochastically dominated by either lotteries a_{μ_2} or c_{μ_2}, this means we can find some $u_i \in \mathcal{U}$ such that $b \in \mathbb{BR}_1[u_i, \mu_2]$. Thus, $L_1^k = \{a, b, c\}$.

Turning to the behavior of the Lk type of Player 2, this type can hold any belief about Player 1's behavior that is a mixture between μ^0 and the degenerate beliefs: $(1, 0, 0)$, $(0, 1, 0)$ and $(0, 0, 1)$. In other words, a Lk type can hold any beliefs over Player 1's play, $\mu_1 \in \Delta(S_1)$. Notice, however, that Player 2 has a strictly dominant strategy, this means that A is always the best response for Player 2 regardless of her beliefs. In other words, the lottery A_{μ_1} first-order stochastically dominates the lotteries B_{μ_1} and C_{μ_1}. Thus we conclude that $L_1^k = \{A\}$.

$$L_1^k = \begin{cases} \{a, b\} & \text{if } k = 1 \\ \{a, b, c\} & \text{if } k \geq 1 \end{cases} \qquad\qquad L_2^k = \{A\} \text{ if } k \geq 1$$

Lastly, we briefly discuss the 2-rationalizable predictions. Again, since A is strictly dominant for Player 2, it is the unique 1-rationalizable action. It follows that the only 2-rationalizable action for Player 1 is c.

$$S_1^2 = \{c\} \qquad\qquad S_2^1 = \{A\}$$

In this game, a rational type who believes that their opponent is rational must hold beliefs of the form $(1, 0, 0)$. Such players believe that they can guarantee themselves a payoff of *exactly 12* with certainty. Notice that reasoners who cannot model and hence predict Player 2's behavior – beyond the belief that Player 2 should play a 1-rationalizable strategy – might reasonably rank DS above IR.

If Player 1 plays c and values the game less that 12 it reveals to the analyst that the player is not confident that Player 2 is rational as the certainty equivalent of the lottery induced by c is lower than 12 only if it assigns a strictly positive probability that Player 2 will choose a dominated action. Further, such valuations shed light on whether the simpler iterative reasoning model from Section 2 or the more general iterative 'top-down' model of reasoning that explicitly allows for uncertainty over rationality predicts participants' behavior more accurately.

Player 1's preferences over IR and DS We first restrict attention to players that are rational *and* believe that their opponents are rational. Consider the preferences of such types over the two diagnostic games: IR and DS. Although DS has a smaller strategy space compared to IR and is dominance-solvable, the game's expected payoff of 12 is strictly lower than the expected payoff of IR in the iterative 'top-down' model of reasoning. In other words, a 'top-down' iterative-reasoner should strictly prefer to play IR over DS. We now relax the assumption of belief in rationality. When considering the iterative 'top-down' model of reasoning, this means that we allow players to place positive weight on the L0 type. Fix $p_0 \in [0, 1)$ as the probability assigned to the L0 type. In IR, the belief of a 'top-down' reasoner takes the following form: $\mu_2^{IR} = p_0(1/4, 1/4, 1/4, 1/4) + p_B(0, 1, 0, 0) + p_C(0, 0, 1, 0)$ for some $p_B, p_C \in [0, 1]$ with $p_0+p_B+p_C = 1$. In DS, the belief of such reasoner is $\mu_2^{DS} = p_0(1/3, 1/3, 1/3)+(1-p_0)(1, 0, 0)$.

First, notice that the lottery $a_{\mu_2^{IR}}^{IR} = \left(0, p_0/4; 12, p_0/4+p_B; 13, p_0/4+p_C; 11, p_0/4\right)$ first-order stochastically dominates the lottery $a_{\mu_2^{DS}}^{DS} = (0, p_0/3 + p_A; 12, p_0/3; 11, p_0/3)$ for all p_0, p_B and

p_C. Further, the lottery $a^{IR}_{\mu_2^{IR}}$ also first-order stochastically dominates the lottery $c^{DS}_{\mu_2^{DS}} = (12, 1 - {}^{2p_0}/_3; 8, {}^{p_0}/_3; 0, {}^{p_0}/_3;)$ for all p_0, p_B and p_C. Thus, any iterative 'top-down' reasoner prefers to play IR over actions a or c in the DS game, regardless of risk preferences.[30]

6 Concluding Remarks

In iterative reasoning models, each player best-responds to the belief that other players reason to some finite level. In this paper, we propose a novel behavior that captures the idea that players may believe that others are rational, yet cannot model their behavior. Reverting to our example from the introduction, it encompasses a situation where a player believes that their opponent can reason to a higher level than they do. We developed a novel experimental design that permits us to identify such behavior, and evaluate it experimentally.

We find that approximately half of the participants made choices inconsistent with a very general and permissive model of iterative 'top-down' reasoning. This is true especially if they believe that their opponents are rational. Among those, 64% behave inconsistently with the iterative 'top-down' model.

Interestingly, approximately 72% of participants exhibit a stable model of reasoning irrespective of the opponent's characteristics. Among the remainder, the results are split: around 12% (16%) made choices (in)consistent with iterative reasoning when playing against an undergraduate (Ph.D.) student but not when playing against a Ph.D. (undergraduate) student.

To conclude, we document strong evidence that behavior may fall outside an iterative 'top-down' model of reasoning, yet players may still use alternative models, which rely on belief in their opponent's rationality, to reason and choose optimal strategies in games.

[30]The only potential caveat here is that there may be an iterative 'top-down' reasoner who is extremely risk seeking *and* at the same time very pessimistic about the rationality of others (high p_0), and as such prefers the lottery $b^{DS}_{\mu_2^{DS}} = (5, {}^{p_0}/_3; 13, 1 - {}^{2p_0}/_3; 0, {}^{p_0}/_3)$ over any lotteries induced by IR. Such choices are extremely rare in our data. Of 470 choices in total, only 8 participants choose to play b in DS and value the game at $13 \leq v \leq 13.25$. As in the analysis presented in Section 4, if we control for such players by focusing on those who play c in DS, the iterative 'top-down' model of reasoning makes the unambiguous prediction that such players rank IR above DS.

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Magic Mirror on the Wall, Who Is the Smartest One of All?

Online Appendix

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A Experimental Results of All Participants

In this section, we replicate and report all results reported in the main text. Table A.1 presents the distribution of actions in the two diagnostic games.

Table A.1: Frequency of Action Choices in the Diagnostic Games

Action	IR	DS
a	298/470	36/470
b	63/470	82/470
c	59/470	352/470
d	50/470	—

All choices made irrespective of opponent type.

We begin by summarizing choice behavior and the preference relation over IR and DS irrespective of the opponent type. Table A.2 lists these results.

Table A.2: Preferences between IR and DS

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	212/470	258/470
Percentage	45.1%	54.9%

All choices made irrespective of opponent type.
$IRM \equiv$ Iterative 'top-down' model of reasoning.

As a next step, we control for participants whose behavior is inconsistent with best-responding across all games and either type. For example, we now remove participants who play a with a valuation $v > 12$, and further exclude those whose valuations exceed the maximum possible payoff given their action choice; e.g., playing b with a valuation $v > 13.25$ or c with a valuation $v > 12.25$ in either of the two control games, MS and NE. As a result, we are now focussing on 186 participants playing against an undergraduate student of any year or discipline and 180 participants playing against a Ph.D. students in Economics, respectively. Table A.3 lists these results of $n = 366$ choices irrespective of opponent type.

Table A.3: Controlling for Best-Response Consistency

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	166/366	200/366
Percentage	45.4%	54.6%

All choices made irrespective of opponent type excluding
all choices that are inconsistent with best-responses in MS and NE.
$IRM \equiv$ Iterative 'top-down' model of reasoning.

Next, we control for participants whose behavior is consistent with a preference for Nash equilibrium in pure strategies and either type. That is, we now remove participants who play c in both DS and NE as well as value this control game weakly above IR. This lets us focus on 173 participants playing against an undergraduate student of any year or discipline and 161 participants playing against a Ph.D. students in Economics, respectively. Table A.4 lists these results of $n = 318$ choices irrespective of opponent type.

Table A.4: Controlling for Nash Equilibrium Preference

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	163/334	171/334
Percentage	48.8%	51.2%

All choices made irrespective of opponent type excluding
all choices that play c in DS and NE and value NE weakly above DS.
$IRM \equiv$ Iterative 'top-down' model of reasoning.

Last, we leverage MS and NE and, in this step, exclude only those choices that value all small games equally; that is, $v_{DS} = v_{MS} = v_{NE}$. This results in concentrating on 137 participants playing against an undergraduate student and 126 participants playing against a Ph.D. students in Economics, respectively. Table A.5 lists these results.

Table A.5: Controlling for Equal Valuations of All Smaller Games

	$IR \succ DS$	$IR \precsim DS$
IRM Prediction	*all*	*nil*
Ratio	129/263	134/263
Percentage	49.0%	51.0%

All choices made irrespective of opponent type excluding all choices that value DS, MS, and NE equally.
$IRM \equiv$ Iterative 'top-down' model of reasoning.

Overall, the inclusion of the controls does not alter the results. Similar to the results reported in the main text, while the ratio of those who weakly prefer DS over IR increases to some extent, using the entire sample also suggests that participants may value the predictability of their opponents' actions.

Turning to choices at the subject-level and a brief discussion of differences in behavior by opponent type. We have established that approximately half of the choices made by these participants are consistent with difficulty of predicting others' behavior. On the full sample, this turns out to be even stronger when we control for valuing all smaller games equally as highlighted above. Table A.6 shows the comparative statics of the ranking over the set of diagnostic games conditional on the opponent's identity (i.e., either an undergraduate student or a Ph.D. student in Economics).

Table A.6: Ranking of IR and DS by Opponent Type

			Undergraduate	
			$IR \succ DS$	$IR \precsim DS$
Ph.D.	$IR \succ DS$	IRM Prediction	*all*	*nil*
		Ratio	67/235	49/235
		Percentage	28.5%	20.9%
	$IR \precsim DS$	IRM Prediction	*nil*	*nil*
		Ratio	29/235	90/235
		Percentage	12.3%	38.3%

$IRM \equiv$ Iterative 'top-down' model of reasoning.

Lastly, we ran ordinary least-square regressions with random effects controlling for order effects as well as the opponent order. In particular, we regressed the difference in valuations of IR and DS ($v_{IR} - v_{DS}$) on the opponent dummy PhD, which is 0 for facing an undergraduate student and 1 for playing against a Ph.D. student in Economics, and the valuations for both MS and NE. Further, we include the game order dummy *DS before IR*, which is 0 if IR is displayed before *DS* and 1 if *DS* is displayed before IR. In addition, we also include the opponent order dummy *PhD before UG*, which is 0 if participants played first against an undergraduate student and afterwards against a Ph.D. student in Economics in the first part of the experiment and 1 if the order is reversed.

Table A.7: OLS Estimations with Random Effects of Difference in Valuations of IR and *DS*

Ranking by Opponent	UG: $IR \succ DS$ PhD: $IR \succ DS$	UG: $IR \precsim DS$ PhD: $IR \succ DS$	UG: $IR \succ DS$ PhD: $IR \precsim DS$	UG: $IR \precsim DS$ PhD: $IR \precsim DS$	*All*
	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$
Intercept	2.474***	−1.075	2.498*	−1.597**	0.069
	(0.831)	(1.101)	(1.379)	(0.685)	(0.682)
PhD	−0.190	3.642***	−3.418***	0.206	0.360*
	(0.186)	(0.290)	(0.350)	(0.148)	(0.170)
v_{MS}	−0.116	−0.043	0.007	0.037	−0.039
	(0.076)	(0.090)	(0.111)	(0.054)	(0.055)
v_{NE}	0.070	0.019	-0.007	0.030	0.067
	(0.078)	(0.094)	(0.115)	(0.057)	(0.058)
DS before IR					0.009
					(0.215)
PhD before UG					-0.225
					(0.219)
σ_ϵ	1.059	1.435	1.286	0.995	1.839
σ_u	0.897	0.750	0.812	0.961	1.002
N	134	98	58	180	470
(Between) R-squared	0.009	0.019	0.009	0.013	0.010

***Significant at the 1 percent level; **Significant at the 5 percent level; *Significant at the 10 percent level

We first split our sample by preference relation over the set of diagnostic games and opponent type (= 2×2) as in Table A.6 and then estimate the model using the full sample. Unlike in the main text, we do not exclude participants from our analysis whose valuations exceed the maximum possible payoff given their action and those who are inconsistent with best-responding in *DS*. Table A.7 lists the results from this analysis.

We find a strong effect of the observed characteristic of the opponent, *Ph.D.*, on the difference in valuations of IR and *DS* for all ranking as long as $DS \succsim IR$ against one opponent type only. This is also mildly true for the full sample, irrespective of the ranking over the set of diagnostic games. As expected, we do not find a strong effect when $DS \prec IR$. Here, we also do not observe a strong effect when $DS \succsim IR$. Overall, these estimation results for all $N = 235$ are in line with the difference in differences of valuations by opponent type and by ranking of IR and DS too. Using the full sample, we also do not find any indication of order effects, either due to presenting participants IR or DS before the other as well as playing each of the four games first against an undergraduate student or a Ph.D. student in Economics in the first part of the experiment.

B Further Analysis of Empirical Value Distributions

Moving beyond summary statistics, we now turn to the empirical distribution of valuations by the ranking of IR and DS induced by the valuations. We now enrich our discussion by leveraging the cardinal information obtained in the valuation task. Figure B.1 visualizes the empirical distributions of the valuations of the two diagnostic games, IR and DS, as well as the two control games, MS and NE. For this analysis we again focus on the 343 choices as summarized in Table 1 in the main text.

For the diagnostic games, the value distribution for DS (IR) is significantly higher (lower) in stochastic dominance when $DS \succsim IR$ than $DS \prec IR$: two-sample Kolmogorov-Smirnov test produces $p < 0.001$.[1] While differences between how the two "groups" value IR and DS are expected given how the groups are defined, the value distributions provide further support for the idea that the behavior of the $DS \succsim IR$ group refelcts reasoning that falls outside of the iterative 'top-down' model of reasoning. First, the large differences between the empirical value distributions in IR indicate that the $DS \succsim IR$ participants face difficulties in modeling and predicting the opponents' behavior in IR – a game where reasoning about rationality plays no predictive role. Second, participants' valuations in DS allows the analyst to infer their (confidence in their) beliefs about rationality: we can infer that participants with $12 \leq v \leq 12.25$ believe that their opponents are rational. Thus, the large difference between the empirical value distributions in DS indicates that the $DS \succsim IR$ group is more likely to believe in rationality relative to the

[1] In this discussion of empirical value distributions, all reported p-values are associated with two-sample Kolmogorov-Smirnov tests.

