Higher Orders of Rationality and the Structure of Games*

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Abstract

Identifying higher orders of rationality is crucial to the understanding of strategic behavior. Nonetheless, the identification of a subject's actual order of rationality from observed behavior in games remains highly elusive. Games may significantly impact and hence invalidate the identified order. To tackle this fundamental problem, we introduce an axiomatic approach that singles out a new class of games, the *e-ring games*. We then present results from a within subject experiment comparing individuals' classification across e-ring games and standard games previously used in the literature. The results show that satisfying the axioms introduced significantly reduces errors and contributes towards a more reliable identification.

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1 Introduction

Bounded rationality have progressively permeated through most fields of economics in recent years, and many areas are incorporating theories of bounded hierarchical reasoning to enhance the realism and robustness of their models, including macroeconomic policy (Angeletos and Lian, 2016), mechanism design (Crawford, 2021; Börgers and Li, 2019; De Clippel, Saran and Serrano, 2019) and jury selection (Van der Linden, 2018), among many others. In monetary policy, for instance, understanding whether individuals are capable of forming higher order beliefs, whether such beliefs are bounded and, if so, what the actual bounds are, can lead the same interest rate policy to have rather different economic implications (García-Schmidt and Woodford, 2019).

In general, the applicability and predictive power of theoretical models that assume bounded hierarchical reasoning are strengthened by the ability to correctly identify the bounds in the population of interest. Indeed, in any interaction between rational agents, optimal behavior depends on the distribution of beliefs about whether others are rational, about whether others believe others are rational, and so on. Typically, the identification of the relevant reasoning bounds is crucial not only to guide economic modeling, but also for making empirical predictions of economic outcomes.[1]

Among the multitude of identification methods employed, the central and most reliable one has been to use the choices of experimental subjects in one or more games to identify the highest possible order of rationality consistent with their choices.[2] Crucially, given that such choices are made in a particular game, the structure of such game can influence and possibly bias the identification exercise. This paper introduces an axiomatic approach to study this problem.

In fact, for such identification method to be externally valid, it seems natural to require that the games used should ensure that (1) whenever a subject's choices are consistent with order k of rationality, those choices should be the outcome of a hierarchical reasoning process with k observable steps, and (2) the associated k steps have not been *induced* by the game (or games) being played, meaning that the structure of the games used does not in itself lead subjects to forming the *right* hierarchy of beliefs.

To better motivate these two requirements, consider the 2/3 beauty contest game with choices from $\{0, 1, \ldots, 100\}$. A strategy consistent with a certain order of rationality k may

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[1] This paper focuses on the identification of orders of rationality and the corresponding concept of rationalizability, but the analysis is also applicable to any model of cognitive hierarchies, including level-k reasoning; see Germano, Weinstein and Zuazo-Garin (2020) for a recent discussion of various models.

[2] See Beard and Beil (1994); Schotter, Weigelt and Wilson (1994); Nagel (1995); Costa-Gomes, Crawford and Broseta (2001); Van Huyck, Wildenthal and Battalio (2002); Costa-Gomes and Weizsacker (2008); Rey-Biel (2009); Healy (2011); Costa-Gomes, Crawford and Iriberri (2013); Burchardi and Penczynski (2014); Georganas, Healy and Weber (2015); Kneeland (2015) among many others. Part of this literature has complemented choice based methods with other methodologies such as eye-tracking or search patterns recorded on computer interfaces. As discussed in Kneeland (2015), these methods are not always fully reliable, they may be difficult to implement in certain contexts and they may influence the way subjects choose in such games.

be chosen for a variety of reasons, raising the possibility of an identification mistake. For example, choosing 17 in such a beauty contest game is consistent with being of order $k = 4$. Nevertheless, given that we do not observe a subject's reasoning process, we cannot exclude that such a choice has been taken for other reasons such as the number corresponding to the subject's birthdate or her most preferred number. However, if the structure of the game allows for the observation of behavior at the different steps of the hierarchy of beliefs, the subject would be classified as being of order k *only if* her behavior at each step is consistent with such a classification, within the same game (that is, consistent at k and at each step from 1 to $k-1$). This motivates requirement (1) above, which contributes to reducing the probability of identification mistakes while maintaining a choice-based approach.[3] At the same time, games that allow to test for behavior at each step of the hierarchy might themselves induce, or *frame*, subjects into thinking hierarchically. Subjects might be pushed into making choices that are of higher order k, or simply into thinking hierarchically, because the structure of the games makes the iterated elimination steps, and hence the associated hierarchy of beliefs, apparent, thereby making the identification flawed. This motivates requirement (2) above, capturing a novel and intuitive notion of framing, which we formally define in the paper.

This paper addresses the highlighted identification problem both theoretically and empirically. On the theoretical side, we use for the first time an axiomatic approach to reduce the potential misidentification of higher orders of rationality. We propose two intuitive properties that pin down a unique and novel class of games we refer to as the *e-ring games*. To the best of our knowledge, none of the games previously used in the literature fulfill both requirements. On the empirical side, we test the validity of the two axioms proposed by comparing behavior across the most prominent classes of games used to identify levels of rationality and the *e-ring games*.

Regarding the theoretical contribution, we formalize the two requirements as follows. The first one, *lower order consistency*, ensures that individual behavior can be tested at *each step* of the hierarchy of beliefs, as in requirement (1) above. This property is the defining feature of the *ring games* used by Kneeland (2015).[4] The second property, *absence of framing*, formalizes

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[3] Applied to the 2/3 beauty contest example, ideally, for a subject that chooses 17 ($k = 4$), we would like to observe the same subject choose first a number between 44–66 ($k = 1$), second a number between 29–43 ($k = 2$), then a number between 19–28 ($k = 3$), all in the same game, which is impossible. Another possibility would be to make a subject play a series of (necessarily) different dominance solvable games. The problem with this is that players' beliefs and hence behavior may change because the games are changing, thereby invalidating the exercise. Notice also that, throughout the paper, for the analysis of beauty contest games (and only for this class of games), we consider that at each step it is weakly dominated actions that are eliminated, instead of strictly dominated ones. This reinforces our message, since with strict domination the orders of rationality quickly become huge: 0 for 100, 1 for 99, and so on.

[4] The *ring(-network) games* introduced by Cubitt and Sugden (1994) and used in Kneeland (2015) are finite dominance solvable static games, where player 1's payoffs depend on player 1's and player 2's actions; player 2's payoffs depend on player 2's and player 3's actions and so on, until player k, whose payoffs depend on player k's and player 1's actions, but has a single strictly dominant action that allows to initiate the dominance solvability procedure.

requirement (2) above by imposing that the payoff structure of the game should be such that each level of the hierarchy of beliefs has multiple payoff interdependencies, and not just ones with lower levels. The property is formulated using the language of graphs and guarantees that the payoff dependencies of the game do not correspond exactly with the "natural" hierarchy of beliefs, hence enabling players to contemplate alternative hierarchies.[5]

Surprisingly enough, lower order consistency and absence of framing greatly narrow down the set of available games. We show that the simplest class of games satisfying both properties, and identifying up to four levels of rationality—the empirically relevant ones—is a specification of a new class of games we present here, the *e-ring games*.[6] An *e-ring game* is a static game with private values, where the incompleteness of information is structured by means of messages automatically sent back and forth between players as in the email game of Rubinstein (1989). This information structure generates a natural one-to-one correspondence between messages and higher-order beliefs.

Our empirical contribution consists in testing experimentally the validity of lower order consistency and absence of framing. We carry out an experiment where all subjects play games from each of the following four classes: eight of our e-ring games, eight ring games as in Kneeland (2015), two simple two-player 4×4 dominance solvable games, and three different versions of the beauty contest game presented in Nagel (1995).[7] We are left with games which satisfy both properties (e-ring games), one of them (ring games) and none of them (4×4 and the beauty contest games) and allowing us to test whether satisfying the properties is effective empirically in addressing the theoretical concerns raised above.

By observing subjects' choices in these games and following the *revealed rationality approach* we categorize subjects within each class of games into five levels depending on the actions they choose. An action is categorized as $R0$ if it is never a best response, as $R1$ if it is a best response to some belief, as $R2$ if it a best response to the belief that the opponent is playing an $R1$ action, and so on. A subject is thus classified as Rk if all her actions are Rk and at least one is not $Rk{+}1$. That is, we assign players the maximal level of higher-order rationality consistent with the choices made (Tan and Werlang, 1988; Lim and Xiong, 2016; Brandenburger, Danieli and Friendenberg, 2017).

The experiment supports our theoretical approach. Indeed, we find evidence that the properties proposed are relevant in the following sense: (1) games that violate lower order consistency, and hence do not test for consistent choices at steps 1 to k, tend to overestimate the distribution

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[5] In what follows, we denote by *natural* hierarchy of beliefs the one that corresponds to the order of elimination of dominated strategies implied by the game.

[6] See Section 3.2 for a justification of why simplicity of the games may be a desirable property in empirical applications.

[7] To be more specific, subjects play versions of the beauty contest game where the average of all subjects' responses is multiplied by 1/3, 2/3 and finally, in the *p-beauty contest game*, by an unspecified number (p) strictly between 0 and 1 and assumed to be commonly known where all subjects have to specify how they would play for any p in the interval.

of types for levels 2 or higher, compared to the ones that satisfy lower order consistency; (2) the ring games, which satisfy lower order consistency but not absence of framing, appear to frame subjects into hierarchical reasoning. In fact, we find that the distribution of types for levels 2 or higher is biased towards the maximum level 4, as compared to the e-ring games that satisfy both properties. Moreover, we find an order effect, whereby subjects having played the ring games before the e-ring games tend to be identified with higher orders in the e-ring games than when the e-ring games are played before the ring games.

The remainder of the paper is organized as follows. Section 2 presents the desirable properties a class of games should satisfy to reliably identify higher orders of rationality, Section 3 introduces the e-ring games and shows that they are characterized by the properties presented in Section 2. Section 4 describes the experimental design and the experimental results. Section 5 concludes. The Online Appendix contains an English translation of the experimental instructions and the payoff matrices of all games used in the experiment.

2 Identification of Rationality Bounds

Despite the importance of understanding the extent to which agents engage in hierarchical reasoning, no consensus has been reached about which games to use to identify individuals' higher order rationality bounds.

In this section, we introduce a novel take on this problem by adopting an axiomatic approach. We proceed as follows. Section 2.1 recalls standard game-theoretic tools that formalize the notion of rationality bound as well as some basic notions concerning its identification. As it is standard in the literature, our identification method relies on the choices observed in a given game to identify the bounds hence making the features of the game crucial for their reliability. Using these basic notions, Section 2.2 proposes two axioms, *lower order consistency* and *absence of framing*, that, by shaping the structure of the game, strengthen the validity of the identification.

2.1 Rationality Bounds and the Structure of Games

Games and Higher-Order Rationality

A *game* is a list $G := \langle T_i, A_i, \pi_i, u_i \rangle_{i \in I}$ where I is a finite set of *players*, and, for each player i, T_i is a finite set of *types*, A_i is a finite set of *actions*, $\pi_i : T_i \to \Delta(T_{-i})$ is a *belief function*, $u_i : T_{-i} \times A_{-i} \to \mathbb{R}$ is a *utility function*.[8] For each $i \in I$ and $t_i \in T_i$ we refer to (i, t_i) as *player-*

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[8] Throughout the paper we let $T := \prod_{i \in I} T_i$ and $A := \prod_{i \in I} A_i$ denote the sets of *type profiles* and *action profiles* respectively; similarly, for each player i, we let $T_{-i} := \prod_{j \neq i} T_j$ and $A_{-i} := \prod_{j \neq i} A_j$ denote the sets of i's opponents' type and action profiles, respectively. For each finite set S the set of probability measures $\mu : 2^S \to [0, 1]$ is denoted by $\Delta(S)$.

type and denote the set of player-types of the game by X_G. The set of (*interim correlated*) *rationalizable* actions of player-type (i, t_i) is $R(i, t_i) := \bigcap_{k \geq 0} R_k(i, t_i)$ where, for each $k \geq 0$, $R_k(i, t_i)$ is (i, t_i)'s set of *kth-order rationalizable* actions, with $R_0(i, t_i) := A_i$ and, for $k \geq 1$,

$$R_k(i,t_i) := \left\{ a_i \in A_i \;\middle|\; \begin{array}{ll} \multicolumn{2}{l}{\text{There exists some } \mu_i \in \Delta(T_{-i} \times A_{-i}) \text{ such that:}} \\ (1) & a_i \in \arg\max\limits_{a_i' \in A_i} \sum\limits_{t_{-i} \in T_{-i}} \sum\limits_{a_{-i} \in A_{-i}} \mu_i[(t_{-i}, a_{-i})] u_i((t_{-i}, t_i), (a_{-i}, a_i')) \\ (2) & \mathrm{marg}_{T_{-i}} \mu_i = \pi_i(t_i) \\ (3) & \mu_i \left[\left\{ (t_{-i}, a_{-i}) \in T_{-i} \times A_{-i} \;\middle|\; a_{-i} \in \prod\limits_{j \neq i} R_{k-1}(j, t_j) \right\} \right] = 1 \end{array} \right\}.$$

Game G is *dominance solvable* if $R(x)$ is a singleton for every $x \in X_G$. Finally, a player-type $x \in X_G$ has *depth* $k \geq 1$, denoted by $d(x) = k$, if $R(x) = R_k(x) \subsetneq R_{k-1}(x)$, and we refer to $\max\{d(x) \,|\, x \in X_G\}$ as the *depth* of G.

