The Winner's Curse: Contingent Reasoning & Belief Formation

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Abstract

Our study compares experimental results from a very simple common-value auction game with results from a transformed version of this game that does not require any conditioning on future events. This transformation allows us to study the importance of this cognitive activity and the role of belief formation in a human subject setting. We observe significant differences in behavior across the two games. In both settings, when facing naïve computerized opponents, subjects' play changes strongly. Overall, the results suggest that both the difficulty of conditioning on future events as well as the challenge to form or evaluate own beliefs explain the frequent occurrences of the winner's curse.

JEL classification: D44, D81, D82

Keywords: Auctions, Winner's curse, Contingent Reasoning, Beliefs

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1 Introduction

The winner's curse (WC) in common-value auctions (CVA) refers to systematic overbidding relative to Bayesian Nash equilibrium that leads to massive losses in laboratory experiments.[1] Not only is this phenomenon one of the most important and robust findings in empirical auction analysis, it has also proven to be difficult to be explained with an empirically valid theory.

Ivanov, Levin and Niederle (2010, henceforth ILN) find evidence against a broad class of "belief-based" models which retain the equilibrium assumption that players best respond to – possibly erroneous – beliefs, such as cursed equilibrium (Eyster and Rabin, 2005), level-k theory (Crawford and Iriberri, 2007) or analogy-based expectation equilibrium (Jehiel, 2005). Charness and Levin (2009) document the difficulty of conditioning on information from hypothetical events, suggesting an explanation that is independent of beliefs. In a reanalysis of ILN's data, however, Camerer, Nunnari and Palfrey (2012) propose an explanation on the basis of Quantal Response equilibrium (QRE), suggesting that imprecise best responses combined with non-equilibrium beliefs could explain the observed behavior.

This discussion shows that the fundamental explanation of the WC is still to be found. A major challenge in the experimental investigation is to disentangle the role of belief formation, conditional reasoning, and best response behavior, ideally in a standard CVA conducted among human subjects. For example, due to the interaction between belief formation and conditional reasoning, Charness and Levin (2009) resort to individual choice settings with computerized opponents in order to control beliefs.

In this paper, we intend to make a step towards illuminating the processes behind the WC. As a starting point, we use a simple first-price CVA adapted from Kagel and Levin (1986). At the core of our investigation, we then propose a transformation of this game that removes the need to engage in conditional reasoning but maintains the strategic nature of the original auction game, that is, optimal strategies and equilibria. In addition to this variation, we manipulate the belief formation in two ways: Strongly – by implementing naïve computer opponents, and more subtly – by analyzing play against human subjects subsequent to play against the naïve computer. Overall, these measures allow us to quantify the influence of conditional reasoning and belief formation on bidding behavior.

We obtain two main results. First, in the transformed game – without the need to condition on winning – subjects avoid the WC to a larger extent than in the original auction. Hence, adding to the results of Charness and Levin (2009), this result shows that contingent reasoning on hypothetical events plays a major role for the WC also in

[1] See Bazerman and Samuelson (1983), Kagel and Levin (1986), Avery and Kagel (1997), Goeree and Offerman (2002), Lind and Plott (1991), Grosskopf et al. (2007), and the literature discussed in Kagel and Levin (2002).

settings with human opponents. Second, however, it is not the only obstacle in avoiding the WC. When playing against a computer that bids naïvely according to the signal, participants bid significantly lower than in the setting with human opponents, irrespective of the transformation. Contrary to the theory of Camerer et al. (2012), this seems to suggest that best responding precisely is not particularly problematic, the belief formation seems to be a much bigger challenge. The role of belief formation is further reflected in the significantly improved performance against human subjects subsequent to playing against a naïve computer opponent with a known strategy. Interestingly, this external "support" in belief formation is especially influencing those subjects that are able to best respond against the computer opponents.

Overall, we infer that subjects do not only struggle to form correct beliefs, they seem to struggle to form any belief in this kind of auction. The necessity to condition on the event of winning reinforces this problem. As it is impossible to condition on winning without a starting belief and as the necessity to condition makes forming beliefs more difficult, the two processes apparently form a nexus of interdependencies that is difficult for subjects to think about. In CVAs, as opposed to other settings, very few subjects therefore reach a belief-based decision.