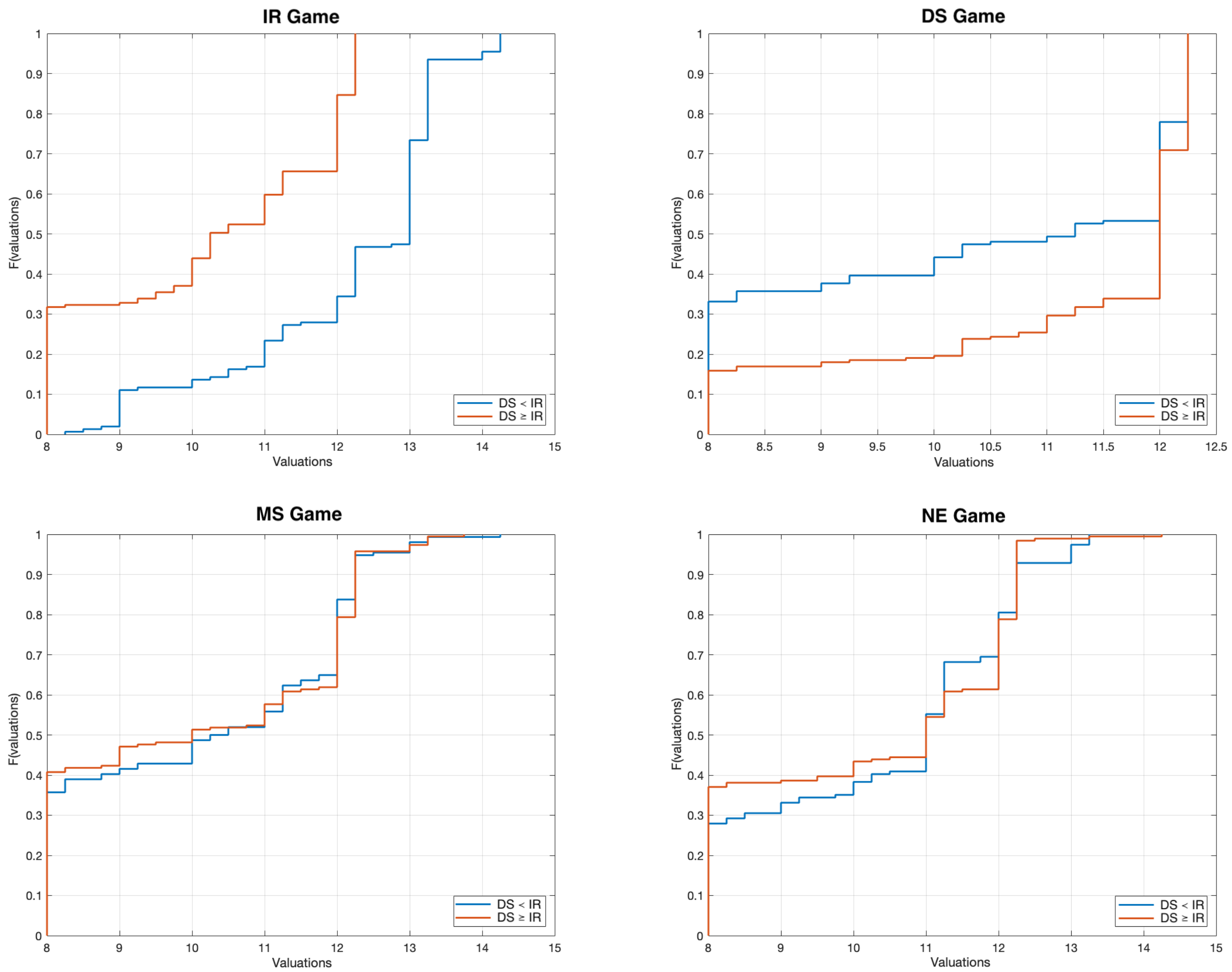


Figure B.1: Empirical Value Distributions of All Games by the Ranking of IR and DS for All $n = 343$ Choices. Top Row: The diagnostic games. Left: IR; Right: DS. Bottom Row: The control games. Left: MS; Right: NE.

$DS \prec IR$ group.

For the two control games, the empirical value distributions by ranking of IR and DS, the two groups of interest, overlap and cross each other several times as well. Thus, it is not surprising that no statistically significant differences can be detected ($p \geq 0.481$). This also supports the hypothesis that the relative preference for DS over IR between the two groups is not driven by a preference for small games or Nash equilibrium in pure strategies *per se* as these two groups value MS and NE similarly.

So far we only visualized the empirical value distributions separately for each game by the ranking of the set of diagnostic games. In Figure B.2, we show the empirical value distributions for all games by the ranking of IR and DS.

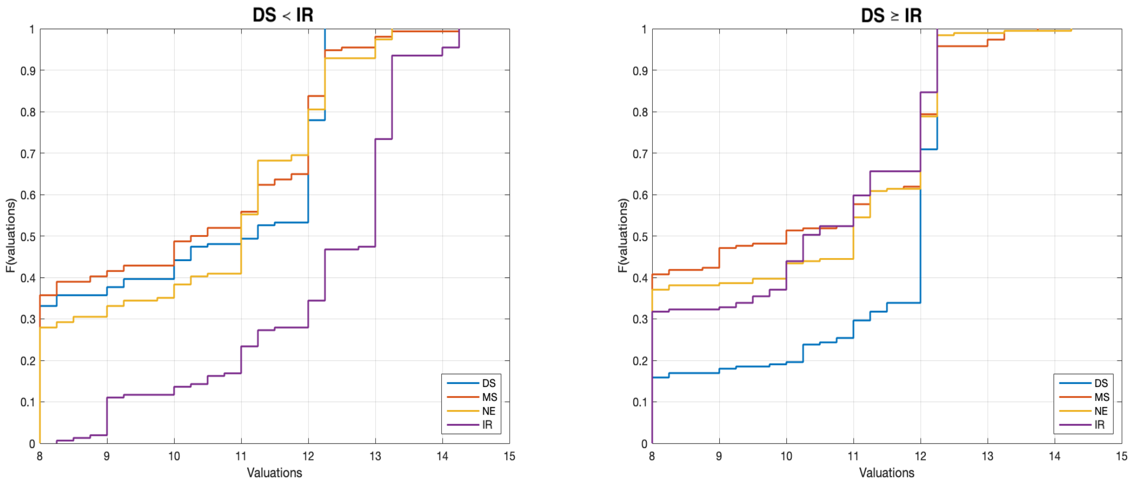


Figure B.2: Empirical Value Distributions of IR, DS, MS, and NE by Ranking of IR and DS

For the $DS \succsim IR$ group, the valuation distribution for DS first-order stochastically dominates the valuation distributions of the two control games (both $p < 0.001$). Further, no statistical differences are observed when comparing the distributions of the two control games ($p = 0.429$). By contrast, when $DS \prec IR$, the valuation distributions of all small games overlap and are statistically indistinguishable from each other with the exception of DS and NE ($p = 0.035$).[2] We interpret these findings as further evidence that for approximately half of our participants, DS is indeed very attractive because it permits easier modeling and hence predicting the opponent's choices. The other half of participants, however, appear not to distinguish between the small games and, *inter alia*, have strictly higher valuations for IR than DS.

C Further Analysis of Opponent Type

By exploiting the cardinal information collected in the valuation task, we are able to detect not only ordinal differences in the ranking over the diagnostic games but also more nuanced differences: whether DS becomes *relatively* more or less attractive conditional

[2]Differences in valuation distributions are not significant: $p = 0.244$ from comparing games DS vs. MS and $p = 0.305$ for MS vs. NE, respectively.

on both the preference relation over *DS* and *IR* as well as the opponent's sophistication. The corresponding difference in differences of valuations $v_{IR} - v_{DS}$ by opponent type are depicted in Figure C.1.

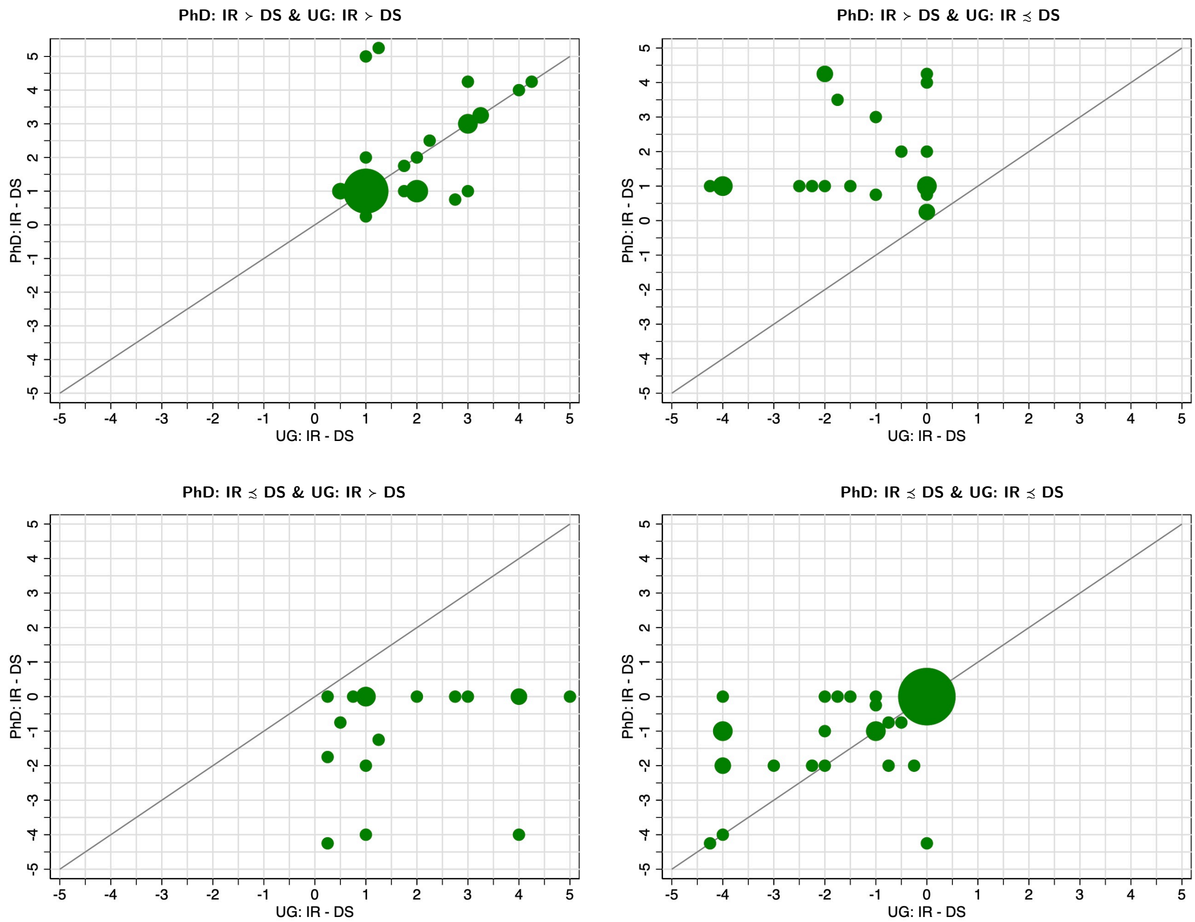


Figure C.1: Difference in Differences of Valuations of *IR* and *DS* by Ranking of *IR* and *DS and* by Opponent Type

As visualized in Figure C.1, depending on the preference relation over the games by opponent type, participants indeed value the games differently when facing either an undergraduate student or a Ph.D. student in Economics. On one hand, when $DS \succsim IR$ against both types, *DS* becomes relatively *less* valuable when playing against a Ph.D. student in Economics. This difference is statistically significant at the 5%-level using both t-test and Wilcoxon's signed-rank test ($p < 0.026$). On the other hand, when $DS \prec IR$ against both types of opponents, *DS* becomes relatively *more* valuable when facing a Ph.D. student in Economics. This difference, however, is not statistically significant ($p >$

0.257 for both tests). Naturally, whenever $DS \prec IR$ against one opponent type but not the other, the differences are statistically significant at the 1%-level (all $p < 0.001$). The direction of these asymmetries in the observed choices by opponent type surprised us. If anything, we conjectured *DS* becoming relatively *more* attractive when playing against a Ph.D. student in Economics conditional on ranking *DS* above *IR* (possibly because experiencing difficulties in predicting the opponent's choices).[3]

D Robustness Test

As a further robustness test and to complement the non-parametric analysis and key elements discussed in Section 4, we ran ordinary least-square regressions with random effects controlling for order effects as well as the opponent order. In particular, we regressed the difference in valuations of *IR* and *DS*, $v_{IR} - v_{DS}$, on the opponent dummy *PhD*, which is 0 when facing an undergraduate student and 1 when playing against a Ph.D. student in Economics, and the valuations for both *MS* and *NE*. Further, we include the game order dummy *DS before IR*, which is 0 if *IR* is displayed before *DS* and 1 if *DS* is shown before *IR*. In addition, we also include the opponent order dummy *PhD before UG*, which is 0 if participants played first against an undergraduate student and afterwards against a Ph.D. student in Economics in the first part of the experiment and 1 if the order is reversed.

To account for the fact that we observe each participant repeatedly and behavior across games for the same participant is not independent, we treat each participant as our units of statistically independent observations. We first split our sample by preference relation over the set of diagnostic games and opponent type (= 2 × 2) as in Table **??** and then estimate the model using the full sample. As above, we exclude participants from our analysis whose valuations exceed the maximum possible payoff given their action,

[3] The findings do not qualitatively change when we restrict attention to those participants who hold the belief that their opponent is rational. When *DS* is ranked above *IR* against both types, *DS* still becomes relatively *less* enticing when playing against a Ph.D. student in Economics. This difference is statistically significant at the 5%-level using both t-test and Wilcoxon's signed-rank test ($p < 0.034$). When *DS* is ranked below *IR*, *DS* still becomes relatively more alluring when facing a Ph.D. student. It is not statistically significant ($p > 0.160$ for both tests), as in the aggregate-choice analysis. As above, when *DS* is ranked above *IR* against one opponent type but not the other, the differences are also statistically significant at the 1%-level (all $p < 0.008$).

those who played any other action than c in *DS*, and those who are inconsistent with best-responding in *MS* and *NE*.[4] Table D.1 lists the results from this analysis.