Thus, we focus on situations of simultaneous choice with possible payoff-uncertainty (in case T_i is not a singleton for some player i). Classic results in Game Theory show that rationalizability and kth-order rationalizability bridge the gap between easily computable predictions and higher-order strategic reasoning: the sets of actions that survive 1 round of iterated elimination of strictly dominated actions for a type-type (i, t_i) coincides with $R_1(i, t_i)$ which, in turn, is the set of actions that could be chosen by a player i with type t_i who was rational; the set of actions that survive 2 rounds coincide with $R_2(i, t_i)$ which, in turn, is the set of actions that could be chosen by a player i with type t_i who was rational and believes that her opponents to be rational; and so on.[9] The idea that the number of iterations that an action survives hints at the strategic sophistication of a subject choosing it provides the foundation for the revealed rationality method, reviewed next.

Identification of Bounds

The procedure, based on inference via observed choices, consists of the following three steps: (1) a game is fixed, (2) a subject is asked to make choices in the role of every type of each player, and (3) this subject's rationality bound is identified as the *highest* $k \geq 0$ such that *every* choice of the subject is k-th order rational and at least one is *not* $(k + 1)$, if such k exists, and

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[9] The duality between the iterated deletion and rationalizability is a rather straightforward corollary of the classic Wald-Pearce Lemma. For details about the case of complete information see Pearce (1984) and Tan and Werlang (1988), and for the case of payoff-uncertainty, Dekel, Fudenberg and Morris (2007) and Battigalli, Di Tillio, Grillo and Penta (2011). Notice that in the latter case the analysis is carried out at the *interim* level, that is, from the perspective of a player i already endowed with a type t_i.

∞ otherwise.[10] This idea is formalized in the following definition and discussed in more detail further below.

Definition 1 (Revealed Rationality Bound) *Let $\mathcal{G}$ be a game. Then:*

(i) A player type *is a pair (i, t_i), where i is a player and t_i is a type for player i. We denote the set of all player types in the game by $X_{\mathcal{G}} := \bigcup_{i \in I} (\{i\} \times T_i)$.*

(ii) A choice vector *is an indexed list $(a_x)_{x \in X_{\mathcal{G}}}$ that ascribes an action $a_x \in A_i$ to each player type $x = (i, t_i)$.*

(iii) The revealed rationality bound *k that corresponds to choice vector $(a_x)_{x \in X_{\mathcal{G}}}$ is given by:*

$$k = \min \left\{ \max \left\{ k' \geq 0 : a_x \text{ is not } (k'+1)\text{-th order rational for } t_i \right\} : x = (i, t_i) \in X_{\mathcal{G}} \right\},$$

if k is a well-defined integer, and $k = \infty$ otherwise.

Thus the set of *player types* $X_{\mathcal{G}}$ represents the different roles that a subject can be asked to play in a game. Notice that, for games with complete information, the set of player types coincides with the set of players of the game. The *choice vector* $(a_x)_{x \in X_{\mathcal{G}}}$ is a description of the actions the subject is observed to have played in each of the roles.

The intuition behind the *revealed rationality bound* k has already been hinted at. If a subject is observed to choose an action that survives k but *not* $(k+1)$ rounds of iterated elimination of strictly dominated actions, then her rationality bound cannot be higher than k. In the opposite case, a subject consistently choosing at the highest possible level that the game allows for, cannot be excluded to have unbounded hierarchical reasoning, that is, $k = \infty$.

Building on these notions, the following definitions will be convenient for discussing the axioms in Section 2.2 and the characterization result in Section 3.2.

Definition 2 (Testing for Bounds) *Let $\mathcal{G}$ be a game. Then, we say that:*

(i) Player type $x = (i, t_i)$ can test for bound *$k \geq 1$ if every action of player i except one fails to be k-th order rational for t_i, and in such case we denote x by x_k.*

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[10] An alternative identification method is the one of *exclusion restriction* used in Kneeland (2015). We do not use this method for three reasons. First, using this identification strategy would eliminate the standard classes of 4 × 4 and BC games, thereby severely limiting our between games comparisons. Second, a main criticism to this approach is that it rules out that subjects may change strategies even when not responding to changes in the payoffs of high-order opponents. To test this, Lim and Xiong (2016) have subjects play the ring games of Kneeland (2015) multiple times (as well as other games), and find up to 77% *non*-compliance with the assumption in the ring games, meaning that 77% of the experimental subjects chose different actions at least once. Third, there are influential theoretical frameworks for which a subject satisfying lower-order rationality might respond to changes in higher order payoffs (see Alaoui and Penta, 2016, 2021; Alaoui, Janezic and Penta, 2020).

(*ii*) *Game* $\mathcal{G}$ can test for bound $k \geq 1$ *if* $X_{\mathcal{G}}$ *contains some player type* x_k *that can test for bound* k*.*

The interpretation of a player type x_k as a *test* to discard whether bound k is reached is straightforward: A subject who fails to choose a k-th order rational action for this type fails the test and her bound is concluded to be strictly below k.[11] In this sense, a game that includes x_k can test for bound k.

Structure of Games

To better visualize the player types and their payoff dependencies resulting from the payoff structure of the game, we introduce some basic notions from the language of graphs. Player types are represented as nodes and payoff dependencies are represented as directed links. A path in a given graph can be seen as mapping a hierarchy of beliefs.

Definition 3 (Graph of a Game) *Let* $\mathcal{G}$ *be a game. The* graph *of* $\mathcal{G}$ *consists of the pair* $(X_{\mathcal{G}}, L_{\mathcal{G}})$*, where the player types* $X_{\mathcal{G}}$ *are nodes, and* $L_{\mathcal{G}}$ *is the set of* directed links*, i.e., pairs of nodes* $(x, x') \in X_{\mathcal{G}} \times X_{\mathcal{G}}$ *such that the following two conditions hold:*

(*i*) x *has no strictly dominant action.*

(*ii*) x*'s expected payoff depends on the actions of* x'*.*

Definition 4 (Path) *Let* $\mathcal{G}$ *be a game with graph* $(X_{\mathcal{G}}, L_{\mathcal{G}})$*. A* path *is a finite sequence of nodes* $(x^{(1)}, x^{(2)}, \ldots, x^{(n)})$*, where the following two conditions hold:*

(*i*) $(x^{(\ell)}, x^{(\ell+1)}) \in L_{\mathcal{G}}$ *for every* $\ell = 1, \ldots, n-1$*.*

(*ii*) *All the nodes except possibly* $x^{(1)}$ *and* $x^{(n)}$ *are pairwise distinct.*

Thus, the *graph* of a game $\mathcal{G}$ summarizes the first-order payoff dependencies in the game. The existence of a directed link from player type x to player type x' ($(x, x') \in L_{\mathcal{G}}$) represents the fact that a rational type x should try to anticipate the choice by x' when evaluating what is optimal for her to do. If x has a strictly dominant action, this is of course not the case, and neither is it if the choice of x' does not affect the expected payoff of x. Higher-order payoff dependencies are captured by *paths*, which represent different possible hierarchies that the first player type in the path ($x^{(1)}$) can conceive when thinking strategically.

Let us now use an example to review these concepts.

Example: Bimatrix Games vs Ring Games. Consider the following two-player bimatrix game where the left matrix describes the payoffs of Player 1 (who has strategies A, B or C) while the right matrix describes the payoff of Player 2 (who has strategies a, b or c).

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[11] There is a unique k-th order rational action for each type in order to minimize the probability that a subject playing randomly accidentally chooses such an action.

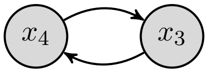
	a	b	c
A	80	20	140
B	60	160	20
C	100	200	40

Player 1

	A	B	C
a	120	20	200
b	20	40	60
c	100	120	80

Player 2

There are two player types that correspond to the two players of the game. Using Definition 2, Player 2 can test for bound 3, since a is the only strategy surviving three rounds of elimination of strictly dominated strategies. That is, Player 2 is x_3 in our notation. Player 1 can test up to bound 4 since C is the only strategy surviving four rounds of elimination of dominated strategies. That is, Player 1 is x_4. Notice that there are no further player types. In fact, even if the game is dominance solvable (with solution (C, a)), it cannot have a player type to test for each bound in the same game. This is a general problem with bimatrix games. This means that a subject capable of forming only first order beliefs, playing as Player 1 and choosing randomly over A and C, has high chances of being classified as if capable of forming higher order beliefs by playing C for example. The structure of the game is captured by the following graph.



The previous problem does not arise in the following game, which is a four-player *ring game* as used in Kneeland (2015).

	d	e	f
a	80	200	120
b	0	80	160
c	180	120	60

Player 1

	g	h	i
d	140	180	40
e	200	80	140
f	0	160	180

Player 2

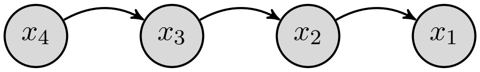
	j	k	l
g	200	140	80
h	160	20	180
i	0	160	160

Player 3

	a	b	c
j	120	160	140
k	80	120	100
l	60	100	80

Player 4

A defining feature of such a four-player ring game is that Player k's payoffs depend only on her own choice and on that of Player $k + 1$, up to Player 4 whose payoffs depend on her own choice and on that of Player 1. Notice that each player corresponds to a different player type, hence allowing the game in the example to also test up to bound 4. In fact, following our notation, we have Player 4 being player type x_1, Player 3 being x_2, Player 2 being x_3 and finally Player 1 being x_4. That is, ring games allow to test for the whole hierarchy of beliefs *within* the same game. In fact, it is enough to make a subject play in each role to test for each bound, *ceteris paribus*. A subject incapable of forming beliefs of order higher than the first, for example, would eventually make a *mistake* when playing in the role of Player 2 or 1. Nevertheless, the very structure of the game that corresponds to the iterative reasoning necessary to solve the game, might make the hierarchy of beliefs more evident to a (rational) subject that would otherwise be incapable of constructing one. This problem becomes more apparent from the graph of the game that, for each player type x_k, admits a unique path of length $k - 1$.



The above discussion further underscores the importance of putting conditions on the structure of the game in order to adequately identify subjects' higher order reasoning bounds. We address this formally in the next section.

2.2 The Two Main Axioms

We here introduce our two main axioms, *lower order consistency* and *absence of framing.*

Lower Order Consistency

The example in the previous section shows that while some games that can test for a bound $k > 1$ can also test for all lower bounds $\ell = 1, \ldots, k-1$, others are more limited and can only test for a subset of these bounds. In particular, some classes of games often used for identification, such as bimatrix games or p-beauty contest games, fail to test for all bounds. In such games, a subject who chooses randomly or non-rationally is likely to be wrongly interpreted as possessing a high rationality bound, as previously hinted.

At a conceptual level, a game that can test for bound k and, when doing so, can also test for bounds $\ell = 1, \ldots, k-1$, makes it harder for subjects with bound strictly below k to pass all these tests, but it should not affect the behavior of a subject with bound k or above. In fact, a subject whose rationality bound is k or above should be expected to pass *all* the tests that correspond to bounds $\ell = 1, \ldots, k$. By contrast, a subject whose rationality bound is $k' < k$ should be expected to fail *at least one* of the tests for bounds $\ell = k' + 1, \ldots, k$.

Consequently, the explicit verification of every step of the reasoning hierarchy imposes additional challenges *only* to relatively unsophisticated subjects, but remains innocuous for sophisticated ones. Implementing such a verification significantly reduces the risk of overestimating a subject's rationality bound and, as a result, seems an obvious requirement if the identification is expected to have any external validity. Our first axiom formalizes this intuition.

Property 1 (Lower Order Consistency) *Game $\mathcal{G}$ is* lower order consistent *if whenever it can test for bound $k \geq 2$ it also can also test for bounds $\ell = 1, \ldots, k-1$.*

Lower order consistency formalizes a property that has been implicitly used in the literature on identification of rationality bounds (see Kneeland, 2015, or Lim and Xiong, 2016). In terms of the graph of the game this property implies that the structure of a game testing up to bound k, has to contain the nodes x_1 to x_k. The following simple observation shows that, in addition to its intuitive appeal, lower order consistency also pins down a rather narrow class of games.

