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CAN MARKET COMPETITION REDUCE ANOMALOUS BEHAVIOURS?*

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Abstract

We use an experiment to study whether market competition can reduce anomalous behaviour in games. In different treatments, we employ two alternative mechanisms, the random mechanism and the auction mechanism, to allocate the participation rights to the red hat puzzle game, a well-known logical reasoning problem. Compared to the random mechanism, the auction mechanism significantly reduces deviations from the equilibrium play in the red hat puzzle game. Our findings show that under careful conditions, market competition can indeed reduce anomalous behaviour in games.

JEL-classification: *C70; C90; D44.*
Keywords: *market competition; market selection hypothesis; auctions; bounded-rationality; red hat puzzle*.

1. INTRODUCTION

Individual anomalous behaviour in experimental game-theory suggest that people are less than fully rational. People are susceptible to psychological biases (e.g., Rabin, 1998; Conlisk, 1996; DellaVigna, 2009; Gabaix, 2017) and are not always able to perform the types deductive reasoning demanded by the equilibrium solution (e.g., Crawford et al., 2013).[1] This should not be surprising to economist who recognise the limits of individual rationality in their day-to-day interactions even when this is

*This project builds on the preliminary study by Choo (2014), improving on the experiment design and procedures. We hence make no further references to the previous study.

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[1]Where possible, we prefer to direct the reader to reviews of the established literature. Also, see Crawford (2013), Harstad and Selten (2013) and Rabin (2013) for a discussion as to how bounded rationality can be incorporated into economic theory.

not always reflected in their professional work (Fehr and Tyran, 2005). Yet, it is not immediately obvious whether individual level bounded rationality necessarily falsifies the applicability of models that assume fully rational players.[2]

Markets are sometimes used to allocate the rights (e.g., permits, licences, contracts) for performing the types of economic tasks modelled in games (i.e., markets select players into the game).[3] A long-standing convention in economics is that markets divert resources to where they are valued the most. If the expected payoffs from the game are higher for the rational players relative to their bounded-rational counterparts, then market competition should result in the allocation of participation rights (i.e., the rights to play the game) to the former. In such circumstances, behaviour in the game may be well approximated by models assuming fully rational players even when this is clearly not the case at the population level.[4] Stated differently, market competition can reduce anomalous behaviour in games.

However, it is not clear whether the above logic will naturally hold. Amongst other reasons, people are vulnerable to *focusing failures* (e.g., Tor and Bazerman, 2003; Idson et al., 2004). In particular, the bounded-rational players may fail to realise how their market behaviour should depend on their expected payoffs from the game. Even if all players anchor their market behaviour on the game, bounded-rational players may also exhibit higher degrees of *over-confidence* (e.g., Camerer and Lovallo, 1999; Hoelzl and Rustichini, 2005) with respect to the expected payoffs from the game. The above considerations suggest that market competition may not always reduce anomalous behaviour in games.

The question as to whether market competition can reduce anomalous behaviour is thus central to much of economic thinking and modelling. This paper seeks to shed light on this question. This task is well suited to laboratory experiments where the confounding forces such as liquidity constrains, beliefs and experiences can be carefully controlled. We focus on the types of anomalous behaviour that are associated with players' inability to apply rational logical reasoning and consider an environment where auctions are used to select players into a game – auctions are one of the simplest and common market mechanism used to allocate economic tasks (e.g., spectrum

[2]Some economists such as Aumann (1985) take the "instrumental view" that the purpose of theory is to contribute to our comprehension of knowledge. Whilst we do not disagree with this view, we believe that it is also important to ask whether theory matches actual behaviour.

[3]Economists often build simple models to focus on the main economic interaction of interest – Lewis Carroll's (1894) map paradox illustrates why a simpler model is sometimes more useful. Markets here can be interpreted as some un-modelled pre-game stage which determines players' participation into the game. This pre-game stage is irrelevant in equilibrium if all players are assumed to be fully rational and the selection outcome does not affect behaviour in the game.

[4]Inversely, competitive markets may exacerbate the influence of the less rational players if their expected payoffs from the game are higher.

auctions, tendering of government projects).

We base our experiment on the 3-player *Red Hat Puzzle* (RHP) game, a close variant of Littlewood's (1953) "Dirty faces problem".[5] To study the influence of market competition, participation rights to the RHP game are allocated by auctions. Players' behaviour in the RHP game are compared against the control treatments where participation rights are randomly distributed. The equilibrium solution in the RHP game does not depend on the selection mechanism (i.e., auction versus random).

We use the RHP game for the following two reasons. Firstly, when modelled as a dynamic Bayesian game with incomplete information, the equilibrium solution relies on players employing logical and epistemological reasoning (i.e., reasoning about the reasoning of others). Furthermore, permutations within the game enable us to vary the complexity of the equilibrium solution. Indeed, Weber (2001), Bayer and Chan (2007) and Bayer and Renou (2016a,b) use this feature of the RHP game to study "steps of individual bounded rationality".[6] Secondly, adherence to the equilibrium solution in the game is Pareto optimal (in expectations) for all players. This ensures that the expected payoffs in the game are always higher for players who know the equilibrium solution and believe that all other players in the game will play to the equilibrium solution.

Our experiment finds that the auction mechanism significantly reduces deviations from the equilibrium behaviour in the RHP game. This is especially the case when players face most complex scenario of the RHP game. Here, the proportion of off equilibrium play drops from 50% in the control treatment to around 20% in the auction treatment. We show the above occurs because the auction mechanism selects "rational" players (i.e., those who know the equilibrium solution) into the RHP game more frequently than the random mechanism.

One closely related concept is the *market selection hypothesis* (e.g Alchian, 1950; Friedman, 1953) which posits that the evolutionary forces in the market will drive out the less rational players.[7] Kendall and Oprea (2018) test the hypothesis in a multi-period laboratory experiment: at each period, players distribute their accumulated

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[5]Variantions of the RHP game are often found in game theory textbooks (e.g. Myerson, 1991; Fudenberg and Tirole, 1991; Maschler et al., 2013), discussions about common knowledge (e.g., Geanakoplos, 1992; Samuelson, 2004) and epistemological reasoning (e.g., Fagin et al., 2004). Littlewood tells it as follows. "Three ladies, A, B, C in a railway carriage all have dirty faces and are all laughing. It suddenly flashes on A: why doesn't B realise C is laughing at her? – Heavens! I must be laughable."

[6]The previous experiments primarily use the RHP game to study *k-level* (e.g., Nagel, 1995; Stahl and Wilson, 1994; Camerer et al., 2004) reasoning behaviour. Though behaviour in this study may also involve some elements of the k-level model, such discussions will be omitted as they divert from the main research agenda.

[7]The market selection hypothesis is the economics analogy of natural selection. However, theoretical research by DeLong et al. (1991) and Blume and Easley (2006) suggests that it is not obvious whether the hypothesis will hold.

wealth over consumption and investment opportunities. To trigger individual biases, returns on investments are linked to a "Monty Hall problem".[8] Consistent with the market selection hypothesis, they find that Bayesian subjects (i.e., those who make less judgement errors with the Monty hall problem) are more likely to "survive" in the long-run.[9,10] This study complements their research by showing that market selection can also be successful in a "static setting".

Our experiment also contributes to several strands of the literature. The most relevant relates to the growing body of experimental evidence highlighting the intricacies between individual level bounded rationality and aggregate level outcomes.

In a price-setting game, Fehr and Tyran (2005, 2008) show that the effects of *money illusion* on aggregated prices depend on the strategic environment (Haltiwanger and Waldman, 1985, 1989).[11] They find that when the environment is one of strategic *complementarity*, prices adjust slowly in response to anticipated monetary shocks. In contrast, the adjustment rate is extremely quick (i.e., prices converge to equilibrium fairly quickly) when the environment is one of strategic *substitutability*.[12] The RHP game can be interpreted as a strategic complementarity environment – deviations by players affect the behaviour of others in the game. In doing so, we show that market competition can help drive outcomes closer to the equilibrium in a strategic complementarity environment.

Kluger and Wyatt (2004) study the effects of individual probability judgement errors on market prices (aggregate outcomes). To do so, they embedded the Monty hall problem into asset markets. They find that individual level heterogeneity is reflected in market prices. In particular, market prices are close to the predicted equilibrium when the market consists of at least two rational players (determined by decisions with the Monty hall problem).[13] Complementing their findings, we find that auction

[8]The Monty Hall Problem is inspired by a popular TV game show, where the host Monty hides a winning prize behind one of three closed doors. Contestants are invited to open a door. However, before the door is actually opened, Monty is pre-committed to opening a non-prize door and then offers the contestant the chance to switch her choice to the other unopened door. The dominant strategy in this problem is to always switch as it offers the contestant a 2/3 chance of picking the prize door.

[9]Kendall and Oprea (2018) devise a "survival index" that is based on subjects' relative share of the wealth. The presumption here is that since wealth is required to make investment decisions, then a test of the market selection hypothesis is whether the less rational people will run out wealth sooner than their rational counterparts.

[10]Fehr and Tyran (2005) argue that the market selection hypothesis may not be applicable in many economic situations. For example, it is difficult to see why a consumer who makes sub-optimal consumption decisions will be driven out of the consumer market.

[11]Money illusion is a cognitive biases associated with confusing nominal and real variables.

[12]Loosely speaking, strategic complementarity is a setting where a small proportion of bounded-rational players can lead to large aggregate level deviations from the equilibrium. In contrast, strategic substitutability is a setting where a small proportion of rational players is sufficient to drive aggregate outcomes close to the equilibrium.

[13]In general, prices in single period markets seem to converge fairly quickly to the equilibrium (e.g.,

bidding behaviour also reflects subjects' knowledge of the RHP game equilibrium solution.

This paper also contributes to the growing body of experiment literature that investigates the influence of selection into games. For example, auctioning participating rights can improve contributions in the threshold public goods game (Broseta et al., 2003), help people coordinate on the efficient equilibrium (Van Huyck et al., 1993) in coordination games and affect behaviour in the Ultimatum game (e.g., Güth and Tietz, 1986; Shachat and Swarthout, 2013).

Finally, we contribute to the body of literature which finds markets to be useful in guiding and solving complex problems. For example, Maciejovsky and Budescu (2005, 2013) show that market prices can help improve subjects' performances in the Wason (1966) selection task, a well-known test of deductive reasoning. Meloso et al. (2009) show that a market-based system of compensation can promote "intellectual discovery" (modelled by solving the *knapsack problem*) better than a patent-based system. Finally, Dreber et al. (2015) show that prediction markets can be useful in predicting the reproducible of scientific research.