Besides the already mentioned papers, our study is closely related to Levin and Reiss (2012). The authors construct a behavioral auction design in which the payment rule incorporates the adverse selection problem that is at the origin of the WC. They observe that the WC is still present in their data. The authors adjust the payment rule but do not transform the auction game as we do.

Due to our use of two basically equivalent games, our paper relates to the broad set of studies that investigate behavior using strategically equivalent games. The largest fraction of those studies considers framing effects that influence subjects' behavior but do not result from the structural nature of the situation (for example Tversky and Kahneman, 1986; Osborne and Rubinstein, 1994). Another methodologically interesting instance is the experimental, so-called "strategy method" in which participants make contingent decisions for all decision nodes they will possibly encounter in a game (Brandts and Charness, 2011). In a different manner, equivalent versions of common games can facilitate the investigation of particular aspects of behavior. For example, Nagel and Tang (1998) use a repeated, normal-form centipede game to investigate learning behavior without aspects of sequential reciprocity. In our study, we craft two equivalent games that differ in the required cognitive processes under investigation: conditional reasoning. To the best of our knowledge, our experiment is the first that uses such a transformation as a means to investigate the impact of a particular cognitive activity in strategic reasoning.

The rest of this paper is organized as follows: Section 2 describes the experimental design and our hypotheses. Section 3 provides our experimental results and Section 4 concludes.

2 Experimental Design and Hypotheses

In our experimental design, we will use two different games: a simplified standard *auction game* and a *transformed auction game* that does not require subjects to condition their decisions on the hypothetical event of winning the auction. The starting point for both games is a standard first-price CVA setting as in Kagel and Levin (1986). There are n bidders and a common value of the auctioned item $W^* \in [\underline{W}, \overline{W}]$ which is the same for each bidder. Each bidder receives a private signal $x_i \in [W^* - \delta, W^* + \delta]$, with $\delta > 0$. Bidders make bids in a sealed-bid first-price auction in which the highest bidder wins the auction and pays his bid. The available actions are $a_i \in [\underline{W}, \overline{W}]$. The payoff of the highest-bidding player who wins the auctions is $u_i = W^* - a_i$. In case a bidder does not make the highest bid his payoff is $u_i = 0$.

2.1 The Games

Simplified Auction Game

We simplify this general setting mainly by allowing only for two signals and by restricting the number of subjects who bid for the commodity to two. Additionally, bidders receive a private binary signal $x_i \in \{W^* - 3, W^* + 3\}$ and this signal is drawn without replacement. Hence, bidders know that the other bidder receives the opposite signal but do not know which. The common value W^* is randomly drawn from the interval $[25, 225]$. To rule out mixed strategy equilibria we only allow absolute bids $a_i \in [x_i - 8, x_i + 8]$. As a tie-breaker in case of identical bids the lower signal player wins the auction.

In order to analyze the structure of this simplified auction game and to easily relate it to the transformed game we express strategies in relative bids $b_i = a_i - x_i$, the difference between the absolute bid a_i and the individual signal x_i. For simplicity, we will call these relative bids just "bids" in the remainder and always specify when we talk about *absolute* bids. Relative to the other player's bid b_j, three general options exist for player i.[2] First, if player i overbids j by at least 6 units – the distance between signals – he always wins the auction irrespective of him receiving the higher or lower signal. Second, by the same token, if player i underbids j by at least 6 units he never wins the auction. Finally, if player i bids less than 6 units apart from player j's bid he only wins the auction when he has received the higher signal, not when he receives the lower signal. Within this range, bidding $b_i = b_j - 6 + \epsilon$, with $\epsilon > 0$ and small, is optimal. Figure 1 illustrates the three possible constellations.

[2]For convenience, we consider a male player i and his female opponent j.

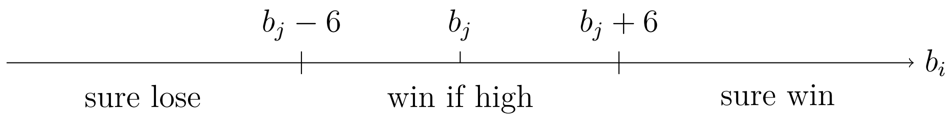

Figure 1: Three areas of relative bids b_i.

