EPISTEMIC EXPERIMENTS: UTILITIES, BELIEFS, AND IRRATIONAL PLAY†

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ABSTRACT. Inspired by the epistemic game theory framework, I elicit subjects’ preferences over outcomes, beliefs about strategies, and beliefs about beliefs in a variety of simple games. I find that the prisoners’ dilemma and the traditional centipede game are both Bayesian games, with many non-selfish types. Many players choose strategies that are clearly inconsistent with their elicited beliefs and preferences. But these instances of “irrationality” disappear when the game is made sequential and the player moves second, suggesting that irrationality is driven by the presence of strategic uncertainty.

Keywords: Behavioral game theory; payoff uncertainty; rationality.

JEL Classification: C72, C90, D03, D81.

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I. INTRODUCTION

In standard experimental research, the researcher begins with the assumption that players are selfish—that they only maximize their own pecuniary payoff—and fully rational. When anomalous behavior is observed, alternative theories are hypothesized that might allow for social preferences or various failures of rationality. Inequality aversion, Level-k, quantal response equilibrium, and cursed equilibrium are all examples of such theories. The art of the experimentalist is in designing new treatments to discriminate and test these alternative models. For example, varying parameters to examine


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comparative statics. Or developing new games that isolate key aspects of the original game of interest.

In this paper we take a far more direct—and less clever—approach to studying strategic behavior. Rather than designing new treatments, we simply measure as many aspects of players’ private information as is feasible with incentive compatible elicitation. But what private information should be elicited? Rather than focusing on the assumptions of any one particular theory, we rely on the general framework of epistemic game theory because it is broad enough to encompass a huge range of theories about strategic behavior. This framework takes the game form—the strategies available and physical outcomes that result—as publicly observable. It then models players’ private information (or, their “state”) as consisting of their utility, the strategy they will choose, and their beliefs about others’ utilities, strategies, and beliefs. This differs from standard game theory in that the strategy is part of the state of the world, rather than derived through some assumed solution concept like Nash equilibrium. It allows us to do more than simply refute an assumed solution concept; it allows us to study properties of the realized state. For example, whether players are rational (best responding to their beliefs, given their utility). Or believe their opponents are rational.

To that end, we run several experiments in which we have subjects play a variety of classic games and, in each, we elicit each player’s utilities over outcomes, belief in their opponent’s utilities, first- and second-order belief over actions, and first-order belief in rationality. This procedure allows us to see the true game being played, and whether it is a complete information game or a Bayesian game. It allows us to determine whether beliefs and actions are in equilibrium. And it gives us some insight into what theories of strategic behavior are consistent not just with strategy choices, but also with these other epistemic constructs.

The amount of elicitation is admittedly extreme, relative to past studies. We have taken steps to ensure that the data are as reliable as possible. We incentivize each elicitation using the binary choice list procedure that underlies the BDM (Becker et al., 1964) value elicitation mechanism, the belief elicitation procedure of Grether (1981) and Karni (2009), and the risk preference elicitation of Holt and Laury (2002). These procedures are incentive compatible as long as choices respect statewise dominance (Azrieli et al., 2017).

It is likely that the presence of elicitation alters how subjects play the game. And playing the game likely alters elicitation responses. As this contamination problem cannot be avoided, we embrace it. We view our experiments as fully contaminated: Subjects are fully aware that both game play and elicitation are happening, and they happen alternately throughout the experiment. Most of the experiments are run on
paper (rather than through a computer interface) so that subjects can work through the questions in any order. They can also change their answers to questions as much as they like before turning in their decision sheets. Our assumption is that this gives rationality its best shot. Any irrational behavior should therefore be particularly surprising, and we would expect it to persist if elicitation procedures were removed. Finally, we note that the games we study are all canonical, and the action frequencies we observe are very much in line with previous studies.

Our first finding is that some players do have non-selfish preferences, and in certain games those non-selfish preferences drastically alter the game being played. For example, in a centipede game form with sharply increasing dollar payoffs, some subjects actually prefer that their opponent plays ‘down’ at the next node rather than themselves playing ‘down’ at the current node. This is plausible, as this gives the opponent a large benefit at a relatively small cost to themselves. These players have a dominant strategy to ‘pass’. But even a selfish player might be willing to pass in this game, because they know it is reasonably likely that their opponent will be a non-selfish type who will pass back. Thus, passing is quite rational, and certainly not due to a failure of backward induction. If we flatten the payoff structure, however, the benefit to the opponent shrinks. Thus, fewer subjects prefer to let their opponent choose down at the next node. The selfish types stop taking the risk of passing, and the standard backwards induction result obtains.

In the prisoners’ dilemma game form, roughly one third of subjects exhibit non-selfish preferences, and one fifth believe their opponent is most likely to have non-selfish preferences. Thus, it is a Bayesian game with multiple preference types. Once we take preferences and beliefs into account, we find that about half of those who cooperate are doing so rationally.

Our second finding, which we also see in the prisoners’ dilemma, is that a sizeable fraction of subjects behave in a way that is inconsistent with rationality, according to their elicited beliefs and utilities. Now, our definition of rationality is quite narrow, assuming two parts: First, that subjects care only about payments to themselves and their opponent, but not about the strategies that led to those payments. We refer to this as consequentialism, and discuss in Section VIII why our methodology forces us to make this assumption. Second, it assumes expected utility preferences. Thus, we refer to rationality more properly as consequentialist expected utility (CEU) rationality. The

1 Selfish players in this game form may not be universally selfish. They are identified as selfish (or, more properly, as consistent with selfishness) because their social preferences are not strong enough to change their best response function to be different from that of a truly selfish person.

2 Following the epistemic game theory literature, ‘rationality’ in this study is defined as maximizing subjective expected utility as measured through elicitation.
Examples of irrationality we observe can therefore be due to failures of consequentialism (for example, preferring to cooperate not because of the outcomes it gives, but because cooperation is perceived as a ‘good’ strategy) or failures of expected utility (for example, ambiguity aversion in the face of strategic uncertainty). In each game we conjecture what we believe to be the cause of the failure, and note that the cause in one game appears quite different from the cause in the next. Thus, we suggest that departures from CEU-rationality may be highly game-specific.

Finally, we see that failures of CEU-rationality are significantly reduced for second movers in sequential-move games. For example, in a $2 \times 2$ coordination game in which each player prefers a different equilibrium, we see players in the simultaneous-move version who play their own preferred equilibrium strategy even though they believe with near certainty that the opponent is going to target the other equilibrium. But when the game is sequential-move and the player sees that the opponent has in fact targeted the other equilibrium, the player goes along with it by best responding rationally. We see this conclusion across all games: the incidence of CEU-irrationality is greatly reduced when strategic uncertainty is removed.

We discuss related literature in Section II. The analytical framework in which we operate—which motivates our choice of what to elicit and also describes how those things are elicited—appears in Section III. We present our results for the centipede game forms in Section V and the prisoners' dilemma game form in Section VI. We then describe results from two other game forms (a dominance solvable game form and an asymmetric coordination game) in Section VII.

II. RELATED LITERATURE

In this section we provide a very incomplete review of relevant literature; future drafts of the paper will provide a more comprehensive review.