The rest of this paper is structured as followed. Section 2 details the RHP game. Building on this, Section 3 details our experiment design. Section 4 summarises our experimental findings. Finally, Section 5 concludes.

2. THE RED HAT PUZZLE (RHP) GAME

There are three players each wearing a coloured hat that can be red or black with equal chance.[14] Each player observes all other hats but her own. Players also receive the public signal that "*there are no red hats*" or "*there is at least one red hat*". The public signal depends on the total number of red hats and is always truthful. The above is common knowledge.

There are $t = 1, 2, 3, 4$ periods. At each period $t < 4$, players are asked "*Do you know your hat colour?*" and they can respond with the actions "*My hat is red*" (a_R), "*My hat is black*" (a_B) or "*I don't yet know*" (a_N). A player leaves the RHP game whenever a_R or a_B is chosen and only progresses to the next period if she had chosen a_N. At each period, players also observe the previous period's actions of every other players. Finally, players at period 4 are asked the same question but can only respond with a_R

Smith, 1962) even when the market consist of "zero intelligence" programmed traders (e.g Gode and Sunder, 1993). The multi-period case is less straightforward as price bubbles (i.e., deviations from the equilibrium) can persist (see Smith et al., 1988, seminar paper).

[14]Amongst the three players, the ex-ante probability of there being 3, 2, 1 and 0 red hats are 1/8, 3/8, 3/8 and 1/8, respectively.

or a_B.[15]

A player's payoff depends whether she is correct (e.g., choosing a_R when hat is red) and the period that she ends the RHP game ($\bar{T}$). Her payoff is derived as

$$\pi = \begin{cases} 1100 - 100\bar{T} & \text{if the player is correct,} \\ 400 - 100\bar{T} & \text{if the player is incorrect.} \end{cases} \tag{1}$$

Equation (1) shows that a player incurs a penalty of 100 each time a_N is chosen and a further penalty of 700 if she is incorrect about her hat colour – no deductions for being correct. This ensures that all players should always seek to correctly resolve their own hat colour in the soonest possible period.

2.1. EQUILIBRIUM

For each player, let $r \in \{0, 1, 2\}$ denote the total number of red hats that she observes. When modelled as a Bayesian game with incomplete information, the *indirect communication equilibrium* (Geanakoplos and Polemarchakis, 1982) is for each player to choose a_N at periods $t < r + 1$ and at period $t = r + 1$, choose a_R (resp. a_B) if her hat is red (resp. black) – henceforth known as the *equilibrium behaviour*. Each player resolves her hat in period $r + 1$ with the equilibrium payoff $\pi^* = 1000 - 100r$.

To illustrate the equilibrium solution, consider the case where all hats are red.[16] Here, each player observes two other red hats (i.e., $r = 2$) and assigns an equal posterior that her hat is red or black hat. Furthermore, despite players' private information and the public signal that there is at least one red hat, Aumann (1976) agreement theorem shows that the only common knowledge fact is that there is at least one red hat.

- *Period 1*: Players choose a_N when asked about their hat.[17]
- *Period 2*: Each player learns that there is at least two red hats – otherwise someone would have chosen a_R in period 1. However, they already know this and there is no revision to their posterior – they will again choose a_N. Nevertheless,

[15] Suppose that player 1 chooses a_B in period 1 whilst players 2 and 3 both choose a_N in period 1. Only players 2 and 3 progress to period 2. In addition, players 2 and 3 observe the previous period's actions of all other players (e.g., player 2 sees that player 1 chose a_B in period 1 and that player 3 chose a_N in period 1).

[16] We refer the reader to Chapters 9 and 10 of Maschler et al. (2013) for a detailed exposition of the equilibrium solution.

[17] Because uncertain players (i.e., those who do not know their own hat colour) incur a "penalty" of 100 whenever a_N is chosen, they should only choose a_N in period t if they expect to resolve their hat at some period $t' > t$. In equilibrium, all uncertain players will alway expect to resolve their hat.

if it was common knowledge that all players performed the same reasoning, it becomes common knowledge that there are at least two red hats.

- *Period 3*: Each player deduces that there must be three red hats – otherwise the other two red hat players would have chosen a_R in period 2. Each player now chooses a_R.

The equilibrium solution is trivial when $r = 0$. When $r > 0$, the equilibrium solution requires players to apply logical and epistemological reasoning (i.e., reasoning about the reasoning of others). Intuitively, the complexity of reasoning involved is increasing with r. Also note that players who observe $r > 0$ need only learn about their own hat colour through the period r actions of those other players they observe to be under a red hat.

2.2. RELATED LITERATURE.

Experiments find that people are heterogeneous in their ability to perform the necessary logical and epistemology reasoning demanded by the equilibrium solution in the RHP game. For example, Weber (2001) finds that only 65% and 45% of experiment subjects adhered to the equilibrium behaviour when observing $r = 1$ and $r = 2$, respectively (all did so when $r = 0$).[18]

In dynamic games, a player's deviation from the equilibrium path can be triggered by their opponents' prior deviations or *strategic uncertainty* (i.e., uncertainties with regards to the purposeful nature of others' actions). Equation (1) implies that for a player who is uncertain about her hat colour, choosing a_N at period $t < r + 1$ is only optimal if she expects to resolve her hat colour at some period $t' > t$. As such, even if a $r > 0$ player knows the equilibrium solution, her optimal strategy will be randomise between a_B and a_R in period 1 if she does not expect to learn about her hat colour from the period r actions of those other players she observes to be under a red hat.

To control for the above concerns, Bayer and Renou (2016a,b) conducted a version of the RHP game where experiment subjects played against computer-players programmed to always play the equilibrium (i.e, adherence to the equilibrium behaviour solely depended on subjects' knowledge of the equilibrium solution).[19] They

[18] In Weber's experiments, players can only choose a_R or a_N at each period and the game ends for all players upon any player choosing a_R. His results are interesting since they involved Caltech undergraduate and graduate students and Caltech students are often skilled at logical puzzles (e.g., Camerer, 2003).

[19] Subjects' in their study were primed that there exist a logical solution in the game. To avoid "logical inconsistencies" their design also includes a condition whereby the RHP game ends whenever a subject deviates from the equilibrium path.

find that only 75% and 44% of subjects adhered to the equilibrium behaviour when observing $r = 1$ and $r = 2$, respectively.

3. EXPERIMENT DESIGN

We investigate whether market competition can reduce anomalous behaviour (i.e., deviations from the equilibrium behaviour) in the RHP game. To do so, we use auctions to allocate the participation rights to the three-player RHP game – this will be compared against our control treatments where the participation rights are randomly allocated. To motivate our experiment design, consider the following thought experiment.

Thought experiment. There are three coloured hats. Two sisters, Ann and Eva, are under the same hat and observe $r' > 0$. The other two hats are worn by Charlie and Dale, respectively. A second-price auction is used to decide which of the two sisters, Ann or Eva, will be selected to play the RHP game against Charlie and Dale (i.e., both sisters bid for rights to play the RHP game).[20] Both sisters always seek to maximise their own payoffs but only Ann knows the equilibrium solution in the RHP game. Consider the ex-ante expected payoff from the RHP game for each sister. If selected into the RHP game, Eva will randomise between a_B and a_R in period 1 with the expected payoff of $\underline{\pi} = 0.5(1000) - 0.5(300)$.[21] By backward deduction, Eva will always bid $\underline{b} = \underline{\pi}$.[22] Ann's expected payoff is more subtle as it depends on whether she expects to resolve her hat in period $r' + 1$. If this is positive, her expected payoff is $\pi^* = 1000 - 100r'$ and she bids $b^* = \pi^*$, where $b^* > \underline{b}$ for all $r' > 0$. If it is instead negative, Ann's expected payoff is similar to Eva and she bids $\underline{b}$.

Ann's bidding behaviour depends on whether she believes that can deduce her hat colour from the period r' actions of the other red hat players.[23] We therefore first consider a treatment where Ann always expects to resolve her hat. To do so, players in the RHP game are always paired against *computer-players* who are programmed to play the equilibrium.

Thereafter, we study behaviour in the RHP game where auction winner (i.e., Ann or Eva) plays against other human players who are themselves selected by the same

[20]The same conclusion can be drawn if a first price or all-pay auction is used instead. We chose to focus on the second price auction as bidding behaviour does not depend on players' risk preferences.

[21]Choosing a_N is strictly dominated for Eva as she incurs a "penalty" of 100 with no obvious benefits.

[22]It is a dominant strategy in the second-price auction to always bid one's valuation.

[23]In equilibrium, a player who observes $r > 0$ need only learn about her own hat colour from the period r actions of those other players she observes to be under a red hat.

auction mechanism. In contrast to above treatment, Ann cannot be sure that she will always resolve her hat in period $r'+1$. Nevertheless, Ann may value the participation rights more than Eva if she anticipates that market competition will also frequently select other "Ann like individuals" into the RHP game.

The experiment design is summarised on Figure 1 and involves four treatments: *Random computer* (RCOM; $n = 54$ subjects), *Market computer* (MCOM; $n = 54$ subjects), *Random human* (RHUM; $n = 54$ subjects) and *Market human* (MHUM; $n = 45$ subjects).[24] Each treatment consist of two independent parts (I and II) for which the instructions are only available at the start of that part. Part I involves 5 independent rounds and 1 random round is payoff relevant. Part II involves 15 independent rounds and 3 random rounds are payoff relevant. Experimental earnings in each round are denoted in "points".

Part I is identical across all treatments. We use part II to differentiate between the *human* (RHUM and MHUM) and *computer* (RCOM and MCOM) treatments. The following subsections detail each part. In each round, subjects interact in fixed-matching groups of 9 players.