Table D.1: OLS Estimations with Random Effects of Difference in Valuations of IR and *DS*

Ranking by Opponent	UG: $IR \succ DS$ PhD: $IR \succ DS$	UG: $IR \precsim DS$ PhD: $IR \succ DS$	UG: $IR \succ IR$ PhD: $IR \precsim DS$	UG: $IR \precsim DS$ PhD: $IR \precsim DS$	*All*
	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$	$v_{IR} - v_{DS}$
Intercept	2.571^{***}	-0.743	2.772	-1.566^{*}	0.246
	(0.933)	(1.338)	(1.742)	(0.925)	(0.866)
PhD	-0.038	3.308^{***}	-2.620^{***}	0.357^{**}	0.291^{*}
	(0.135)	(0.378)	(0.502)	(0.179)	(0.173)
v_{MS}	-0.050	-0.119	-0.216	0.079	-0.071
	(0.091)	(0.111)	(0.174)	(0.065)	(0.067)
v_{NE}	-0.018	0.046	0.105	-0.025	0.073
	(0.088)	(0.119)	(0.160)	(0.076)	(0.073)
DS before IR					-0.030
					(0.277)
PhD before UG					-0.197
					(0.281)
σ_ϵ	0.619	1.276	1.141	0.884	1.375
σ_u	1.241	0.549	1.215	1.025	1.471
N	96	53	33	109	291
(Between) R-squared	0.030	0.514	0.426	0.031	0.012

***Significant at the 1 percent level; **Significant at the 5 percent level; *Significant at the 10 percent level

We find a strong effect of the observed characteristic of the opponent, *Ph.D.*, on the difference in valuations of IR and *DS* for all ranking as long as $DS \succsim IR$ against at least one opponent type. This is also mildly true for the full sample, irrespective of the ranking over the set of diagnostic games. As expected, we do not find a strong effect of type when $DS \prec IR$. These estimation results are in line with the difference in differences of valuations by opponent type and by ranking of IR and *DS*, as depicted in Figure C.1. We do not find any indication of order effects, either due to presenting participants IR or *DS* before the other as well as playing each of the four games first against an undergraduate student or a Ph.D. student in Economics in the first part of the experiment.

[4]We replicated the same analysis on the entire sample and report the results in the Online Appendix.

E Detailed Non-Choice Data Analysis

In this section, we report detailed results that were only concisely presented in the main text in Section 4.4. As text data required more data cleaning and preprocessing, we performed the following steps. For normalization, we converted the data to a consistent format, e.g., lowercasing. Next, in terms of tokenization we split text into words, phrases, symbols, or other meaningful elements. Further, we removed common words that may not add value to the analysis, i.e., stop word removal. In addition, we reduced words to their base or root form, that is, stemming or lemmatization. Lastly, in order to handle special characters and punctuation, we removed or replaced non-alphanumeric characters as necessary.

E.1 Exploratory Data Analysis

In order to identify the most common words or phrases, we begin with a simple and straightforward frequency analysis. The top ten most common words across the entire dataset, excluding common English stop words are "player" (200 occurrences), followed by "choose (198), "highest" (113), "12" (66), "option" (64), "best" (56), "action" (49), "earnings" (48), "pick" (48), and "row" (47), respectively.

Next we turn to length analysis, which involves examining the distribution of text lengths across our dataset to gain insights into the structure and the nature of the text by ranking over the two diagnostic games and for each game separately. Figure E.1 visualizes the implementation of the two diagnostic games. It appears that participants tend to write more detailed comments, measured by average word and sentence count, about their reasoning in games that they prefer. For example, participants who rank *IR* above *DS* write, on average, 35.03 (1.5) words (sentences) in *IR* but only 29.33 (1.14) words (sentences) in *DS*. By contrast, those who rank *DS* above *IR* write 31.53 (1.33) words (sentences) in *DS* and just 30.25 (0.97) words (sentences) in *IR*.

We move on to visualize key terms and their frequencies as word clouds in Figure E.2.

In the next step of our exploratory analysis, we focus on differences in participants'

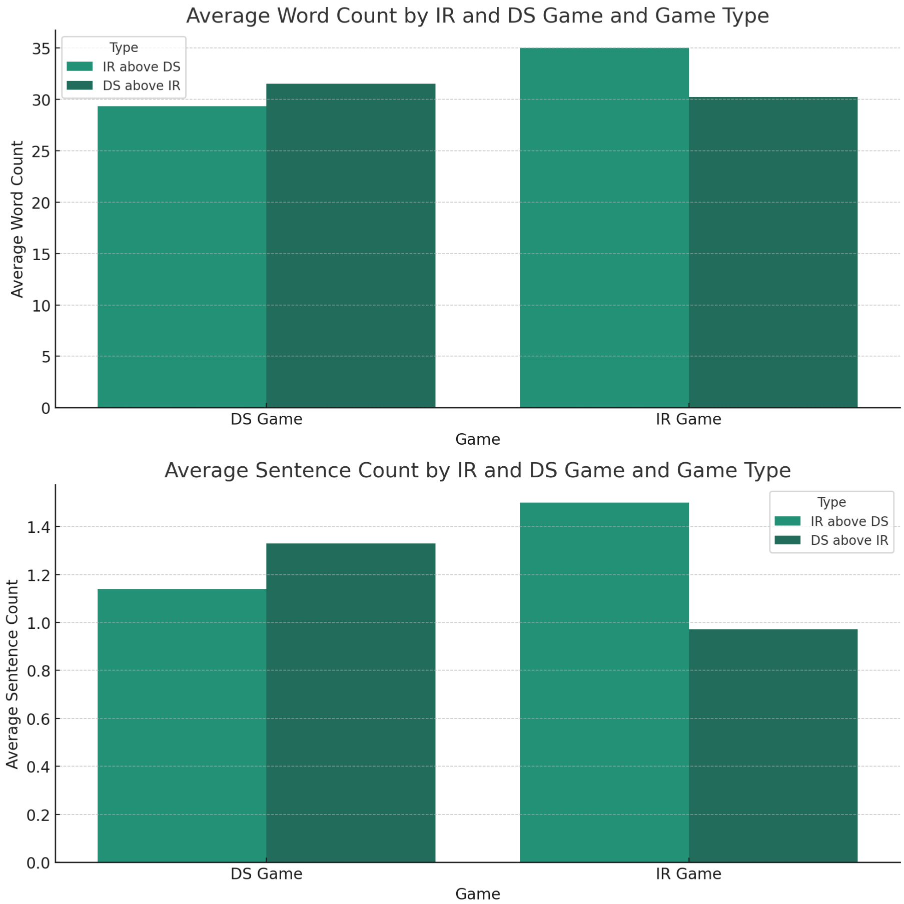


Figure E.1: Average Word Count (top) and Average Sentence Count (bottom)

Figure E.2: Word Clouds by the Ranking of *IR* and *DS*. Top Row: *IR* Game; Bottom Row: *DS* Game. Left Column: $IR \succ DS$; Right Column: $IR \precsim DS$.

notes. In particular, we highlight the unique words most commonly used within each ranking over the games. Figure E.3 illustrates these unique keywords by ranking and for each game separately.

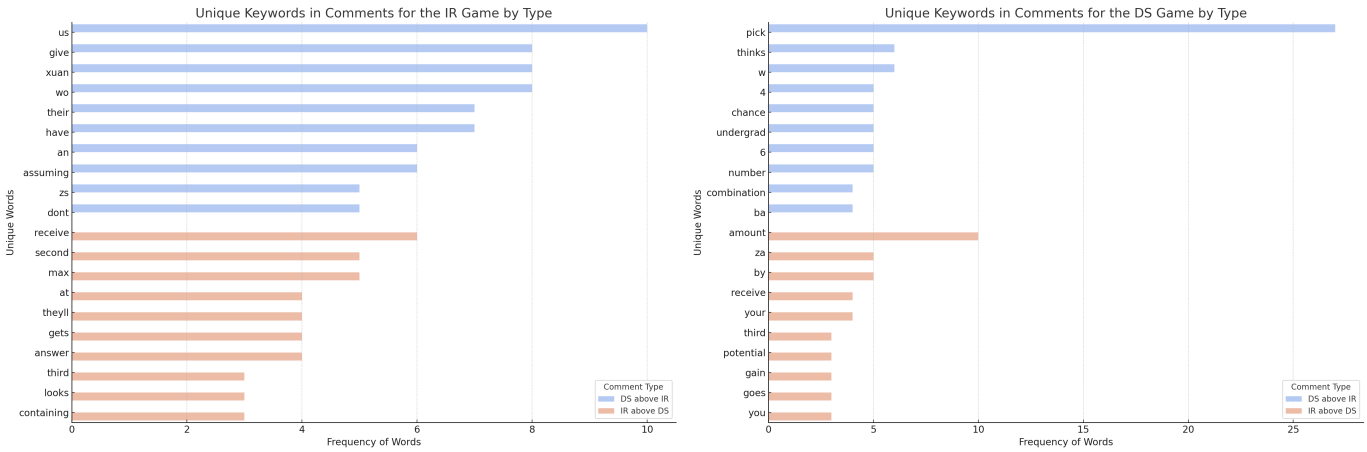


Figure E.3: Unique Keywords Used by the Ranking of IR and DS. Left Column: IR Game; Right Column: DS Game.

Before we conclude our exploratory analysis, we delve into complexity indicators. As we have seen in Figure E.1, participants' ranking over the two diagnostic games, as inferred by their choices, is associated with higher average word and sentence counts. The frequency of complexity-related keywords within notes written could serve as a proxy for participants' ability to express more complex reasoning processes in the diagnostic game that they rank above the other. Here, we focus on two specific measures that can serve as proxies for the complexity discussed: complexity keyword frequency and average comment length. First, the frequency of predefined complexity-related keywords within participants' notes can serve as a direct indicator of a strategic complexity discussion. Higher frequencies of these keywords may suggest more in-depth strategic considerations. The complexity keywords used in the analysis are terms that hint at strategic thinking, decision-making processes, and considerations of various options or outcomes. Examples of such keywords are "strateg," "decid," "choos," "option,“ "think," "consider," "outcome," "possibl," or "predict." Second, longer comments might indicate more elaborate discussions, potentially reflecting the ability to express higher strategic complexity. The average note length for each ranking over DS and IR can thus serve as a proxy for the level of detail and complexity in the discussions. Figure E.4 illustrates these two complexity measures.

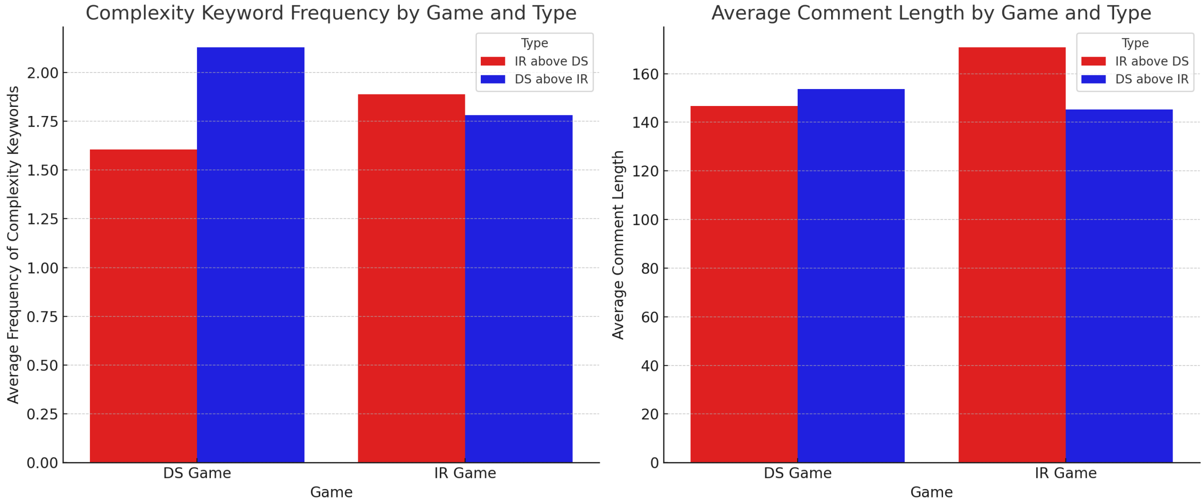


Figure E.4: Complexity Measures by Ranking of IR and DS and IR and DS Game. Left: Complexity Keyword Frequency; Right: Average Length of Notes Taken.

In DS, notes made by those who rank DS above IR tend to include more complexity-related keywords and are slightly longer on average compared to notes taken by participants who rank DS below IR. This is suggestive evidence that discussions involving those who prefer DS over IR might delve deeper into strategic deliberation when it comes to predicting behavior in DS. In IR, however, both ranking types show a higher frequency of complexity keywords compared to DS, with those who rank IR above DS notes being significantly longer on average. This is suggestive evidence that IR prompts more complex strategic deliberations, especially for $IR \succ DS$, where the discussions are not only more frequent in terms of complexity-related keywords but also more detailed, as indicated by the longer comment length. Overall, these findings suggest that the strategic complexity discussed in participants' notes varies by both diagnostic game and ranking over the games, with discussions in DS by those who rank DS above IR and discussions in IR by those who rank IR above DS exhibiting higher levels of complexity, as indicated by both the frequency of complexity-related keywords and the average comment length.

E.2 Feature Extraction

We now proceed with feature extraction such as Bag-of-Words (BoW) to represent the notes to "their future-self" as a matrix of token counts; Term-Frequency-Inverse-Document-Frequency (TF-IDF) to reflect the importance of a term to a comment relative to the overall corpus; as well as Word-Embeddings and thus use pre-trained vectors like Word2Vec and GloVe to capture semantic meanings of words. In Figure E.5, we highlight and visualize the word embeddings for words found in our dataset, projected into two dimensions using principal component analysis (PCA) for ease of visualization. Each point represents a word, and its position in the space is determined by the PCA transformation of the document-term matrix, simulating how words might be represented in a high-dimensional embedding space.

This serves as a visual approximation of word relationships based on their occurrence across notes written by participants. Words that are closer together in this two-dimensional space are more likely to have similar contexts within the dataset. By contrast, words that are further apart are less related.e22

E.3 Modeling and Analysis

Let us now turn to more elaborate modeling and techniques. We begin with topic analysis on participants' notes and use Latent-Dirichlet-Allocation (LDA), a popular method for topic modeling. This approach allows us to identify distinct topics present in the notes and to understand the distribution of these topics across the two games and rankings over the games.