Weibull (2004) notes that game theory cannot be tested without information about preferences, and is careful to distinguish between games and game forms. He also discusses how players’ preferences might depend on their opponents’ preferences (building on Levine, 1998), and players may update their preferences mid-game as they infer their opponent’s preferences from their actions. We do not test for this possibility because we elicit utilities only once for each game.

To our knowledge, the only other study in which players’ preferences over game outcomes are elicited is Brunner et al. (2016). They elicit each subject’s ordinal ranking over outcomes and then reveal these rankings to their opponent before playing a game.

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What we call a game form he calls a “game protocol”. We prefer “game form” because it is consistent with the mechanism design literature.
They find that Nash equilibrium play increases significantly—compared to a baseline in which the ordinal rankings are not revealed—though the minmax and maxmax solution concepts are more predictive than Nash even when preferences are revealed.4

Fischbacher et al. (2001) and Fischbacher and Gachter (2010) elicit players’ best response functions in public goods settings and use this to show that the presence of non-selfish players (in particular, imperfect conditional cooperators) drives both contributions to the public good and the decline in contributions over time. Fischbacher and Gachter (2010) also elicit the mode of players’ beliefs about the contributions of others, and find that the elicited best response to that modal belief does not perfectly predict play.

We study several centipede game forms that vary only in the terminal node payoffs. Garcia-Pola et al. (2016) also vary payments in centipede game forms and find correlations between payments and behavior that are similar to our results. They do not elicit subjects’ preferences; instead, they estimate a mixture model containing a wide range of proposed behavioral types, some of which are based on social preferences. They claim that preference-based theories explain too little of the data, and that non-equilibrium theories (with selfish preferences) such as quantal response equilibrium and level-k explain why many subjects choose to pass.

III. Analytical Framework

We describe first the framework for two-player simultaneous-move games and game forms. The set of players is $I = \{1, 2\}$. There is a set of physical outcomes $X$ that can be paid to the subjects. These are typically dollar payments to each player, so let $X = X_1 \times X_2$, where $X_i$ is the set of possible payments to player $i$. For example, $x = (\$5, \$10)$ is the outcome in which player 1 receives $5 and player 2 receives $10. The experimenter chooses a game form, which is a tuple $\Gamma = (I, (S_i)_{i}, \pi)$, where each $S_i$ (for $i \in I$) is the set of strategies available to player $i$ and $\pi : S_1 \times S_2 \rightarrow X$ is the outcome function that specifies a physical outcome for each strategy profile $s \in S = S_1 \times S_2$. Let $\pi_i$ denote the projection of $\pi$ onto $X_i$.

The game form is fixed by the experimenter and publicly observable. The players’ preferences, strategies, and beliefs, on the other hand, are all private information. We refer to these as the state of player $i$. Players form beliefs about the states of their opponent, and the experimenter can use incentive compatible elicitation techniques to elicit the state (or components of the state) from each player.

4Revealing the elicited data to the opponent creates an incentive for subjects to misrepresent their preferences, but Brunner et al. (2016) find no evidence of such manipulations in their data.
Formally, a state of player $i$ is a tuple $\omega_i = (u_i, s_i, \tau_i)$ whose components we now describe. The first is player $i$’s cardinal utility function $u_i : X \to \mathbb{R}$, defined over physical outcomes. Using a randomizing device, the experimenter can also generate lotteries over $X$ of the form $(q, x; 1-q, x')$, denoting that $x$ is paid with probability $q$ and $x'$ is paid otherwise. For any $x$, the value of $u_i(x)$ can be elicited by selecting outcomes $\overline{x}$ and $\underline{x}$ such that $u_i(\overline{x}) > u_i(x) > u_i(\underline{x})$ and then finding the probability $q^* \in [0, 1]$ such that player $i$ is indifferent between $x$ and $(q^*, \overline{x}; 1-q^*, \underline{x})$. Assuming expected utility and normalizing $u_i(\overline{x}) = 1$ and $u_i(x) = 0$, indifference at $q^*$ means that $u_i(x) = q^*$. In the lab we elicit each player $i$’s cardinal utility for each $x$ in the range of $\pi$ (meaning, for each possible outcome of the game form) by finding the indifference probability for that $x$.

Recall that $X = X_1 \times X_2$, so player $i$’s utility $u_i(x_1, x_2)$ can depend on both players’ payoffs. Player $i$ is said to be consistent with selfishness in $\Gamma$ (or, simply, selfish in $\Gamma$) if for every $x'$ and $x$ in the range of $\pi$, $x_i' > x_i$ implies $u_i(x') > u_i(x)$. It is possible for someone to be consistent with selfishness in some games, but not others. For example, someone who is somewhat altruistic may be consistent with selfishness in zero-sum game forms, but not in dictator game forms.

The second component of player $i$’s state is her strategy choice $s_i$. Players in this framework do not choose mixed strategies. Instead, ‘mixing’ happens in players’ uncertainty about their opponents’ pure strategy choices. For example, in matching pennies Ann might believe there is a 50% chance Bob is in a state where he plays ‘heads’, and 50% he’s in a state where he plays ‘tails’. This perspective stems from Aumann (1987), who views mixed strategy equilibrium as a property of players’ beliefs about each other, rather than their actual play of the game.

The last component of a state identifies these beliefs over strategies, as well as beliefs over utilities, beliefs over beliefs, and so on. Let $p^1_i(u_{-i}, s_{-i})$ be player $i$’s first-order belief about $u_{-i}$ and $s_{-i}$. This belief allows for correlation between $u_{-i}$ and $s_{-i}$. Player $i$ also forms beliefs about her opponent’s first order belief $p^1_{-i}$, so let $p^2_i(p^1_{-i}, u_{-i}, s_{-i})$ be $i$’s second-order belief. An entire infinite hierarchy of beliefs $\tau_i = (p^1_i, p^2_i, p^3_i, \ldots)$ can thus be constructed. For notational simplicity, let $p_i^{1\alpha}(s_{-i})$, $p_i^{1\alpha}(u_{-i})$, and $p_i^{2\alpha}(p^1_{-i})$ denote the respective marginal distributions of $p^1_i$ and $p^2_i$.

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5To ensure $u_i(\overline{x}) > u_i(x) > u_i(\underline{x})$, we choose $\overline{x}$ and $\underline{x}$ such that $\overline{x}_i > x_i > \underline{x}_i$ for each $i$ for every $x$ in the range of $\pi$. If in fact $u_i(\overline{x}) < u_i(x)$ or $u_i(x) > u_i(\underline{x})$ then we would observe $q^* = 1$ or $q^* = 0$, respectively.

6If players actually mix, then there would be some (possibly internal) randomization device. Different realizations of that randomization device would then correspond to different possible states of the player, differing only in the $s_i$ component.