3.1. DESIGN: PART I

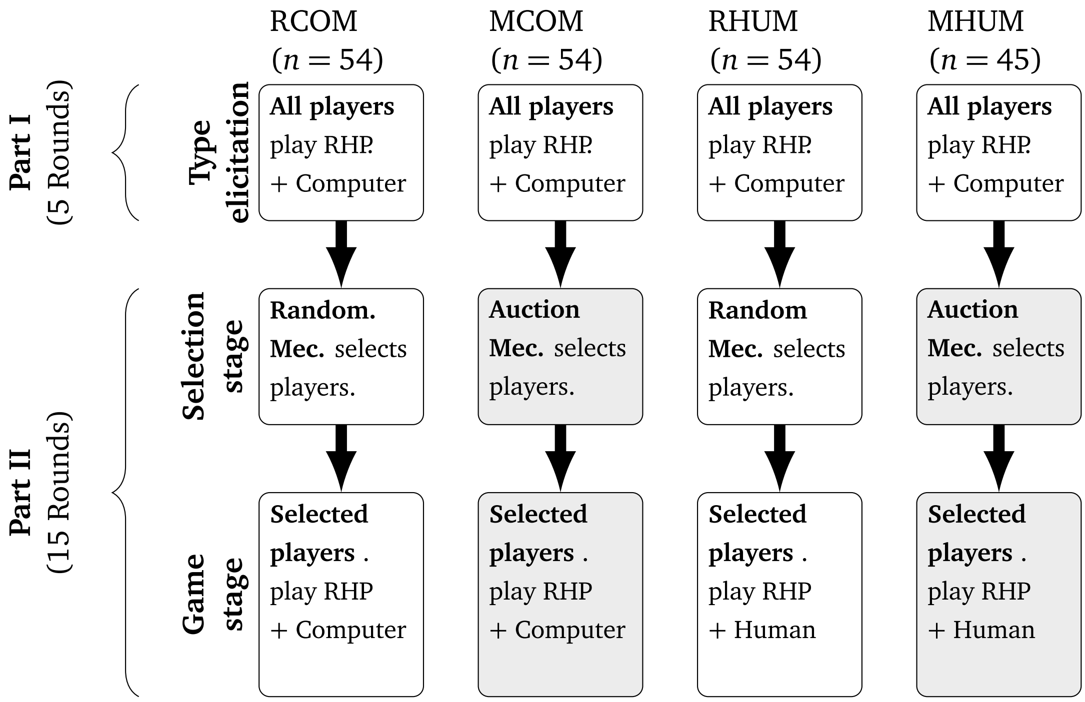
At each round, subjects play the 3-player RHP game without feedback against *computer-players* (i.e., a computer programme makes decisions for the two other hat players). The computer-players are programmed to always best respond to the actions of others at each period t. Appendix B details the computer-players' programmed rules.[25] We use subjects' behaviour in part I to elicit their understanding of the RHP game equilibrium solution.

3.2. DESIGN: PART II

Each round involves three hats with three players under each hat – we refer to the players in the same hat as a *silo*. Players in the same matching-group are randomly assigned to one of three silos in each round.

[24] The experiment was conducted at the Smith Experimental Economics Research Center in June 2019. Inexperienced subjects were recruited from the student cohort at the Shanghai Jiao Tong University via ORSEE (Greiner, 2015). The experiment was programmed with zTree (Fischbacher, 2007). The instructions are detailed in Appendix C. The experimental data and software are available upon request.

[25] Subjects are informed that the computer-players are programmed to always maximise their own points and to always resolve their own hat colour in a logical manner. Furthermore, subjects are reminded that the computer can never "cheat" and will always base its decisions on the public signal, its observations of the other hat colours and the decisions of the other players in the RHP game. As such, computer-players may also be incorrect about their hat colour when the subject deviates from the equilibrium path.



Note. There are 4 treatments each consisting of 2 independent parts. In each round of part II, subjects interact in fixed matching groups of 9 players – part I involves individual decision-making task. We recruited 54 subjects (6 matching groups) in each of the RCOM, MCOM and RHUM treatments and 45 subjects (5 matching groups) the MHUM treatment.
+ Computer: All players in part I and selected players in part II play the RHP game against computer-players who are programmed to play according to the equilibrium solution.
+ Human: Selected players in part II play the RHP game against other selected players.

Figure 1: Summary of experiment design.

Players in each silo observe the public signal and the other two hat colours (i.e., players of the same silo observe the same r). Each silo selects one player to participate in the RHP game. The treatments differ on the selection mechanism.

- *RHUM and RCOM (random mechanism)*. Each silo randomly selects one player to enter the RHP game.
- *MHUM and MCOM (auction mechanism)*. Each silo uses a second-price auction to sell the participation rights to the RHP game – players are endowed with 1500 and submit their bids after observing r and the public signal. The auction winner (i.e., the highest bidder) is selected into the RHP game and pays the second highest bid price in her silo.[26] Finally, auction winners only observe the selling price of their own silo. This prevents players from learning about their hats from the prices of other markets.

The selection process is common knowledge. The selected players in the human (RHUM and MHUM) treatments play the RHP game as described in Section 2 – the selected players' hat colours correspond to the their silo's hat colour.[27,28] More specifically, each of the three players in the RHP game is one who has been selected from their respective silos. In contrast to the human treatments, the selected players in the computer (RCOM and MCOM) treatments play the RHP game against two other computer-players (programmed as in part I).

The end of round payoffs for the non-selected and selected players are as follows

$$\Pi = \begin{cases} 1500 & \text{if not selected by auction or random mechanism,} \\ 1500 - z + \pi & \text{if selected by auction mechanism,} \\ 620 + \pi & \text{if selected by random mechanism,} \end{cases} \tag{2}$$

where $z \in [0, 1500]$ is the auction purchase price and π is the player's payoff from the RHP game (see equation (1)). In the MHUM and MCOM treatments, non-selected players keep their endowment of 1500 points and selected players pay z for the rights to participate in the RHP game. In RHUM and RCOM treatments, non-selected players receive a fixed payment of 1500 points and selected players receive a lower fixed payment of 620 points – as described in the following paragraph, this is lower to keep the average payoff consistent across all treatments.

[26] We use the second-price auction as it is a dominant strategy to bid ones' valuation. In the case of a tie, a random mechanism determines the auction winner.

[27] Suppose that players in silo A are under a red hat and observe two other red hats. The selected player in silo A will play the version of the RHP game where she is under a red hat and $r = 2$.

[28] Whilst the RHP game was ongoing in the experiment, the computers screens were blank for subject who were not selected by the auction or random mechanisms.

Equilibrium The selection mechanism does not affect the equilibrium in the RHP game. All players will expect to resolve their hats in period $r+1$ and bid $b^* = 1000-100r$.[29] The equilibrium payoffs for selected players in the MHUM and MCOM treatments are therefore 1500 points. The payoffs for the selected players in the RHUM and RCOM treatments are calibrated such that they will on average also earn approximately 1500 points.[30]

3.3. DESIGN: OTHER INFORMATION

Subjects in part II interacted in fixed matching groups of 9 participants. We also pre-generated a sequence of states of nature (i.e., hat colours) and administered the sequence to each session.

The experiment sessions took about 120 minutes and the mean earnings in the RCOM, MCOM, RHUM and MHUM treatments were \$19.80, \$20.20, \$19.90 and \$20.10 USD, respectively.[31] In the ex-post experiment survey, subjects also completed the non-incentivised three question cognitive reflective test (CRT, Frederick, 2005) and were asked about any prior familiarity (e.g., heard or know the puzzle) with the RHP game or similar puzzles.[32] We find no significant between-treatment differences in CRT (Fisher exact, $p = 0.721$; mean 2.45).[33] Around, 42%, 48%, 52% and 47% (Fisher exact, $p = 0.889$) of subjects in the RCOM, MCOM, RHUM and MHUM treatments, respectively, indicated that they have heard about the RHP game or similar puzzles.[34] Importantly, these observations suggest that the sample population is broadly similar across all treatments.

[29]If everyone in the bids b^*, then the random and auction mechanism are also identical in sense that players in each silo are randomly selected into the RHP game.

[30]The equilibrium payoff in the RHP game depends only on r. Since each hat has an equal chance of being red or black, a player has a 2/8, 4/8 and 2/8 chance of observing $r = 0$, $r = 1$ and $r = 2$, respectively. The expected earnings in the RHUM and RCOM treatments will therefore be

$$\Pi^* = 620 + \frac{2}{8}(1000) + \frac{4}{8}(900) + \frac{2}{8}(800) = 1520$$

which is very close to the equilibrium payoff for selected players in the MHUM and MCOM treatments.

[31]The experiments were conducted in China. Subjects earnings in parts I (one random round) and II (three random rounds) were converted to cash at the exchange rate of 1 point to 0.02 yuan. In addition, subjects also received a 10 yuan show up payment. The currency exchange rate during the period of the experiment was around USD\$1 to 6.67 yuan.

[32]Due to a software glitch, we failed to conduct the ex-post survey for 2 matching groups (i.e., 18 subjects) in the RCOM treatment. Nevertheless, the glitch did not affect the main experiment.

[33]Mean CRT score in our sample is higher than the original findings by Frederick (2005). This may be because the test is increasingly used in experiments. Indeed, Haigh (2016) find that performances in the CRT increases with prior exposure to the test.

[34]We find no significant correlation between prior familiarity (i.e., heard of the puzzle) and performances in the cognitive reflective test (Spearman, $\rho = 0.051$, $p = 0.479$).

4. RESULTS.

Define a subject to be in *agreement* if she adheres to the equilibrium behaviour in the RHP game given r and her hat colour.[35] Building on this, we define the *agreement frequency* as the proportion of agreement players in the RHP game – a higher agreement frequency indicates lower levels of anomalous behaviour. Finally, we use the short-hand R_0, R_1 and R_2 to denote instances where players observe $r = 0$, $r = 1$ and $r = 2$ red hats, respectively.

To study the influence of market competition, we compare agreement frequencies across the relevant human and computer treatments. Previous RHP game experiments (e.g., Weber, 2001; Bayer and Renou, 2016a) find the R_2 equilibrium solution to be too complicated for the “average" subject. This suggests that if market competition does indeed reduce anomalous behaviour, the reduction should be most prominent for the R_2 case.

4.1. CAN MARKET COMPETITION REDUCE ANOMALOUS BEHAVIOUR?

Panel A of Table 1 details the agreement frequencies in part II of the RCOM, MCOM, RHUM and MHUM treatments.[36] For example, 45 of the 78 randomly selected subjects in the RCOM treatment were in agreement when R_2 is observed (agreement frequency of 0.58). The final row details the *aggregated* agreement frequencies in the respective treatments.

We first focus on the computer treatments (i.e., MCOM and RCOM) where being in agreement only depends on players’ knowledge of the equilibrium solution.

[35] A player who deviates from the equilibrium path is never defined as being in agreement even when it is a logical best response.