Lemma 1 *Let $\mathcal{G}$ be a game that satisfies lower order consistency. Then, for any $k \geq 1$,*

- (i) *If $\mathcal{G}$ can test for bound k, then it has at least k distinct player types, of which one has a strictly dominant action.*
- (ii) *If $\mathcal{G}$ can test for bound k but not for bound $k+1$, then it is dominance solvable in exactly k rounds.*

Proof. Part (i) follows from the definition of lower order consistency. To see this notice that, if $\mathcal{G}$ can test for bound k, it can also test for bounds $\ell = 1, \ldots, k-1$, and hence $X_{\mathcal{G}}$ contains player type x_ℓ for each $\ell = 1, \ldots, k$, where, by definition, x_1 has a strictly dominant action. Part (ii) follows from Definition 2 and from the definition of lower order consistency. ■

Absence of Framing

Mounting evidence from behavioral economics shows that individual behavior can be influenced by the context in which decisions are taken. Applied to the identification of rationality bounds, this suggests that the game employed may shape the actual reasoning process and *frame* the subjects (i.e., influence their reasoning process) in a way that *induces* the form of hierarchical thinking that is the object of the identification. Obviously, such a phenomenon would compromise the external validity of the identification by giving rise to the following two issues. First, subjects who would not normally engage in hierarchical thinking may be induced to do so by the game. Second, subjects with some order of hierarchical thinking may be induced to think in higher orders. To further illustrate this specific notion of framing, consider the following two situations:

$G1$. *A ring-like game with three players.* The game is dominance solvable. Player 1's payoffs only depend on her own choices, Player 2's payoffs depend on her choices and those of Player 1, and Player 3's payoffs depend on her own and those of Player 2. Furthermore, for each $k = 1, 2, 3$, Player k has a unique k-order rational action, so that each Player k can be identified with player type x_k. Figure 1 illustrates the graph of game $G1$. Notice that Player 3's second order belief has *only* one possible ordering that is consistent with the payoff dependency of the game: her first order belief is about Player 2's choices and her second order belief, about Player 2's first order belief about Player 1's choices.

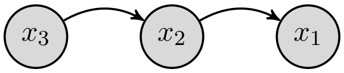


Figure 1: Game $G1$.

- $G2$. *A variation of* $G1$. Take $G1$ and introduce an additional action $\bar{a}_3$ for Player 3 satisfying the following features: (*i*) $\bar{a}_3$ is strictly dominated for Player 3, (*ii*) Player 1's payoffs are independent of $\bar{a}_3$, and (*iii*) if Player 3 chooses $\bar{a}_3$ Player 2's worst possible option is to play her unique 2-nd order rational action of $G1$, independent of Player 1's choice. Obviously, the game is still dominance solvable, and, for each $k = 1, 2, 3$, Player k has a unique k-th order rational action and can thus be identified with player type x_k. However, the payoff dependency becomes slightly (though minimally) more intricate, as depicted in Figure 2. Notice that now Player 3's second order belief has *two* possible orderings that are consistent with the payoff dependencies represented in the graph: (1) her first order belief is about Player 2's choices and the second, about Player 2's first order belief about Player 1's choices; (2) her first order belief is about Player 2's choices and her second order beliefs, about Player 2's first order belief about Player 3's choices.

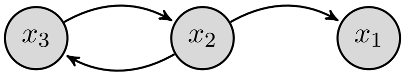


Figure 2: Game $G2$.

The comparison between the two scenarios is insightful. The multiplicity of orderings that can be used to construct the belief hierarchy in $G2$ leaves it open to the subject which hierarchy, if any, to follow. By contrast, the absence of multiplicity in the payoff dependency of $G1$ *frames* subjects to reason hierarchically.[12] Notice that this concern gains particular salience if the game is assumed to satisfy lower order consistency. In fact, the property requires the existence of a different player type to test for each bound. This can influence the subjects' reasoning process by exposing the belief hierarchy that represents the *inductive structure* of the game (i.e., the exact ordering of iterated elimination that solves the game).[13]

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[12] Of course, the distinction above deals with subjects that, unlike what the standard model of higher-order reasoning admits, do not form *joint* beliefs about their opponents' behavior and higher-order beliefs (i.e., Player 2 may have a joint belief about Players 1 and 3's behavior in $G2$). However, this is immaterial for the argument: ideally, we want to avoid that players having difficulties in forming these joint conjectures are categorized *as if* they were able to form them.

[13] The intuition is well conveyed in Kneeland (2015), whose ring games provide a major step forward towards the identification of rationality bounds by implicitly requiring lower order consistency: "A particularly salient effect of ring games (relative to standard normal form games) is that they may make iterative reasoning more natural. This might happen if the ring game highlights the higher-order dependencies between the players or

To minimize this notion of framing, a game used to identify higher orders of rationality should allow each player type to be able to construct belief hierarchies about other players types' behavior that are alternative to the one associated with the inductive structure of the game. This can be achieved by enriching the payoff dependencies so that, for player types that test for bound 2 and above, payoff dependencies do not only refer to player types that test for lower bounds. Given this, it is easy to formalize a minimum requirement of the payoff dependencies of the game which prevents making the inductive structure of the game immediately apparent.

Property 2 (Absence of Framing) *A lower order consistent game $\mathcal{G}$ that can test for bound $k \geq 2$ is* framing-free *if there exist:*

(*i*) *For any $\ell = 2, \ldots, k$, two distinct paths of length $\ell - 1$ that start at x_ℓ.*

(*ii*) *For any $\ell = 3, \ldots, k$, two distinct paths of length $\ell - 2$ that start at x_ℓ.*

Let us provide some further intuition for the axiom. First, requiring $\mathcal{G}$ to be lower order consistent ensures that, if the game contains a player type x_k, then it also contains player types $x_1, \ldots, x_{k-1}$. Second, condition (*i*) says that a player type x_ℓ that tests for bound ℓ is considered to be *framed* if no distinct paths of length $\ell - 1$ that start at x_ℓ exist (by definition, one always exists). The interpretation is simple and visually intuitive in Figure 1. There, the payoff dependencies allow for a single path of length 1 departing from x_2, making it immediately apparent for x_2 that it is x_1 the type whose choice she cares about. This implies that a subject not capable of forming a hierarchy of beliefs might be helped by the structure of the game to behave *as if* she could. On the contrary, the presence of two distinct paths departing from x_2 in the graph in Figure 2, one towards a player who has no strictly dominant action, makes the inductive structure of the game less apparent.

The same intuition, visually represented in the left graph in Figure 3, where x_4 is interpreted as being partially framed, explains why we also require condition (*i*) for player types that test for bounds above 2. Here, the fact that there are not two distinct strategic paths of length 3 departing from x_4 results in the inductive structure of the game being easily recognizable for x_4, if she excludes herself from the belief hierarchy.

Figure 3: Games with some framing.

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if it induces backward induction reasoning because of the presentation of the game. Here we face a catch-22: we must depart from typical games to achieve reliable choice based inference, but doing so unavoidably raises concerns of this sort."

In addition to condition (*i*), condition (*ii*) is also required for types that test for bounds 3 or above, in order to avoid situations such as the one in the right graph in Figure 3, where, again x_4 would be considered to be partially framed. The reason is that the fact that there is a unique path of length 2 that departs from x_4 results in the necessity of her first-order beliefs only pertaining player type x_3 immediately apparent to x_4.[14] This implies that a subject that can form up to second order beliefs, when playing as player type x_4, would immediately see the inductive structure of the game, hence behaving *as if* capable of forming third order beliefs. Finally, Figure 4 displays two different games in which no player type is framed. In the next section, we show that the game on the left is a particular specification of the new class of games to be introduced.

Figure 4: Games that are framing-free.

3 From the Axioms to the Structure of Games

In this section, we first present a new class of games, the *e-ring games*, and show that the simplest dominance solvable specification of this class is characterized lower order consistency and absence of framing.

3.1 E-Ring Games

An *e-ring game* is a two-player static game with private values in which players automatically receive a finite number of messages, and where each player's own payoffs depend on the number of messages that the player received as well as on the actions chosen by both players. Nature chooses the number of messages received by each player, whereby player 2 either has the same number of messages as player 1 or she has one more message than player 1.

The following example illustrates an e-ring game with three actions that is similar to the ones used in our experiments. It also shows that such specification can test for bounds up to 4.

Example: E-Ring Game of Depth 4. There are two players, Player 1 (the sender) who chooses rows, and Player 2 (the receiver) who chooses columns. Each player is initially informed about the number of messages she receives, and the payoffs depend only on the number of

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[14] The requirement in Property 2 could be made more stringent and ask for every x_ℓ to have two distinct paths of length j for every $j = 1, \dots \ell{-}1$. It is important to emphasize that, while this may be a theoretically compelling alternative, it would be unnecessarily demanding for the characterization result we present in Proposition 1; it would not add any extra bite to the already narrow taxonomy we obtain there.

messages a player receives as well as on the actions chosen by both players. Each player either gets 1 or 2 messages, whereby Player 2 either has the same number or one more message than Player 1. To figure out the payoffs of the opponent, players can compute the number of messages received by the opponent as follows. Player 1 with 1 message knows her opponent has either 1 or 2 messages, each event with equal probability ($p_1 = 1/2$); Player 1 with 2 messages knows for sure the other player also has 2 messages. Similarly, Player 2 with 1 message knows for sure that her opponent also has 1 message; while Player 2 with 2 messages knows her opponent has either 1 or 2 messages, each event with equal probability ($p_2 = 1/2$).

Consider the following payoff matrices, where, respectively, A, B, C are the actions of Player 1 and a, b, c the actions of Player 2, and where $u_1(t_1)$ are the payoffs of Player 1 when she receives t_1 messages, and $u_2(t_2)$ the payoffs of Player 2 when she receives t_2 messages.

Player 1

	a	b	c
A	80	60	80
B	200	120	140
C	120	100	180

$t_1 = 1$

	a	b	c
A	60	80	40
B	80	20	20
C	160	120	180

$t_1 = 2$

Player 2

	A	B	C
a	80	40	60
b	160	140	100
c	180	80	140

$t_2 = 1$

	A	B	C
a	20	40	80
b	180	160	120
c	100	140	200

$t_2 = 2$

The above payoff structure has a unique (interim correlated) rationalizable action for all players and number of messages. Player 1 with 2 messages (payoff matrix $u_1(2)$) has a strictly dominant action C. Player 2 with 2 messages (payoff matrix $u_2(2)$), seeing this and the fact that Player 1 with 1 message (payoff matrix $u_1(1)$) has A as strictly dominated action, (and knowing that she faces Player 1 with $t_1 = 1, t_1 = 2$ with equal probability), has a unique strict best reply c. Player 1 with 1 message, given the above and seeing that Player 2 with 1 message has a as a strictly dominated action (and again knowing that she faces Player 2 with $t_2 = 1$, $t_2 = 2$ with equal probability) has a unique strict best reply C. Finally, Player 2 with 1 message (payoff matrix $u_2(1)$), knowing that for sure she faces Player 1 with 1 message and that she plays C as unique best reply, also has a unique strict best reply c. Thus $((C, C); (c, c))$ is the unique rationalizable strategy profile.

Now, we show that this particular game can test up to bound 4. According to Definition 1 we have the set of player types $X_{\mathcal{G}} = \{(1, 1), (1, 2), (2, 1), (2, 2)\}$ so that the payoff matrix that corresponds to each player type (i, t_i) is $u_i(t_i)$. Moreover, notice that according to Definition 2, we have that $x_1 = (1, 2)$, $x_2 = (2, 2)$, $x_3 = (1, 1)$, and $x_4 = (2, 1)$, where each player type x_k is the unique one used to test for rationality bound k. This is easy to see: C is the only rational action for $(1, 2)$, c is the only 2nd order rational action for $(2, 2)$, C is the only 3rd order rational action for $(1, 1)$ and c is the only 4th order rational action for $(2, 1)$. Thus the revealed rationality method yields the classification given in Table 1.

	x_1	x_2	x_3	x_4
$R4$	C	c	C	c
$R3$	C	c	C	b
$R2$	C	c	B	b, c
$R1$	C	b	B, C	b, c

Table 1: Choice vectors and revealed rationality bounds.

In addition, a subject playing a dominated action would be classified as $R0$ (A or B in the case of x_1, and A or a in the case of the remaining player types).[15] □

The next definition formalizes the general class of *e-ring games.*

Definition 5 (E-Ring Game) *An* e-ring game of depth k *(even) is a list* $\mathcal{G} = \langle T_i, A_i, u_i, \pi_i \rangle_{i=1,2}$, *where, for each player* i*:*

1. $T_i = \{1, 2, \ldots, k/2\}$ *is a set of types.*
2. A_i *is a finite set of actions.*
3. $u_i : T_i \times A_1 \times A_2 \to \mathbb{R}$ *is a payoff function.*
4. $\pi_i : T_i \to \Delta(T_{-i})$ *is a belief-map such that, for fixed* $p_1, p_2 \in (0, 1)$,

$$\pi_1(t_1)[t_2] = \begin{cases} p_1 & \text{if } t_2 = t_1 \\ 1 - p_1 & \text{if } t_2 = t_1 + 1 \end{cases} \qquad \pi_2(t_2)[t_1] = \begin{cases} p_2 & \text{if } t_1 = t_2 - 1 \\ 1 - p_2 & \text{if } t_1 = t_2 \end{cases}$$

for $1 \le t_1 < k/2$ *and* $1 < t_2 \le k/2$, *and otherwise* $\pi_1(k/2)[k/2] = 1$ *and* $\pi_2(1)[1] = 1$.