7It is necessary that $p^2_i$ also include beliefs over $u_{-i}$ and $s_{-i}$—despite the redundancy with $p^1_i$—to capture any believed correlation between $s_{-i}$ and $p^1_{-i}$. It is common in theoretical work to assume coherency—meaning the marginal of each $p^b_i$ agrees with $p^{b-1}_i$—and common knowledge of coherency, but we do not elicit enough data to test this assumption. See Dekel and Siniscalchi (2015, pp.625–626) for details.
To elicit $p_i^{1s}(s_{−i})$ we simply find the probability $q_i^*$ such that $i$ is indifferent between an act which pays outcome $x$ if $−i$ plays $s_{−i}$ (and $x$ otherwise) and a lottery that pays $x$ with probability $q_i^*$ (and $x$ otherwise). Because $p_i^{1u}$ and $p_i^{2p}$ have non-singleton supports, we elicit only the mode of these distributions by having the player announce their best guess of the elicited values of $u_{−i}$ and $p_{−i}^{1s}$, respectively, and paying them $x$ if their guess is correct.\footnote{We also elicit their belief that each of these guesses is correct by finding the probability $q_i^*$ that makes the subject indifferent between an act that pays $x$ if their guess is correct and a lottery that pays $x$ with probability $q_i^*$.}

Consequentialism is the idea that players only care about the payoffs that result from their strategy choices. And rationality describes a player whose strategy is a best response to their beliefs, given utility $u_i$. Combining these concepts, Player $i$ is said to be consequentialist expected utility rational (or, CEU-rational) at state $ω_i = (u_i,s_i,τ_i)$ if $s_i$ maximizes $∑_{s_{−i}} p_i^{1s}(s_{−i})u_i(π(s_i,s_{−i}))$. Otherwise, they are CEU-irrational.

Letting $R_{−i}$ be the set of states $ω_{−i}$ for which $−i$ is CEU-rational, we can elicit player $i$’s belief about $R_{−i}$ by finding the probability $q_i^*$ at which they are indifferent between an act that pays $x$ if $ω_{−i} ∈ R_{−i}$ (and $x$ otherwise) and a lottery that pays $x$ with probability $q_i^*$ (and $x$ otherwise). Since the actual state is not directly observed, we rely on player $−i$’s elicitation data to determine whether or not $ω_{−i} ∈ R_{−i}$.

At state $ω = (ω_i,ω_{−i})$, the (Bayesian) game induced by $Γ$ at $ω$ is $G(ω) = (I,S,((u_i∘π)_{i∈I},(τ_i)_{i∈I}))$, where $u_i(π(s_i,s_{−i}))$ is $i$’s utility over strategy profiles (rather than outcomes) at state $ω_i = (u_i,s_i,τ_i)$.\footnote{Bayesian games here do not necessarily have a common prior.} The experimenter selects the game form $Γ$, but cannot observe the actual game $G(ω)$ without eliciting players’ utilities and beliefs. Notice that even if the game form is commonly observed, the induced game may be one of incomplete information due to uncertainty about the state.

We also study the centipede game form, which has multiple stages. In that case, simply augment this framework by adding histories of the form $h^t = (a^1,a^2,...,a^{t−1})$, where $t$ is the index of the current decision node and, for each $t' < t$, $a^{t'} ∈ \{T,P\}$ is the action (either Take or Pass) chosen by the active player at the $t'$th decision node. Beliefs now form a conditional probability system (see Myerson, 1991), where $p_i^k(⋅|h^t)$ denotes $i$’s $k$th order belief when the game play has reached history $h^t$. We can therefore elicit strategies (complete contingent plans), utilities, and beliefs at every realized history (including at the initial history $φ$). First-order beliefs over strategies are now over complete contingent plans, and easily elicited at any node by asking the player the probability with which her opponent plans to take at each decision node. This is compared to the actual plan reported by the opponent to determine payment.
Many methodological issues arise when eliciting these variables. We defer discussion of these issues—and the detailed description of our elicitation techniques—to Section VIII.

IV. EXPERIMENTAL DESIGNS

We report three experiments in which subjects play multiple game forms. In the first—which we denote by CENT—subjects play a fixed six-node centipede game form four times against different opponents. We perform elicitation only in the last two periods. We report three different treatments—denoted by CENT-LO, CENT-HI, and CENT-ALL—that differ only in their payoffs. Each subject participated in only one of the three treatments. In the second experiment—denoted by SIM—subjects play five simultaneous 2 × 2 game forms one time, without feedback, and with elicitation performed in each game. In the third—denoted SEQ—a new group of subjects play sequential-move versions of the same five game forms. Specifically, the row player chooses an action in the first stage and then the column, upon observing the row player’s action, chooses an action in the second stage. Again we perform elicitation in every game.

Our elicitation procedure is the same regardless of the game form, and regardless of whether it is a simultaneous-move game form or a multistage game form. For each i, we elicit at the initial history

1. \( u_i(\pi(S)) \) (cardinal utilities for all outcomes in the game form),
2. \( \arg \max_{u_{-i}} p_i^{1u}(u_{-i}|\emptyset) \) (the mode of i’s initial belief about \(-i\)’s utility), and
3. \( \max_{u_{-i}} p_i^{1u}(u_{-i}|\emptyset) \) (the density at the mode of that belief about \( u_{-i} \)).

At every history \( h^t \) (including the initial history) we also elicit from all players (regardless of whether they are active or not)

4. \( s_i \) (i’s chosen strategy, expressed as a complete contingent plan),
5. \( p_i^{1s}(s_{-i}|h^t) \) (i’s belief distribution over \( s_{-i} \)),
6. \( \arg \max_{p_{-i}} p_i^{2p}(p_{-i}^{1s}(|h^t)|h^t) \) (the mode of i’s current belief about \(-i\)’s current belief about \( s_i \)),
7. \( \max_{p_{-i}} p_i^{2p}(p_{-i}^{1s}(|h^t)|h^t) \) (the density of that mode), and
8. i’s current belief that \(-i\) is rational.\(^{10}\)

We describe in Section VIII how we elicit each of these objects in an incentive compatible way.

\(^{10}\)Recall that in single-stage games, the only non-terminal history is the initial history. According to the framework, \( s_i \) and \( u_i \) should not vary across histories. We measure \( s_i \) at each history to see if in fact it is stable. We measure \( u_i \) only at the initial history. In the centipede game form, if player i’s action at \( h^t \) terminates the game, then player i knows that she will not observe any further components of \( s_{-i} \). In that case we do not elicit \( p_i^{1s}(s_{-i}|h^t) \) or i’s belief in \( R_{-i} \) since the elicitation would not be strictly incentive compatible.
Subjects in the CENT experiment (centipede game forms) interacted anonymously via a custom-built computer interface. The game tree was visible during all elicitation questions. For example, when eliciting cardinal utilities for outcomes, the subject filled in his cardinal utility for each outcome directly below that outcome on the computer screen. After entering utilities for all seven outcomes, the computer then showed a table with the outcomes ranked from best to worst according to the reported utilities, and the subject was asked to confirm that the ranking of outcomes was as they prefer.

We did not use the strategy method; subjects’ elicited strategies at each node (which are complete contingent plans specifying at what node they plan on choosing Take, if ever) determined whether the game proceeded to the next node or not. Subjects learned whether their opponent chose Pass or Take after each node, but nothing else until the experiment was finished. At the end of the experiment the subjects were given a page with 16 binary choices between gambles designed to estimate their risk and ambiguity attitudes (Holt and Laury, 2002).

The treatments CENT-LO, CENT-HI, and CENT-ALL simply vary the payoffs in the game. The number of subjects in each treatment are 54, 36, and 62, respectively. The specific game forms are shown in the Results section below.