Transformed Auction Game

The transformed game is a common-value auction without private signals in which the rules of winning mimic the structure of the auction game described above. It therefore results in the exact same situation as depicted in figure 1.

Two players are informed of the two potential values the item can have, W_1^* or $W_2^* = W_1^* + 6$. In analogy to the auction game, the ranges of the values are $W_1^* \in [25, 219]$ and $W_2^* \in [31, 225]$. Subjects are allowed to absolutely underbid W_1^* by 5 units and absolutely overbid W_2^* by 5 units, $a_i \in [W_1^* - 5, W_2^* + 5]$. To see the parallels to the auction game, note that the average value of both subjectively possible common values corresponds to the value of the private signal in the auction game and the values W_1^* and W_2^* correspond to the possible values of the item from the point of view of this signal. Relating the relative bids b_i to the average of both common values, $b_i = a_i - \frac{W_1^* + W_2^*}{2}$, we again have $b_i \in [-8, 8]$, as in the auction setting. In this formulation of the game, which of the two common values arises for which player depends on chance and on the bids of the two players, exactly following the structure of the auction game and figure 1.

If player i overbids player j by at least 6 units, he wins the auction for sure and for him both values realize with probability of 0.5 (sure win). Conversely, if player i underbids player j by at least 6 units, he does not win the auction and his payoff is 0 for sure (sure lose). Lastly, if the difference between both players' bids is smaller than 6 units, with 0.5 probability player i or player j wins the auction and realizes the *smaller* value W_1^* (win if high). The loser obtains a payoff of 0.

Note that these rules already incorporate the conditioning on the event of winning in the "win if high" rule. Overall, the general design and the rules of the transformed game simply make explicit what in the auction game is implicitly given and has to be understood by the subjects.

2.2 Transformation

The transformation as presented here is designed to remove the need to condition on winning. It is done in a way that the players' make the same optimal bids and face identical uncertainty. However, transforming the auction in this fashion changes a game with private information into one without. In contrast to the original auction, the bidders in the transformed auction have common knowledge that the value of the item is either

W_1^* or W_2^*.[3] The transformation therefore not only removes the need to condition, it also changes the information sets of the players.

We implement this transformation for two reasons. First, there are convincing arguments and evidence that, in contrast to the differential need to engage in conditional reasoning, the particular differences in the informational structure between the games do not influence the behavior of the experimental subjects. The equilibrium consists of strategies of constant relative bidding, irrespective of the absolute realization of the signal.[4] The observed behavior is in accordance with this equilibrium prediction. There is therefore no reason and no incentive to differentiate potential opponents with higher and lower signals. Then, based on observed actions, there is evidence that a large majority of subjects does not form beliefs. Hence, these subjects surely did not get to the point where they even differentiate between opponents with different signals. From a pilot study, we have evidence that the few subjects who indeed form beliefs and deliberate about their opponent's behavior do so without differentiating the absolute value of their opponent's signal.[5] Finally, in the computer treatments the games only differ in the need to condition and yield similar differences as in the human opponent setting.

Second, while it is in principle possible to implement the transformed game as a fully strategically equivalent game, this would be very complicated to implement experimentally. Such a game would use the standard signal structure but replace the auction rule with rules set in terms of relative bids like in the transformed game. It follows that the description of the game setting would be in absolute bids, whereas the rules would use a relative perspective. Finally, profit calculations would again have to rely on absolute bids. Implementing and describing these changes of perspective would be very cumbersome and also constitute a major difference to the intuitive standard auction. A deterioration of the bidding behavior would not be attributable to the conditioning. Furthermore, it would not be certain that the subjects indeed approach the game in terms of the described rules and not according to the equivalent, standard rules they may know intuitively. It is an advantage of our transformation that it generates a distinct setting that is not perceived as a standard auction.