In turn, we examine what topics are most relevant or correlate with participants' ranking over the two diagnostic games and the two games of interest, respectively. To do so, we study the distribution of topics within each note to participants' "future self" and then aggregate this information by ranking and game. We assign the most dominant topic to each note based on the LDA model output and compute the proportion of each topic within each type–game combination.[5] Figure E.6 visualizes the topic distribution

[5]In this section of the Appendix, we use the terms "type" and "ranking over the games" interchangeably.

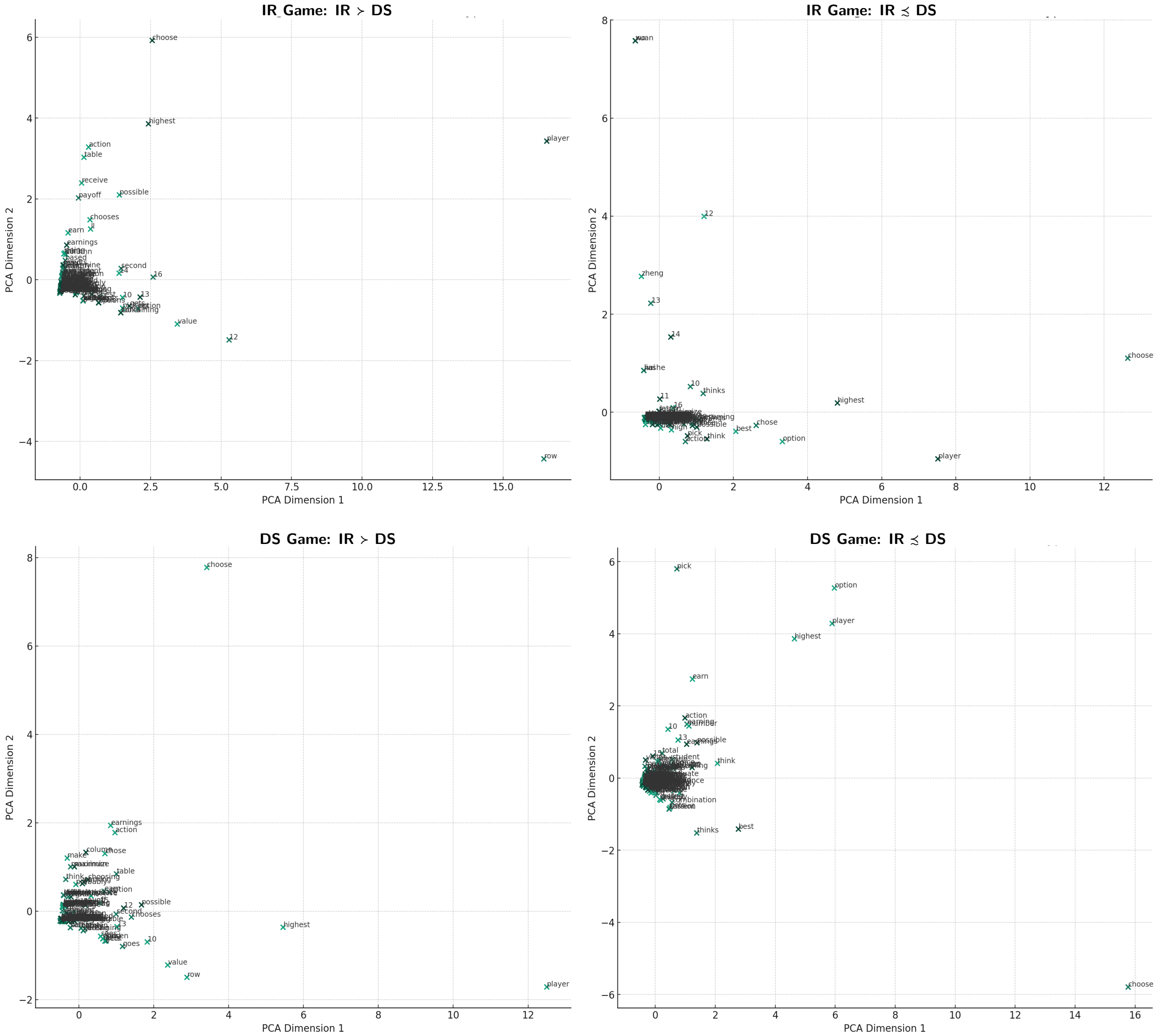


Figure E.5: Simulated Word Embeddings by the Ranking of IR and DS. Top Row: IR Game; Bottom Row: DS Game. Left Column: $IR \succ DS$; Right Column: $IR \precsim DS$.

of the two diagnostic games by participants' ranking over these.

These proportions indicate qualitative evidence that a higher emphasis on Topic 3 (in both games) is associated with ranking DS above IR, while ranking IR above DS is associated with more emphasis on Topic 2 in DS and Topics 4 and 5 in IR.

In the next step, we focus on sentiment analysis to determine the sentiment expressed in the notes, in particular, whether participants are more positive, negative, or neutral in their expressions. Average sentiment polarities by ranking over the two diagnostic games differ significantly. For those who rank DS above IR, the average sentiment polarity is approximately 0.162 while those participants who prefer IR over DS display an average

Table E.1: Topic Analysis Using Latent Dirichlet Allocation

Topic	Keywords	Interpretation
1	choose, option, think, player, best, highest, ll, possible, thinks, going	Seems to be about making decisions or choices, considering the best or highest options available.
2	12, choice, 13, 10, 15, 11, action, earnings, choices, ca	Appears to focus on numerical aspects or quantitative choices, potentially related to specific actions or earnings.
3	player, highest, chose, option, choose, pick, best, earning, earnings, make	Similar to Topic 1, this topic also revolves around decision-making, focusing on choosing the best or highest earning options.
4	player, row, highest, choose, action, best, 12, possible, 14, second	Could be discussing strategies involving rows or positions, with a focus on choosing the best or highest-ranking actions.
5	earn, pick, earning, player, choose, highest, column, earnings, maximize, max	Centered around maximizing earnings or benefits, with emphasis on picking or choosing options that yield the highest earnings.

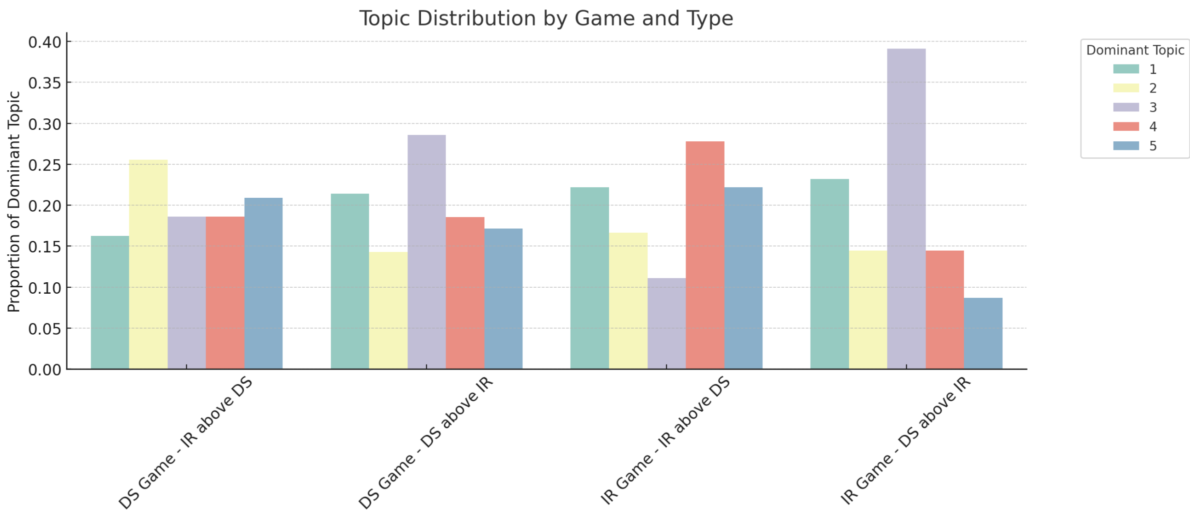


Figure E.6: Topic Distribution by Ranking of IR and DS. Games on the Left: DS Game; Games on the Right: IR Game.

sentiment polarity of roughly 0.128.

These results suggest that participants who rank DS above IR, on average, express

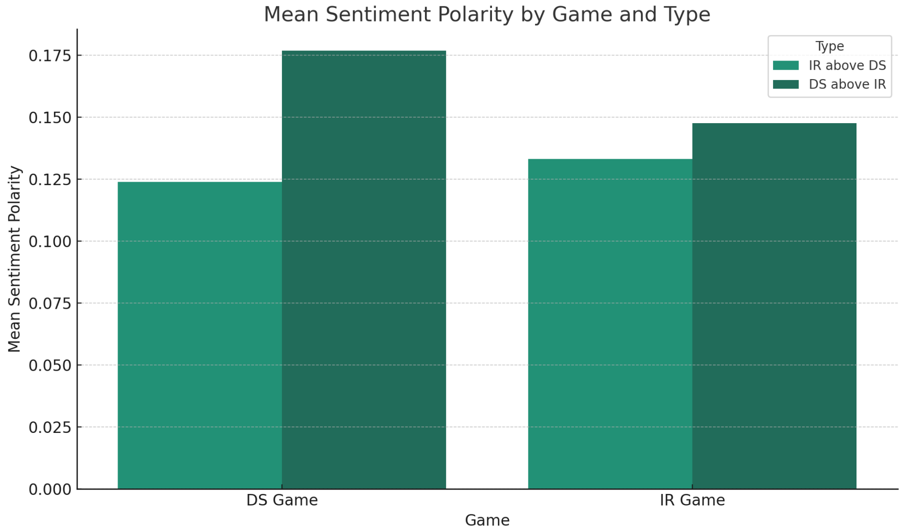


Figure E.7: Average Sentiment Polarity by Ranking of *IR* and *DS*. Left: *DS* Game; Right: *IR* Game.

comments with slightly more positive sentiment compared to those who prefer *IR* over *DS*. However, as Figure E.7 highlights and in line with participants ranking over the games, whenever *DS* is ranked above (below) *IR* the notes to their "future-self" indicate that they are also more positive (negative) in *DS* compared to *IR*.

We complement our sentiment analysis by analyzing the use of modal verbs that might indicate certainty or predictions in participants' notes to further explore confidence and prediction behavior. Figure E.8 illustrates the average certainty modal verbs count by ranking over the games and *DS* and *IR*, respectively.

The analysis of modal verbs that offers suggestive evidence of certainty or predictions shows that whenever a given participant ranks one diagnostic game over the other, then their choices are also associated with more certainty modal verbs per note written. For those who rank *DS* above *IR*, the average verbs count decreases from 0.914 to 0.478 when moving from *DS* to *IR*, suggesting a stronger confidence or a greater willingness to make firm predictions in *DS*. By contrast, participants who prefer *IR* over *DS* feature an increase in their average certainty modal verbs count from 0.698 in *DS* to 0.889 in *IR*, potentially indicating an increased confidence or predictive stance in *IR*.

Finally, we conclude our in-depth text analysis with a cluster analysis where we group texts based on similarity of content. We perform a cluster analysis on participants' notes,

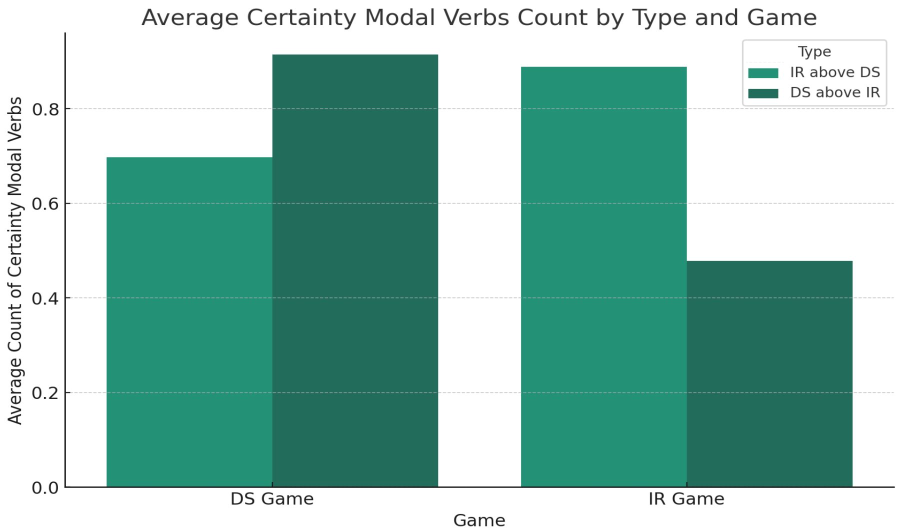


Figure E.8: Average Certainty Modal Verbs Count by Ranking of *IR* and *DS*. Left: *DS* Game; Right: *IR* Game.

use the document-term matrix (DTM), and apply a clustering algorithm to group participants' notes to their "future-self" based on their textual content. The common approach for clustering textual data that we follow here is the K-Means algorithm, which partitions the notes into clusters with similar word usage patterns. In a first step, we use both the elbow method and the silhouette score based on our dataset's characteristics to determine the appropriate number of clusters, eventually settling on five clusters.[6] Next, we apply the K-Means clustering algorithm to the DTM. To understand the content of each cluster identified, we offer here the most frequent and distinctive words in participants' notes belonging to each cluster. This involves analyzing the text data to identify keywords that are particularly representative of the comments within each cluster. These are summarized in Table E.2.

These keywords offer some qualitative insights into the thematic content of each cluster. While Clusters 1 and 4 seem to focus on numeric values and options, possibly related to strategic decisions or evaluations within games, other clusters like Cluster 2 emphasize decision-making with terms like "choose" and "chooses," alongside positional references like "highest" and "table." By contrast, Cluster 3 reflects contemplation and

[6]Details are available upon request.

Table E.2: Cluster Analysis Keywords

Cluster	Keywords
1	player, row, 12, value, gets, 10, option, 13, highest, 16
2	highest, player, choose, possible, option, table, chooses, chose, column, assuming
3	choose, player, think, best, will, earnings, thinks, option, highest, maximize
4	choose, 12, highest, pick, player, best, choice, 10, chose, earn
5	player, action, choose, earnings, highest, best, think, pick, chose, option

strategy with words like "think," "best," and "maximize," possibly indicating a focus on optimizing outcomes. Lastly, Cluster 5 mixes elements of decision-making like "choose" or "option" with an emphasis on outcomes as, e.g., "earnings" or "highest." Figure E.9 visualizes the discussions and considerations present within participants' notes, categorized by the clustering algorithm based on textual content similarities by ranking over the diagnostic games and for each of the games individually.