Subjects in the SIM and SEQ experiments (2 × 2 game forms) were given a booklet of seven pages. Each of the first five pages showed a game form at the top, followed by the eight elicitation questions immediately below. For example, the third page of the booklet showed the Prisoners’ Dilemma game form at the top and all elicitation questions about that game form below. The specific game forms are shown in the results section. The sixth and seventh pages contain 16 individual binary decisions intended to measure the subject’s risk aversion and ambiguity aversion. Each subject filled in his answers to all questions on all pages on all pages and turned it in to the experimenter. The experimenter then matched each booklet with that of the corresponding opponent and calculated payments.

The SEQ experiment is identical to SIM, except that row players moved first and column players second. Specifically, row players were asked to enter each strategy choice into a computer terminal immediately after making it, and the computer then transmitted the choice anonymously to the corresponding column player. Column players were instructed to wait until they could see their row player’s choice in each game before filling out that page of their own booklet.

At the end of each experiment subjects were paid for only one randomly-selected decision (Allais, 1953). This method is incentive compatible assuming subjects’ preferences over gambles satisfy monotonicity (which is strictly weaker than expected utility; see Azrieli et al., 2017 for details). Subjects for all experiments were recruited via ORSEE.
(Greiner, 2015) from a database of potential subjects at Ohio State University. One hundred fifty subjects participated in the second experiment, and sixty four in the third. Instructions, screenshots, and the booklets used are all available in an online appendix.

V. THE CENTIPEDE GAME AS A BAYESIAN GAME

![Figure I](image_url)

**Figure I.** (a) A three-node segment of a centipede game form. (b) The game with ‘selfish’ utilities. (c) The game with other-regarding preferences.

To understand the incentives in a centipede game form—and to preview our results—consider an arbitrary three-node segment of a centipede game form, shown in panel (a) of Figure I. A three-node segment is simply the smaller centipede game form created by taking three consecutive decision nodes from a larger centipede game and removing the option to Pass at the third node. The one in Figure I is taken from the first three nodes of our Treatment 1. Panel (a) shows the actual game form. Panel (b) shows the utilities for a hypothetical player who is consistent with selfishness. Panel (c) shows the utilities of a (hypothetical) non-selfish player who exhibits some degree of altruism.

Now consider the incentive of each subject to choose Pass at the root node of this segment. If the selfish player believes the second mover will Pass with probability $p$, then her best response is to Pass at the first node if and only if $p \geq (17-16)/(22-16) = 1/6$. Thus, her ‘basin of attraction’ for Pass—the set of beliefs such that Passing is a best response—is the interval $[1/6, 1]$. We refer to the size of this basin as $SizeBAP$, which here equals $5/6$.\footnote{This is inspired by a similar measure analyzed by Dal Bó and Fréchette (2011) for repeated prisoners’ dilemmas.} $SizeBAP$ thus provides a measure of how ‘tempted’ a player is to Pass.\footnote{In the larger game with more than three nodes, $SizeBAP$ is only an approximate measure of the true temptation to Pass.} If Passing is not too risky (in terms of utilities, not dollars), then the $SizeBAP$ will be large.

For the altruistic subject in panel (c), Pass is a strictly dominant strategy. Intuitively, she is willing to sacrifice $1 to give her opponent $6, and so she faces no temptation to choose Take. Her $SizeBAP$ is therefore 1.00. Importantly, this subject is *not playing a*
**centipede game.** If we observe her choosing Pass, we should not conclude that backwards induction was invalidated.

Finally, consider the again the selfish player from panel (b) playing the three-node game form against a pool of subjects in which Pass is a dominant strategy for 1/3 of her opponents. The selfish player could reasonably believe that her randomly-drawn opponent will Pass with probability $p = 1/3 > 1/6$, and thus she will rationally choose Pass in response. This subject is also *not playing a centipede game.* She is playing a Bayesian game with heterogeneity in utilities. Consequently, her choice of Pass in early nodes should not be viewed as a failure of backwards induction.

This simplified example illustrates our main finding: We see non-selfish preferences in much of our data, these subjects tend to choose Pass, and the presence of these non-selfish types also induces those who are consistent with selfishness to Pass as well.

**CENT-LO Treatment:**

![Game form](image)

**Figure II.** The CENT-LO treatment. Top: The game form. Bottom left: Across all 3-node game segments, the percentage of subjects who have a dominant strategy to Take or Pass (or neither). Bottom middle: The temptation to Pass for subjects without a dominant strategy, as measured by $\text{SizeBAP}$. Bottom right: Actual outcome frequencies.
the opponent Passes and the player subsequently Takes). The \textit{SizeBAP} based on selfish dollar payments is therefore $5/6 \approx 0.83$ at every node.

We take the elicited utilities for each subject and calculate for each 3-node segment whether they have a dominant strategy to Pass, a dominant strategy to Take, or neither. We do this for the last period only. The resulting histogram (combining all 3-node segments) is shown in the bottom left panel. Over 40% of subjects have a dominant strategy, and the vast majority of them have a dominant strategy to Pass. Thus, we see a substantial incidence of altruism-like preferences in this game form.

In the middle histogram we take those subjects who have no dominant strategy and calculate the \textit{SizeBAP} measure for each 3-node segment. Again, the larger the \textit{SizeBAP}, the more the selfish subject is willing to Pass. The \textit{SizeBAP} here is typically large, often nearly as high as the dollar-based measure of 0.83. Given that 40% of subjects have a dominant strategy to Pass, we should expect that many of these subjects will best respond by choosing Pass as well.

The histogram of actual game outcomes (for the final period) is shown in the bottom right panel. In no case does any player Take in the first three nodes. The modal outcome is for players to Pass until the very last decision node, and then Take. This behavior is not paradoxical, however; it is easily rationalized given the preferences we observe. Again, this is a Bayesian game, and the selfish types are willing to Pass because (1) it is not very risky (the \textit{SizeBAP} is large), and (2) they believe there are non-selfish types who will Pass. Also, note that in 20% of games the last mover Passes, providing clear support for the presence of non-selfish preferences in the game itself.

Next we consider a centipede game form in which the risk to Passing is much higher. In the CENT-HI treatment (shown in Figure III) Passing risks $2$ to gain only $1$. The resulting \textit{SizeBAP} based on dollar payoffs is $1/3$. Examining elicited preferences, we now see that far fewer subjects have a dominant strategy, and among them a slight majority have a dominant strategy to play Down. Of the 71% of subjects who have no dominant strategy, most have a low \textit{SizeBAP}. They would need to believe that more than half of subjects will play Pass in order to rationalize Passing, but the distribution of preferences simply do not support that belief. And the game typically ends much earlier as a result. In fact, over 2/3 of games end in the first two nodes.