[36] Table A1 in the appendix details the agreement frequencies over each round.

	computer			human		
	RCOM	MCOM	z score	RHUM	MHUM	z score
Panel A. *Agreement frequencies (all silos).*						
R_0	1.00 (n=48)	1.00 (n=48)	*na*	0.98 (n=48)	0.95 (n=40)	0.75
R_1	0.97 (n=144)	0.99 (n=144)	1.15	0.93 (n=144)	0.93 (n=120)	0.09
R_2	0.58 (n=78)	0.71 (n=78)	1.67*	0.50 (n=78)	0.85 (n=65)	4.34***
Aggregated	0.86 (n=270)	0.91 (n=270)	1.74*	0.82 (n=270)	0.91 (n=225)	3.06***
Panel B. *Agreement frequencies (competitive silos only).*						
R_0	1.00 (n=48)	1.00 (n=48)	*na*	0.98 (n=48)	0.95 (n=40)	0.75
R_1	0.97 (n=144)	0.99 (n=144)	1.15	0.93 (n=144)	0.93 (n=120)	0.09
R_2	0.63 (n=71)	0.78 (n=69)	1.93*	0.53 (n=74)	0.84 (n=64)	3.96***
Aggregated	0.88 (n=263)	0.93 (n=261)	2.09**	0.83 (n=266)	0.91 (n=224)	2.70***

Note. Each cell on Panels A and B details the corresponding agreement frequency with the number of observations in parenthesis. We also include the z-test score for between-treatment comparison of agreement frequencies. *Competitive* silos are silos which contain at least one sophisticated type.
***, ** and * indicate $p < 0.01$, $p < 0.05$ and $p < 0.10$, respectively.

Table 1: Agreement frequencies (Part II).

Result 1 *Market competition reduces anomalous behaviour in the red hat puzzle game when human players interact with computer-players who are programmed to play the equilibrium.*

Support for Result 1. Aggregated agreement frequencies in the RCOM and MCOM treatments are 0.86 and 0.91 (z-test, $p = 0.081$), respectively.[37] The between treatment differences are mainly driven by the R_2 case where market competition reduces anomalous behaviour in the RHP game by around 31 % – subjects in both treatments were almost always in agreement for the R_0 and R_1 cases.[38] End of round payoffs are significantly higher for selected subjects in the MCOM relative to RCOM treatments.[39]

Equation (1) suggests that players who do not expect to resolve their hat should always end the RHP game in period 1. Indeed, 70% and 73% of “disagreement" (i.e., those who are not in agreement) subjects in the RCOM and MCOM treatments, respectively, ended the RHP game in period 1 when observing R_2. Finally, we find

[37]Unless otherwise stated, all test in this study are two-tailed.

[38]The frequencies of anomalous behaviour in the MCOM and RCOM treatments are 0.29 and 0.42, respectively. Hence, market competition reduces anomalous behaviour by $(0.42-0.29)/0.42 \approx 31\%$.

[39]We use the multi-level random effects model to regress subjects' payoffs on the MCOM treatment dummy – data organised by rounds, subjects and matching groups at the first, second and third levels, respectively. The coefficient for the MCOM dummy is both positive and significant ($p = 0.050$).

little evidence for *learning*. The R_2 case agreement frequencies in the first (resp. last) 5 rounds of RCOM and MCOM treatments are 0.60 and 0.67 (resp. 0.56 and 0.73), respectively.

Building on Result 1, we now turn our attention to the human treatments (i.e., MHUM and RHUM) where being in agreement not only depends on players' knowledge of the equilibrium solution but also the behaviour of the other selected players in the RHP game.

Result 2 *Market competition reduces anomalous behaviour in the red hat puzzle game when human players interact with other human players.*

Support for Result 2. Aggregated agreement frequencies in the RHUM and MHUM treatments are 0.82 and 0.91 (z-test, $p = 0.002$), respectively.[40] The between treatment differences are mainly driven by the R_2 case where market competition reduces anomalous behaviour in the RHP game by around 70% – subjects in both treatments were almost always in agreement for the R_0 and R_1 cases.[41] End of round payoffs are significantly higher for selected subjects in the MHUM relative to RHUM treatments.[42]

Around 44% and 50% of disagreement subjects in the RHUM and MHUM treatments, respectively, ended the RHP game in period 1 when R_2 is observed. Interpretations here are less obvious since subjects may deviate from the equilibrium path in period 2 if they do not believe that they can deduce their own hat colour in period 3 given the actions of others in period 1. Finally, we document little evidence for learning.[43]

Agreement frequencies in the RHUM and RCOM treatments are not significantly different when R_2 (z-test, $p = 0.335$) is observed. In contrast, we find agreement frequencies to be significantly higher in the MHUM relative to MCOM treatment for R_2 is observed (z-test, $p = 0.045$). We reserve further discussion on this matter to Section 4.4.

[40] In Appendix A, we provide further evidence for Result 2 with the group level analysis.

[41] There were only 1 and 2 instances in the RHUM and MHUM treatments, respectively, where subjects were not in agreement when observing R_0. This inevitably resulted in their peers (i.e., those observing R_1) also not being in agreement.

[42] We use the multi-level econometric model to regress payoffs on the MHUM treatment dummy. The treatment dummy is positive and significant ($p < 0.001$).

[43] Agreement frequencies in the first (resp. last) 5 rounds of RHUM and MHUM treatments are 0.43 and 0.83 (resp. 0.54 and 0.85), respectively, when R_2. Weber (2001) also find no evidence of learning in the RHP game when subjects play against other subjects. In contrast, Bayer and Renou (2016b) find some evidence of learning in the RHP game when subjects get to repeatedly play against the computer. However, we recognise that the random mechanism in the MCOM treatment limits subjects' ability to repeatedly play the RHP game.

4.2. HOW DOES MARKET COMPETITION REDUCE ANOMALOUS BEHAVIOUR?

To better understand how market competition reduces anomalous behaviour in the RHP game, we assume that the population of players can be partitioned into *sophisticated* and *unsophisticated* types.[44] Both types know the RHP game equilibrium solutions to the R_0 and R_1 cases. In contrast, only the sophisticated type knows the equilibrium solution to the R_2 case. These assumptions are motivated by the experimental data.

A plausible explanation to Result 1 and 2 is that market competition increases the proportion of sophisticated types entering the RHP game when R_2 is observed. To see this more clearly, we use subjects' behaviour in part I to classify them into types.

4.2.1. SUBJECTS' TYPES.

All subjects played 5 rounds ($1 \times R_0$ round; $2 \times R_1$ rounds; $2 \times R_2$ rounds) of the RHP game against computer-players in part I of the respective treatments without feedback. Around 100% and 92% of subjects were always in agreement for the R_0 and R_1 rounds, respectively. We therefore use their decisions over both R_2 rounds to classify them into types.

- *Sophisticated type*: Subjects who are always in agreement over both R_2 rounds (44% of all subjects) or only in agreement during the second R_2 round (12% of all subjects).[45]
- *Unsophisticated* type: Subjects who are never in agreement over both R_2 rounds (36% of subjects) or only in agreement during the first R_2 round (8% of subjects) – the latter condition assumes that sophisticated types do not make "mistakes".

As can be expected, we find no significant between treatment-difference in the prior distribution of sophisticated types in the RCOM (56%) and MCOM (50%), RHUM (54%) and MHUM (63%) treatments (Fisher Exact, $p = 0.390$). Cognitive reflective test scores are significantly higher for sophisticated relative to unsophisticated types (Mann-Whitney, $p < 0.001$). We find no significant between type differences in prior familiarity with the RHP game (z-test, $p = 0.105$).

[44] We use the term sophisticated and unsophisticated as opposed to rational and bounded-rational as we cannot precisely measure ones rationality. Furthermore, the concept of a rational player may include a broad range of characteristics that may not be fully captured by the RHP game.

[45] The latter condition allows for a minority of subjects to learn about the equilibrium through repeated play even when there is no feedback. The results in this paper also hold if we will use a stricter criteria that sophisticated types are only those who were in agreement over both R_2 rounds. In all but one instance, sophisticated types are always in agreement whenever R_1 is observed (part I).

computer				human		
RCOM	MCOM	z score		RHUM	MHUM	z score
Panel A. *Proportion of sophisticated types amongst subjects who entered the RHP game (part II) in rounds where R_2 is observed.*						
58% (n=78)	72% (n=78)	1.84*		53% (n=78)	89% (n=65)	2.84**
Panel B. *Proportion of sophisticated types amongst subjects who entered the RHP game (part II) in rounds where R_2 is observed (Competitive silos only).*						
63% (n=71)	82% (n=69)	2.35**		50% (n=74)	88% (n=64)	4.63***

Note. Each cell denotes the proportion of sophisticated types with the number of observations in parenthesis. We also include the z-test score for between-treatment comparison of agreement frequencies. *Competitive* markets are markets which contain at least one sophisticated type.
***, ** and * indicate $p < 0.01$, $p < 0.05$ and $p < 0.10$, respectively.

Table 2: Proportion of sophisticated types.

4.2.2. MARKET COMPETITION AND TYPES.

Panel A of Table 2 details the proportion of sophisticated types amongst those who are selected (random or auction) into the RHP game when R_2 is observed.

Result 3 *Market competition increases the proportion of sophisticated types entering the red hat puzzle game when players observe two red hats.*

Support for Result 3. The proportion of sophisticated types entering the RHP game (R_2 case) are significantly higher in the MCOM (72%) treatment relative to the RCOM (58%) treatment (z-test, $p = 0.065$). Likewise, the proportion of sophisticated types are significantly higher in the MHUM (89%) treatment relative to the RHUM (53%) treatment (z-test, $p < 0.001$).

When R_2 is observed in part II, subjects' types are strongly correlated with being in agreement (Spearman's $\rho = 0.638$, $p < 0.001$). The correlation for types and agreement for the R_0 (Spearman's $\rho = -0.118$, $p = 0.111$) and R_1 (Spearman's $\rho = 0.072$, $p = 0.088$) cases are much weaker. Furthermore, we find no significant between-treatment differences in the proportion of sophisticated types entering the RHP game when R_0 or R_1 is observed in the computer (RCOM vs. MCOM; z-test, $p \geq 0.682$) and human (RHUM vs. MHUM; z-test, $p \geq 0.374$) treatments. These observations are consistent with the assumption that both sophisticated and unsophisticated types know the equilibrium solution when R_0 and R_1.