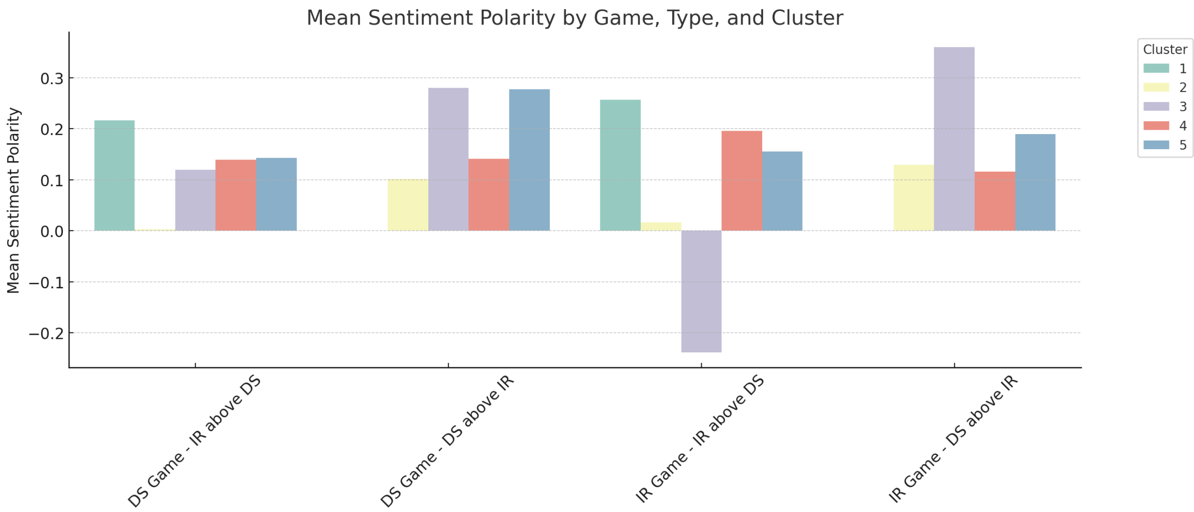


Figure E.9: Topic Distribution by Ranking of IR and DS. Games on the Left: DS Game; Games on the Right: IR Game.

As can be seen in Figure E.9, clusters are differently distributed across the two diagnostic games and across the ranking over the games. In particular, positive sentiment to Cluster 1 is associated with ranking IR above DS, while positive sentiment to Cluster 3 is associated with ranking DS above IR.

Magic Mirror on the Wall, Who Is the Smartest One of All?

Online Appendix: Experimental Interface

— Implementation and Main Experiment —

Yoram Halevy Johannes C. Hoelzemann Terri Kneeland

January 12, 2025

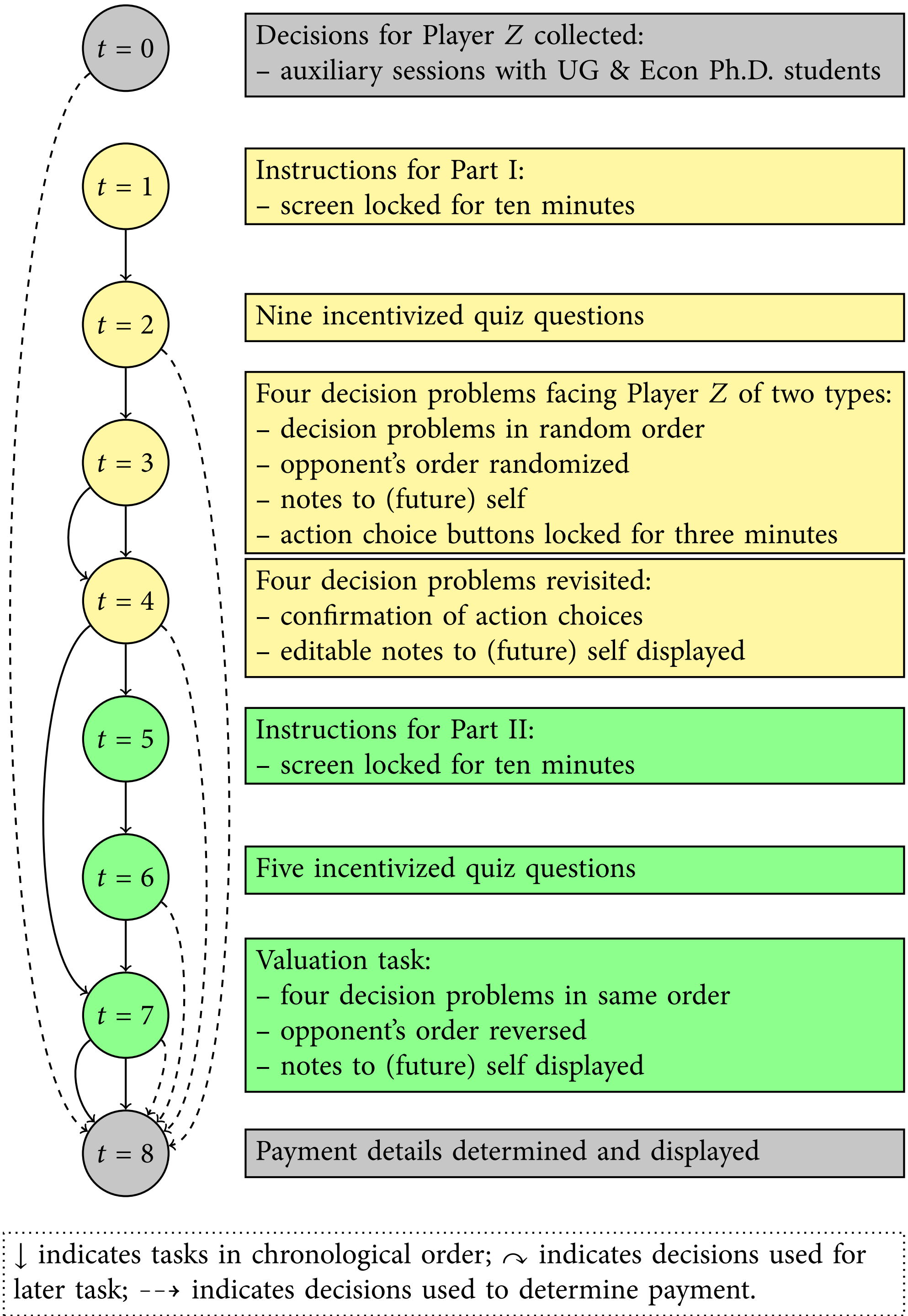


Figure 1: Timeline of the Experiment

Instructions

Welcome. This is an experiment in the economics of decision-making. If you pay close attention to these instructions, you can earn a significant amount of money that will be paid to you at the end of the experiment via interac e-transfer.

To participate in this online experiment, you will need to use Chrome or Safari on your notebook or personal computer (other browsers and mobile phones are not supported). If you are using a browser or device that is not supported, please copy the experiment link, open one of these supported browsers on a notebook or pc and paste the link into the address bar.

Your computer screen will display useful information. Remember that the information on your computer screen is PRIVATE. To insure best results for yourself and accurate data for the experimenters, please DO NOT COMMUNICATE or interact with other people on other media at any point during the experiment. If you have any questions, or need assistance of any kind, please call +1-647-XXX-ZZZZ or use Skype (j.hoelzemann@utoronto.ca) anytime from 8am to 8pm Toronto time (EST) and one of the experimenters will help you privately. We expect the experiment to take up to 90 minutes to complete, but you can take as much time as you want to finish it (until this experiment terminates at 8pm EST).

This experiment has two parts. In each part you will face four decision-making problems. During the experiment, and in order to determine your payment, you will be randomly matched with **another** participant (see below for details), who already made her/his choices in a previous session.

The other participants (Players Z and Y)

The other participant (called "Player Z") with whom you will be matched with is either an undergraduate student from any year or discipline at The University of Toronto or an Economics PhD student who took several advanced courses that are highly relevant for this experiment. You will not learn whether the other participant is an undergraduate student from any year or discipline or an Economics PhD student until the experiment concludes. Therefore, you will always be asked to make two choices: one if Player Z is an undergraduate student from any year or discipline and another if (s)he is an Economics PhD student.

Player Z participated in a previous experimental session in which (s)he was matched with another participant ("Player Y") who participated in the same session and played your role. When Player Z was an undergraduate student from any year or discipline, so was Player Y; and when Player Z was an Economics PhD student, so was Player Y.

The choices Player Z made are used to determine your earnings in the current session, but you will not be told which choices Player Z made when you make your choices. You can, however, attempt to reason about the choices Player Z made.

PART 1

The Basic Idea

This part has four different problems. In each round, you will face a different decision problem similar to the one below.

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	6
	d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

In order to assist you to choose an action, when you move your mouse over a row in the `Your Earning' table on the left, the action will be highlighted in yellow in both tables: a row on the left table, and a column on the right table. By left clicking your mouse over a row it will remain highlighted, and you can unhighlight it by clicking your mouse again or clicking another row.

Similarly, when you move your mouse over a row that corresponds to an action of Player Z in the 'Player Z's Earnings' on the right, the row will be highlighted in green on the right table and the corresponding column will be highlighted in green on the left table. Clicking your mouse over the row will keep it highlighted, and clicking it again (or clicking another action) will unhighlight it.

Please try to highlight actions for you and Player Z in the earnings tables above.

Your earnings in each problem depend on your choice of action (between: a, b, c, d) and Player Z's choice of action (between A, B, C, D). Your earnings possibilities are presented in tables like the ones above. In each problem, your earnings are given by the blue numbers in the left table. Your choice of action determines the row in the `Your Earnings' table and Player Z's choice of action determines the column in the same table. The blue number in the cell corresponding to any combination of actions (yours and Player Z's) represents your earnings.

Player Z's earnings are given in the right table. This table is important because it may help you figure out which action Player Z chose when s/he faced this decision problem. Player Z's choice of action determines the row in Player Z's earnings table, while Player Y's choice of action determines the column in this table. The number in the cell corresponding to any combination of actions (Player Z's and Player Y's) represents Player Z's earnings.

Finally, Player Y had an identical earnings table to yours (the one on the left side of the screen), and her/his earnings depended on Player Y's choice of action as well as on Player Z's (just like yours). You can therefore consult your earnings table in order to try and figure out what was Player Y's choice of action, and so forth.

In summary, your choice of action and Player Z's choice of action affect your earnings, while Players Z and Y earnings depend on both of their chosen actions. Just like you know Player Z's earnings table, Player Y knew Player Z's earnings table and Player Z knew Player Y's earnings table.

For example, if you choose action "b" and Player Z chose action "B" then your earnings would be $1. If Player Y chose action "b" too then Player Z's earnings were $4. If, however, Player Y chose action "d" then Player Z's earnings were $30. If you choose action "c" and Player Z chose action "A", your earnings would be $13. If Player Y chose action "c" too then Player Z's earnings were $3. If, however, Player Y chose action "d" player Z's earnings were $18. Numbers in the example are just an example and do not intend to suggest how anyone should make their choices.

Problem structure

The problems that you will face will take one of two forms. One problem will have four possible actions for both you (e.g. a, b, c or d) and Player Z (e.g. A, B, C or D) as in Example Problem 1. The other three problems will have three possible choices for both you (e.g. a, b, or c) and Player Z (e.g. A, B, or C) as in Example Problem 2. In these three problems your earnings table is always the same, while the earnings table for Player Z changes in each problem (remember that Player Y's earnings and potential actions are always identical to yours).

Example Problem 1

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Example Problem 2

Your Earnings

Your action	Player Z's action: A	B	C
a	3	15	1
b	8	0	4
c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c
A	13	5	8
B	7	9	10
C	10	6	12

Notice that your earnings generally depend on Player Z's chosen action. When considering which action to choose you may consider how likely it is that Player Z chose each action. This, in turn, may depend on which action Player Z believed that Player Y (who had the same actions and earning as you) will choose. As Player Y's earnings depended on Player Z's choice too (just like yours), Player Y's chosen action may have depended how likely (s)he believed that Player Z will choose each action.

Finally, to choose an action you must click on the rectangular button around the action's name (the lowercase letter next to the row, on the margin of the left table), after it has been activated (turned blue).

The four decision problems

There will be four problems: you will face different decision problems with different earnings tables and possible actions. You will need to choose two actions in each problem: one if Player Z is an undergraduate student from any year or discipline and a second action if Player Z is an Economics PhD student (the actions could be the same or different, it is totally up to you). After you chose the two actions, you will advance to the next screen and play a new decision problem. In one of these problems each player has four possible actions and in the other three problems each player has three possible actions. In the problems with three possible actions your (and Player Y's) earnings table is always the same, while Player Z's earnings table changes in each decision problem. (Remember that Player Y's earnings and potential actions are always identical to yours.)

Note that the earnings tables in each problem are different, so you should look carefully at them before making your choice. You will be required to spend some time on each problem, after which the rectangular buttons that allow you to choose an action will be activated. You can continue and deliberate your choices after the buttons have been activated.

Once you have completed the four problems, you will have another opportunity to revisit your choices and confirm them. You will then advance to a second part of the experiment.

Payment

You will earn a participation payment of $5.00 for participating in this experiment.

Before the actual experiment starts, you will be asked to answer several (9 in Part 1 and additional 5 in Part 2) questions. You will earn 25 cents for answering each question correctly on your first trial. If you make a mistake, you will not receive a payment for that question, but you must answer it correctly in order to move to the next question.

In addition to the participation payment and the payment for answering the quiz correctly, one decision problem that counts will be randomly selected for payment at the end of the experiment. You will be paid your earnings in that decision problem as described above or a monetary amount (that is independent of yours or Player Z's chosen actions). Any of the four problems could be the one selected, so you should treat each problem as if it will be the one determining your payment.

You will be informed of your payment, the decision problem chosen for payment, and the choices of you and Player Z only at the end of the experiment. You will not learn any other information about the choices of other participants during the experiment. The identity of Player Z will never be revealed.

Finally, after completing the experiment you will be paid electronically via interac e-transfer with the e-mail address you entered on the previous page.

Frequently Asked Questions

Q1. Is this some kind of psychology experiment with an agenda you haven't told us?
No. It is an economics experiment. If we do anything deceptive or don't pay you cash as described, then you can complain to the University of Toronto Research Ethics Board and we will be in serious trouble. These instructions are meant to clarify how you earn money, and our interest is in seeing how people make decisions.