Finally, we test a ‘winner take all’ version of the centipede game form in our CENT-ALL treatment (Figure IV). Here, Passing risks almost the entire payoff for a gain of $4$. The \textit{SizeBAP} for a selfish subject is $0.22$ at their first decision node, $0.18$ at their second, and $0.15$ at their third. Looking at elicited utilities, we see that over 80% have no dominant strategy in this game form. Thus, this is reasonably close to a complete-information game. Even the \textit{SizeBAP} measures are close to the selfish dollar-based
values of 0.18–0.22. Arguably this game form provides the best test of a true complete-information centipede game to date. And the predictions of backwards induction (and extensive form rationalizability) are largely confirmed: The first mover plays Down in 68% of games, and no game proceeds beyond the third node.\footnote{Recall this is for the fourth period, but even in the first period 68\% of first movers chose Take at the first node. This drops to 52\% in period 2, 55\% in period 3, and back to 68\% in period 4. Across all periods, 94\% of games ended in the first three nodes.}

In summary, our elicitation data suggest that most centipede game forms induce Bayesian games.\footnote{In the appendix we report two additional treatments. CENT-MID is between CENT-LO and CENT-HI in terms of the dollar-based \textit{SizeBAP}, though more similar to CENT-LO. And the results are similar to CENT-LO. CENT-CONST tests a constant-sum game form with only four decision nodes. The \textit{SizeBAP} is high for the first node, but drops quickly in subsequent nodes. We see the vast majority of subjects choosing Take in the first node, with the remaining games ending at the second node. Thus, the results are similar to CENT-ALL.} There are subjects whose preferences are consistent with selfishness, but also those with non-selfish preferences. A larger presence of non-selfish types gives a clear incentive for selfish types to choose Pass early in the game. But, if the
payoffs are changed so that the riskiness of Passing is increased, then more players become consistent with selfishness, and so the selfish types no longer have an incentive to Pass. Consequently, players Take earlier.

VI. IRRATIONAL PLAY IN THE PRISONERS’ DILEMMA

Simultaneous Moves

\[
\begin{array}{c|cc}
\text{C} & \text{D} \\
\hline
\text{C} & $10, $10 & $1, $15 \\
\text{D} & $15, $1 & $5, $5 \\
\end{array}
\]

Figure V. The Prisoners’ Dilemma Game Form

In the SIM experiment subjects play five $2 \times 2$ simultaneous-move game forms. The third game form in that experiment is the classic Prisoners’ Dilemma game form, shown in Figure V. In our data, 30.4% of subjects choose cooperation. This is in line with previous experiments using similar payoffs but no elicitation (see Mengel, 2014 for a recent

\[\text{Recall that becoming consistent with selfishness does not necessarily mean they became uniformly selfish. It just means that, with these payoffs, their social preferences are not strong enough to push their best responses away from the selfish best response.}\]

\[\text{In the actual experiment the strategies were labeled “A” and “B”.}\]
The obvious rationalization for this level of cooperation is that some subjects have social preferences. Using preference elicitation data, we can observe whether such preferences exist, and whether they actually rationalize the strategic choices.

Using elicited preferences, we classify subjects into four types, based on their best response structure. ‘Selfish’ types have a dominant strategy to defect. ‘Conditional Cooperators’ prefer $D$ in response to $D$, and $C$ in response to $C$. ‘Reverse’ types prefer $C$ in response to $D$, and $D$ in response to $C$. For these two types, their best response in the game depends on their beliefs about their opponent’s strategy, which in turn might depend on their beliefs about the frequencies of the various types. Finally, ‘Unconditional Cooperators’ have a dominant strategy to cooperate. The fourth column of Table I shows the frequency of each of these types among our 148 subjects in this experiment for whom we have valid preference data. Indeed, roughly 30% have non-selfish preferences.

<table>
<thead>
<tr>
<th>Pref. Type</th>
<th>$BR(C)$</th>
<th>$BR(D)$</th>
<th>% Subj.</th>
<th>$s_i = C$</th>
<th>% Rational</th>
<th>$s_i = D$</th>
<th>% Rational</th>
<th>Overall % Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selfish</td>
<td>$D$</td>
<td>$D$</td>
<td>68.7%</td>
<td>18</td>
<td>0%</td>
<td>83</td>
<td>100%</td>
<td>82.2%</td>
</tr>
<tr>
<td>Cond.Coop.</td>
<td>$C$</td>
<td>$D$</td>
<td>19.3%</td>
<td>18</td>
<td>83%</td>
<td>11</td>
<td>55%</td>
<td>72.4%</td>
</tr>
<tr>
<td>Reverse</td>
<td>$D$</td>
<td>$C$</td>
<td>2.7%</td>
<td>1</td>
<td>100%</td>
<td>3</td>
<td>33%</td>
<td>50.0%</td>
</tr>
<tr>
<td>Uncond.Coop.</td>
<td>$C$</td>
<td>$C$</td>
<td>9.3%</td>
<td>8</td>
<td>100%</td>
<td>6</td>
<td>0%</td>
<td>57.1%</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td>100%</td>
<td>45</td>
<td>53.3%</td>
<td>103</td>
<td>87.4%</td>
<td>77.0%</td>
</tr>
</tbody>
</table>

The 30% cooperation rate we observe matches very closely the percentage of non-selfish types we observe in our utility elicitation. Unfortunately, the presence of non-selfish preferences does not fully rationalize the cooperation we observe. The remaining columns of Table I show, for each type, the number choosing each strategy and the percentage of those that are CEU-rational (meaning their strategy choice maximizes their expected utility, given their elicited beliefs and utilities). For example, of the 101 Selfish types, only 83 of them (82.2%) choose their dominant strategy of defecting. Of the 18 Conditional Cooperators who cooperated, 3 (17%) should have defected according to CEU-rationality. And of the 11 who defected, 45% should have cooperated. Perhaps most surprisingly, of the 14 Unconditional Cooperators, six chose to defect despite having utilities such that cooperation is a dominant strategy.

Thus, we conclude that the Prisoners’ Dilemma is also a Bayesian game, featuring mostly Selfish and Conditional Cooperator types. But it is a Bayesian game in which 23% of subjects violate CEU-rationality. In particular, almost half of those who cooperated should have defected, given their stated preferences and beliefs.

---

$^{17}$Two of the 150 subjects did not fill in utility elicitation answers in their booklet for this game form.
Why do we see these violations of CEU-rationality? Our data provides no answers, but we conjecture that a failure of consequentialism is to blame. Many subjects who cooperate do so knowing that the outcomes it will generate will be inferior. But they have a preference for the act of cooperating above and beyond what the outcomes alone generate. In other words, we conjecture that subjects cooperate even though they know they are hurting themselves by doing so.

**Sequential Moves**

![Diagram of Sequential Moves]

**Figure VI.** Frequencies of choices and fractions of subjects who are CEU-Rational in the sequential-move Prisoners’ Dilemma game form.

In the SEQ experiment subjects played the sequential-move version of the Prisoners’ Dilemma game. The game form and action frequencies are shown in Figure VI. We see that 62% of first movers defect, which is slightly lower than the defect rate of 70% in the simultaneous-move game. Interestingly, every one of the 18 second movers subsequently defect. And all of them report preferences for which the \((D,D)\) outcome is preferred to the \((D,C)\) outcome, meaning all of the are CEU-rational.

When the first mover cooperates, two thirds of second movers reciprocate. But, unlike the simultaneous-move game, cooperation by second movers is well predicted by their preferences. Of the 8 that reciprocate, 7 report Conditional Cooperator preferences for which the \((C,C)\) outcome is preferred to the \((C,D)\) outcome. And of the 4 that defect, 3 report preferences consistent with selfishness. Aggregating across all second movers, we see that 28 out of 30 acted perfectly in line with their elicited preferences. In other words, preference reversals (between elicitation and game play) were rare.