Notice that the type structure of the e-ring games builds on the communication structure of the email games of Rubinstein (1989) with two important differences. First, in the email games players can receive any arbitrary number of messages, and, second, they face the same 2 × 2 payoff matrices for essentially any number of messages received. To further clarify the relation

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[15] In this example, we explain our identification strategy *as if* subjects switched roles. In the experiment detailed in Section 4, we achieve this by reassigning Player 1's matrix with 2 messages to Player 2 with 1 message while reallocating the other matrices to maintain the dominant solvability structure.

between types in an e-ring game, consider player i who has received ℓ messages. By Definition 5, this player's type is $t_i = \ell$ and the payoff she obtains from action profile (a_1, a_2) is given by $u_i(\ell, a_1, a_2)$. However, Player i is uncertain about the number of messages received by the other player and hence also about the latter's type and payoff function. In particular, Player 1 of type $t_1 = \ell$ knows that, with probability p_1, Player 2 is of type $t_2 = \ell$ and that, with probability $1-p_1$, Player 2 is of type $t_2 = \ell+1$ (with the exception of type $t_1 = k/2$, who knows that Player 2 is of type $t_2 = k/2$ for sure). Similarly, Player 2 of type $t_2 = \ell$ knows that, with probability p_2, Player 1 is of type $t_1 = \ell - 1$ and that, with probability $1 - p_2$, Player 1 is of type $t_1 = \ell$ (with the exception of type $t_2 = 1$, who knows that Player 1 is of type $t_1 = 1$ for sure).

3.2 Simplest Lower Order Consistent and Framing-Free Games

The theoretical appeal of lower order consistency and absence of framing for the identification of rationality bounds has been discussed in Section 2. We now turn to the question of the implementation of both axioms, and, more specifically, to the characterization of games satisfying the axioms and the complexity they entail. As previously mentioned, standard games used in the literature such as bimatrix games and the beauty contest games do not satisfy, in general, lower order consistency. This creates potential overestimation concerns related to subjects choosing randomly (or not following any hierarchical reasoning procedure) being easily identified as having high rationality bounds. A different family of benchmark games, the ring games, while satisfying lower consistency, do not satisfy absence of framing. Again, this causes potential overestimation concerns, related this time to the identification procedure altering the object of identification itself due to framing.

Besides our two axioms, and attending to simplicity of implementability, we will focus on the characterization of games satisfying two additional requirements. First, we restrict our attention to games that can test for bound up to 4, since from the experimental literature the first four levels seem to be the empirically relevant ones. Second, we order games following *minimality* criteria according to which, all things equal, we favor the lowest possible number of players, player types, actions per player and directed links. Minimality may be important for resources-saving empirical implementations but also to minimize the complexity of the game to avoid as much as possible artificially generating noise in the data.

The following proposition shows that the only games enhancing the external validity of the identification (according to lower order consistency and absence of framing) that satisfy the aforementioned simplicity criteria are dominance solvable e-ring games with depth 4 and 2 actions per player:

Proposition 1 *Let $\mathcal{G}$ be a game. Then, $\mathcal{G}$ is minimal within the class of games that can test for bound 4 and satisfy lower order consistency and absence of framing if and only if $\mathcal{G}$ is a dominance solvable e-ring game of depth* 4 *with 2 actions per player.*

Proof. The 'if' part is immediate (simply notice that such e-ring games have a graph as the one depicted on the left of Figure 4 and are clearly minimal) so we focus on the 'only if' one. Lemma 1 implies that $\mathcal{G}$ is dominance solvable, contains player types x_1, x_2, x_3 and x_4 and has a set of links containing (x_4, x_3), (x_3, x_2) and (x_2, x_1). Also, by definition, there is no link starting from x_1. Minimality allows for excluding the presence of further player types and ensures that there are only two players, so that x_1 and x_3 must belong to one player and x_2 and x_4, to the other—the directed links whose existence we previously concluded precludes any other configuration. This excludes the presence of links (x_3, x_1), (x_2, x_4) and (x_4, x_2). Given this, absence of framing implies the presence of links (x_3, x_4) and (x_2, x_3). Finally, minimality excludes the presence of link (x_4, x_1). We are thus left with the graph depicted on the left of Figure 4, which corresponds to the graph of a dominance solvable e-ring game of depth 4. ■

The next section shows how these games were implemented in the experiment to test the properties proposed.

4 Experiment

4.1 Experimental Design

The experiment consisted of four tasks and a non-incentivized questionnaire. In the first task, subjects chose an action in a pair of standard two player 4×4 dominance solvable games. In each of the subsequent two tasks, subjects chose actions in a set of eight ring games and eight e-ring games. The set of eight ring games and the set of eight e-ring games were presented in different random orders to each of the subjects, respectively. In the final task, subjects were presented with the beauty contest game as in Nagel (1995) and had to choose a number for two different versions of the game (one where the average of all players' numbers was multiplied by 2/3 to determine the winner, and another where the average was multiplied by 1/3) and a more general version, where subjects were asked to explain a general strategy about how they would choose for any (unspecified) commonly known number p between 0 and 1 (both not included) that could be announced publicly in the beauty contest game. For this final task, subjects were told that they could either choose a number, a mathematical formula or provide any text which would show their reasoning process.

Our experimental design intends to compare the distribution of orders of rationality identified by the e-ring games with the ones identified by benchmark games used in the literature (ring games, dominance solvable games such as our 4×4 games and the p-beauty contest games) to empirically classify individuals according to the revealed rationality approach and hence test the importance of the properties proposed. We chose these classes of games as they are the ones most frequently used in the literature for the identification of the empirical distribution of higher orders of rationality. Moreover, they are particularly convenient to test the empirical validity of the two axioms proposed in Section 2.2, since the 4×4 dominance solvable games and the beauty contest games do not satisfy lower order consistency, while the ring games satisfy lower order consistency but not absence of framing.

In both the e-ring and the ring games, each subject can play four possible actions in each of the eight games for a total of 65,536 possible action profiles.[16] In both the e-ring and the ring games, there are 801 action profiles that do not violate any of the predicted action profiles of types $R1$-$R4$, independently of subjects' role following the revealed rationality approach. Thus, it is unlikely for a subject to be classified as a rational type by random chance since there is 1.2% probability of being identified as $R1$-$R4$ while playing randomly in either game.[17]

We designed eight treatments, differing in three aspects: (*i*) whether the ring game was played before or after the e-ring game; (*ii*) whether the payoff matrices used in the ring and e-ring games remained constant (non-permuted) across decisions, while either varying the player's position (ring game) or the number of messages received (e-ring game), or whether the actions in such matrices were reshuffled (permuted); and (*iii*) whether the 1/3 version of the beauty contest game was played before or after the 2/3 one. A translation of the original Spanish instructions as well as the actual games used for each of the tasks can be found in the Online Appendix.

4.2 Laboratory Implementation

The experiment was conducted at the Engineering School of Universidad Carlos III in Madrid (Spain) in April, 2018. This particular school was selected due to being one of the most prestigious universities in the country. Accordingly, the average grade in the entrance to university exam of our pool of participants is 12 (out of 14 possible points). The importance of this decision is twofold. First, very sophisticated subjects should be *less* influenced by the structure of the game in their reasoning process, hence making the test of the axioms stricter. Second, if such a particular pool of subjects showed bounds in their hierarchical reasoning, then this would cast a stronger doubt on the underlying assumption in economic modeling that individuals are unbounded in their reasoning process.

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[16] In the implementation we decided to have 4 actions for each player type in both classes of games for the following two reasons. The first one is that with only two actions per player type in the e-ring games, the unique action of level l for each player type x_l would be risk dominant, thus bringing new potential concerns in the identification. This means that at least three actions were needed. The second one is that, to avoid assuming that the subjects maximize expected utility in the e-ring games, we needed to have strict dominance to test for each bound, hence making it necessary to have at least one dominated action for each player type. However, to ensure comparability of the choice data, given that the ring games have three undominated actions for each player type, we added a strictly dominated action to the ring games and an undominated to e-ring games. Thus, all games have 4 actions.

[17] Of the 729 possible rational action profiles, 648 would be identified as $R1$ (88.9%), 72 as $R2$ (9.9%), 8 as $R3$ (1.1%) and 1 as $R4$ (0.1%).

All undergraduate engineering students from the school were sent an email message announcing two experimental sessions and they were confirmed on a first-come first-served basis. 229 students participated. No subject participated in more than one session. Subjects made all decisions using a booklet including all instructions stapled in the order determined by their treatment assignment and the randomization of the order of eight ring and e-ring games, the answer sheets and a post-experimental questionnaire. Sessions were closely monitored resembling exam-like conditions in order to ensure independence across participants' responses and compliance with our instructions.

Instructions were read aloud and included examples of the payoff consequences of several actions in each of the tasks. Participants answered a demanding comprehension test prior to each of the tasks. A majority of subjects (71%) answered all 13 questions correctly. We made sure that all remaining issues were clarified before proceeding to the actual experiment.[18]

Participants received no feedback, neither after playing each of the games nor after finishing each of the tasks, and were monitored such that they would not move from one task to another unless instructed. Once all four tasks were completed, subjects filled up a questionnaire, which included non-incentivized questions about the reasoning process used to choose in each of the tasks, as well as questions about knowledge of game theory and demographics. Subjects were given 4 minutes to complete the first task, 20 minutes each for the second and third tasks, and 9 minutes for the final task. The two experimental sessions lasted around 110 minutes each.

We provided high monetary incentives for 10 randomly selected participants, instead of paying all subjects a lower amount of money.[19] One of the twenty decisions was randomly selected for payment at the end of the experiment for each of these 10 participants. Subjects were randomly and anonymously matched into groups of 2-players (e-ring and 4×4 games), 4-players (ring games) or all players (p-BC games) depending on the game selected, and were paid based on their choice and the choices of their group members in the selected game. Subjects received €100 plus the euro value of their payoff in the selected game. Average payments for these selected participants were €174.

4.3 Experimental Results

We start with the revealed rationality approach, whereby the choices made by the individual in a given class of games determine an upper bound for the level of higher-order rationality of that individual. The key question we address is whether that upper bound is also a good lower bound for the level of rationality of the individual. We claim that both Property 1 and Property 2, each contribute in different ways towards reducing the gap between the upper and

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[18] Although our analysis uses the full sample of participants, results are robust to using the subsample of subjects who made no mistakes in the tests.

[19] See Alaoui and Penta (2021) for a theoretical justification of this design choice that should give higher incentives to achieve higher levels in the hierarchy of beliefs.

the lower bound. Next we provide some evidence in favor of such a claim.

Experimental Evidence for Property 1 (Lower Order Consistency). Games that satisfy lower order consistency and identify an individual as being of level $k \geq 2$ ensure that such individual makes choices that are consistent with level k also in decisions that test for levels $\ell = 1, \ldots, k-1$ within the same game. In other words, games satisfying lower order consistency allow for the application of the revealed rationality principle at each step of the hierarchy of beliefs from level 1 up to level k within the same game.

To check that the requirement has bite, we compare the classification of individuals' levels of rationality obtained using the e-ring and ring games, which do satisfy lower order consistency (LOC games), with the levels obtained with the 4×4 and the beauty contest games that do not satisfy lower order consistency (non-LOC games). We distinguish between subjects that reveal not to have higher order beliefs in rationality ($R0$-$R1$) from those who do ($R2$-$R3$-$R4$). To see that the 4×4 and the two beauty contest games are not as good at accurately identifying higher order levels $R2$, $R3$, and $R4$ when identifying individuals as such, we look at two tests.

Test 1.1. First, we take the identification of subjects as being $R0$ or $R1$ by LOC games as valid, and look at how many of these subjects are *misclassified* as being $R2$, $R3$, or $R4$ by the non-LOC games. Second, we take the identification of subjects as being $R0$ or $R1$ by non-LOC games as valid, and look at how many of these subjects are *misclassified* as being $R2$, $R3$, or $R4$ by the LOC games.

Consider first all subjects that are identified as being of level $R0$ or $R1$ in the e-ring and ring games (52 subjects). The share of these subjects that are also identified as being of levels $R2$, $R3$ or $R4$ in the 4×4 and in the two beauty contest games are as follows (where the numbers in parenthesis give the shares out of all the 73 subjects that have been revealed as being of level at most $R0$ or $R1$ at least twice in the e-ring and ring games):

$$4 \times 4\text{: } 63.5\%\,(57.5\%) \quad 2/3\text{-BC: } 84.6\%\,(89.0\%) \quad 1/3\text{-BC: } 38.5\%(43.8\%).$$

Next, for comparison, consider all subjects that are identified as being of level $R0$ or $R1$ in at least two games of the 4×4 and the two beauty contest games (48 subjects).[20] We calculate the share of these subjects who are also identified as being of levels $R2$, $R3$ or $R4$ in e-ring or ring games. This leads to the following shares (the numbers in parenthesis give the shares out of all subjects that have been revealed being of level at most $R0$ or $R1$ at least twice, that is in at least two decisions among all relevant decisions in the 4×4 and the two beauty contest games (50 subjects)):

$$\text{E-ring games: } 35.4\%\,(38.0\%) \quad \text{Ring games: } 43.8\%\,(44.9\%).$$

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[20] We do not consider all three games because the number of subjects satisfying this very strict condition is too small to make statistically significant comparisons.

The numbers show that for individuals that have been classified as not having higher order beliefs, the non-LOC games, with the exception 1/3-BC games, are significantly more likely to misclassify those individuals as having higher order beliefs, than the e-ring and ring games that are LOC games.

Test 1.2. First, we take subjects identified as being $R2$, $R3$ or $R4$ in each of the non-LOC games, and look at how many of these subjects are classified as being $R0$ or $R1$ by the LOC games. Second, we take subjects identified as being $R2$, $R3$ or $R4$ in each of the LOC games, and look at how many of these subjects are classified as being $R0$ or $R1$ by the non-LOC games.