[3] To see that the auction does not lead to common knowledge of the possible values of the item note the following. The signal x_i implies an information set composed of the following two value and signal pairs: $\{(x_i - 3, s_i = \text{high}), (x_i + 3, s_i = \text{low})\}$. These two indistinguishable cases imply the following beliefs about the information set of the opponent j expressed in terms of x_i, $\{(x_i - 3, s_j = \text{low}), (x_i - 9, s_j = \text{high})\}$ when $s_i = \text{high}$ and $\{(x_i + 9, s_j = \text{low}), (x_i + 3, s_j = \text{high})\}$ when $s_i = \text{low}$. It can be seen that higher order beliefs diverge further.

[4] We disregard in the experiment a small range of signal values close to the boundaries for which the equilibrium strategies do not feature this property.

[5] In a trial session, we implemented the auction game with a communication design similar to Burchardi and Penczynski (2014). In this setting, groups of two communicate about the bidding decision in a way that subjects have an incentive to share their reasoning about the game. The minority of subjects that form beliefs about how others potentially bid does not allude to the possible absolute values of the signal. Furthermore, no subject is concerned with boundary signals and their implication for their own bidding strategy.

2.3 Equilibrium

To find the equilibria of the auction game, consider the best response function to the opponent's bid b_j. If player j bids high values, $b_j \in [3, 8]$, it is optimal for player i to follow the second option and never win the auction. In this case, winning the auction would result in weak losses for sure because the opponent is bidding – even with the lower signal – at least the commodity's value. Hence, the best response is to bid anything that is relatively below the opponent's bid by at least 6 units, $BR(b_j) \in [-8, b_j - 6]$.

If player j bids values $b_j \in [-8, 3]$, it is optimal for player i to relatively underbid the opponent by slightly less than 6 points, making sure that he only wins the auction when he has received the higher signal. Hence, the best response function is $BR(b_j) = b_j - 6 + \epsilon$. By construction, player j cannot bid low enough to cause a best response of overbidding by at least 6 and thus surely winning the auction. Only if $b_j \leq -15$ was possible, the best response would be $BR(b_j) = b_j + 6$ since it would be more profitable to surely win than to only win with the high signal.

With the best responses being either to underbid by at least 6 or by nearly 6, the unique equilibrium is for both players to bid $b_i = b_j = -8$. Players then only win the auction when they receive the higher signal, leading to an expected payoff of $Eu_i = \frac{1}{2}(-3 - b_i) = 2.5$. If player i, however, deviated to "sure win" bidding $b_i = b_j + 6 = -2$, he would only receive an expected payoff of $Eu_i = \frac{1}{2}(-3 - b_i) + \frac{1}{2}(+3 - b_i) = \frac{1}{2}(-1 + 5) = 2$.

Additionally, subjects always have incentives to deviate from any pair of strategies in which not both subjects bid $b_i = b_j = -8$. When both players bid higher values than -8, at least one player has an incentive to underbid the other player because, as outlined before, best responses are either underbidding by at least 6 or nearly 6 (if such an underbidding is possible). These underbidding incentives only vanish when no underbidding is possible any more and subjects bid -8. If only one player bids more than -8, this player has an incentive to also bid -8 because of the outlined best response functions. By construction of the transformed game, the equilibrium is the same as in the auction game: underbidding by $b_i = -8$ corresponds to an absolute bid of $a_i = W_1^* - 5$.

These equilibrium considerations so far do not take into account that subjects receiving a signal close to 25 or 225 can infer the commodity's real value. This might not only influence those subjects' strategies that receive signals close to 25 or 225, but through higher order beliefs it could also influence those subjects' strategies that receive signals well within the interval $[25, 225]$. In Appendix A.3 we show, however, that this influence vanishes very quickly and that $b_i = -8$ remains the equilibrium strategy for all realizations of the commodity's value that occur in the experiment.

2.4 Experimental Design

The specific games implemented in the experiment differ along 2 dimensions. First, we implement the described simplified auction game and the transformed game to pick up difficulties due to conditional reasoning.