From this we conclude that strategic uncertainty plays a large role in violations of CEU-rationality. Once strategic uncertainty is removed, these CEU-rationality violations are diminished.
VII. OTHER EXAMPLES OF IRRATIONAL PLAY

A Dominance Solvable Game Form

\[
\begin{array}{cc}
L & R \\
U & 10, 15 & 5, 15 \\
D & 5, 10 & 1, 1 \\
\end{array}
\]

Figure VII. The Dominance Solvable Game Form

The first of five game forms that subjects face in the SIM experiment is the dominance solvable game form shown in Figure VII. In terms of monetary payoffs, the row player has a strict dominant strategy to play \(U\). Anticipating this, a money-maximizing column player should best respond with \(R\).

<table>
<thead>
<tr>
<th>Pref. Type</th>
<th>BR(D)</th>
<th>BR(U)</th>
<th>% Subj.</th>
<th>(s_i = L)</th>
<th>No.</th>
<th>% Rational</th>
<th>(s_i = R)</th>
<th>No.</th>
<th>% Rational</th>
<th>Overall</th>
<th>% Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selfish</td>
<td>(L)</td>
<td>(R)</td>
<td>91.9%</td>
<td>15</td>
<td>53</td>
<td>100%</td>
<td>1</td>
<td>0</td>
<td>0%</td>
<td>77.9%</td>
<td></td>
</tr>
<tr>
<td>DomStrat L</td>
<td>(L)</td>
<td>(L)</td>
<td>5.3%</td>
<td>3</td>
<td>1</td>
<td>0%</td>
<td>1</td>
<td>100%</td>
<td>0%</td>
<td>75.0%</td>
<td></td>
</tr>
<tr>
<td>DomStrat R</td>
<td>(R)</td>
<td>(R)</td>
<td>2.7%</td>
<td>1</td>
<td>1</td>
<td>100%</td>
<td>1</td>
<td>0</td>
<td>100%</td>
<td>50.0%</td>
<td></td>
</tr>
<tr>
<td>Reversed</td>
<td>(R)</td>
<td>(L)</td>
<td>0.0%</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td>100%</td>
<td>19</td>
<td></td>
<td>15.8%</td>
<td>55</td>
<td>98.2%</td>
<td></td>
<td>77.0%</td>
<td></td>
</tr>
</tbody>
</table>

Table II. The four types of column players in the Dominance Solvable game form, their best responses, the percentage of each type, the number that play each strategy, and the percentage of those that are CEU-rational.

In our data, 100% of row players play \(U\), but only 75% of column players choose \(R\). The mystery, then, is why 25% choose to play \(L\).

The rationality data for column players is shown in Table II. First, note that this is close to a complete information game in which almost all players are consistent with selfishness. And those types are rational if and only if they play Right. This means every one of them were sure enough that their row player would play Up that Right was in fact their best response. Thus, the 15 subjects consistent with selfishness who chose Left all violated CEU-rationality. A histogram of those 15 subjects’ first-order beliefs (Figure VIII) reveals that, indeed, they were all at least 80% sure the row player would choose Up. The best response for all 15 of them is to play Right, yet these 15 chose Left.

\[\text{All 75 row players choose Up. Of those, 71 are consistent with selfishness. The remaining four do not have a dominant strategy, but Up is also their best response (given their beliefs), so all 75 row players were CEU-rational in this game.}\]

\[\text{Four subjects report preferences such that Left was a dominant strategy, and three of the four play Left. But such preferences seem implausible because } (U, L) \text{ gives payoffs that are both dominated by } (U, R) \text{ and}\]
Our conjecture is that many of the 15 selfish column players who played Left did so to avoid the ($1, $1) outcome. But, since we elicited their cardinal utilities, their distaste for ($1, $1) in the game must either be due to some non-expected-utility form of loss-averse preferences, or to a failure of consequentialism. In particular, a subject might view ($1, $1) as somewhat undesirable when viewed as a dollar payoff, but especially contemptible as a game outcome. In this case, their preference over strategies in the game is not derived from more than just their beliefs and their preferences over outcomes.

Next we consider the same game, but played sequentially. The data for this game from the SEQ experiment are shown in Figure IX. Again, all row players choose Up, and all do so rationally because all have preferences consistent with selfishness. But now 30 out of 32 column players choose Right. And all do so rationally because all report preferences such that ($15, $15) $\succ$ ($10, $5). Thus, we view these four subjects most likely as noisy data.
Comparing the simultaneous-move to the sequential-move version of the game, we find there is not a significant difference in preference types of column players (92% selfish up to 94% selfish, giving a Wilcoxon $p$-value of 0.746), but there is a significant reduction in their incidence of irrationality (23% irrational down to 3% irrational, giving a Wilcoxon $p$-value of 0.013). As in the prisoners’ dilemma, we see that removing strategic uncertainty nearly wipes out violations of CEU-rationality.

**An Asymmetric Coordination Game**

<table>
<thead>
<tr>
<th>U</th>
<th>$15, $5</th>
<th>$2, $1</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>$1, $2</td>
<td>$5, $10</td>
</tr>
</tbody>
</table>

**Figure X.** The Asymmetric Coordination Game Form

The fifth and final game form subjects encounter in the SIM experiment is the asymmetric coordination game form shown in Figure X. Both $(U,L)$ and $(D,R)$ are pure-strategy equilibria (in terms of dollar payoffs), but coordination is difficult because the two players prefer different equilibria. In addition, the row player gets a higher payoff in his more-preferred equilibrium than the column player gets in hers.

<table>
<thead>
<tr>
<th>Row’s Type</th>
<th>$BR(L)$</th>
<th>$BR(R)$</th>
<th>% Subj.</th>
<th>$s_i = D$</th>
<th>No.</th>
<th>% Rational</th>
<th>$s_i = U$</th>
<th>No.</th>
<th>% Rational</th>
<th>Overall</th>
<th>% Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selfish</td>
<td>$U$</td>
<td>$D$</td>
<td>94.7%</td>
<td>5</td>
<td>60%</td>
<td>63</td>
<td>68%</td>
<td>67.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Col’s Type</th>
<th>$BR(D)$</th>
<th>$BR(U)$</th>
<th>% Subj.</th>
<th>$s_i = L$</th>
<th>No.</th>
<th>% Rational</th>
<th>$s_i = R$</th>
<th>No.</th>
<th>% Rational</th>
<th>Overall</th>
<th>% Rational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selfish</td>
<td>$R$</td>
<td>$L$</td>
<td>92.0%</td>
<td>31</td>
<td>84%</td>
<td>38</td>
<td>29%</td>
<td>53.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table III.** Choices and CEU-rationality for row and column players who are consistent with selfishness.

In this game form 93% of subjects report preferences that are consistent with selfishness. For the remaining analysis we focus only on those subjects. Of the 68 row players, 63 chose Up, clearly targeting their more-preferred equilibrium. The majority of these do so rationally, but a full 32% report beliefs and utilities such that Down is actually a better response. Column players exhibit this behavior even more frequently: The majority of Column players play Right (targeting their own preferred equilibrium), even though 71% of them report beliefs and utilities such that Left is a best response.

In other words, we see a strong tendency for players to target their preferred equilibrium even when they are reasonably sure their opponent is going to target the opposite equilibrium. Those that don’t target their preferred equilibrium, however, are far more
rational: 84% of column players who choose Left do so because they believe (correctly) that the row players are likely to choose Up. Here it is hard to argue that irrational subjects are avoiding the ($1, $2) outcome, because targeting their preferred equilibrium exposes them to getting ($2, $1), and subjects view these as similarly bad outcomes. The average reported utility difference between them is only 4.3, with 41% of subjects reporting no difference at all. Thus, we conjecture here that failures of CEU-rationality are due either to a form of optimism that is not reflected in elicited beliefs, or a stubbornness that is not captured when eliciting utilities for outcomes in isolation.