Consider all subjects that are identified as being of level $R2$, $R3$ or $R4$ in the 4×4 and in the two beauty contest games (respectively, 164, 207 and 118 subjects). For each of these three populations separately, we calculate the share of individuals who are also identified as being of level $R0$ or $R1$ in the e-ring and ring games. We obtain the following shares (where the numbers in parenthesis give the shares of subjects that have been revealed as being of level at most $R0$ or $R1$ at least twice in the e-ring and ring games):

$$4 \times 4\text{: } 20.1\%\,(25.6\%) \quad 2/3\text{-BC: } 21.3\%\,(31.4\%) \quad 1/3\text{-BC: } 16.9\%\,(27.1\%).$$

Next, for comparison, consider all subjects that are identified as being of level $R2$, $R3$ or $R4$ in the e-ring game and then in the ring games (respectively, 139 and 116 subjects). For each of these two populations separately, we calculate the share of individuals who are also identified as being of level $R0$ or $R1$ in at least two games of the 4×4 and the two beauty contest games. We obtain the following shares (where the numbers in parenthesis give the shares out of all subjects revealed as being of level at most $R0$ or $R1$ at least twice in the 4×4 and the two beauty contest games):

$$\text{E-ring games: } 12.2\%\,(13.7\%) \quad \text{Ring games: } 18.1\%\,(15.8\%).$$

The numbers show that for individuals that have been classified as having higher order beliefs by non-LOC games, there are significantly more that are then classified as not having higher order beliefs by LOC games than the other way around. Again, the 1/3-BC seems to be an exception.

In both tests we observe that games that do not satisfy Property 1 tend to be nosier in the identification of higher orders of rationality, potentially reducing the external validity of the identified distribution.

Experimental Evidence for Property 2 (Absence of Framing). Next, we build on the established empirical relevance of Property 1 to check the importance of requiring absence of framing (Property 2). Again, we consider two tests.

Test 2.1. We consider all subjects that are identified as being of level $R0$ or $R1$ in at

	$R4$	$R3$	$R2$
E-ring game	8.3% (10.0%)	16.7% (18.0%)	35.4% (38.0%)
Ring game	20.8% (22.0%)	25.0% (26.0%)	43.8% (44.0%)

Table 2: Cumulative distribution of higher-order rationality levels for e-ring and ring games for subjects identified as being of level $R0$ or $R1$ in at least two games of the 4×4 and the two beauty contest games (48 subjects) (in parenthesis for subjects revealed as being of level at most $R0$ or $R1$ at least twice in the 4×4 and the two beauty contest games (50 subjects)).

least two games of the 4×4 and the two beauty contest games (48 subjects) (or alternatively, revealed as being of level at most $R0$ or $R1$ at least twice in the 4×4 and the two beauty contest games). Such individuals that do not show higher order beliefs in any of these games have a higher probability of not having been misidentified. We focus on this particular population because the strongest effects of framing (from the e-ring and ring games), if present, should be highlighted within a population that shows otherwise no evidence of higher order beliefs. Table 2 presents the cumulative distribution function of the rationality levels as classified by the e-ring and ring games. We find that the ring games consistently classify subjects in higher categories than the e-ring games. In fact, as is clear from Table 2, the distribution of levels identified by the ring games first order stochastically dominates the one identified by the e-ring games (significant at the 1% level using the Kolmogorov-Smirnov test in both cases).

Test 2.2. We find further evidence of the relevance of Property 2 when comparing treatments in which the ring games and the e-ring games were presented in different orders to subjects, we find generally higher levels of rationality in the e-ring games when they are played after having played the ring games (126 subjects), than when played in the opposite order (103 subjects). We find the average identified level by the e-ring game increases by 9.8%. Also, the Kolmogorov-Smirnov test is significant at the 1% level.[21]

Both tests suggest that Property 2 reduces misclassification of subjects as satisfying higher order rationality.

Finally, we report the empirical correlation between the orders of rationality identified by the various games and the results of the standardized tests used for admittance to university in Spain. We find that it is highest for the e-ring games among all the classes of games used. We view this as potential further evidence that e-ring games, as the only games satisfying both

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[21] When looking at the levels identified by the ring games, we find slightly lower levels of rationality when the ring games are played after having played the e-ring games, than when they are played beforehand. The average level identified by the ring game decreases by 3.5% when the ring games are played after the e-ring games.

properties, are less noisy in identifying higher order rationality. These correlations are:

E-ring games: 0.24 Ring games: 0.12 4 × 4: 0.06 2/3-BC: 0.16 1/3-BC: 0.08.

Notice that while, statistically, e-ring games may tendentially outperform the 4×4 and the beauty contest games, due to the higher number of choices and hence the higher informative content of the classification, there should be no difference between e-ring games and ring games in terms of informativeness of the classification as they both have 8 choices.

5 Conclusion

The identification of a reliable distribution of orders of rationality in the population is a crucial prerequisite for predicting behavior in many applications, including price formation and oligopolistic competition, mechanism and institutional design or monetary policy. This identification is a highly problematic exercise. A fundamental issue, addressed here for the first time, is that standard games used so far do not allow for the observation of behavior at the different steps of the hierarchy of beliefs and, when they do, they might frame individuals into thinking in levels, thereby compromising the very exercise.

This paper tackles this apparent contradiction by taking an axiomatic approach. Two intuitive properties are introduced that, at a practical level, narrow down the class of games that can be used for identification to a single class: the *e-ring games*. The empirical evidence presented suggests that both properties are relevant in reducing the misidentification. As a result, e-ring games might constitute a useful starting point for the study of higher order rationality.

The introduction of the axiomatic approach in this literature might be important per se, by enabling a more transparent discussion of what features of the game enhance the external validity of the identification. On one hand, the axioms make explicit what is required of the games to be used. On the other, by being stated explicitly, the axioms can be tested, discarded, and alternatives can be thought of, thus pushing the discussion in the literature forward in a more structured way.

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Higher Orders of Rationality and the Structure of Games: Appendix (not for publication)*

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A Experimental Instructions

Thanks for participating in our study. We hope you find it interesting. You are about to participate in an economic experiment on decision making. PLEASE DO NOT COMMUNICATE with any other participant during the experiment and follow our instructions. If you have a question, or you need kind of help, raise your hand and one of the experimenters will talk to you.

A.1 Basic Description of the Experiment

The experiments contains four tasks and a questionnaire, on top of some basic tests to make sure that you understand each task. In each task, you will have to take several decisions. In those decisions you will be randomly matched with other participants in the experiment. Each time you decide you will have to choose among four actions, while the other participants you will be matched with will also choose among four actions.

Your earnings in each of the decisions will depend on the combination of your action and the action chosen by the participants you are matched with in that particular decision.

Your goal is to maximize your earnings in each decision you take. Thus, your goal is not to beat other participants, earning more than them or trying to help them, but

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earn as much as you can for yourself, taking into account that your earnings depend on your actions and the actions by the other participants (and that their earnings also depend on your actions).

After the experiment we will randomly choose 10 Participants to pay the according to one of their choices (and the participants they are matched with in such decision) in one of the tasks of one of the decisions randomly chosen.

Even if we will only pay 10 Participants, in order to provide reasons for everyone to take the study seriously, we will pay those chosen participants 100 euros on top of the amount of euros determined by the decision. For example, if as a consequence of your choice and the choice by your matched participant in the chosen decision your earnings are 120, we will pay you 220 euros. Similarly,if your earnings in that decision are 70, we will pay you 170 euros.

Any of the tasks and decisions can be chosen to determine payments. Similarly any Participant has equal probability of being chosen to be paid. Therefore, you should treat each decision as the one that really determines your payments. None will learn who has been chosen to be paid, nor which are the tasks nor the decisions chosen, until the experiment concludes. The identity of the parched participants in each task and decision will never be revealed.

Please turn this page to read the instructions of the first task. Thanks!

A.2 Task PG

In this task you will have to make 2 choices.

For each choice, your earnings appear On the Table labeled “YOUR EARNINGS”. Notice that the numbers appearing on the “YOUR EARNINGS TABLE” correspond to your earnings as a consequence of your choice (A, B, C or D) and the choice made by the matched participant in the same decision (a, b, c or d). The earnings of the matched participant in that decision appear on the table on the right, labeled “OTHER EARNINGS”.

For example, if in the next decision you choose “B” and your matched participant chooses “d”, your earnings will be 8 euros, while the arnings of your matched participant will be 30 euros. Earnings in the example are just and example, and do not intend to suggest how any participant should choose.

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	1	2	3	4
	B	5	6	7	8
	C	9	10	11	12
	D	13	14	15	16

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	17	18	19	20
	b	21	22	23	24
	c	25	26	27	28
	d	29	30	31	32

Understanding test:

Fir the tables displayed above, please indicate your earnings and the earnings by the matched participants in the cases in which you choose the following actions:

YOUR CHOICE	Other choice	YOUR EARNINGS	Other earnings
A	*c*		
B	*d*		
D	*c*		

Now that instructions are clear, please choose in the following 2 decisions.

Please take your time to decide. If you want, you can use the blank spaces to take notes. Once you have decided, please circle your decision. You will have a total of 4 minutes for this task. **Please do not start with the next task until everyone is instructed to do so.**

A.3 Task RG

In this task you will have to take 8 decisions. Your earnings in each decision depend on your choice and the choices of 3 other Participants you are randomly matched with, to whom we will refer as “Participant 2”, “Participant 3” and “Participant 4”. Each time you choose, you must choose among 4 actions. Each of the other 3 participants will also choose among 4 actions.

For each decision, your earnings are shown in the first table, labeled “YOUR EARNINGS”. Notice that numbers in the “YOUR EARNINGS” table correspond to your earnings as a consequence of your choice in such decision and that of Participant 2 in the same decision. Similarly, Participant 2’s earnings depend on her decisions and those of Participant 3, while Participant 3’s earnings depend on her choices and those of Participant 4, whose earnings depend on Participant 4’s choices and YOUR choices.

All earnings are shown in tables like the ones below, labeled “P2 EARNINGS”, “P3 EARNINGS” and “P4 EARNINGS”, corresponding to each respective participant. Your choice determines the row selected on the first table and the choice by Participant 2 determines the column selected in the same table. You can choose among actions a, b, c or d and Participant 2 chooses among e, f, g or h. The cell corresponding to the combined actions chosen by the two of you determines your earnings.

For example, if you chosse c, Participant 2 chooses e, Participant 3 chooses k, and Participant 4 chooses m, then you would earn 9, Participant 2 would earn 19, Participant 3 would earn 41, and Participant 4 would earn 51.

The earnings tables will be different for each decision. You must carefully look at the earnings in each of the tables before choosing each decision.

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	1	2	3	4
	b	5	6	7	8
	c	9	10	11	12
	d	13	14	15	16

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	17	18	19	20
	f	21	22	23	24
	g	25	26	27	28
	h	29	30	31	32

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	33	34	35	36
	j	37	38	39	40
	k	41	42	43	44
	l	45	46	47	48

P4 Earnings

		Participant 1			
		a	*b*	*c*	*d*
Participant 4	*m*	49	50	51	52
	n	53	54	55	56
	o	57	58	59	60
	p	61	62	63	64

Understanding Test:

For the decisions in the tables above, please choose the correct answer.

1. Your earnings depend on your choices and the choices of which other participant?
   - Participant 2
   - Participant 3
   - Participant 4

2. Assume you choose a, Participant 2 chooses f, Participant 3 chooses i and Participant 4 chooses o, what would your earnings be?
   - 10 • 18 • 2 • 57

3. Assume Participant 2 chooses g, Participant 3 chooses j, and Participant 4 chooses n. Which choice would give you the highest earnings?
   - a • b • c • d

Now that instructions are clear, please choose int he following 8 decisions.

Please take your time to decide. If you want, you can use the blank spaces to take notes. Once you have chosen, please circle your decision. You will have a total of 20 minutes for this task. **Please do not start with the following task until instructed to do so.**

A.4 Task ERG

A.4.1 Sender

In this task there will be a sender and a receiver. Your role will be **SENDER** and you will have to take 8 decisions.

The basic idea is that the sender automatically sends a message to the receiver. However, the receiver may receive the message or the message may be lost. Both events can occur with equal probability. That is, with probability 1/2 the receiver gets your message, and with probability 1/2 the receiver does not get the message and the message is lost. In the case where your message is lost, no more messages are sent- But if the receiver gets your message, a confirmation message is automatically send from the receiver to the sender. Again, both events can occur with equal probability. That is, with probability 1/2 you receive the confirmation message, but with probability 1/2 you do not get the confirmation message and the message is lost. In both cases, no more messages are sent so that, independently of the participants' role, each participant receives 0 or 1 message.

Notice that the tables used to determine the earnings **depend on the number of messages received**.

WE WILL TELL THE NUMBER OF MESSAGES YOU RECEIVE IN EACH DECISION. WE WILL NOT TELL YOU THE NUMBER OF MESSAGES YOUR MATCHED PARTICIPANT RECEIVES.