Second, to investigate the belief formation, we not only confront subjects with fellow human opponents but also implement both games with naïve computerized opponents. Subjects are informed that the computer follows the strategy $b^C = 0$, implying that she absolutely bids exactly according to her signal or the expected value of the item, respectively. These computerized games remove strategic uncertainty and the subjects' need to form beliefs. By themselves, they allow to observe whether subjects are able to best respond in the two forms of the game. The best response turns out to be $BR(b^C) = -5.99$ (win if high) as the experiment subjects have to round their bids to one cent of a unit. In combination with a subsequent game against the human opponent (AH, TH), the computerized treatments helps subjects to have a starting point for thinking about humans.[6]

Our experiment consists of four treatments that differ in the sequence of the specific games played: the *AH (AuctionHuman)*, the *TH (TransformedHuman)*, the *AC (AuctionComputer)*, and the *TC (TransformedComputer)* treatment. The treatment name is derived from the first game in each treatment. The treatments are divided in parts I and II, the *AH* treatment starts with the auction game in part I and has the transformed game in part II. In the *TH* treatment, this sequence is reversed. Within each part of these two treatments, the opponents switch from human to computer opponents. Subjects are informed about the computer opponent only after they have finished the initial three periods. In the *AC* and *TC* treatments the switch is reversed from computer to human opponents. Figure 2 illustrates the sequence of events in all four treatments.

In all treatments, the general instructions and the instructions for the games are read aloud. Subjects play each specific game for three consecutive periods against randomly chosen subjects or the computer. Subjects are informed that they will first make all 12 decisions in the experiment before receiving any feedback.[7]

In the auction, we implement a common value that is a random variable uniformly distributed over $[45, 205] \subset [25, 225]$ and accordingly in the transformed game. We do this in order to avoid common values near 25 or 225 for which subjects could draw inferences from their signal about the true value. We truthfully communicate to subjects that values

[6]We deliberately do not implement a more complex or realistic strategy for the computerized opponents since subjects do not have to be able to best respond to complex belief distributions in the human opponent games either. When subjects realize in a first step that underbidding by $BR(b^C) = -5.99$ is the best response to naïve play, they might recognize the equilibrium strategy in a second step.

[7]Because subjects do not receive any feedback after playing one period, in principle, it would have been possible to just implement one period per game. However, implementing three periods allows us to see whether subjects consistently play the same strategy across three periods as well as for different values of the signal.