Comment. When R_2 is observed, the optimal strategy is for the unsophisticated types to end the RHP game in period 1. If the sophisticated type in MHUM and RHUM treatments anticipates this, then it may be possible for them to learn about their own hat colour in period 2 through the period 1 deviations of others in rounds where all three hats are red (i.e., the sophisticated type sees $r = 2$) – the equilibrium is for the sophisticated type to resolve her hat in period 3.[46,47] There were 9 and 3 instances where a sophisticated type observing R_2 in the RHUM and MHUM treatments, respectively, ended the RHP game in period 2 after observing that one or more of her opponents had ended the RHP game in period 1. Here, 88% and 67% of the above instances in the respective treatments resulted in the sophisticated type choosing a_R, a strategy that is consistent with resolving one's hat colour through the deviations of others – such instances will not be classified as being in agreement. However, such occurrences were relative rare and do not affect the conclusions from Result 2. For example, if subjects following such a strategy were also classified as being in agreement, the R_2 case agreement frequencies in the MHUM and RHUM treatments will be 0.60 and 0.88 (z-test, $p = 0.0002$), respectively.

4.3. BIDDING BEHAVIOUR.

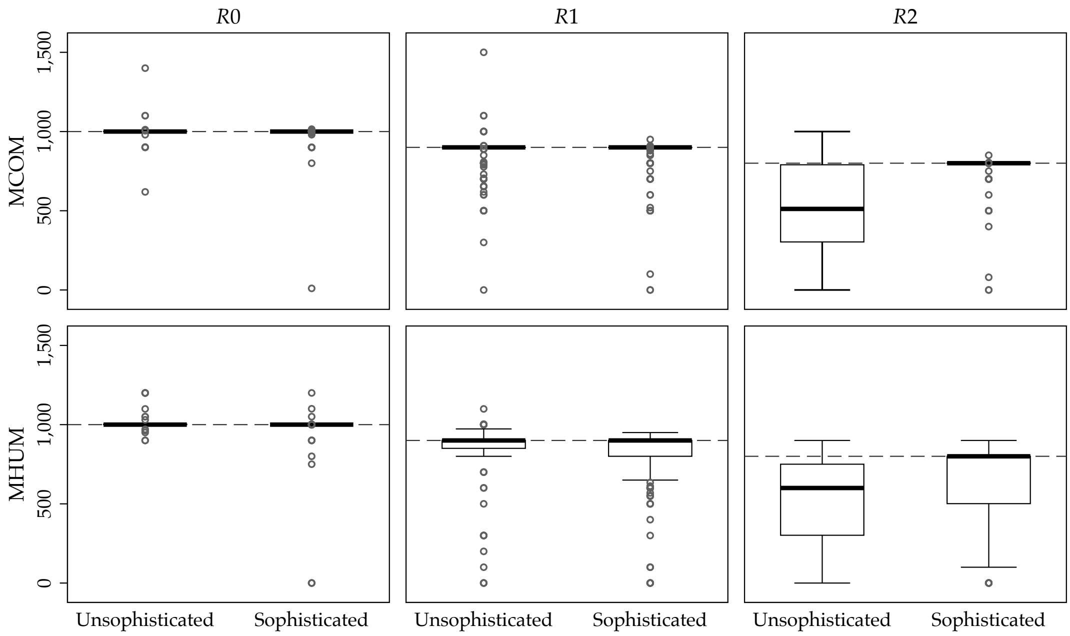
We base Result 3 on our classification of sophisticated and unsophisticated types. This naturally raises the question as to how informative our classification procedures is. This see this more clearly, we focus on subjects' bidding behaviour.

Sophisticated and unsophisticated types are assumed to only differ in their knowledge of the equilibrium solution when R_2 is observed. In the MCOM treatment, selected players also know that they will always play against computer-players (i.e., sophisticated types know that they can resolve their hats in period 3). As such, whilst sophisticated types in the MCOM treatment will always bid the equilibrium (i.e., $b^* = 1000 - 100r$), unsophisticated types in the MCOM treatment will only bid the equilibrium when R_0 and R_1 are observed, and bid lower than the sophisticated type when R_2 is observed.

The boxplots on Figure 2 detail the distribution of bids (in points) by all unsophisticated and sophisticated types (not just those who entered the RHP game) in the MCOM (top row) and MHUM (bottom row) treatments when R_0, R_1 and R_2 are

[46] Suppose that a sophisticated type (say Ann) observing $r = 2$ notices that one other red hat player had chosen a_B or a_R in period 1. Ann immediately deduces that the player must have randomised. However, if Ann also believes that the player randomises become she sees two other red hats, Ann will immediate deduce her hat to be red – she chooses a_R in period 2.

[47] Such concerns will not be relevant in the MCOM and RCOM treatments as subjects interact with computer-players programmed to always play the equilibrium.



Note. We report the bids (denoted in points) of all subjects in the MCOM (top row) and MHUM (bottom row) treatments. The dash horizontal line denote the equilibrium bid price.

Figure 2: Boxplot distribution of bids.

observed – the dash lines denote the equilibrium price.[48] For each subject, we define Δ as the absolute deviation between his bid and the equilibrium price.

Result 4 *Bidding behaviour in the MCOM treatment is consistent with the assumed behaviour of sophisticated and unsophisticated types.*

Support for Result 4. Focusing on the MCOM treatment, we find no significant differences in the bids of sophisticated and unsophisticated when R_0 (Mann-Whitney, $p = 0.289$) and R_1 (Mann-Whitney, $p = 0.743$) are observed. Furthermore, $\Delta \leq 5$ for 86% (resp. 77%) of bids involving the R_0 (resp. R_1) case. Bids are significantly higher for sophisticated relative to unsophisticated types when R_2 (Mann-Whitney, $p < 0.001$) is observed. Here, $\Delta \leq 5$ for 83% and 14% of bids by sophisticated and unsophisticated types, respectively.

The MCOM and MHUM treatments differ in that selected players in the latter will play the RHP game against other human players.[49] This implies that sophisticated types in the MHUM treatment may not always expect to learn about their hat colour

[48]Around 25%, 17% and 21% (resp. 28%, 17% and 8%) of bids in the MCOM (resp. MHUM) treatment occurred above the equilibrium price for the R_0, R_1, and R_2 cases, respectively. However, we note that such bids are very often only marginally higher than the equilibrium price. For example, around 75% of these bids (i.e., those above the equilibrium) are less than 5 points above the equilibrium price.

[49]The bids of sophisticated and unsophisticated types in the MHUM treatment are significantly dif-

when R_1 or R_2 are observed and thus "shade" their bids (i.e., bid less than the equilibrium price). If this is indeed the case, we should expect:

- Sophisticated types: bids are lower in the MHUM treatment relative to MCOM treatment when R_1 and R_2 are observed.
- Unsophisticated types: bids are lower in the MHUM treatment relative to MCOM treatment when R_1 is observed, and equal in both treatments when R_2 is observed.[50]

Result 5 *There is some evidence that human players "shade" their bids when they know that they will interact with other human players in the red hat puzzle game.*

Support for Result 5. Sophisticated types in the MHUM treatment submit significantly lower bids than sophisticated types in the MCOM treatment when R_1 (Mann-Whitney, $p = 0.003$) and R_2 (Mann-Whitney, $p < 0.001$) are observed. The bids of unsophisticated types in the MCOM and MHUM treatments are not significantly different when R_2 is observed (Mann-Whitney, $p = 0.889$). Finally, as expected, bids for unsophisticated types are lower in the MHUM relative to MCOM treatment when R_1 is observed, however, the difference is not significant (Mann-Whitney, $p = 0.486$).

4.4. COMPETITIVE SILOS

A necessary condition for market competition to reduce anomalous behaviour in the RHP game is for the silo to contain at least one sophisticated type.[51] Against this backdrop, we define a R_2 case silo to be *competitive* if it consists of at least one sophisticated type – all silos where subjects observe R_0 and R_1 are always defined as competitive.

Panel B of Table 1 details the agreement frequencies in the respective treatments when only subjects from competitive silos are considered. Consistent with Results 1 and 2, we again find aggregated agreement frequencies to be significantly higher in the MCOM relative to RCOM (z-test, $p = 0.034$) treatment and in the MHUM relative to RHUM (z-test, $p = 0.007$) treatment. However, we now find no significant between-differences in the agreement frequencies between the auction (MCOM vs. MHUM; z-test, $p = 0.367$) and random (RCOM vs. RHUM; z-test, $p = 0.192$)

ferent when R_2 (Mann-Whitney, $p < 0.001$) is observed but not when R_1 is observed (Mann-Whitney, $p = 0.113$). Surprisingly, they are also significantly different when R_0 (Mann-Whitney, $p = 0.023$) is observed.

[50] Strategic uncertainties should only affect bidding behaviour if subjects know the equilibrium.

[51] Experimental limitations restrict the size of each silo to 3 subject. Hence, it is possible for a silo to only contain unsophisticated types.

treatments when R_2 is observed. This suggests that moving from computer-players to human players has no significant influence on agreement frequencies in the RHP game. For completeness, Panel B of Table 2 details the proportion of sophisticated types when only competitive silos are considered.

5. CONCLUSION

In this paper we study whether market competition can reduce anomalous behaviour in games. To do so, we use the red hat puzzle (RHP) game where anomalous behaviour are linked with players' inability to perform the necessary steps of logical and epistemological reasoning. We use an auction mechanism to allocate the participation rights into the RHP game. Our experiment shows that market competition significantly decreases deviation from equilibrium play in the RHP game – this holds independently of whether players in the RHP game interact with human players or computer-players who are programmed to behave rationally.

Taken together, this experiment shows that market competition can reduce individual anomalous behaviour in games. Our findings suggest that individual level bounded rationality does not necessarily falsify the applicability of models that assume fully rational players. This is because with carefully designed incentives, market competition can result in the allocation of decision-making rights (i.e., the rights for performing economic task) to the rational players.

However, our findings do not lead us to conclude that markets can *always* correct or offset individual anomalous behaviours. Firstly, there are some situations (e.g., consumer market) where a market competition for participation rights simply does not exist – players cannot be excluded from the interaction. Secondly, market competition can also exacerbate anomalous behaviour if the bounded-rational players value participation rights more than their rational counterparts.[52] For example, Choo et al. (2019) show that it is possible to incentivise the less rational players to bid higher in auctions and hence increase deviations from the equilibrium in the p-beauty contest (Nagel, 1995) game. Also, markets may not always be desirable. For example, Offerman and Potters (2006) find that auctioning participation rights increases collusion in oligopoly markets. Kogan et al. (2011) find that asset market prices can drive people to coordinate on a less efficient equilibrium.