Q2. Is there a "correct" choice of action? Is this kind of a test?
No. Your optimal action depends on your belief which action did Player Z choose. Different people may hold different beliefs.

This button will be activated after 10 minutes. Please take your time to read through the instructions.

Next

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

1. If you choose action 'a' and Player Z chose action 'C' what would your earnings be?

A $15

B $13

C $1

D $6

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

2. If Player Z chose action 'C' and Player Y chose action 'a', what were Player Z's earnings?

A $13

B $10

C $1

D $8

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

3. If Player Z chose action 'A', which action would give you the highest earnings?

- A a
- B b
- C c

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

4. If Player Y chose action 'a', which action would give Player Z the highest earnings?

A A

B B

C C

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

5. If Player Z chose action 'B', which action would give you the highest earnings?

A a

B b

C c

Quiz

Your Earnings

	Player Z's action				
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

	Player Y's action				
		a	b	c	d
Player Z's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

6. If you choose action 'c' and the Player Z chose action 'A' what would be your earnings?

A $8

B $13

C $3

D $10

Quiz

Your Earnings

	Player Z's action			
Your action	A	B	C	D
a	7	12	8	4
b	7	1	9	10
c	13	2	10	16
d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

	Player Y's action			
Player Z's action	a	b	c	d
A	13	8	3	18
B	16	4	13	30
C	10	21	16	12
D	19	5	9	21

Use the above earnings table to answer the following questions:

7. If Player Z chose action 'B' and Player Y chose action 'd', what were Player Z's earnings?

A $10

B $5

C $30

D $4

Quiz

Your Earnings

		Player Z's choice			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

8. If Player Z chose action 'D', which action would give you the highest earnings?

A a

B b

C c

D d

Quiz

Your Earnings

	Player Z's choice				
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Player Y had the same actions and earnings as you.

Player Z's Earnings

	Player Y's action				
		a	b	c	d
Player Z's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

9. If Player Y chose action 'a', which action would give Player Z the highest earnings?

A A

B B

C C

D D

You have successfully finished the quiz. The experiment follows.

You will face four problems: In each problem you will choose one action if Player Z is an undergraduate student from any year or discipline (red earnings table)

and a second action if Player Z is a PhD student in Economics (blue earnings table).

In one of these problems each player has four possible actions and in the other three problems each player has three possible actions.

In the problems with three possible actions your (and Player Y's) earnings table is always the same, while Player Z's earnings table changes in each decision problem.

You are encouraged to make use of "Your Notes" (including editing them) which is a box located below the decision problem. This text will be displayed later and will help you during the second part of the experiment. You can use it in any way you wish but it will be most beneficial for you if you record your reasoning that led you to choose your action.

When you are ready please click "next" to start the experiment.

Next

Problem 1
- Z = Undergraduate ←
- Z = PhD

Problem 2
- Z = Undergraduate
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 1 - Player Z is an undergraduate student from any year or discipline

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

Your action	Player Z's action: A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c
A	6	15	10
B	3	8	9
C	4	13	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

column A of player Z has highest possible outcome regardless of which letter I choose. I'm assuming they'll choose column A and for this reason i chose column c.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ←

Problem 2
- Z = Undergraduate
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 1 - Player Z is a PhD student in Economics

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	15	10
	B	3	8	9
	C	4	13	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

Z will always choose A, so I choose C

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ←
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 2 - Player Z is an undergraduate student from any year or discipline

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	16	9
	B	10	3	8
	C	8	10	10

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I think Player Z would choose C because it has the most consistent earning. If Player Z chose C, I would only earn something if I chose A. I'm choosing A in hopes that Player Z will not also choose A

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 2 - Player Z is a PhD student in Economics

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	16	9
	B	10	3	8
	C	8	10	10

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I think a PhD student would know the optimal earning for both assuming that both parties are cooperative. I think they would assume I go with A, for them, the best return would be B. So I'm sticking with A.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ←
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 3 - Player Z is an undergraduate student from any year or discipline

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

Your action	Player Z's action: A	B	C	D
a	0	12	13	11
b	4	14	0	6
c	10	0	11	12
d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c	d
A	12	0	16	7
B	14	0	5	11
C	12	16	0	10
D	8	4	0	12

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

oh four! Okay so new 0s. Lets start with what I've been doing... For Z: A: max=16, min=0, range=16 (DAMN, high risk) B: max=14, min HWM, all have 0s, so all have high risk. Same with Y's. So looks like range isn't the best measure here. *remember! This is an undergrad. Let's go with the strategy of maximizing for both. (maybe PhDs would try to maximize both too. That distinction might be a red herring. Why would they not? That's how contracts are signed anyway) (would

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ←

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 3 - Player Z is a PhD student in Economics

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is a PhD student in Economics.

Instructions

Your Earnings

Your action	Player Z's action: A	B	C	D
a	0	12	13	11
b	4	14	0	6
c	10	0	11	12
d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c	d
A	12	0	16	7
B	14	0	5	11
C	12	16	0	10
D	8	4	0	12

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

yeah I really think they'd do the same thing, make it good for everyone. Maybe this is testing how people think about phd students in economics hahaha. No but really, the avgs of C and a are the best for the respective peoples. So on that alone, this should be good.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 4
- Z = Undergraduate ←
- Z = PhD

Problem 4 - Player Z is an undergraduate student from any year or discipline

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

Your action \ Player Z's action	A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action \ Player Y's action	a	b	c
A	13	5	10
B	14	3	9
C	6	16	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

As this is an undergrad student, i assume they will straight away go to their highest earning column (c w/ 16) but as they can see if i chose to get the best outcome for them i would end up getting zero, so then i went to the second best option (b w/14) however the biggest earning for me was in row b but for them it was just 3, so I chose option a so they can get their highest reward but also decided to go with option a as each of the rows have a chance of getting zero but this row has the

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 4
- Z = Undergraduate ✓
- Z = PhD ←

Problem 4 - Player Z is a PhD student in Economics

Please choose an action by clicking one of the buttons that is at the margin of "Your Earnings" table. Each button will be automatically activated after 3 minutes.

Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	10
	B	14	3	9
	C	6	16	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I have a better chance of earning more with the #12 and $11 in option a, so if player Z chooses option A in predicting I will choose A so they will get $13, I chose C so I will get $12

You have completed the four problems. Now you have the opportunity to revisit your choices.

You have completed the four problems: In each problem you chose one action if Player Z is an undergraduate student from any year or discipline (red earnings table)

and a second action if Player Z is an Economics PhD student (blue earnings table).

In one of these problems each player had four possible actions and in the other three problems each player had three possible actions.

In the problems with three possible actions your (and Player Y's) earnings table was always the same, while Player Z's earnings table changed in each decision problem.

You will have the opportunity to revisit your choices and confirm them. You are encouraged to make use of "Your Notes" (including editing them) which is a box located below the decision problem. This text will be displayed later and will help you during the second part of the experiment. You can use it in any way you wish but it will be most beneficial for you if you record your reasoning that led you to choose your action.

When you are ready please click "next" to revisit your choices and confirm them.

Next

Problem 1
- Z = Undergraduate ←
- Z = PhD

Problem 2
- Z = Undergraduate
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 1 - Player Z is an undergraduate student from any year or discipline:

Please confirm your choice of action

You chose action **c**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	15	10
	B	3	8	9
	C	4	13	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

column A of player Z has highest possible outcome regardless of which letter I choose. I'm assuming they'll choose column A and for this reason i chose column c.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ←

Problem 2
- Z = Undergraduate
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 1 - Player Z is a PhD student in Economics:

Please confirm your choice of action

You chose action **c**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	15	10
	B	3	8	9
	C	4	13	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

Z will always choose A, so I choose C

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ←
- Z = PhD

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 2 - Player Z is an undergraduate student from any year or discipline:

Please confirm your choice of action

Player Z is an undergraduate student from any year or discipline.

You chose action **a**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

Your action \ Player Z's action	A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action \ Player Y's action	a	b	c
A	6	16	9
B	10	3	8
C	8	10	10

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I think Player Z would choose C because it has the most consistent earning. If Player Z chose C, I would only earn something if I chose A. I'm choosing A in hopes that Player Z will not also choose A

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ←

Problem 3
- Z = Undergraduate
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 2 - Player Z is a PhD student in Economics:

Please confirm your choice of action

Player Z is a PhD student in Economics.

You chose action **a**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	16	9
	B	10	3	8
	C	8	10	10

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I think a PhD student would know the optimal earning for both assuming that both parties are cooperative. I think they would assume I go with A, for them, the best return would be B. So I'm sticking with A.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ←
- Z = PhD

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 3 - Player Z is an undergraduate student from any year or discipline:

Please confirm your choice of action

Player Z is an undergraduate student from any year or discipline.

You chose action **a**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	0	12	13	11
	b	4	14	0	6
	c	10	0	11	12
	d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	12	0	16	7
	B	14	0	5	11
	C	12	16	0	10
	D	8	4	0	12

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

oh four! Okay so new 0s. Lets start with what I've been doing... For Z: A: max=16, min=0, range=16 (DAMN, high risk) B: max=14, min HWM, all have 0s, so all have high risk. Same with Y's. So looks like range isn't the best measure here. *remember! This is an undergrad. Let's go with the strategy of maximizing for both. (maybe PhDs would try to maximize both too. That distinction might be a red herring. Why would they not? That's how contracts are signed anyway) (would

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ←

Problem 4
- Z = Undergraduate
- Z = PhD

Problem 3 - Player Z is a PhD student in Economics:
Please confirm your choice of action

Player Z is a PhD student in Economics.

You chose action **a**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	0	12	13	11
	b	4	14	0	6
	c	10	0	11	12
	d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	12	0	16	7
	B	14	0	5	11
	C	12	16	0	10
	D	8	4	0	12

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

yeah I really think they'd do the same thing, make it good for everyone. Maybe this is testing how people think about phd students in economics hahaha. No but really, the avgs of C and a are the best for the respective peoples. So on that alone, this should be good.

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 4
- Z = Undergraduate ←
- Z = PhD

Problem 4 - Player Z is an undergraduate student from any year or discipline:

Please confirm your choice of action

Player Z is an undergraduate student from any year or discipline.

You chose action **a**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

Your action	Player Z's action: A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c
A	13	5	10
B	14	3	9
C	6	16	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

As this is an undergrad student, i assume they will straight away go to their highest earning column (c w/ 16) but as they can see if i chose to get the best outcome for them i would end up getting zero, so then i went to the second best option (b w/14) however the biggest earning for me was in row b but for them it was just 3, so I chose option a so they can get their highest reward but also decided to go with option a as each of the rows have a chance of getting zero but this row has the

Problem 1
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 2
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 3
- Z = Undergraduate ✓
- Z = PhD ✓

Problem 4
- Z = Undergraduate ✓
- Z = PhD ←

Problem 4 - Player Z is a PhD student in Economics:

Please confirm your choice of action

Player Z is a PhD student in Economics.

You chose action **c**.

You have a final opportunity to confirm or revise your choice of action in the decision problem below. In order to proceed to the next screen please click on your final choice of action in the table below.

Instructions

Your Earnings

Your action	Player Z's action		
	A	B	C
a	0	12	11
b	5	13	0
c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action		
	a	b	c
A	13	5	10
B	14	3	9
C	6	16	9

Your Notes:

In the space below you can write down the reasoning behind your choice of action. What you type will be displayed later on in the experiment and will help you when making choices in Part 2 of the experiment.

I have a better chance of earning more with the #12 and $11 in option a, so if player Z chooses option A in predicting I will choose A so they will get $13, I chose C so I will get $12

Instructions

PART 2

The Basic Idea

In this part of the experiment, you will be asked to make a sequence of choices between playing the four decision problems (against an undergraduate student from any year or discipline and against an Economics PhD student) in Part 1 and sure amounts. There are no correct choices. Your choices depend on your preferences and beliefs, so different participants will usually make different choices. You will be paid according to your choices, so read these instructions carefully and think before you decide.

Example of Choice Problems

In all the choice problems you will face in this part you will be asked to choose between payments from the decision problems you made in Part 1 and sure amounts. All choice problems will be organized in lists that share a simple structure, which is explained below. The following example illustrates, but is not directly related to the choice problems that determine your payment.

Suppose you have $5.50, and are asked to make a series of choices between keeping the $5.50 and receiving money amounts that vary from $0 to $10. As long as you like to have more money to less, this is how you would fill in this list of choices.

Choice Problem	A	B	Choose A or B
0	$5.50	$0	A
1	$5.50	$1	A
2	$5.50	$2	A
3	$5.50	$3	A
4	$5.50	$4	A
5	$5.50	$5	A
6	$5.50	$6	B
7	$5.50	$7	B
8	$5.50	$8	B
9	$5.50	$9	B
10	$5.50	$10	B

Notice the structure:

- Option A (in this case, keeping your $5.50) is the same on every line of the list, but option B improves as you go down the list

- There is a unique choice problem in which you switch from A to B. In the example above, it is choice problem 6.

Suppose now that Option A would be more valuable. For example, suppose it is $7.50 instead of $5.50. How would it affect your choices?

Instead of switching from A to B in choice problem 6, you would switch in choice problem 8. This has a general lesson:

- The more valuable Option A is, the later you would switch from A to B.

One can replace Option A with an amount that may depend on Player Z's action. For example, consider the following Option A: Suppose Player Z can choose between Left and Right.

	Player Z chose Left	**Player Z chose Right**
Option A	$5.50	$5.50

In this case your payment is independent of the action chosen by Player Z, as in either case you will earn $5.50. Therefore, this option is identical to the first Option A discussed above and you will switch from A to B in choice problem 6.

Consider, however, the following Option A:

	Player Z chose Left	**Player Z chose Right**
Option A	$8.50	$0

The value of this option depends on how likely you think Player Z chose Left.

If you are sure that (s)he chose Left, then the value is $8.50 and you will switch from A to B in choice problem 9 in the list.

If, however, you believe that Player Z may have chosen Right, then the value of Option A would fall, and you will switch to B in an earlier choice problem. Moreover, the more likely you believe (s)he chose Right -- the lower would be the value of Option A for you, and you would switch from A to B in an earlier choice problem.

The Protocol

The following choice problems are organized in 4 pairs (8 lists), where Option A changes across lists and represents your earnings from each of the 4 decision problems from Part 1 against the two potential Player Z (undergraduate students from any year or discipline and Economics PhD students).