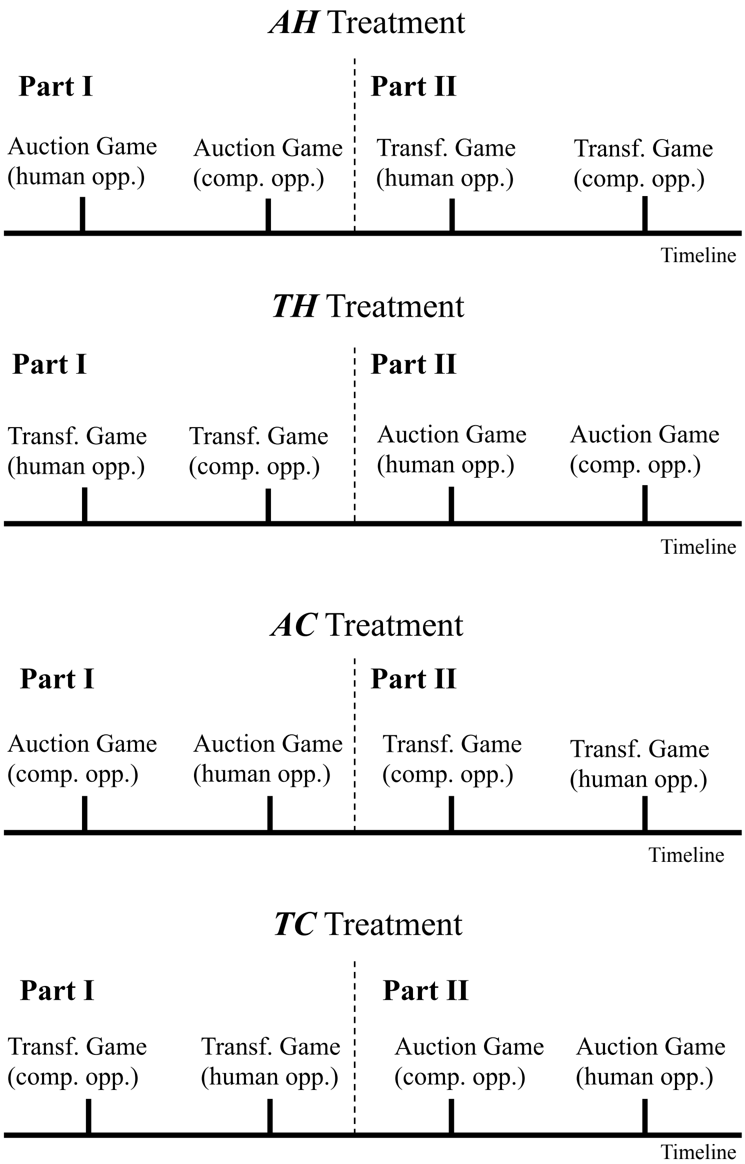

Figure 2: Sequence of games in the four treatments.

are no lower than 25 and no higher than 225.

2.5 Hypotheses

In the main text, we will focus on analyzing subject's behavior in Part I of the four treatments. Appendix A.4, however, provides an analysis of the data of part II. There, we derive hypotheses about learning patterns across treatments depending on the relevance of conditional reasoning and belief formation.

Our first hypothesis focusses on the role of conditional reasoning. If the operation of conditioning on the hypothetical event of winning is a major obstacle to forming beliefs and best responding – as suggested by Charness and Levin (2009) – we should observe that subjects in the transformed game (*TH*) are to a larger extent able to avoid the WC due to lower bids than in the auction game (AH). To the extent that the influence does not only work through the belief formation, this difference will not only arise in the human opponent games but also when the two games are played with a transparent, computerized opponent.

> ***Hypothesis 1 (Conditional reasoning):*** *Due to the cognitive ease, subjects make lower bids and avoid the WC more often in the transformed game compared to the auction game, both with human and computerized opponents.*

We will mainly analyze this hypothesis by a between-subject comparison of the first (and the second) game of the AH and the TH treatment. Moreover, comparing the second (and the first) games of the AC and the TC treatment provides an additional control.

Hypothesis 2 relates to the possibility that with human opponents both strategic uncertainty and belief formation present an independent obstacle to avoiding the WC in themselves. We will analyze two manipulations, this hypothesis is thus divided into two parts, (a) and (b).

In the games against computer opponents, neither strategic uncertainty nor belief formation can prevent to best respond correctly. Therefore, analyzing how subjects' behavior is different when facing a computer opponent compared to facing a human opponent reveals the relevance of these characteristics. We can make this comparison of the two settings by a within-subject analysis for the AH and the TH treatment. Additionally, using the AC and the TC treatment, we can corroborate our finding also between-subject. Our hypothesis 2 follows Ivanov et al. (2010) who provide evidence against "belief-based" models and whose results suggest that subjects have a more general problem to form beliefs about their opponents at all.

> ***Hypothesis 2a (Belief formation, upper bound):*** *In each game, subjects make lower bids and avoid the WC more often when playing against computerized opponents than when playing against human opponents.*

The comparison in hypothesis 2a delivers an upper bound on the relevance of belief formation since both strategic uncertainty and belief formation do not play a role in the computerized games.

We provide a weaker test for the relevance of belief formation by giving subjects a hint for starting thinking about their opponents. In particular, in the AC and TC treatment subjects face human opponents *after* they played against computerized opponents. Thus providing subjects with a starting point for their belief formation diminishes the belief formation problem in the presence of strategic uncertainty. This comparison provides a lower bound on the relevance of belief formation since far from all aspects of belief formation are removed. Importantly, in the AC treatment, subjects might not only improve their behavior because a starting point for their beliefs improves their belief formation process, but they might also learn how to condition on the event of winning by playing against human opponents first. Treatment *TC* allows us to tell these two possibilities apart.

> ***Hypothesis 2b (Belief formation, lower bound):*** *Subjects make lower bids and avoid the WC more often in the auction or transformed game with human opponents if this game is played after the setting with computerized opponents compared to when it is played first.*

The experiments were conducted at the University of Mannheim in Spring and Autumn 2014. Overall, 12 sessions with 10 to 22 subjects in each session were run. In total, 182 subjects participated.[8] Participants received a show-up fee of 4€. We used *Taler* as an experimental currency where each Taler was worth 0.50€. Subjects received an initial endowment of 8 Taler in Part I and II of the experiment from which losses were subtracted and to which gains were added. Even if participants made losses in both parts, they kept their initial show-up fee. Sessions lasted on average 60-75 minutes and subjects earned on average 14.40€.