[52] For example in games that resemble the centipede game, it is possible for the rational player (i.e., one that plays the sub-game perfect equilibrium) to value the participation right less than the bounded-rational players (i.e., one that uses some non-equilibrium model of behaviour).

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ONLINE APPENDIX

A. FURTHER INFORMATION

Table A1 details the agreement frequencies (part II) at each round of the respective treatments. Each cell details the observed number of agreement subjects in the RHP game with the agreement frequency in parenthesis. The final row details the pooled agreement frequencies for the R_0, R_1 and R_2 cases.

For each *group* (i.e., the trio of subjects in the RHP game) let the event *BBB*, *RBB*, *RRB* and *RRR* denote the outcomes where there are zero, one, two and three red hat players, respectively, within the group. Define a group to be in EQ if all subjects are in agreement and the EQ frequency as the proportion of EQ groups. Table A2 details the EQ frequency in the MHUM and RHUM treatments.[53] We see that aggregated EQ frequencies are significantly higher in the MHUM relative to RHUM treatments (z-test, $p = 0.0106$). In fact, the between-treatment differences are driven by the instances where there are at least two red hats (i.e., *RRB* and *RRR*) in the group. In contrast, there are no significant between-treatment differences in EQ frequencies when there are at most one red hat (i.e., *BBB* and *RBB*) hat.

B. COMPUTER RULES

The equilibrium behaviour in the RHP game is for each player to choose a_N at periods $t < r + 1$ and at period $t = r + 1$, choose a_R (resp. a_B) if her hat is red (resp. black). The computer-players are programmed with the following rules:

Rule-1: Choose a_B in period 1 if $r = 0$ and the public signal is “there are no red hats".

Rule-2: Choose a_R in period 1 if $r = 0$ and the public signal is “there is at least one red hat".

Rule-3: Choose a_N in period 1 if $r > 0$.

Rule-4: Choose a_N in period $1 < t < r + 1$ if $r > 0$ and the other red hat player(s) chooses a_N in period $t - 1$.

Rule-5: Choose a_R in period $t = r + 1$ if $r > 0$ and the other red hat player(s) chooses a_N in period $t - 1$.

[53]The measure of EQ frequency is irrelevant in the computer treatments since subjects always interact with computer-players.

	RCOM			MCOM			RHUM			MHUM		
	R_0	R_1	R_2	R_0	R_1	R_2	R_0	R_1	R_2	R_0	R_1	R_2
	♯ of agreement subjects (Agreement Frequency)											
I	6(1.00)	11(0.92)		6(1.00)	12 (1.00)		6(1.00)	11(0.92)		5(1.00)	10(1.00)	
II		12(1.00)	1(0.17)		12 (1.00)	5(0.83)		12(1.00)	3(0.50)		9(0.90)	5(1.00)
III		11(0.92)	4(0.67)		12(1.00)	3(0.50)		11(0.92)	4(0.67)		9(0.90)	4(0.80)
IV	6(1.00)	12(1.00)		6(1.00)	12(1.00)		6(1.00)	12(1.00)		5(1.00)	10(1.00)	
V			13(0.72)			12(0.67)			6(0.33)			12(0.80)
VI		12(1.00)	4(0.67)		12(1.00)	4(0.67)		12(1.00)	3(0.50)		10(1.00)	5(1.00)
VII		12(1.00)	3(0.50)		12(1.00)	6(1.00)		12(1.00)	5(0.83)		10(1.00)	4(0.80)
VIII	18(1.00)			18(1.00)			18(1.00)			15(1.00)		
IX		11(0.92)	2(0.33)		12(1.00)	5(0.83)		11(0.92)	4(0.67)		10(1.00)	4(0.80)
X	6(1.00)	12(1.00)		6(1.00)	12(1.00)		6(1.00)	12(1.00)		4(0.80)	8(0.80)	
XI	6(1.00)	11(0.92)		6(1.00)	12(1.00)		5(0.83)	11(0.92)		5(1.00)	10(1.00)	
XII		11(0.92)	3(0.50)		12(1.00)	4(0.67)		11(0.92)	3(0.50)		10(1.00)	5(1.00)
XIII			11(0.61)			11(0.61)			6(0.33)			12(0.80)
XIV	6(1.00)	12(1.00)		6(1.00)	11(0.92)		6(1.00)	12(1.00)		4(0.80)	8(0.80)	
XV		12 (1.00)	4(0.67)		11(0.92)	5(0.83)		12(1.00)	5(0.83)		8(0.80)	4(0.80)
Total	48(1.00)	139(0.96)	45(0.57)	48(1.00)	142(0.98)	55(0.71)	47(0.98)	134(0.93)	39(0.50)	38(0.95)	112(0.93)	55(0.85)

Note. Each cell denotes the observed number of agreement subjects (selected subjects in part II) with the agreement frequency in parenthesis.

Table A1: Agreement frequencies in Part II over rounds.

Treatment	*BBB*	*RBB*	*RRB*	*RRR*	*Aggregated*
RHUM	1.00 (n=6)	0.97 (n=30)	0.62 (n=42)	0.17 (n=12)	0.70 (n=90)
MHUM	1.00 (n=5)	0.92 (n=25)	0.83 (n=35)	0.80 (n=10)	0.87 (n=75)
z score	NA	0.76	2.03^{**}	2.97^{***}	2.56^{**}

Note. Each cell denotes the proportion of EQ groups with the number of observations in parenthesis. We also include the z-test score for between-treatment comparison of EQ frequencies.
***, ** and * indicate $p < 0.01$, $p < 0.05$ and $p < 0.10$, respectively. respectively.

Table A2: EQ frequencies in the MHUM and RHUM treatments.

Players	Human	Computer	Computer
Hat	Red	Black	Black
Observe	$r = 0$	$r = 1$	$r = 1$
Period 1	a_N	a_N	a_N
Period 2	a_N	a_R	a_R
Period 3	a_R	-	-
Period 4	-	-	-

Table B1: Example 1

Rule-6: Choose a_B in period $t = r + 1$ if $r > 0$ and the other red hat player(s) chooses a_R in period $t - 1$.

Rule-7 Uniformly randomise between a_B and a_R at period $t > 1$ if the above rules cannot be accomplished.

Rules 1–6 imply that the computer-players will best-respond at each period t given their observations r, the public signal and the previous period's actions of the other players. The computer-players may possibly be incorrect about their own hat colour if the human player deviates from the equilibrium path in manner than is undetectable. Table B1 shows one such example. Here, there is only one red hat and each computer player observes $r = 1$. The human player chooses a_N in period 1 (as opposed to a_R). This incorrectly informs the computer players that their hats are red – they had choose a_R in period 2. In period 3, the human ends the RHP game – he observes that the two other computer-players choose a_R in period 2.

Rule 7 imply that the computer-players will randomise if it detects that some player had deviated from the equilibrium path. Table B2 provides an example. Here, the human player chooses a_R in period 1 (as opposed to a_N). This deviation is undetected by the centre computer-player who response by choosing a_B in period 2. In contrast, the right computer-player knows that the human-player has deviated from the equilibrium path. Anticipating that it will no longer be able to resolve its own hat

Players	Human	Computer	Computer
Hat	Red	Red	Black
Observe	$r = 1$	$r = 1$	$r = 2$
Period 1	a_R	a_N	a_N
Period 2	-	a_B	randomise
Period 3	-	-	-
Period 4	-	-	-

Table B2: Example 2

Players	Human	Computer	Computer
Hat	Red	Red	Red
Observe	$r = 2$	$r = 2$	$r = 2$
Period 1	a_N	a_N	a_N
Period 2	a_R	a_N	a_N
Period 3	-	randomise	randomise
Period 4	-	-	-

Table B3: Example 3

colour, it therefore randomises between a_R and a_B.

In Example 3 (Table B3), we see that the human player chooses a_N in period 1 and a_R in period 2. In period 3, the computer-players immediately know that someone had deviated from the equilibrium since it cannot be that one red hat player chooses a_N and the other chooses a_R. The computer players thus randomise in period 3.

C. EXPERIMENT INSTRUCTIONS.

The following subsections detail the translated version of the instructions (the instructions were written in Mandarin). The experiment consist of two parts (I and II) and subjects only received the instructions for part II at the end of part I.

Where necessary in part II, we use "*text*" and "text" to distinguish between portions of the instruction that are unique to the computer (RCOM and MCOM) and human (RHUM and MHUM) treatments, respectively. We also use "text" and "text" to distinguish between portions of the instruction that are unique to the random (RCOM and RHUM) and auction (MCOM and MHUM) mechanism treatments.

Subjects received the instructions for parts I and II on their desk. The experimenter also read the instructions together with the subjects. At the end of each instructions is a set of control questions which the subjects had to correctly answer to begin the experiment.

To ensure readability, all references to Tables, Figures and Section in the instructions will be embedded in the label ordering of the appendix.

C.1. INSTRUCTIONS PART I

First of all, thank you for your participation! Please note that you are not allowed to talk with other participants during this experiment. If you have a question, please raise your hand and we will answer your question in private. In order to minimise distractions, please turn off your mobile phone and put away anything else that could distract you from the experiment (e.g. books, study notes or electronic devices). You are only allowed to use the computer for the purposes of this experiment. Note that violation of these rules may lead to an immediate exclusion from the study and from all payments.

At no time during this study will you learn the identity of the other participants and no other participants will learn anything about your identity. Also, no other participant will learn what you earn during the study: At the end of the study, the amount of money you have earned will be paid out to you in private. Hence, no other participant will know your choices and how much money you earn in this study. If you follow the instructions and apply them carefully, you can earn some money in additional to the 10 yuan show-up fee which we will give you in any case.

The experiment will consist of two parts (Part I and Part II). Your earnings in this experiment will depend on your decisions in Parts I and II. In the following, we present the instructions for Part I of the experiment. The Part II instructions will be available at the end of Part I.

Outcome	$O1$	$O2$	$O3$	$O4$	$O5$	$O6$	$O7$	$O8$
Player A's Hat	Black	Black	Black	Red	Black	Red	Red	Red
Player B's Hat	Black	Black	Red	Black	Red	Black	Red	Red
Player C's Hat	Black	Red	Black	Black	Red	Red	Black	Red

Table C1

C.1.1. PART I.