Therefore, you will know which table is used to determine your earnings. However, given that we are not telling you the number of messages that your matched participant has received in each decision, it is possible that you do not know which table is used to determine his/her earnings. Similarly, your matched participant know the number of messages s/he has received but does not know how many messages you have received. Therefore, the other participant knows which table is used to determine his/her earnings but it is possible that s/he doe snot know which table is used to determine yours.

For each decision and number of messages received by each participant, your earnings are represented on the tables on the left, labeled "Your Earnings". The matched participant's earnings are on the tables on the right, labeled "Other earnings". Under each earnings table we indicate whether the earnings correspond to the case where the participant has received 0 or 1 messages. Before choosing each decision, we will tell you the number of messages you have received. Your match participant will see his/her earnings and your earnings table,and, on top of that, s/he will know how many messages s/he has received, but s/he will not know how many messages you have received.

The cell that determines your earnings is selected as a consequence of your choice (A, B, C or D), the choices of the matched participant (a, b, c or d) and the number of messages YOU HAVE RECEIVED. Similarly, the other participant's earnings depend on his/her choices (a, b, c or d), your choices (A, B, C or D) and the number of messages that S/HE HAS RECEIVED.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	1	2	3	4
B	5	6	7	8
C	9	10	11	12
D	13	14	15	16

You: 0 messages

Your earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	17	18	19	20
b	21	22	23	24
c	25	26	27	28
d	29	30	31	32

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	33	34	35	36
B	37	38	39	40
C	41	42	43	44
D	45	46	47	48

You: 1 message

Your earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	49	50	51	52
b	53	54	55	56
c	57	58	59	60
d	61	63	63	64

Other: 1 message

For example, if in the decision above you choose "C" and the other participant chooses "b", your earnings will be 10 euros in the case where you have received 0 messages, no matter how many messages your matched participant has received. Similarly, your earnings will be 42 euros if you receive 1 message, no matter how may messages your matched participant has received. Regarding the other participant's earnings, they will be 23 euros if s/he has received 0 messages, no matter how many messages you have received, and 55 euros if s/he has received 1 message, no matter how many messages you have received. Numbers in the example are just and example and do not intend to suggest how anyone should choose their actions

Understanding Test:

1. If you have received 0 messages, how many messages can the RECEIVER have received?
   • 0 • 1 • 0 or 1

2. If the RECEIVER has received 0 messages, how many messages could you have received?
   - 0 • 1 • 0 or 1

3. If you have received 1 message, how many messages can the RECEIVER have received?
   - 0 • 1 • 0 or 1

4. If the RECEIVER has received 1 message, how many messages could you have received?
   - 0 • 1 • 0 or 1

For the tables above, please indicate your earnings and those of your matched participants for the cases in which you have received the following amount of messages. Notice that in some cases more than 1 answer are possible.

YOUR CHOICE	Other choice	YOUR messages	Your Earnings	Other earnings
D	c	0		
B	d	1		
A	b	0		

Now that instructions are clear, please choose in the following 8 decisions. The earnigns tables will be different for each decision. You should carefully look at the earnings tables before deciding.

Please take your time to decide. If you want, you can use the blank spaces to take notes. Once you decide, please circle your decision. You will have a total of 20 minutes for this task. **Please do not start with the next task until instructed to do so.**

A.4.2 Receiver

In this task there will be a sender and a receiver. Your role will be **RECEIVER** and you will have to take 8 decisions.

The basic idea is that the sender automatically sends a message to the receiver. However, the receiver may receive the message or the message may be lost. Both events can occur with equal probability. That is, with probability 1/2 you get the message, and with probability 1/2 you do not get the message and the message is lost. In the case where the message is lost, no more messages are sent, but if you get the sender's message, a confirmation message is automatically send from the receiver to the sender. Again, both events can occur with equal probability. That is, with probability 1/2 the sender receives your confirmation message, but with probability 1/2 the sender does not get your confirmation message and the message is lost. In both cases, no more messages are sent so that, independently of the participants' role, each participant receives 0 or 1 message.

Notice that the tables used to determine the earnings **depend on the number of messages received**.

WE WILL TELL THE NUMBER OF MESSAGES YOU RECEIVE IN EACH DECISION. WE WILL NOT TELL YOU THE NUMBER OF MESSAGES YOUR MATCHED PARTICIPANT RECEIVES.

Therefore, you will know which table is used to determine your earnings. However, given that we are not telling you the number of messages that your matched participant has received in each decision, it is possible that you do not know which table is used to determine his/her earnings. Similarly, your matched participant know the number of messages s/he has received but does not know how many messages you have received. Therefore, the other participant knows which table is used to determine his/her earnings but it is possible that s/he does not know which table is used to determine yours.

For each decision and number of messages received by each participant, your earnings are represented on the tables on the left, labeled "Your Earnings". The matched participant's earnings are on the tables on the right, labeled "Other earnings". Under each earnings table we indicate whether the earnings correspond to the case where the participant has received 0 or 1 messages. Before choosing each decision, we will tell you the number of messages you have received. Your match participant will see his/her earnings and your earnings table,and, on top of that, s/he will know how many messages s/he has received, but s/he will not know how many messages you have received.

The cell that determines your earnings is selected as a consequence of your choice (A, B, C or D), the choices of the matched participant (a, b, c or d) and the number of messages YOU HAVE RECEIVED. Similarly, the other participant's earnings depend on his/her choices (a, b, c or d), your choices (A, B, C or D) and the number of messages that S/HE HAS RECEIVED.

YOUR EARNINGS

Other choices

Your choices

	a	b	c	d
A	1	2	3	4
B	5	6	7	8
C	9	10	11	12
D	13	14	15	16

You: 0 messages

YOUR EARNINGS

Your choices

Other choices

	A	B	C	D
a	17	18	19	20
b	21	22	23	24
c	25	26	27	28
d	29	30	31	32

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices

	a	b	c	d
A	33	34	35	36
B	37	38	39	40
C	41	42	43	44
D	45	46	47	48

You: 1 message

YOUR EARNINGS

Your choices

Other choices

	A	B	C	D
a	49	50	51	52
b	53	54	55	56
c	57	58	59	60
d	61	63	63	64

Other: 1 message

For example, if in the decision above you choose "*C*" and the other participant chooses "*b*", your earnings will be 10 euros in the case where you have received 0 messages, no matter how many messages your matched participant has received. Similarly, your earnings will be 42 euros if you receive 1 message, no matter how may messages your matched participant has received. Regarding the other participant's earnings, they will be 23 euros if s/he has received 0 messages, no matter how many messages you have received, and 55 euros if s/he has received 1 message, no matter how many messages you have received. Numbers in the example are just and example and do not intend to suggest how anyone should choose their actions

Understanding Test:

1. If you have received 0 messages, how many messages can the SENDER have received?
   • 0 • 1 • 0 or 1

2. If the SENDER has received 0 messages, how many messages could you have received?
   • 0 • 1 • 0 or 1

3. If you have received 1 message, how many messages can the SENDER have received?
   • 0 • 1 • 0 or 1

4. If the SENDER has received 1 message, how many messages could you have received?
   • 0 • 1 • 0 or 1

For the tables above, please indicate your earnings and those of your matched participants for the cases in which you have received the following amount of messages. Notice that in some cases more than 1 answer are possible.

YOUR CHOICE	Other choice	YOUR messages	Your Earnings	Other earnings
D	c	0		
B	d	1		
A	b	0		

Now that instructions are clear, please choose in the following 8 decisions. The earnings tables will be different for each decision. You should carefully look at the earnings tables before deciding.

Please take your time to decide. If you want, you can use the blank spaces to take notes. Once you decide, please circle your decision. You will have a total of 20 minutes for this task. **Please do not start with the next task until instructed to do so.**

A.5 Task BC

In this final task you will have to take 3 decisions. If this was the task chosen to determine payments, one of the 3 choices will be randomly chosen and the winner in such task will be paid 150 euros. The winner in each of the three decisions will be determined as follows.

Decision 1

All participants in the experiment must pick a number between 0 and 100 (both included). To select the winner, we will compute the average of the numbers between 0 and 100 of all participants and we will multiply it by 1/3. The participant whose number is the closest, above or below, to the average of the numbers between 0 and 100 selected by all participants multiplied by 1/3 will win. In case of a tie, the winner will be randomly selected among all the participants that are part of the tie.

You have a maximum of 2 minutes.

What number do you choose?.........

Decision 2

All participants in the experiment must pick a number between 0 and 100 (both included). To select the winner, we will compute the average of the numbers between 0 and 100 of all participants and we will multiply it by 2/3. The participant whose number is the closest, above or below, to the average of the numbers between 0 and 100 selected by all participants multiplied by 2/3 will win. In case of a tie, the winner will be randomly selected among all the participants that are part of the tie.

You have a maximum of 2 minutes.

What number do you choose?.........

Decision 3

This last decision is similar to the ones taken in the first and second decisions of this task. The only difference is that this time we want you to explain the reasoning you follow to choose a number between 0 and 100 for any value of the number, between 0 and 1 (both NOT INCLUDED), call it “P”, for which the average of the numbers between 0 and 100 selected by all participants is multiplied.

You can use words, formulas or numbers to explain your reasoning, but in any case please explain why you choose what you choose.

Once we collect every participant's explanations we will randomly draw some value for P between 0 and 1 (both EXCLUDED) and we will apply to your reasoning or mathematical formulae. Again, the winner will be that who comes closer (either from above or below) to P times the average of the numbers resulting from the formulae of every participant. In case of multiple winners the final one is randomly chosen among those who gave the winning number. Despite we do not specify a value for P yet, you should give your explanation assuming that participant will make their choices once all of them know P's value and that such value will be the same for every participant.

You have 5 minutes to write here your explanation, mathematical formula or reasoning process. You can use the other side of this page in case you need further space.

A.6 Final Questionnaire

1. Name:
2. Email (in order to contact you in case we need to pay you):
3. In case you came recommended by some participant of the experiment in December 2017 please give us their name so that we can pay them.
4. Gender:
   ● Male ● Female
5. Age:
6. What degree are you pursuing?
7. Which year are you in?
8. In case you took a university access exam indicate the score you obtained (and the possible maximum score): ....
9. Please explain which reasoning process you followded to make your choice in Decision 1 in Task RG (you can take a look to the decision but do not change your answer):
10. Please explain which reasoning process you followded to make your choice in Decision 3 in Task ERG (you can take a look to the decision but do not change your answer):

11. Please explain which reasoning process you followded to make your choice in Decision 1 in Task PG (you can take a look to the decision but do not change your answer)):

12. Have you ever taken a course on Game Theory?: YES NO

13. (In case you are familiar with it) Did you rely on your knowledge on Game Theory to make your choices in the experiment?: YES NO

14. Any final comment about our research?:

B Games: Non Permuted

B.1 4×4

Task PG

Decision 1

YOUR EARNINGS

Other choices

Your choices

	a	b	c	d
A	80	20	140	20
B	60	160	20	140
C	100	200	40	60
D	140	100	60	80

OTHER EARNINGS

Your choices

Other choices

	A	B	C	D
a	40	20	200	80
b	20	40	60	40
c	100	120	20	120
d	80	80	180	100

Circle your choice: *A* *B* *C* *D*

Decision 2

YOUR EARNINGS

Other choices

Your choices

	a	b	c	d
A	80	100	100	0
B	0	20	20	40
C	20	0	60	180
D	60	60	80	160

OTHER EARNINGS

Your choices

Other choices

	A	B	C	D
a	120	0	60	0
b	0	140	40	120
c	40	80	120	60
d	20	180	80	40

Circle your choice: *A* *B* *C* *D*

B.2 Ring Games

Task RG

Decision 1

YOUR EARNINGS

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	100	80	200	120
	b	180	0	80	160
	c	80	180	120	60
	d	20	60	40	100

P2 EARNINGS

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	20	60	80	0
	f	140	180	40	80
	g	200	80	140	60
	h	0	160	180	100

P3 EARNINGS

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	200	140	80	100
	j	160	20	180	140
	k	0	160	160	120
	l	140	60	40	60

P4 EARNINGS

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	120	160	140	100
	n	80	120	100	80
	o	60	100	80	60
	p	40	140	60	20

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 2

YOUR EARNINGS

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	20	40	60	80
	b	80	60	20	40
	c	40	20	80	60
	d	140	120	200	100

P2 EARNINGS

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	200	80	160	140
	f	180	100	120	180
	g	80	180	80	160
	h	120	60	40	80

P3 EARNINGS

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	20	40	80	60
	j	140	160	100	120
	k	180	100	140	100
	l	120	80	180	200

P4 EARNINGS

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	140	200	120	100
	n	160	100	80	180
	o	80	60	40	60
	p	200	140	160	120

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 3

Your Earnings

Participant 2

		e	*f*	*g*	*h*
You	*a*	200	140	80	100
	b	160	20	180	140
	c	0	160	160	120
	d	140	60	40	60

P2 Earnings

Participant 3

		i	*j*	*k*	*l*
Participant 2	*e*	120	160	140	100
	f	80	120	100	80
	g	60	100	80	60
	h	40	140	60	20

P3 Earnings

Participant 4

		m	*n*	*o*	*p*
Participant 3	*i*	100	80	200	120
	j	180	0	80	160
	k	80	180	120	60
	l	20	60	40	100