For example, suppose that in Part 1 you faced the following decision problem and chose action 'c' when Player Z is an undergraduate student from any year or discipline:

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

In the choice problems you will be asked to choose between Option A (you choose 'c' and being paid from this Part 1 decision problem, when the payment depends on the action chosen by Player Z), and sure amounts, as above. In other words, you can think of Option A as:

	Player Z chose 'A'	Player Z chose 'B'	Player Z chose 'C'
Option A	$6	$9	$5

Obviously, when deciding how much you value this Option A, you need to consider how likely it is that Player Z will choose actions A, B or C. The more likely you think Player Z chose 'B' the closer would be the value to 9, and the more likely you think that Player Z chose 'C', the closer it would be to 5. In determining these likelihoods, you need to consult Player Z's earnings table, and possibly Player Y's earnings table (that is identical to yours) – as it may affect how likely Player Z believed Player Y chose each action and therefore Player Z's earnings.

If you want you can fill in the choice list by clicking the lowest line you wish to choose Option A, then automatically all the lines above the one you chose will be marked as Option A too. In addition, by clicking on the first line you wish to choose Option B, then all lower lines will automatically be marked as Option B. You can adjust your choices as many times as you wish. When you are ready to proceed, you can click on the "Next" button at the bottom of the page.

You will see each list exactly once and there will not be a screen asking you to confirm your choices as in Part 1 of the experiment.

Payment

One of the choice problems in one of the lists will be randomly selected by the computer, and your choice in that choice problem will determine your payment.

Your choice (A or B) in the randomly-selected choice problem will determine your payment in the whole experiment. If you chose B, you will get the payment specified in B on that choice problem. If you chose A, your payment will depend on the action you chose in the decision problem in Part 1, if your Player Z is an undergraduate student from any year or discipline or an Economics PhD student, and on the action chosen by Player Z.

So, in order to determine the value of each Option A (the choice problem in which you will switch from A to B in the list), you need to consider how likely it is that Player Z chose each action in the specific decision problem.

This protocol of determining payments suggests that you should choose in each choice problem as if it is the only problem that determines your payment.

This button will be activated after 10 minutes. Please take your time to read through the instructions.

Next

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Suppose that in Part 1 you faced the above decision problem and chose action 'c' when Player Z is an undergraduate student from any year or discipline. (To highlight row 'c' please click on that row.) Refer to the list below to answer the following questions.

Choice Problem	A	B	Choose A or B
0	Earnings from the decision problem	$0	
1	Earnings from the decision problem	$2	
2	Earnings from the decision problem	$4	
3	Earnings from the decision problem	$5	
4	Earnings from the decision problem	$6	
5	Earnings from the decision problem	$7	
6	Earnings from the decision problem	$8	
7	Earnings from the decision problem	$9	

8	Earnings from the decision problem	$10	
9	Earnings from the decision problem	$10.50	
10	Earnings from the decision problem	$11	
11	Earnings from the decision problem	$11.50	
12	Earnings from the decision problem	$12	
13	Earnings from the decision problem	$12.50	
14	Earnings from the decision problem	$13	
15	Earnings from the decision problem	$14	
16	Earnings from the decision problem	$15	
17	Earnings from the decision problem	$16	
18	Earnings from the decision problem	$18	
19	Earnings from the decision problem	$20	
20	Earnings from the decision problem	$22	
21	Earnings from the decision problem	$24	

Use the above earnings tables to answer the following questions:

1. What is Option 'A'?

A $3 if Player Z chose 'A', $15 if Player Z chose 'B'; $1 if Player Z chose 'C'

B $8 if Player Z chose 'A', $0 if Player Z chose 'B'; $4 if Player Z chose 'C'

C $6 if Player Z chose 'A', $9 if Player Z chose 'B'; $5 if Player Z chose 'C'

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Suppose that in Part 1 you faced the above decision problem and chose action 'c' when Player Z is an undergraduate student from any year or discipline. (To highlight row 'c' please click on that row.) Refer to the list below to answer the following questions.

Choice Problem	A	B	Choose A or B
0	Earnings from the decision problem	$0	
1	Earnings from the decision problem	$2	
2	Earnings from the decision problem	$4	
3	Earnings from the decision problem	$5	
4	Earnings from the decision problem	$6	
5	Earnings from the decision problem	$7	
6	Earnings from the decision problem	$8	
7	Earnings from the decision problem	$9	

8	Earnings from the decision problem	$10	
9	Earnings from the decision problem	$10.50	
10	Earnings from the decision problem	$11	
11	Earnings from the decision problem	$11.50	
12	Earnings from the decision problem	$12	
13	Earnings from the decision problem	$12.50	
14	Earnings from the decision problem	$13	
15	Earnings from the decision problem	$14	
16	Earnings from the decision problem	$15	
17	Earnings from the decision problem	$16	
18	Earnings from the decision problem	$18	
19	Earnings from the decision problem	$20	
20	Earnings from the decision problem	$22	
21	Earnings from the decision problem	$24	

Use the above earnings tables to answer the following questions:

2. What option gives you more money in Choice 2?

A A

B B

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	**6**	**9**	**5**

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Suppose that in Part 1 you faced the above decision problem and chose action 'c' when Player Z is an undergraduate student from any year or discipline. (To highlight row 'c' please click on that row.) Refer to the list below to answer the following questions.

Choice Problem	A	B	Choose A or B
0	Earnings from the decision problem	$0	
1	Earnings from the decision problem	$2	
2	Earnings from the decision problem	$4	
3	Earnings from the decision problem	$5	
4	Earnings from the decision problem	$6	
5	Earnings from the decision problem	$7	
6	Earnings from the decision problem	$8	
7	Earnings from the decision problem	$9	

8	Earnings from the decision problem	$10	
9	Earnings from the decision problem	$10.50	
10	Earnings from the decision problem	$11	
11	Earnings from the decision problem	$11.50	
12	Earnings from the decision problem	$12	
13	Earnings from the decision problem	$12.50	
14	Earnings from the decision problem	$13	
15	Earnings from the decision problem	$14	
16	Earnings from the decision problem	$15	
17	Earnings from the decision problem	$16	
18	Earnings from the decision problem	$18	
19	Earnings from the decision problem	$20	
20	Earnings from the decision problem	$22	
21	Earnings from the decision problem	$24	

Use the above earnings tables to answer the following questions:

3. What option gives you more money in Choice Problem 8?

A A

B B

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	**6**	**9**	**5**

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Suppose that in Part 1 you faced the above decision problem and chose action 'c' when Player Z is an Economics PhD student. (To highlight row 'c' please click on that row.) Refer to the list below to answer the following questions.

Choice Problem	A	B	Choose A or B
0	Earnings from the decision problem	$0	
1	Earnings from the decision problem	$2	
2	Earnings from the decision problem	$4	
3	Earnings from the decision problem	$5	
4	Earnings from the decision problem	$6	
5	Earnings from the decision problem	$7	
6	Earnings from the decision problem	$8	
7	Earnings from the decision problem	$9	

8	Earnings from the decision problem	$10	
9	Earnings from the decision problem	$10.50	
10	Earnings from the decision problem	$11	
11	Earnings from the decision problem	$11.50	
12	Earnings from the decision problem	$12	
13	Earnings from the decision problem	$12.50	
14	Earnings from the decision problem	$13	
15	Earnings from the decision problem	$14	
16	Earnings from the decision problem	$15	
17	Earnings from the decision problem	$16	
18	Earnings from the decision problem	$18	
19	Earnings from the decision problem	$20	
20	Earnings from the decision problem	$22	
21	Earnings from the decision problem	$24	

Use the above earnings tables to answer the following questions:

4. Suppose that you are sure that Player Z chose action 'C'. What option gives you more money in Choice Problems 2 and 4, respectively?

A A & A

B A & B

C B & A

D B & B

Quiz

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Player Y had the same actions and earnings as you.

player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Suppose that in Part 1 you faced the above decision problem and chose action 'c' when Player Z is an Economics PhD student. (To highlight row 'c' please click on that row.) Refer to the list below to answer the following questions.

Choice Problem	A	B	Choose A or B
0	Earnings from the decision problem	$0	
1	Earnings from the decision problem	$2	
2	Earnings from the decision problem	$4	
3	Earnings from the decision problem	$5	
4	Earnings from the decision problem	$6	
5	Earnings from the decision problem	$7	
6	Earnings from the decision problem	$8	
7	Earnings from the decision problem	$9	

8	Earnings from the decision problem	$10	
9	Earnings from the decision problem	$10.50	
10	Earnings from the decision problem	$11	
11	Earnings from the decision problem	$11.50	
12	Earnings from the decision problem	$12	
13	Earnings from the decision problem	$12.50	
14	Earnings from the decision problem	$13	
15	Earnings from the decision problem	$14	
16	Earnings from the decision problem	$15	
17	Earnings from the decision problem	$16	
18	Earnings from the decision problem	$18	
19	Earnings from the decision problem	$20	
20	Earnings from the decision problem	$22	
21	Earnings from the decision problem	$24	

Use the above earnings tables to answer the following questions:

5. Suppose that you are sure that Player Z chose action 'C'. What option gives you more money in Choice Problem 5

A A

B B

You have finished the quiz. Part 2 of the experiment follows.

You will see each list exactly once and there will not be a screen asking you to confirm your choices as in Part 1 of the experiment.

You will be able to consult your notes from Part 1 of the experiment.

When you are ready please click "next" to start Part 2 of the experiment.

Next

List 1
- Z = PhD ⟵
- Z = Undergraduate

List 2
- Z = PhD
- Z = Undergraduate

List 3
- Z = PhD
- Z = Undergraduate

List 4
- Z = PhD
- Z = Undergraduate

List 1 - Player Z is a PhD student in Economics

In Part 1 you chose action **c**. Therefore, if you choose Option A below you will play action **c** and be paid **$12, $8, or $0** depending on the action chosen by Player Z who is a PhD student in Economics.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	**12**	**8**	**0**

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	15	10
	B	3	8	9
	C	4	13	9

Your Notes:

Z will always choose A, so I choose C.

Your Decision:

Option A	Option B
Your earnings from the decision problem	$8.00
Your earnings from the decision problem	$8.25
Your earnings from the decision problem	⋮
Your earnings from the decision problem	$13.75
Your earnings from the decision problem	$14.00

Next

List 1
- Z = PhD ✓
- Z = Undergraduate ←

List 2
- Z = PhD
- Z = Undergraduate

List 3
- Z = PhD
- Z = Undergraduate

List 4
- Z = PhD
- Z = Undergraduate

List 1 - Player Z is an undergraduate student from any year or discipline

In Part 1 you chose action **c**. Therefore, if you choose Option A below you will play action **c** and be paid **$12, $8, or $0** depending on the action chosen by Player Z who is an undergraduate student from any year or discipline.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	**12**	**8**	**0**

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	15	10
	B	3	8	9
	C	4	13	9

Your Notes:

column A of player Z has highest possible outcome regardless of which letter I choose. I'm assuming they'll choose column A and for this reason i chose column c..

Your Decision:

Option A	Option B
Your earnings from the decision problem	$8.00
Your earnings from the decision problem	$8.25
Your earnings from the decision problem	⋮
Your earnings from the decision problem	$13.75
Your earnings from the decision problem	$14.00

Next

List 1
- Z = PhD ✓
- Z = Undergraduate ✓

List 2
- Z = PhD ⟵
- Z = Undergraduate

List 3
- Z = PhD
- Z = Undergraduate

List 4
- Z = PhD
- Z = Undergraduate

List 2 - Player Z is a PhD student in Economics

In Part 1 you chose action **a**. Therefore, if you choose Option A below you will play action **a** and be paid **$0, $12, or $11** depending on the action chosen by Player Z who is a PhD student in Economics.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	16	9
	B	10	3	8
	C	8	10	10

Your Notes:

I think a PhD student would know the optimal earning for both assuming that both parties are cooperative. I think they would assume I go with A, for them, the best return would be B. So I'm sticking with A..

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next

List 1
- Z = PhD ✓
- Z = Undergraduate ✓

List 2
- Z = PhD ✓
- Z = Undergraduate ←

List 3
- Z = PhD
- Z = Undergraduate

List 4
- Z = PhD
- Z = Undergraduate

List 2 - Player Z is an undergraduate student from any year or discipline

In Part 1 you chose action **a**. Therefore, if you choose Option A below you will play action **a** and be paid **$0, $12, or $11** depending on the action chosen by Player Z who is an undergraduate student from any year or discipline.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	**0**	**12**	**11**
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	6	16	9
	B	10	3	8
	C	8	10	10

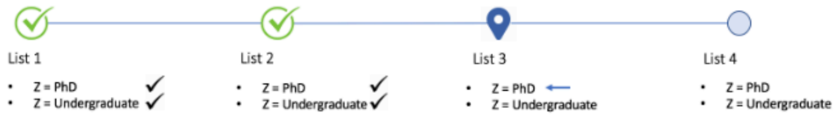
Your Notes:

I think Player Z would choose C because it has the most consistent earning. If Player Z chose C, I would only earn something if I chose A. I'm choosing A in hopes that Player Z will not also choose A.

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next



List 3 - Player Z is a PhD student in Economics

In Part 1 you chose action **a**. Therefore, if you choose Option A below you will play action **a** and be paid **$0, $12, $13, or $11** depending on the action chosen by Player Z who is a PhD student in Economics.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is a PhD student in Economics.

Instructions

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	**0**	**12**	**13**	**11**
	b	4	14	0	6
	c	10	0	11	12
	d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	12	0	16	7
	B	14	0	5	11
	C	12	16	0	10
	D	8	4	0	12

Your Notes:

yeah I really think they'd do the same thing, make it good for everyone. Maybe this is testing how people think about phd students in economics hahaha. No but really, the avgs of C and a are the best for the respective peoples. So on that alone, this should be good..