Part I of the experiment will consist of two practice (nonpaying) rounds and five decision-making rounds. At each round, you will participate in the guessing game and earn points. The amount of points earned will depend on your decisions in the guessing game. At the end of Part I, the computer will randomly pick one of the 5 rounds for payment. Your points in that round will be converted into cash at the exchange rate of 1 point = 0.02 yuan. The instructions are organised as follows:

- Section C.1.2 will detail the guessing game.
- Section C.1.3 will provide further information as to the other participants you will interact with in the guessing game.
- Section C.1.4 is a set of control questions to ensure that you understand the experiment design.

C.1.2. THE GUESSING GAME.

There are 3 players (player A, player B and player C). Each player is given a hat which could either be Red or Black with equal chance. Each player does not observe his own hat colour. Each player observes the hat colour of the other two players. Each player receives a hint about the total number of red hats. There are two possible hints

- Hint 1: There is at least one red hat (i.e., one or more of the players has a red hat).
- Hint 2: There are no red hats (i.e., all players have black hats).

Table C1 provides a summary of all possible outcomes in the guessing game – each outcome is equally likely. Here are some examples to help you better understand the setup of the guessing game.

Example: Suppose that all hats are red (outcome $O8$ on Table C1). Then all players will be informed that “there is at least one red hat". Player A observes that B's and C's hats are red. Player B observes that A's and C's hats are red. Player C observes that A's and B's hats are red.

Example: Suppose that only players A and B have red hats (outcome $O7$ on Table C1). Again, all players will be informed that "there is at least one red hat". Player A observes that B's hat is red and C's hat is black. Player B observes that A's hat is red and C's hat is black. Player C observes that A's and B's hats are red.

Example: Suppose that all hats are red (outcome $O1$ on Table C1) and all players informed that "there are no red hats". Player A observes that B's and C's hats are black. Player B observes that A's and C's hats are black. Player C observes that A's and B's hats are black.

** Reminder. You may sometimes learn about your own hat colour through the hint that receive and your observations about the other players' hat colours. Note that in setting up the guessing game, there is always an equal chance that your hat is red or black.**

Your task in the guessing game is to guess the colour of your own hat. There are 4 guessing opportunities which we call periods (i.e., period 1, period 2, period 3 and period 4). At each period, you will see the question:

"What is the colour of your hat?"

and you can respond with the following choices: (RED) My hat is Red, (BLACK) My hat is Black, (WAIT) I dont yet know the colour of my hat.

The rules are as follows:

- You end the guessing game when (RED) or (BLACK) is chosen. Example: If you choose (RED) in period 1, you end the guessing game in period 1.
- You only proceed to the next period when (WAIT) is chosen. Example: If you choose (WAIT) in period 1, you will proceed to period 2 where you will again see the same question "What is the colour of your hat".
- The choices of all players are public information in the following period. Example: If you are in period 2, you will observe the period 1 choices of the other two players.
- You can only choose between (RED) or (BLACK) in period 4.

Here are some examples to help you understand your task in the guessing game.

Example: Suppose that you are player A and you see that Bs hat is red and C's hat is black. In period 1, you see the question "what is your hat colour" and you choose (RED). You ended the guessing game in period 1.

	Player A (you) Hat colour: ??	Player B Hat colour: Red	Player C Hat colour: Black
Decisions in Period 1	(WAIT)	(RED)	(WAIT)

Table C2

	Player A (you) Hat colour: ??	Player B Hat colour: Red	Player C Hat colour: Black
Decisions in Period 1	(WAIT)	(RED)	(WAIT)
Decisions in Period 2	(WAIT)	-	(BLACK)

Table C3

Example: Suppose that you are player A and you see that B's hat is red and C's hat is black. In period 1, you see the question "what is your hat colour" and you chose (WAIT). In period 2, you will again see the question "what is your hat colour". In addition, you are provided information about the choices of the other players in period 1. Table C2 is an example of what you might observe. Here, you see that player B chose (RED) in period 1. You also see that player C choose (WAIT) in period 1.

Example: Suppose that you are player A and you see that B's hat is red and C's hat is black. In period 1, you see the question "what is your hat colour" and you chose (WAIT). In period 2, you will again see the question "what is your hat colour" and the choices of the other players in period 1. Suppose that you chose (WAIT). In period 3, you will again see the question "what is your hat colour" and the choices of the other players in period 2. Table C3 is an example of what you might observe in period 3. Here you see that player B did not participate in period 2 (i.e., he ended the guessing game in period 1) and player C choose (BLACK) in period 2.

** Reminder: At every period, you will see the decisions of the other players from the previous period. You may possibly learn about your own hat colour through the decisions of others.**

The points that you earn in the guessing game will depend on: (a) The period that you ended the guessing game, (b) Whether you guessed correctly or incorrectly about your own hat colour. Table C4 summarises how your points are computed. You can see that you start the guessing game with 1000 points and receive a 100 points deduction each time you choose (WAIT). When you end the guessing game, you receive no deductions if you guessed correctly. However, you receive a deduction of 700 points if you guessed incorrectly. Here are some examples to help you understand how your points are computed.

	You chose (RED) or (BLACK) and your guess is correct	You chose (RED) or (BLACK) and your guess is incorrect
End guessing game in Period 1	1000 points	300 points
End guessing game in Period 2	900 points	200 points
End guessing game in Period 3	800 points	100 points
End guessing game in Period 4	700 points	0 points

Table C4

Example: Suppose that your hat is Black. You choose (WAIT) in period 1 and (BLACK) in period 2. You receive $1000 - 100 = 900$ points.

Example: Suppose that your hat is Black. You choose (WAIT) in period 1 and (RED) in period 2. You receive $1000 - 100 - 700 = 200$ points.

Example: Suppose that your hat is Black. You choose (WAIT) in period 1 and (WAIT) in period 2 and (BLACK) in period 3. You receive $1000 - 100 - 100 = 800$ points.

Example: Suppose that your hat is Black. You choose (WAIT) in period 1 and (WAIT) in period 2 and (RED) in period 3. You receive $1000-100-100-700 = 100$ points.

** Reminders. Notice from the Table C4 that each player maximises his own points by correctly guessing his own hat colour in the soonest possible period. Hence, it may be possible to learn about your hat colour through the decisions of other players. In setting up the guessing game, there is always an equal chance that you hat is red or black. This means that if you do not know your hat colour but chose (BLACK) in period 1, there is an equal chance that you are correct or incorrect.**

C.1.3. INFORMATION ABOUT THE OTHER PARTICIPANTS THAT YOU INTERACT WITH IN THE GUESSING GAME.

At each round, you will be interacting with computer-players in the guessing game. This means that:

- If you are player A, then players B and C are computers.
- If you are player B, then players A and C are computers.
- If you are player C, then players A and B are computers.

The computer players programmed to be in a similar position as yourself and can never cheat. This means that they observe your hat colour and the hat colours of their fellow computer players but not their own hat colour. Their decisions at each period will depend on the number of black and red hats that they observe, your decisions in the guessing game and the decision of the other computer player in the guessing game.

The computer-players are programmed to: (i) To always maximise their own points, (ii) To always guess their own hat colour in a logical manner. This means that it will base its decisions on the hint received, its observations of the other hat colours and the decisions of the other players in the guessing game.

C.1.4. CONTROL QUESTIONS

Please answer the following control questions on the computer.

Q1. What is the probability that you are given a red hat? (25%; 50%, 75%)

Q2. Suppose that outcome $O3$ (see Table C1) is chosen. Player A will observe a total of ___ red hat(s).

Q3. Suppose that outcome $O8$ (see Table C1) is chosen. Player A will observe a total of ___ red hat(s).

Q4. If you choose (BLACK) in period 1, you will proceed to period 2. (True; False)

Q5. If you choose (WAIT) in period 1, you will proceed to period 2. (True; False)

Q6a. Suppose that you are Player A and you chose (WAIT) in period 1 and (WAIT) in period 2. In period 3, you observe the following (see Table C5). Player C chose (WAIT) in period 1 and (RED) in period 2. (True; False)

Q6b. Player B did not proceed to period 2. (True; False)

Q6c. Player C will proceed to period 3. (True; False)

Q7. Suppose that your hat is red. You chose (WAIT) in period 1 and (RED) in period 2. You receive ___ points.

Q8. Suppose that your hat is red. You chose (WAIT) in period 1 and (BLACK) in period 2. You receive ___ points.

Q9. Suppose that your hat is red. You chose (WAIT) in period 1, (WAIT) in period 2 and (RED) in period 3. You receive ___ points.

Q10. Suppose that your hat is red. You chose (WAIT) in period 1, (WAIT) in period 2 and (BLACK) in period 3. You receive ___ points.

	Player A (you)	Player B	Player C
Decisions in Period 1	(WAIT)	(BLACK)	(WAIT)
Decisions in Period 2	(WAIT)	-	(RED)

Table C5

Q11. At each round of the guessing game, the other participants that you interact with are computer-players. (True; False)

Q12. If you are player A, then Players B and C are computers. (True; False)

Q13. At each period of the guessing game, the computer players are programmed to always submit the most logical decision. (True; False)

C.2. PART II.

Part II of the experiment consists of 2 practice (nonpaying) rounds and 15 decision-making rounds. At each round, you will earn points. The amount of points earned in each round will depend on your decisions in that round. At the end of Part II, the computer will randomly pick 3 of the 15 rounds for payment. Your points in that round will be converted into RMB at the exchange rate of 1 point = 0.02 yuan. The following instructions are organised as follows:

- Section C.2.1 will detail the experimental design of a round.
- Section C.2.2 will provide further information as to the other participants you will interact with in each round in the guessing game.
- Section C.2.3 is a set of control questions to ensure that you understand the experiment design.

C.2.1. DESCRIPTION OF AN EXPERIMENTAL ROUND.

You and two other participants in this room will be randomly paired together to form a group (each group consist of three participants). One participant in your group will receive a ticket. The ticket enables the owner to:

- Participate in the guessing game. That is, only the ticket owner will be one of the Hat-players in the guessing game.
- Receive points from participating in the guessing game.

** Reminder: The guessing game consist of exactly three hat-players. The participant in your group who is allocated the ticket will be one of the three hat-players. We will provide further information about the other hat-players in Section C.2.2 of the instructions. **

There are four stages in each round:

- Stage 1: You are provided some information about the guessing game.
- Stage 2: One participant in your group will receive the ticket.
- Stage 3: The participant with the ticket will participate in the Guessing game.
- Stage 4: The payoffs for all participants are computed.