P4 Earnings

You

		a	*b*	*c*	*d*
Participant 4	*m*	20	60	80	0
	n	140	180	40	80
	o	200	80	140	60
	p	0	160	180	100

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 4

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	200	80	160	140
	b	180	100	120	180
	c	80	180	80	160
	d	120	60	40	80

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	20	40	80	60
	f	140	160	100	120
	g	180	100	140	100
	h	120	80	180	200

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	140	200	120	100
	j	160	100	80	180
	k	80	60	40	60
	l	200	140	160	120

P4 Earnings

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	20	40	60	80
	n	80	60	20	40
	o	40	20	80	60
	p	140	120	200	100

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 5

YOUR EARNINGS

Participante 2

Tú	*e*	*f*	*g*	*h*
a	120	160	140	100
b	80	120	100	80
c	60	100	80	60
d	40	140	60	20

P2 EARNINGS

Participant 3

Participant 2	*i*	*j*	*k*	*l*
e	100	80	200	120
f	180	0	80	160
g	80	180	120	60
h	20	60	40	100

P3 EARNINGS

Participant 4

Participant 3	*m*	*n*	*o*	*p*
i	20	60	80	0
j	140	180	40	80
k	200	80	140	60
l	0	160	180	100

P4 EARNINGS

You

Participant 4	*a*	*b*	*c*	*d*
m	200	140	80	100
n	160	20	180	140
o	0	160	160	120
p	140	60	40	60

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 6

YOUR EARNINGS

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	140	200	120	100
	b	160	100	80	180
	c	80	60	40	60
	d	200	140	160	120

P2 EARNINGS

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	20	40	60	80
	f	80	60	20	40
	g	40	20	80	60
	h	140	120	200	100

P3 EARNINGS

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	200	80	160	140
	j	180	100	120	180
	k	80	180	80	160
	l	120	60	40	80

P4 EARNINGS

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	20	40	80	60
	n	140	160	100	120
	o	180	100	140	100
	p	120	80	180	200

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 7

YOUR EARNINGS

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	20	60	80	0
	b	140	180	40	80
	c	200	80	140	60
	d	0	160	180	100

P2 EARNINGS

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	200	140	80	100
	f	160	20	180	140
	g	0	160	160	120
	h	140	60	40	60

P3 EARNINGS

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	120	160	140	100
	j	80	120	100	80
	k	60	100	80	60
	l	40	140	60	20

P4 EARNINGS

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	100	80	200	120
	n	180	0	80	160
	o	80	180	120	60
	p	20	60	40	100

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 8

YOUR EARNINGS

Participant 2

You	*e*	*f*	*g*	*h*
a	20	40	80	60
b	140	160	100	120
c	180	100	140	100
d	120	80	180	200

P2 EARNINGS

Participant 3

Participant 2	*i*	*j*	*k*	*l*
e	140	200	120	100
f	160	100	80	180
g	80	60	40	60
h	200	140	160	120

P3 EARNINGS

Participant 4

Participant 3	*m*	*n*	*o*	*p*
i	20	40	60	80
j	80	60	20	40
k	40	20	80	60
l	140	120	200	100

P4 EARNINGS

Tú

Participant 4	*a*	*b*	*c*	*d*
m	200	80	160	140
n	180	100	120	180
o	80	180	80	160
p	120	60	40	80

Circle your choice: *a* *b* *c* *d*

B.3 E-ring Games

B.3.1 Sender

Task ERG

In all decisions in this task you will be a **SENDER**.

Decision 1

You have received **0 messages**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	60	80	40
	B	200	20	140	120
	C	120	140	180	160
	D	160	120	100	140

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	40	60	80
	b	160	140	100	120
	c	180	80	140	100
	d	200	100	20	160

Other: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	80	40	80
	B	80	20	20	40
	C	160	120	180	100
	D	40	60	80	60

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	180	120	160	140
	b	20	40	80	60
	c	100	140	200	160
	d	200	20	180	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 2

You have received **0 messages**.

YOUR EARNINGS

Other choices

Your choices	a	b	c	d
A	120	100	180	100
B	140	140	100	120
C	80	40	60	20
D	60	120	200	80

You: 0 messages

OTHER EARNINGS

Your choices

Other choices	A	B	C	D
a	180	100	140	120
b	100	120	160	60
c	60	20	80	40
d	120	80	200	140

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices	a	b	c	d
A	60	40	20	80
B	200	160	120	140
C	80	20	60	40
D	40	20	40	60

You: 1 message

OTHER EARNINGS

Your choices

Other choices	A	B	C	D
a	20	60	40	60
b	140	200	100	120
c	100	160	180	80
d	80	40	200	100

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 3

You have received **1 message**.

Your Earnings

Other choices

Your choices

	a	b	c	d
A	80	40	20	40
B	200	180	120	100
C	160	160	200	20
D	180	20	180	80

You: 0 messages

Other earnings

Your choices

Other choices

	A	B	C	D
a	20	60	20	80
b	120	180	100	140
c	60	80	40	20
d	40	20	80	60

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	b	c	d
A	180	80	60	100
B	100	120	80	60
C	80	60	20	40
D	60	20	180	120

You: 1 message

Other earnings

Your choices

Other choices

	A	B	C	D
a	80	100	160	120
b	100	180	60	140
c	20	40	20	80
d	40	140	200	100

Other: 1 message

Circle your choice: A B C D

Task ERG

Decision 4

You have received **1 message**.

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	180	120	100	100
	B	20	80	60	40
	C	80	140	120	120
	D	200	60	80	80

You: 0 messages

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	80	80	20	60
	b	60	40	80	20
	c	120	140	160	100
	d	40	60	20	20

Other: 0 messages

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	80	60	40	20
	B	140	180	80	100
	C	160	100	100	60
	D	180	120	20	140

You: 1 message

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	40	20	60	80
	b	160	80	120	100
	c	80	100	160	180
	d	140	60	140	160

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 5

You have received **1 message**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	60	80	40
	B	200	20	140	120
	C	120	140	180	160
	D	160	120	100	140

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	40	60	80
	b	160	140	100	120
	c	180	80	140	100
	d	200	100	20	160

Other: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	80	40	80
	B	80	20	20	40
	C	160	120	180	100
	D	40	60	80	60

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	180	120	160	140
	b	20	40	80	60
	c	100	140	200	160
	d	200	20	180	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 6

You have received **1 message**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	120	100	180	100
B	140	140	100	120
C	80	40	60	20
D	60	120	200	80

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	180	100	140	120
b	100	120	160	60
c	60	20	80	40
d	120	80	200	140

Otro: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	60	40	20	80
B	200	160	120	140
C	80	20	60	40
D	40	20	40	60

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	20	60	40	60
b	140	200	100	120
c	100	160	180	80
d	80	40	200	100

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 7

You have received **0 messages**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	40	20	40
	B	200	180	120	100
	C	160	160	200	20
	D	180	20	180	80

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	20	60	20	80
	b	120	180	100	140
	c	60	80	40	20
	d	40	20	80	60

Other: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	180	80	60	100
	B	100	120	80	60
	C	80	60	20	40
	D	60	20	180	120

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	100	160	120
	b	100	180	60	140
	c	20	40	20	80
	d	40	140	200	100

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 8

You have received **0 messages**.

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	180	120	100	100
	B	20	80	60	40
	C	80	140	120	120
	D	200	60	80	80

You: 0 messages

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	80	80	20	60
	b	60	40	80	20
	c	120	140	160	100
	d	40	60	20	20

Other: 0 messages

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	80	60	40	20
	B	140	180	80	100
	C	160	100	100	60
	D	180	120	20	140

You: 1 message

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	40	20	60	80
	b	160	80	120	100
	c	80	100	160	180
	d	140	60	140	160

Other: 1 message

Circle your choice: *A* *B* *C* *D*

B.3.2 Receiver

Task ERG

In all decisions in this task you will be a **RECEIVER**.

Decision 1

You have received **0 messages**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	40	60	80
B	160	140	100	120
C	180	80	140	100
D	200	100	20	160

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	60	80	40
b	200	20	140	120
c	120	140	180	160
d	160	120	100	140

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	180	120	160	140
B	20	40	80	60
C	100	140	200	160
D	200	20	180	80

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	60	80	40	80
b	80	20	20	40
c	160	120	180	100
d	40	60	80	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 2

You have received **0 messages**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	180	100	140	120
B	100	120	160	60
C	60	20	80	40
D	120	80	200	140

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	120	100	180	100
b	140	140	100	120
c	80	40	60	20
d	60	120	200	80

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	20	60	40	60
B	140	200	100	120
C	100	160	180	80
D	80	40	200	100

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	60	40	20	80
b	200	160	120	140
c	80	20	60	40
d	40	20	40	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 3

You have received **1 message**.

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	20	60	20	80
B	120	180	100	140
C	60	80	40	20
D	40	20	80	60

You: 0 messages

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	40	20	40
b	200	180	120	100
c	160	160	200	20
d	180	20	180	80

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	100	160	120
B	100	180	60	140
C	20	40	20	80
D	40	140	200	100

You: 1 message

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	180	80	60	100
b	100	120	80	60
c	80	60	20	40
d	60	20	180	120

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 4

You have received **1 message**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	80	20	60
	B	60	40	80	20
	C	120	140	160	100
	D	40	60	20	20

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	180	120	100	100
	b	20	80	60	40
	c	80	140	120	120
	d	200	60	80	80

Other: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	40	20	60	80
	B	160	80	120	100
	C	80	100	160	180
	D	140	60	140	160

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	60	40	20
	b	140	180	80	100
	c	160	100	100	60
	d	180	120	20	140

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 5

You have received **1 message**.

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	40	60	80
B	160	140	100	120
C	180	80	140	100
D	200	100	20	160

You: 0 messages

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	60	80	40
b	200	20	140	120
c	120	140	180	160
d	160	120	100	140

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	180	120	160	140
B	20	40	80	60
C	100	140	200	160
D	200	20	180	80

You: 1 message

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	60	80	40	80
b	80	20	20	40
c	160	120	180	100
d	40	60	80	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 6

You have received **1 message**.

Your Earnings

Other choices

Your choices	*a*	*b*	*c*	*d*
A	180	100	140	120
B	100	120	160	60
C	60	20	80	40
D	120	80	200	140

You: 0 messages

Other earnings

Your choices

Other choices	*A*	*B*	*C*	*D*
a	120	100	180	100
b	140	140	100	120
c	80	40	60	20
d	60	120	200	80

Otro: 0 messages

Your Earnings

Other choices

Your choices	*a*	*b*	*c*	*d*
A	20	60	40	60
B	140	200	100	120
C	100	160	180	80
D	80	40	200	100

You: 1 message

Other earnings

Your choices

Other choices	*A*	*B*	*C*	*D*
a	60	40	20	80
b	200	160	120	140
c	80	20	60	40
d	40	20	40	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 7

You have received **0 messages**.

YOUR EARNINGS

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	20	60	20	80
	B	120	180	100	140
	C	60	80	40	20
	D	40	20	80	60

You: 0 messages

OTHER EARNINGS

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	80	40	20	40
	b	200	180	120	100
	c	160	160	200	20
	d	180	20	180	80

Other: 0 messages

YOUR EARNINGS

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	80	100	160	120
	B	100	180	60	140
	C	20	40	20	80
	D	40	140	200	100

You: 1 message

OTHER EARNINGS

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	180	80	60	100
	b	100	120	80	60
	c	80	60	20	40
	d	60	20	180	120

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 8

You have received **0 messages**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	80	20	60
	B	60	40	80	20
	C	120	140	160	100
	D	40	60	20	20

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	180	120	100	100
	b	20	80	60	40
	c	80	140	120	120
	d	200	60	80	80

Other: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	40	20	60	80
	B	160	80	120	100
	C	80	100	160	180
	D	140	60	140	160

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	60	40	20
	b	140	180	80	100
	c	160	100	100	60
	d	180	120	20	140

Other: 1 message

Circle your choice: *A* *B* *C* *D*

C Games: Permuted

C.1 Ring Games

Task RG

Decision 1

YOUR EARNINGS

Participant 2

You

	e	f	g	h
a	100	80	200	120
b	180	0	80	160
c	80	180	120	60
d	20	60	40	100

P2 EARNINGS

Participant 3

Participant 2

	i	j	k	l
e	20	60	80	0
f	140	180	40	80
g	200	80	140	60
h	0	160	180	100

P3 EARNINGS

Participant 4

Participant 3

	m	n	o	p
i	200	140	80	100
j	160	20	180	140
k	0	160	160	120
l	140	60	40	60

P4 EARNINGS

You

Participant 4

	a	b	c	d
m	120	160	140	100
n	80	120	100	80
o	60	100	80	60
p	40	140	60	20

Circle your choice: a b c d

Task RG

Decision 2

YOUR EARNINGS

Participant 2

You	e	f	g	h
a	20	40	60	80
b	80	60	20	40
c	40	20	80	60
d	140	120	200	100

P2 EARNINGS

Participant 3

Participant 2	i	j	k	l
e	200	80	160	140
f	180	100	120	180
g	80	180	80	160
h	120	60	40	80

P3 EARNINGS

Participant 4

Participant 3	m	n	o	p
i	20	40	80	60
j	140	160	100	120
k	180	100	140	100
l	120	80	180	200