The data from the SEQ experiment are summarized in Figure XI. As we saw in the previous games, irrationality essentially disappears once strategic uncertainty is removed. The vast majority of first movers target their preferred equilibrium by choosing Up, after which 26 out of 28 second movers acquiesce and choose Left. We conjecture that the remaining two are exhibiting spiteful behavior—punishing first movers for targeting their preferred equilibrium—and therefore are violating consequentialism.

VIII. ELICITATION METHODOLOGY

We begin by describing how exactly we elicit various quantities in the experiment. We follow this with a discussion of methodological issues—including incentive compatibility and order effects—that arise from these procedures.
For each cell of the game form’s matrix we elicit the subject’s cardinal utility for that outcome. Each question is described to the subject as a 101-item binary choice list. For example, if the top-left cell of the game has payoffs ($5, $10), then to elicit the subject’s cardinal utility for that cell’s outcome the subject is asked to consider the list shown in Figure XII. The subject is asked at what probability they would switch from choosing Option A to choosing Option B. One row is then randomly selected, and the subject’s choice for that row is paid. In practice, the entire list is not given each time; rather, the subject is shown an example list in the instructions, but is only asked for their switch point in the actual experiment.

If we normalize $u(0, 0) = 0$ and $u(20, 20) = 1$, then a switch point of $q^*$ represents the subject’s cardinal utility for ($5, $10), since indifference implies $u(5, 10) = q^*u(20, 20) + (1 - q^*)u(0, 0) = q^*$. Notice that the elicited cardinal utility captures both risk aversion and social preferences. If this question is chosen for payment, only one of the two subjects (selected at random) is paid. This ensures that $i$’s choice truly determines the final payment of both $i$ and $-i$, and that the subjects receive no other payments.

All randomness in the experiment is resolved using die rolls or draws from a Bingo cage.

We assume subjects have a unique switch point. Reporting that switch point generates a two-stage gamble in which the question number is first chosen, and then the selected alternative for that question is paid out. (If Option A is selected then the second stage is degenerate.) As long as preferences over these two-stage gambles respects statewise monotonicity, the procedure is incentive compatible; see Azrieli et al. (2017) for details.

---

**Eliciting Cardinal Utilities**

*Table*

<table>
<thead>
<tr>
<th>Option A</th>
<th>or</th>
<th>Option B</th>
</tr>
</thead>
<tbody>
<tr>
<td>You get $5 and they get $10</td>
<td>or</td>
<td>0% chance you both get $20</td>
</tr>
<tr>
<td>You get $5 and they get $10</td>
<td>or</td>
<td>1% chance you both get $20</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
<tr>
<td>You get $5 and they get $10</td>
<td>or</td>
<td>100% chance you both get $20</td>
</tr>
</tbody>
</table>

**Figure XII.** The choice list used in cardinal utility elicitation.

---

The three first movers who chose Down may have done so out of fear of such spiteful behavior. Unfortunately we cannot test this because we cannot incentivize these players’ beliefs in the counterfactual event in which they chose Up.
Eliciting Beliefs

We elicit subjects’ beliefs about a variety of events, including which strategy their opponent plays, whether their opponent’s elicitation data is consistent with CEU-rationality, whether their guess of their opponent’s utility is correct, and so on. In general, eliciting beliefs about any event $E$ is done by asking the subject to consider his switch point in a 101-question list similar to Figure XII, except Option A is now “You get $20 if $E$ occurs” and Option B is “You get $20 with probability $p$”, with $p$ varying from 0% to 100%. If this elicitation question is chosen for payment, both players are paid independently based on their own choice from one randomly-selected row.

Again, assuming a unique switch point, this procedure is incentive compatible as long as players’ preferences over two-stage gambles respects statewise monotonicity.

Eliciting Modes of Others’ Beliefs

Belief distributions that live in spaces with more than one dimension (such as beliefs over the opponent’s four utility values) are difficult to elicit in practice. Instead, we ask subjects to report their two most likely guesses of the realized value. For example, we first ask the subject to report their best guess of the four utility values submitted by their opponent. We then ask their belief that their guess is correct. This is done using the procedure described above, where event $E$ is now the event that “your guess is correct”.

Given a fixed guess, it is clear that reporting the true belief for that guess is optimal under eventwise monotonicity. When choosing which guess to report, it is clear that reporting the guess that has the highest probability (the subject’s “best guess”) is also optimal. Doing so maximizes both the value of Option A in the list, and the number of rows for which Option A is paid.

To elicit the subject’s second-most-likely value, we simply ask them to report a second guess—which must be different from the first—and the probability this guess is correct. Again they are paid via the above mechanism. Given that they cannot report their most likely guess, their optimal report is their second-most-likely guess.21

CEU-Rationality

It may seem that $i$’s belief in CEU-rationality does not need to be elicited separately, as it could be inferred from their beliefs about opponent’s strategies, beliefs, and utilities. But since we only elicit marginal beliefs, this is not the case. For example, suppose $i$

---

21The subject could switch which report is their first- and second-best, but their probabilities of each guess being correct would then reveal which is truly their best guess.
believes $-i$ plays two possible strategies $s_{-i}$ and $\tilde{s}_{-i}$ and has two possible beliefs $\hat{p}_{-i}$ and $\tilde{p}_{-i}$. Utility is known to be $u_{-i}$. Player $-i$ is rational at $(\hat{s}_{-i}, \hat{p}_{-i})$ and $(\tilde{s}_{-i}, \tilde{p}_{-i})$, but not at $(\hat{s}_{-i}, \tilde{p}_{-i})$ or $(\tilde{s}_{-i}, \hat{p}_{-i})$. Suppose $i$ reports that both strategies are equally likely and both beliefs are equally likely. This could come from a belief that the two are perfectly correlated, so that $i$ assigns probability one to $-i$ being CEU-rational. Or it could come from a belief that the two are independently drawn, so that $i$ assigns probability $1/2$ to $-i$ being CEU-rational. She could even believe they are negatively correlated, putting zero probability on CEU-rationality. Without information about the joint distribution, we cannot infer anything about $i$’s belief in CEU-rationality from her marginal beliefs alone. Thus, we elicit beliefs about CEU-rationality directly in our experiment.

In order to elicit beliefs about CEU-rationality we must first explain CEU-rationality. To do this, we teach subjects simple expected utility calculations, and say that their opponent is “consistent” (rather than “rational”) if their action choice gives a higher expected utility than the unchosen action. We then ask the subject’s belief that their opponent’s action choice is “consistent”.

**Contamination**

The elicitation of beliefs and utilities likely alters game play. And explaining “consistency” to subjects may make them more likely to be consistent in their own choices. We therefore conjecture that our elicitation procedures (weakly) increase the incidence of CEU-rationality, and that our data represents an upper bound on the level of CEU-rationality one might expect in typical experiments. Since we still observe significant levels of CEU-irrationality across games, we expect that the presence of CEU-irrationality is robust and would be even more prevalent in experiments without elicitation.