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next

List 1	List 2	List 3	List 4
• Z = PhD ✓ • Z = Undergraduate ✓	• Z = PhD ✓ • Z = Undergraduate ✓	• Z = PhD ✓ • Z = Undergraduate ←	• Z = PhD • Z = Undergraduate

List 3 - Player Z is an undergraduate student from any year or discipline

In Part 1 you chose action **a**. Therefore, if you choose Option A below you will play action **a** and be paid **$0, $12, $13, or $11** depending on the action chosen by Player Z who is an undergraduate student from any year or discipline.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action			
		A	B	C	D
Your action	a	**0**	**12**	**13**	**11**
	b	4	14	0	6
	c	10	0	11	12
	d	13	8	6	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action			
		a	b	c	d
Player Z's action	A	12	0	16	7
	B	14	0	5	11
	C	12	16	0	10
	D	8	4	0	12

Your Notes:

oh four! Okay so new 0s. Lets start with what I've been doing... For Z: A: max=16, min=0, range=16 (DAMN, high risk) B: max=14, min HWM, all have 0s, so all have high risk. Same with Y's. So looks like range isn't the best measure here. *remember! This is an undergrad. Let's go with the strategy of maximizing for both. (maybe PhDs would try to maximize both too. That distinction might be a red herring. Why would they not? That's how contracts are signed anyway) (would Undergrad's? Why would they not, they'd be stupid to just choose the highest one for themselves without considering Z) A: avg=8.75 B: avg=7.5 C: 9.5 D: 6 ~~~~ aaah I see. Yeah see? The highest value for both are 0 for the respective player ou tricky stuff. Z has two max 16s. But C is the best in terms of avg. Lets look at Y now too a: 9 (dang that's good too!) b: 6 c: 8.23 d: 6.75 so a is best for Y. Yeah, I can see Ca being one. Ca: Z=12 Y=13 Cc: Z=16 Y=10 Ba: Z=14 Y=12 (not as good as Ca) Dangerous for Y, is there any chance Z would choose A? Well, avg of C is better, and both have the max 16, so probably not?.

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next

List 1
- Z = PhD ✓
- Z = Undergraduate ✓

List 2
- Z = PhD ✓
- Z = Undergraduate ✓

List 3
- Z = PhD ✓
- Z = Undergraduate ✓

List 4
- Z = PhD ⟵
- Z = Undergraduate

List 4 - Player Z is a PhD student in Economics

In Part 1 you chose action **c**. Therefore, if you choose Option A below you will play action **c** and be paid **$12, $8, or $0** depending on the action chosen by Player Z who is a PhD student in Economics.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is a PhD student in Economics.

Instructions

Your Earnings

Your action	Player Z's action: A	B	C
a	0	12	11
b	5	13	0
c	**12**	**8**	**0**

Player Y had the same actions and earnings as you.

Player Z's Earnings

Player Z's action	Player Y's action: a	b	c
A	13	5	10
B	14	3	9
C	6	16	9

Your Notes:

I have a better chance of earning more with the #12 and $11 in option a, so if player Z chooses option A in predicting I will choose A so they will get $13, I chose C so I will get $12.

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next

List 1
- Z = PhD ✓
- Z = Undergraduate ✓

List 2
- Z = PhD ✓
- Z = Undergraduate ✓

List 3
- Z = PhD ✓
- Z = Undergraduate ✓

List 4
- Z = PhD ✓
- Z = Undergraduate ←

List 4 - Player Z is an undergraduate student from any year or discipline

In Part 1 you chose action **a**. Therefore, if you choose Option A below you will play action **a** and be paid **$0, $12, or $11** depending on the action chosen by Player Z who is an undergraduate student from any year or discipline.

(Note that you can still use the highlighting tool like in Part 1 of the experiment, but you cannot change your action.)

Option A: the earnings from the game when Player Z is an undergraduate student from any year or discipline.

Instructions

Your Earnings

		Player Z's action		
		A	B	C
Your action	a	**0**	**12**	**11**
	b	5	13	0
	c	12	8	0

Player Y had the same actions and earnings as you.

Player Z's Earnings

		Player Y's action		
		a	b	c
Player Z's action	A	13	5	10
	B	14	3	9
	C	6	16	9

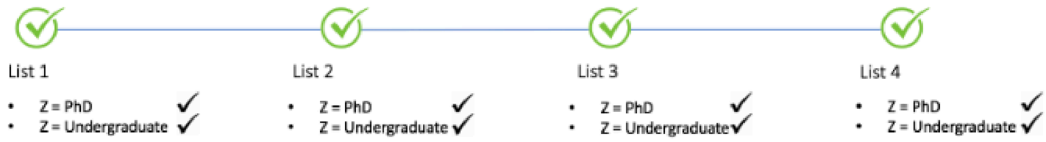
Your Notes:

As this is an undergrad student, i assume they will straight away go to their highest earning column (c w/ 16) but as they can see if i chose to get the best outcome for them i would end up getting zero, so then i went to the second best option (b w/14) however the biggest earning for me was in row b but for them it was just 3, so I chose option a so they can get their highest reward but also decided to go with option a as each of the rows have a chance of getting zero but this row has the highest other two earnings and i think it is unlikely for them to choose a in the end..

Your Decision:

Option A			Option B
Your earnings from the decision problem	○	○	$8.00
Your earnings from the decision problem	○	○	$8.25
Your earnings from the decision problem	○	○	⋮
Your earnings from the decision problem	○	○	$13.75
Your earnings from the decision problem	○	○	$14.00

Next



This is the end of the experiment.

Your payment is being calculated. Please click "Next" to go to next page to learn your payment for this experiment.

Next

Thank you for participating in this experiment!

Choice Problem **24** in **List 1 - Player Z is a PhD student in Economics** was randomly selected for payment.

You chose action **c** and your opponent chose action **A**.

		Other participant's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

In that choice problem you selected option **B**.

You earned **$3.50** from the quiz and **$13.75** from your choice.

In addition, you will receive a participation fee of **$5.00**.

As a result, your total earnings are **$22.25**.

You will receive your payment as an Interac e-transfer. If you encounter any problems, please contact Johannes Hoelzemann at j.hoelzemann@utoronto.ca or 647-YYY-ZZZZ.

Magic Mirror on the Wall, Who Is the Smartest One of All?

Online Appendix: Experimental Interface

— Auxiliary Experiment —

Yoram Halevy Johannes Hoelzemann Terri Kneeland

January 12, 2025

Instructions

Welcome. This is an experiment in the economics of decision-making. If you pay close attention to these instructions, you can earn a significant amount of money that will be paid to you at the end of the experiment via interac e-transfer.

Your computer screen will display useful information. Remember that the information on your computer screen is PRIVATE. To insure best results for yourself and accurate data for the experimenters, please DO NOT COMMUNICATE or interact with other people on other media at any point during the experiment. If you have any questions, or need assistance of any kind, please call +1-647-XXX-ZZZZ or use Skype (j.hoelzemann@utoronto.ca) anytime from 8am to 8pm Toronto time and one of the experimenters will help you privately.

In this experiment, you will face four rounds of decision-making problems. During the experiment, and in order to determine your payment, you will be randomly matched with another participant in this session.

The Basic Idea

There will be four different rounds. In each round, you will be presented with an interactive decision problem similar to the one below.

Your Earnings

		Other participant's action			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	6
	d	3	10	11	6

Other Participant's Earnings

		Your action			
		a	b	c	d
Other's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Your earnings in each problem depend on your choice of action (between: a, b, c, d) and the other participant's choice of action (between A, B, C, D). Your earnings possibilities are presented in tables like the ones above. In each problem, your earnings are given by the blue numbers in the left table, labelled 'Your Earnings'. The other participant's earnings are given in the right table, labelled 'Other Participant's Earnings'. Your choice of action determines the row in the `Your Earnings' table and the other participant's choice of action determines the column in the same table. The blue number in the cell corresponding to any combination of actions (yours and the other participant's) represent your earnings. Similarly, the other participant's choice of action determines the row in the 'Other Participant's Earnings' table, while your choice of action determines the column in this table. The number in the cell corresponding to any combination of actions (yours and the other participant's) represents the other participant's earnings. In summary, your choice of action AND the other participant's choice of action affect both your earnings and the other participant's earnings.

For example, if you choose action "b" and the other participant chooses action "B" your earnings would be $1 and the other participant's earnings would be $4. If you choose action "c" and the other participant chooses action "A", your earnings would be $13 and the other participant's earnings would be $3. Numbers in the example are just an example and do not intend to suggest how anyone should make their choices.

Problems

The problems that you will face will take one of two forms. The problem will either have four possible actions for both you (e.g. a, b, c or d) and the other participant (e.g. A, B, C or D) as in Example Problem 1. Or, the problem will have three possible choices for both you (e.g. a, b, or c) and the other participant (e.g. A, B, or C) as in Example Problem 2.

Example Problem 1

Your Earnings

		Other participant's action			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Other Participant's Earnings

		Your action			
		a	b	c	d
Other's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Example Problem 2

Your Earnings

		Other Participant's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Other Participant's Earnings

		Your action		
		a	b	c
Other participant's action	A	13	5	8
	B	7	9	10
	C	10	6	12

In order to assist you to choose an action, when you move your mouse over a row in the `Your Earning' table on the left, the action will be highlighted in yellow in both tables: a row on the left table, and a column on the right table. By left clicking your mouse over a row it will remain highlighted, and you can unhighlight it by clicking your mouse again or clicking another row. Similarly, when you move your mouse over a row that corresponds to an action of the other participant in the `Other participant's Earnings' on the right, the row will be highlighted in green on the right table and the corresponding column will be highlighted in green on the left table. Clicking your mouse over the row will keep it highlighted, and clicking it again (or clicking another action) will unhighlight it.

Please try to highlight actions for you and the other participant in Problems 1 and 2 above.

Finally, to choose an action you must click on the radio button around the action name (the lowercase letter next to the row, on the margin of the left table), after it has been activated (turned blue).

The Rounds

There will be four rounds. You will need to choose an action in each round, as described above. After you have confirmed your choice of action you will advance to the next screen and play a new round.

The earnings tables in each round are different, so you should look carefully at them before making your choice. You will be required to spend at least 5 minutes on each round. You may spend more than 5 minutes on each round if you wish.

The Other Participants

At the beginning of the experiment, you will be randomly matched with another participant with whom you will be matched for all four rounds. Your match is participating in this session. You do not know which actions the other participant chooses when you make your choices of actions. You can, however, attempt to reason about the actions the other participant will choose.

Payment

You will earn a participation payment of $5.00 for participating in this experiment.

In addition to the participation payment, one round will be randomly selected for payment at the end of the experiment. You will be paid your earnings in that round as described above. Any of the four rounds could be the one selected. So you should treat each round like it will be the one determining your payment.

Before the actual experiment starts, you will be asked to answer 6 questions. You will earn 50 cents for answering each question correctly on your first trial. If you make a mistake, you will not receive a payment for that question, but you must answer it correctly in order to move to the next question.

You will be informed of your payment, the round chosen for payment, and the choices of you and of the other participant only at the end of the experiment. You will not learn any other information about the choices of other participants during the experiment. The identity of the other participants to which you will be matched will never be revealed.

Finally, after completing the experiment you will be paid electronically via interac e-transfer with the e-mail address you entered on the previous page.

Frequently Asked Questions

Q1. Is this some kind of psychology experiment with an agenda you haven't told us? Answer. No. It is an economics experiment. If we do anything deceptive or don't pay you cash as described, then you can complain to University of Toronto Research Ethics Board and we will be in serious trouble. These instructions are meant to clarify how you earn money, and our interest is in seeing how people make decisions.

Q2. Is there a "correct" choice of action? Is this kind of a test? No. Your optimal action depends on your belief which actions will other participants choose. Different people may hold different beliefs.

This button will be activated after 10 minutes. Please take your time to read through the instructions.

Next

Quiz

Your Earnings

	Other participant's action			
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Other Participant's Earnings

	Your action			
		a	b	c
Other's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

1. If you choose action 'a' and the other participant chose action 'C' what would your earnings be?

A $15

B $13

C $1

D $6

Quiz

Your Earnings

	Other participant's action			
Your action		A	B	C
	a	3	15	1
	b	8	0	4
	c	6	9	5

Other Participant's Earnings

	Your action			
Other's action		a	b	c
	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

2. If you choose action 'a' and the other participant chose action 'C' what would the other participant's earnings be?

A $13

B $10

C $1

D $8

Quiz

Your Earnings

		Other participant's action		
		A	B	C
Your action	a	3	15	1
	b	8	0	4
	c	6	9	5

Other Participant's Earnings

		Your action		
		a	b	c
Other's action	A	13	5	8
	B	7	9	10
	C	10	6	12

Use the above earnings table to answer the following questions:

3. If the other participant chose action ‘A’, which action would give you the highest earnings?

A a

B b

C c

Quiz

Your Earnings					
		Other participant's action			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Other Participant's Earnings					
		Your action			
		a	b	c	d
Other's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

4. If you choose action 'c' and the other participant chose action 'A' what would be your earnings?

A $8

B $13

C $3

D $10

Quiz

Your Earnings

	Other participant's action				
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Other Participant's Earnings

	Your action				
		a	b	c	d
Other's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

5. If you choose action 'd' and the other participant chose action 'B' what would be the other participant's earnings?

A $10

B $5

C $30

D $4

Quiz

Your Earnings

		Other participant's choice			
		A	B	C	D
Your action	a	7	12	8	4
	b	7	1	9	10
	c	13	2	10	16
	d	3	10	11	6

Other Participant's Earnings

		Your action			
		a	b	c	d
Other's action	A	13	8	3	18
	B	16	4	13	30
	C	10	21	16	12
	D	19	5	9	21

Use the above earnings table to answer the following questions:

6. If the other participant chose action 'D', which action would give you the highest earnings?

A a

B b

C c

D d

Round 1

Please choose one action from below. Each button will be automatically activated after 3 minutes.

Instructions

Your Earnings

		Other participant's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Other Participant's Earnings

		Your action		
		a	b	c
Other's action	A	13	5	10
	B	14	3	9
	C	6	16	9

Round 2

Please choose one action from below. Each button will be automatically activated after 3 minutes.

Instructions

Your Earnings

		Other's action			
		A	B	C	D
Your action	a	0	12	13	11
	b	4	14	0	6
	c	10	0	11	12
	d	13	8	6	0

Other Participant's Earnings

		Your action			
		a	b	c	d
Other's action	A	12	0	16	7
	B	14	0	5	11
	C	12	16	0	10
	D	8	4	0	12

Round 3

Please choose one action from below. Each button will be automatically activated after 3 minutes.

Instructions

Your Earnings

		Other participant's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Other Participant's Earnings

		Your action		
		a	b	c
Other's action	A	6	16	9
	B	10	3	8
	C	8	10	10

Round 4

Please choose one action from below. Each button will be automatically activated after 3 minutes.

Instructions

Your Earnings

		Other participant's action		
		A	B	C
Your action	a	0	12	11
	b	5	13	0
	c	12	8	0

Other Participant's Earnings

		Your action		
		a	b	c
Other's action	A	6	15	10
	B	3	8	9
	C	4	13	9