P4 EARNINGS

You

Participant 4	a	b	c	d
m	140	200	120	100
n	160	100	80	180
o	80	60	40	60
p	200	140	160	120

Circle your choice: a b c d

Task RG

Decision 3

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	0	160	160	120
	b	160	180	20	140
	c	200	80	140	100
	d	140	40	60	60

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	100	160	140	120
	f	60	100	80	60
	g	80	120	100	80
	h	20	140	60	40

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	20	100	40	60
	j	180	160	80	0
	k	80	60	120	180
	l	100	120	200	80

P4 Earnings

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	80	60	20	0
	n	180	160	0	100
	o	140	80	200	60
	p	40	180	140	80

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 4

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	120	80	40	60
	b	180	180	120	100
	c	80	160	80	180
	d	200	140	160	80

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	80	40	20	60
	f	180	80	120	200
	g	140	100	180	100
	h	100	160	140	120

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	80	40	60	60
	j	160	80	100	180
	k	140	120	200	100
	l	200	160	140	120

P4 Earnings

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	80	40	60	20
	n	60	20	80	40
	o	40	60	20	80
	p	100	120	200	140

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 5

YOUR EARNINGS

		Participante 2			
		e	*f*	*g*	*h*
Tú	*a*	40	140	20	60
	b	80	120	80	100
	c	60	100	60	80
	d	120	160	100	140

P2 EARNINGS

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	120	80	200	100
	f	160	0	80	180
	g	100	60	40	20
	h	60	180	120	80

P3 EARNINGS

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	100	160	180	0
	j	80	180	40	140
	k	60	80	140	200
	l	0	60	80	20

P4 EARNINGS

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	60	60	40	140
	n	140	20	180	160
	o	120	160	160	0
	p	100	140	80	200

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 6

YOUR EARNINGS

Participant 2

You	*e*	*f*	*g*	*h*
a	120	140	160	200
b	180	100	80	160
c	60	60	40	80
d	100	200	120	140

P2 EARNINGS

Participant 3

Participant 2	*i*	*j*	*k*	*l*
e	140	120	100	200
f	80	60	40	20
g	40	20	60	80
h	20	40	80	60

P3 EARNINGS

Participant 4

Participant 3	*m*	*n*	*o*	*p*
i	140	80	160	200
j	180	100	120	180
k	80	60	40	120
l	160	180	80	80

P4 EARNINGS

You

Participant 4	*a*	*b*	*c*	*d*
m	200	80	180	120
n	120	160	100	140
o	100	100	140	180
p	60	40	80	20

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 7

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	200	140	80	60
	b	140	40	180	80
	c	20	80	60	0
	d	0	180	160	100

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	140	200	80	100
	f	160	0	160	120
	g	20	160	180	140
	h	60	140	40	60

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	80	100	120	80
	j	120	140	160	100
	k	60	80	100	60
	l	40	60	140	20

P4 Earnings

		You			
		a	*b*	*c*	*d*
Participant 4	*m*	200	80	100	120
	n	120	180	80	60
	o	80	0	180	160
	p	40	60	20	100

Circle your choice: *a* *b* *c* *d*

Task RG

Decision 8

50

Your Earnings

		Participant 2			
		e	*f*	*g*	*h*
You	*a*	180	140	100	100
	b	140	100	160	120
	c	20	80	40	60
	d	120	180	80	200

P2 Earnings

		Participant 3			
		i	*j*	*k*	*l*
Participant 2	*e*	200	140	120	100
	f	60	80	40	60
	g	100	160	80	180
	h	140	200	160	120

P3 Earnings

		Participant 4			
		m	*n*	*o*	*p*
Participant 3	*i*	80	20	60	40
	j	20	60	40	80
	k	40	80	20	60
	l	140	200	120	100

P4 Earnings

		Tú			
		a	*b*	*c*	*d*
Participant 4	*m*	160	80	200	140
	n	80	180	80	160
	o	120	100	180	180
	p	40	60	120	80

Circle your choice: *a* *b* *c* *d*

C.2 E-ring Games

C.2.1 Sender

Task ERG

In all decisions in this task you will be a **SENDER**.

Decision 1

You have received **0 messages**.

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	80	60	80	40
	B	200	20	140	120
	C	120	140	180	160
	D	160	120	100	140

You: 0 messages

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	40	60	80
	b	160	140	100	120
	c	180	80	140	100
	d	200	100	20	160

Other: 0 messages

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	80	40	80
	B	80	20	20	40
	C	160	120	180	100
	D	40	60	80	60

You: 1 message

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	180	120	160	140
	b	20	40	80	60
	c	100	140	200	160
	d	200	20	180	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 2

You have received **0 messages**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	120	100	180	100
B	140	140	100	120
C	80	40	60	20
D	60	120	200	80

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	180	100	140	120
b	100	120	160	60
c	60	20	80	40
d	120	80	200	140

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	60	40	20	80
B	200	160	120	140
C	80	20	60	40
D	40	20	40	60

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	20	60	40	60
b	140	200	100	120
c	100	160	180	80
d	80	40	200	100

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 3

You have received **1 message**.

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	20	40	80	40
	B	180	20	180	80
	C	200	160	160	20
	D	120	180	200	100

You: 0 messages

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	60	20	40	80
	b	120	140	100	180
	c	20	80	20	60
	d	40	60	80	20

Other: 0 messages

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	80	180	100
	B	180	20	60	120
	C	20	60	80	40
	D	80	120	100	60

You: 1 message

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	20	80	20	40
	b	100	140	60	180
	c	80	120	160	100
	d	40	100	200	140

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 4

You have received **1 message**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	100	120	180	100
B	80	60	200	80
C	120	140	80	120
D	60	80	20	40

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	120	100	160	140
b	60	20	80	40
c	80	60	20	80
d	40	20	20	60

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	40	60	80	20
B	20	120	180	140
C	100	100	160	60
D	80	180	140	100

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	180	160	100
b	160	100	120	80
c	40	80	60	20
d	140	160	140	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 5

You have received **1 message**.

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	160	100	120	140
	B	200	140	20	120
	C	120	180	140	160
	D	80	80	60	40

You: 0 messages

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	80	40	60	80
	b	100	80	140	180
	c	120	140	100	160
	d	160	100	20	200

Other: 0 messages

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	40	80	60	60
	B	80	20	20	40
	C	160	180	120	100
	D	60	40	80	80

You: 1 message

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	140	120	160	180
	b	160	140	200	100
	c	60	40	80	20
	d	80	20	180	200

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 6

You have received **1 message**.

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	200	120	80
	B	140	100	140	120
	C	80	60	40	20
	D	120	180	100	100

You: 0 messages

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	120	100	140	180
	b	40	20	80	60
	c	60	120	160	100
	d	140	80	200	120

Otro: 0 messages

Your Earnings

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	40	40	20	60
	B	200	120	160	140
	C	80	60	20	40
	D	60	20	40	80

You: 1 message

Other earnings

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	60	60	40	20
	b	80	160	180	100
	c	120	200	100	140
	d	100	40	200	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 7

You have received **0 messages**.

YOUR EARNINGS

		Other choices			
		a	b	c	d
Your choices	A	80	40	40	20
	B	160	160	20	200
	C	200	180	100	120
	D	180	20	80	180

You: 0 messages

OTHER EARNINGS

		Your choices			
		A	B	C	D
Other choices	a	20	20	60	80
	b	120	100	180	140
	c	40	80	20	60
	d	60	40	80	20

Other: 0 messages

YOUR EARNINGS

		Other choices			
		a	b	c	d
Your choices	A	180	80	100	60
	B	80	60	40	20
	C	100	120	60	80
	D	60	20	120	180

You: 1 message

OTHER EARNINGS

		Your choices			
		A	B	C	D
Other choices	a	80	160	100	120
	b	100	60	180	140
	c	40	200	140	100
	d	20	20	40	80

Other: 1 message

Circle your choice: A B C D

Task ERG

Decision 8

You have received **0 messages**.

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	180	120	100	100
B	80	140	120	120
C	20	80	40	60
D	200	60	80	80

You: 0 messages

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	20	80	60
b	60	80	40	20
c	40	20	60	20
d	120	160	140	100

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	60	20	40
B	160	100	60	100
C	140	180	100	80
D	180	120	140	20

You: 1 message

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	40	60	20	80
b	160	120	80	100
c	140	140	60	160
d	80	160	100	180

Other: 1 message

Circle your choice: *A* *B* *C* *D*

C.2.2 Receiver

Task ERG

In all decisions in this task you will be a **RECEIVER**.

Decision 1

You have received **0 messages**.

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	80	40	60	80
	B	160	140	100	120
	C	180	80	140	100
	D	200	100	20	160

You: 0 messages

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	80	60	80	40
	b	200	20	140	120
	c	120	140	180	160
	d	160	120	100	140

Other: 0 messages

Your Earnings

Other choices

		a	*b*	*c*	*d*
Your choices	*A*	180	120	160	140
	B	20	40	80	60
	C	100	140	200	160
	D	200	20	180	80

You: 1 message

Other earnings

Your choices

		A	*B*	*C*	*D*
Other choices	*a*	60	80	40	80
	b	80	20	20	40
	c	160	120	180	100
	d	40	60	80	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 2

You have received **0 messages**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	180	100	140	120
B	100	120	160	60
C	60	20	80	40
D	120	80	200	140

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	120	100	180	100
b	140	140	100	120
c	80	40	60	20
d	60	120	200	80

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	20	60	40	60
B	140	200	100	120
C	100	160	180	80
D	80	40	200	100

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	60	40	20	80
b	200	160	120	140
c	80	20	60	40
d	40	20	40	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 3

You have received **1 message**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	60	20	40	80
B	120	140	100	180
C	20	80	20	60
D	40	60	80	20

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	20	40	80	40
b	180	20	180	80
c	200	160	160	20
d	120	180	200	100

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	20	80	20	40
B	100	140	60	180
C	80	120	160	100
D	40	100	200	140

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	60	80	180	100
b	180	20	60	120
c	20	60	80	40
d	80	120	100	60

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 4

You have received **1 message**.

Your Earnings

Other choices

Your choices	a	b	c	d
A	120	100	160	140
B	60	20	80	40
C	80	60	20	80
D	40	20	20	60

You: 0 messages

Other earnings

Your choices

Other choices	A	B	C	D
a	100	120	180	100
b	80	60	200	80
c	120	140	80	120
d	60	80	20	40

Other: 0 messages

Your Earnings

Other choices

Your choices	a	b	c	d
A	80	180	160	100
B	160	100	120	80
C	40	80	60	20
D	140	160	140	60

You: 1 message

Other earnings

Your choices

Other choices	A	B	C	D
a	40	60	80	20
b	20	120	180	140
c	100	100	160	60
d	80	180	140	100

Other: 1 message

Circle your choice: A B C D

Task ERG

Decision 5

You have received **1 message**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	40	60	80
B	100	80	140	180
C	120	140	100	160
D	160	100	20	200

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	160	100	120	140
b	200	140	20	120
c	120	180	140	160
d	80	80	60	40

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	140	120	160	180
B	160	140	200	100
C	60	40	80	20
D	80	20	180	200

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	40	80	60	60
b	80	20	20	40
c	160	180	120	100
d	60	40	80	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 6

You have received **1 message**.

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	120	100	140	180
	B	40	20	80	60
	C	60	120	160	100
	D	140	80	200	120

You: 0 messages

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	60	200	120	80
	b	140	100	140	120
	c	80	60	40	20
	d	120	180	100	100

Otro: 0 messages

YOUR EARNINGS

		Other choices			
		a	*b*	*c*	*d*
Your choices	*A*	60	60	40	20
	B	80	160	180	100
	C	120	200	100	140
	D	100	40	200	80

You: 1 message

OTHER EARNINGS

		Your choices			
		A	*B*	*C*	*D*
Other choices	*a*	40	40	20	60
	b	200	120	160	140
	c	80	60	20	40
	d	60	20	40	80

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 7

You have received **0 messages**.

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	20	20	60	80
B	120	100	180	140
C	40	80	20	60
D	60	40	80	20

You: 0 messages

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	40	40	20
b	160	160	20	200
c	200	180	100	120
d	180	20	80	180

Other: 0 messages

YOUR EARNINGS

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	160	100	120
B	100	60	180	140
C	40	200	140	100
D	20	20	40	80

You: 1 message

OTHER EARNINGS

Your choices

Other choices

	A	*B*	*C*	*D*
a	180	80	100	60
b	80	60	40	20
c	100	120	60	80
d	60	20	120	180

Other: 1 message

Circle your choice: *A* *B* *C* *D*

Task ERG

Decision 8

You have received **0 messages**.

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	80	20	80	60
B	60	80	40	20
C	40	20	60	20
D	120	160	140	100

You: 0 messages

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	180	120	100	100
b	80	140	120	120
c	20	80	40	60
d	200	60	80	80

Other: 0 messages

Your Earnings

Other choices

Your choices

	a	*b*	*c*	*d*
A	40	60	20	80
B	160	120	80	100
C	140	140	60	160
D	80	160	100	180

You: 1 message

Other earnings

Your choices

Other choices

	A	*B*	*C*	*D*
a	80	60	20	40
b	160	100	60	100
c	140	180	100	80
d	180	120	140	20

Other: 1 message

Circle your choice: *A* *B* *C* *D*