The experiment was designed so that there is no natural ordering of game play and elicitation. In the SIM and SEQ experiments, strategy choices and elicitation questions are all presented on the same page. Although the strategy choice is the first question on each page, subjects are free to answer them in any order and go back and change their answers. Additionally, the instructions make it clear that both strategy choices and elicitation questions will be asked. Thus, we view this as a “fully contaminated” experiment in which game play is contaminated by elicitation and elicitation is contaminated by game play.

To test the effect of contamination, we ran an additional experiment called SIM-NOELICIT that is identical to the SIM experiment, but with no elicitation questions. Subjects simply made choices in the five games (again, with one game per page in the booklet) and were paid for one randomly-chosen game. [RESULTS HERE].
**Consequentialism**

\[
\begin{array}{c|cc}
 & L & R \\
\hline
U & $5,$5 & $5,$5 \\
D & $100,$5 & $5,$5 \\
\end{array}
\]

**Figure XIII.** A game form in which consequentialism is likely to fail.

Traditional game theory takes as primitive cardinal payoffs of the form \( u_i(s_i, s_{-i}) \). Since these utilities are defined over payoffs, they can depend on more than just the physical payoffs \( \pi(s_i, s_{-i}) \). This is likely in the game shown in Figure XIII. For the row player, \((U, L)\) generates a payoff of \((5, 5)\) (instead of \((100, 5)\)) because the row player chose to play up. It is her own fault she did not get $100. The profile \((D, R)\) also generates a payoff of \((5, 5)\), but this time the fault belongs to the opponent. It seems entirely plausible that, for the row player, \( u_i(U, L) \neq u_i(D, R) \), even though \( \pi(U, L) = \pi(D, R) \).

Ideally, we would elicit \( u_i(s_i, s_{-i}) \) instead of \( u_i(\pi(s_i, s_{-i})) \), avoiding the need to assume consequentialism. To our knowledge, however, it has not yet been demonstrated that \( u_i(s_i, s_{-i}) \) is an elicitable quantity. And we conjecture that it cannot be elicited in an incentive-compatible way. In particular, the row player in Figure XIII who knows she will select \( s_i = D \) cannot be paid in the counterfactual event that \( s_i = U \). Thus, \( u_i(U, L) \) cannot be incentivized in the play of this game. One might construct related decision problems or games that might be used to infer \( u_i(U, L) \), but by changing the game or decision problem we change the embedded meaning of the strategies and therefore cannot be sure that they are interpreted by the subject as truly identical to \((U, L)\). However, a formal proof that \( u_i(s_i, s_{-i}) \) cannot be elicited remains elusive, and is left open for future research. For the current project, we simply assume consequentialism and concede that all failures of rationality could in fact be failures of consequentialism.

**References**


ONLINE APPENDIX

APPENDIX A. PROOF OF THEOREM ??

Let $\Omega_{-i}(\omega_i)$ be the set of states $\omega_{-i}$ to which player $i$ in state $\omega_i$ assigns positive probability. Now fix any state $\omega_i \in B_{i,\sigma_i}(R_{-i} \cap [\sigma_i] \cap [u_{-i}])$. This means player $i$ at $\omega_i$ puts probability one on a set of states $\hat{\omega}_{-i} = (\hat{u}_{-i}, \hat{s}_{-i}, \hat{r}_{-i})$ in which $-i$ has utility $\hat{u}_{-i} = u_{-i}$, $-i$ has first-order beliefs $\hat{p}^{1s}_{-i} = \sigma_i$, and $-i$ is rational, meaning $\hat{s}_{-i}$ maximizes the expectation of $u_{-i}(\pi(\cdot))$ against $\sigma_i$. In other words, at every $\hat{\omega}_{-i} \in \Omega_{-i}(\omega_i)$, $\hat{s}_{-i}$ is a best response to $\sigma_i$ for utility $u_{-i}(\pi(\cdot))$.

Now assume that, in addition, $\omega_i \in [\sigma_{-i}]$. This means that for each $s'_{-i} \in \text{supp}(\sigma_{-i})$, player $i$ puts positive probability on some state $\omega'_{-i} = (u'_{-i}, s'_{-i}, \tau'_{-i})$ in which $-i$ plays $s'_{-i}$. In other words, each $s'_{-i} \in \text{supp}(\sigma_{-i})$ is a component of some state $\omega'_{-i} \in \Omega_{-i}(\omega_i)$. But we established above that at any state in $\Omega_{-i}(\omega_i)$ it must be that $s'_{-i}$ is a best response to $\sigma_i$ for utility $u_{-i}(\pi(\cdot))$. So, each $s'_{-i} \in \text{supp}(\sigma_{-i})$ is a best response to $\sigma_i$ for utility $u_{-i}(\pi(\cdot))$.

A symmetric argument shows that each $s_i \in \text{supp}(\sigma_i)$ must be a best response to $\sigma_{-i}$ for utility $u_i(\pi(\cdot))$. Thus, $(\sigma_i, \sigma_{-i})$ constitute a Nash equilibrium of the game $G(\omega)$, which has utilities $u_i(\pi(\cdot))$ and $u_{-i}(\pi(\cdot))$.

APPENDIX B. ADDITIONAL CENT TREATMENTS

CENT-MID Treatment:

![Diagram of the CENT-MID treatment with game outcome frequencies and sizeBAP histogram]

**Figure XIV.** The CENT-MID treatment.
Figure XIV shows the design and data from the CENT-MID treatment. A subject who Passes (in any 3-node segment) risks $1 to gain $3. The resulting $SizeBAP$ for a selfish subject is $3/4$, which is in between that of CENT-LO ($5/6$) and CENT-HI ($1/3$) though much more similar to CENT-LO. Seventy-four subjects participated in this treatment, across five sessions. The results are similar to CENT-LO: Over 40% of subjects have a dominant strategy to pass. Those that don’t have a dominant strategy typically have a high $SizeBAP$; certainly high enough to rationalize Passing when over 40% of opponents are expected to Pass unconditionally. And game play generally confirms this prediction. Though not quite as striking as CENT-LO, we see almost no early play of Take, with the modal incidence of Take occurring at the fourth out of six decision nodes.

**CENT-CONST Treatment:**

![Diagram showing game structure and outcomes](image)

**Figure XV.** The CENT-CONST treatment.

Figure XV show the design and data from a constant-sum version of the game. We therefore denote this treatment by CENT-CONST. This treatment differs in that the game form has only four decision nodes, it is repeated five times instead of four, and we only perform elicitation in the fifth period. Because the game is constant-sum the $SizeBAP$s necessarily vary. For the first mover, the $SizeBAP$s at his two decision nodes are 0.86 and 0.32. For $SizeBAP$ for the second mover is 0.46. Although the first node has a fairly high $SizeBAP$, we see that the vast majority of first movers Take at the first node. This is likely because all second movers in fact choose Take, meaning the first mover would need to have a $SizeBAP$ of 1.00 (a dominant strategy to Pass) for her to
choose Pass.\textsuperscript{22} Even in the first period 55% of games end at the first node, 35% at the second node, and the remaining 10% at the third node. In periods 2–5 the game reaches the third node only once; thus, learning does not play a large role in this treatment.

\textsuperscript{22}We do not elicit first-order beliefs of future actions from players who are choosing Take in the current node, because they know the future nodes will not be reached. Of those who chose Pass at the first node, the average belief is that the second mover will take at the next node with probability 63%.