In the next few pages, we will explain each stage in detail.

STAGE I. Information about the guessing game

As in part I of the experiment, the relevant information about the guessing game is the number of other red hats that you observe and the hint that you receive as a Hat-player in the guessing game. There are three hats (hats A, B and C). Each hat is assigned a colour which can be red or black with equal chance. Your group will be randomly assigned to one of the hats. (remember that You and two other participants in this room will be paired together to form a group).

** Reminder. After this assignment, the hat colour of each hat is fixed for this round. **

You cannot observe your own hat colour but can observe the colour of other hats. In addition, you will also receive the hints:

- Hint 1: There is at least one ted hat amongst the three hats.
- Hint 2: There are NO red hats amongst the three hats.

Suppose that your group is assigned to hat A. This means that all participants in your group (including yourself) will observe the colours of hats B and C (but not hat A). Also, all participants in your group will receive the same hint (either hint 1 or hint 2). Table C6 provides a summary of all possible outcomes.

Example: Suppose that your group is assigned to hat A and the computer chooses $O5$. All participants in your group will observe that hat B and hat C are red and receive the hint that “there is at least one red hat amongst the three hats". However, no participant in your group observes the colour for hat A.

Outcome	$O1$	$O2$	$O3$	$O4$	$O5$	$O6$	$O7$	$O8$
Player A's Hat	Black	Black	Black	Red	Black	Red	Red	Red
Player B's Hat	Black	Black	Red	Black	Red	Black	Red	Red
Player C's Hat	Black	Red	Black	Black	Red	Red	Black	Red

Table C6

Example: Suppose that your group is assigned to hat B and the computer chooses $O2$. All participants in your group will observe that hat A is black and hat C is red. All participants in your group will receive the hint that "there is at least one red hat amongst the three hats". However, no participant in your group observes the colour for hat B.

STAGE II. Allocating the Ticket

After all participants in your group have received the information about the guessing game, the ticket is allocated to one of the three participants within your group.

The tickets will be randomly assigned in your group. In other words, the program randomly picks one of the three participants within your group and gives him a ticket. Please note: Team members who do not receive tickets will receive 1500 points. The team member who gets the ticket will get 620 points of initial points.

We will use an auction to sell the ticket. Each participant is given 1500 points. Thereafter, each participant in your group submits a bid. A bid is the maximum amount you are willing to pay for the ticket.

** Important: The minimal bid amount you allowed to submit is 0 points. And the bid maximum amount you allowed to submit is 1500 points. **

After the all participants in your group have submitted their bids, we will rank all the 3 bids and sell the ticket to the participant with the highest bid. The "ticket owner" (i.e., the participant who receives the ticket) is therefore the participant with the highest bid in your group. However, the ticker owner will only need to pay the second highest bid amount. If there are more than one participant with the same highest bids, the ticket owner will be randomly selected amongst the participants who submitted the highest bids. Table C7 shows three examples to help you better understand how the tickets are sold. In all examples, your group has been allocated to hat A. We therefore label participants A1, A2 and A3 as the first, second and third participant, respectively, in the group.

Example: Participants A1, A2 and A3 submit the bids 100 points, 200 points and 300 points, respectively. The ticket owner is A3 as he submitted the highest bid (i.e.,

	Example 1			Example 2			Example 3		
Participants in your group	A1	A2	A3	A1	A2	A3	A1	A2	A3
Bid (points)	100	200	300	100	200	100	100	200	200
Ranks within each group	3	2	1	2	1	2	2	1	1
ticker owner	A3			A2			A3		
Price paid by ticket owner	200 points			100 points			200 points		

Table C7: Only applicable to the auction mechanism treatments

300 points). The second highest-bid is 200 points. In this example, participant A3 purchases the ticket need only pay 200 points.

Example: Participants A1, A2 and A3 submit the bids 100 points, 200 points and 100 points, respectively. The ticket owner is A2. The second highest-bid is 100 points. In this example, participant A2 purchases the ticket at 100 points.

Example: Participants A1, A2 and A3 submit the bids 100 points, 200 points and 200 points, respectively. Here, the highest bids are submitted by participants A2 and A3 – there is a draw and the computer will randomly determine whether participant A2 or A3 will be the ticket owner. This also means that the highest and second highest bids are both 200 points. In this example, participant A3 is randomly selected by the computer to be the ticket owner. Participant A3 purchases the ticket at 200 points.

** Reminder: Note that ticket holder will never pay more than his bid. In fact, the ticket holder may even sometimes pay less than his bid (i.e., if the second highest bid is less than the ticket holder's bid). **

STAGE III. Participating in the Guessing game

Only the participant with a ticket will participant in the guessing game (i.e., he will be a hat player in the guessing game).

Example: Suppose that participants 1, 2 and 3 are randomly assigned to hat A, and the ticket is sold randomly given to participant 2. This means that participant 2 will be the hat-player A in the guessing game.

Example: Suppose that participants 1, 2 and 3 are randomly assigned to hat B, and the ticket is sold randomly given to participant 2. This means that participant 2 will be the hat player B in the guessing game.

STAGE IV. Computing payoffs

Your points will depend on (a) Whether you received a ticket and (b) If you received a ticket, whether you correctly guess your hat colour in the guessing game. If you

	You chose (RED) or (BLACK) and your guess is correct	You chose (RED) or (BLACK) and your guess is incorrect
End guessing game in Period 1	1000 points	300 points
End guessing game in Period 2	900 points	200 points
End guessing game in Period 3	800 points	100 points
End guessing game in Period 4	700 points	0 points

Table C8

did not receive a ticket, your payoff is 1500 points. If you received a ticket, your payoff depends on your decision in the guessing game with regards to your hat colour i.e., Payoff = 620 + (Points from the guessing game) Table 2 below summarizes the possible revenues in the guessing game.

Your points will depend on (a) Whether you purchased a ticket and (b) If you purchased a ticket, whether you correctly guess your hat colour in the guessing game. If you did not purchase a ticket, your payoff is simply your endowment (i.e., 1500 points). If you purchased a ticket, your payoff depends on the purchase price and your decision in the guessing game with regards to your hat colour i.e., Payoff = 1500 (Ticket purchase price) + (Points from the guessing game)

Table C8 again details the ticket holder's (i.e., the hat player) payoff from the guessing game which depends on the period that the ticket holder ends the guessing game and whether he is correct. Here are some examples to help you better understand how your payoff is computed.

Example: Suppose that participants 1, 2 and 3 are randomly assigned to hat A. Participant 2 enters the guessing game as hat player A (receives the ticket). In the guessing game, hat player A (participant 2) chooses (WAIT) in period 1 and (RED) in period 2. If hat A is red, the payoffs to participants 1, 2 and 3 are: (participant 1) 1500 points, (participant 2) 620+900=1520 points, (participant 3) 1500 points. Note: participants 1 and 2 receive 1500 points as they did not participate in the guessing game.

Example: Suppose that participants 1, 2 and 3 are randomly assigned to hat A, and the ticket is sold to participant 2 at the price of 500 points. Participant 2 enters the guessing game as hat player A. In the guessing game, hat player A (participant 2) chooses (WAIT) in period 1 and (RED) in period 2. If hat A is red, the payoffs to participants 1, 2 and 3 are: (participant 1) 1500 points, (participant 2) 1500-500+900=1900 points, (participant 3) 1500 points. Note: participants 1 and 2 receive 1500 points as they did not participate in the guessing game.

Example: Suppose that participants 1, 2 and 3 are randomly assigned to Hat A.

Participant 2 enters the guessing game as hat player A (receives the ticket). In the guessing game, participant 2 chooses (WAIT) in period 1 and (BLACK) in period 2. If hat A is red, the payoffs to participants 1, 2 and 3 are: (participant 1) 1500 points, (participant 2) 620+200=8200 points, (participant 3) 1500 points.

Example: Suppose that participants 1, 2 and 3 are randomly assigned to Hat A, and the ticket is sold to participant 2 at the price of 500 points. Participant 2 enters the guessing game as hat player A. In the guessing game, participant 2 chooses (WAIT) in period 1 and (BLACK) in period 2. If hat A is red, the payoffs to participants 1, 2 and 3 are: (participant 1) 1500 points, (participant 2) 1500-500+200=1200 points, (participant 3) 1500 points.

C.2.2. INFORMATION ABOUT THE OTHER HAT PLAYERS.

As in part I of the experiment, the other players that assigned to hats besides your group's hat, are computer players.

Example: If your group is randomly assigned to hat A, then the hat A player in the guessing game will be the ticket holder from your group. In contrast, the hat B and C players in the guessing game will be computer players.

Example: If your group is randomly assigned to hat B, then the hat B player in the guessing game will be the ticket holder from your group. In contrast, the hat A and C players in the guessing game will be computer players.

*** Reminder. The computer players programmed to be in a similar position as you. They observe your hat colour and the hat colours of their fellow computer players but not their own hat colour. Their decisions at each period will depend on the number of black and red hats that they observe and the choices that all hat players make across the different periods. Also, the computer hat players are programmed to: (a) Where possible, to always maximise their own payoffs, (b) Where possible, to always predict their own hat colour in a logical manner, (c) The computer hat players cannot "cheat". They will try to correctly predict their own hat through a logical manner. ***

Please note that unlike the first part of the experiment, the other two players who participate in the guessing game are not computer players, but are selected from their respective groups. They are chosen in a similar way to you: they are players in the other two groups that are [randomly selected by the program to get tickets] / [purchased a ticket].

Example: If your group is randomly assigned to hat A, then the hat A player in the guessing game will be the ticket holder from your group. The hat B player: the [randomly selected player] / [player who purchased a ticket] amongst the group of three participants under hat B. The hat C player: the [randomly selected player] /

[player who purchased a ticket] amongst the group of three participants under hat C.

Example: If your group is randomly assigned to hat B, then the hat B player in the guessing game will be the ticket holder from your group. The hat A player: the [randomly selected player] / [player who purchased a ticket] amongst the group of three participants under hat A. The hat C player: the [randomly selected player] / [player who purchased a ticket] amongst the group of three participants under hat C.

C.2.3. CONTROL QUESTIONS.

Please answer the following control questions

Q1. At each round you will be randomly matched with two other participants in this room to form a group. (True/False)

Q2. In each round, your group will be randomly assigned to one hat. (True/False)

Q3. 3. In each round, what is the probability that your group is assigned to a black hat is ___ .