3 Results

In the following, the results are presented in terms of subjects' bids and payoffs. The summary statistics and tests use the average bids and payoffs over the three periods of each specific game. Only the percentage of incidences of winners incurring losses is calculated using the per period information.

In addition to their mere magnitude, we distinguish bids in four categories by whether they can be a valid best response. In the human subject games, the important thresholds are at $b_i = -8, -5, -3$. The first category is playing the equilibrium, bidding $b_i = -8$.[9] The next threshold is the best response to a naïve strategy, $b_j = 0$, which we round up from the precise value $b_i = -5.99$ to $b_i = -5$ because some subjects do not bid non-integer values. Finally, for any belief, bidding $b_i > -3$ yields a weakly lower expected payoff than bidding less. Whenever j bids very high values ($b_j \geq 3$) no positive payoffs can be obtained. Positive payoffs can be achieved for lower bids of j only by bidding lower than -3. Overall, we think that bids $b_i \in [-8, -5]$ represents plausible behavior. Bids $b_i \in (-5, -3]$ might still be a best response to some forms of implausible beliefs, while bids above are dominated by other bids when positive payoffs are possible.

[8] The experimental software was developed in z-Tree (Fischbacher, 2007). For recruitment, ORSEE was used (Greiner, 2004).

[9] Actually, given the empirical distribution of subjects' behavior in each treatment, equilibrium play is not a best response, but it is close. In the auction game, bidding $b_i = -7.97$ is the best response. In the transformed game, bidding $b_i = -7.99$ is the best response.

Table 1: Summary Statistics - *AH* & *TH* Treatments.

Means (Std. deviation)		*AH* Auction game	*TH* Transf. game	Wilcoxon rank sum *p*-value
Human opponents	Bids	–1.80 (2.63)	–4.00 (2.61)	0.000
	Payoffs	–0.56 (1.55)	0.55 (1.37)	0.001
Comp. opponents	Bids	–3.37 (3.30)	–5.00 (2.53)	0.007
	Payoffs	0.17 (1.53)	0.81 (1.56)	0.004
Wilcoxon signed rank (within treatment)	Bids	0.000	0.020	
p-value	Payoffs	0.001	0.184	

Notes: The last column reports two-sided *p*-values of Wilcoxon rank sum tests that evaluates whether the distribution of bids and payoffs is different between treatments. The last rows report two-sided *p*-values of Wilcoxon signed rank tests that evaluate whether the distribution of bids and payoffs is different within-subject between the human and the computerized setting.

For the games against computer opponents, a similar picture emerges in which we distinguish precise and approximate best response behavior, $b_i = 5.99$ and $b_i \in (5.99, 5]$, respectively, from non-best response behavior $b_i < -5.99$ and $b_i > -5$.

3.1 Hypothesis 1

We will first analyze subjects behavior in part I of the *AH* and *TH* treatment. In the auction game with human opponents, 61% of all subjects who win the auction incur a loss whereas only 32% of subjects in the transformed game do so. In line with these observations, in the auction game with computerized opponents, 45% of those subjects who win the auction game face a loss whereas only 13% of those subjects do so in the transformed game. These outcomes follow from bidding behavior illustrated in Table 1 on page 12. Both against human and computerized opponents, average bids are significantly lower and thus closer to the equilibrium or best response in the transformed game compared to the auction game. The differences in payoffs are significantly different irrespective of the opponents. Against human opponents, subjects lose money in the auction game while they win money in the transformed game.[10]

[10]The figures of table 1 provide evidence against the idea that differences in the informational structure of the auction and the transformed game lead to behavioral differences in these games. First, there is a significant difference between the auction and the transformed game in the version with computerized opponents. With computerized opponents, higher order beliefs in the auction game, however, do not matter, because the computer follows a known and fixed strategy in both games. Second, although the magnitude of the difference between the two games is slightly larger in the version with human opponents compared to computerized opponents (2.2 vs. 1.6) it is still roughly of the same size, suggesting that at least the main difference between the two games is with respect to conditioning not the informational

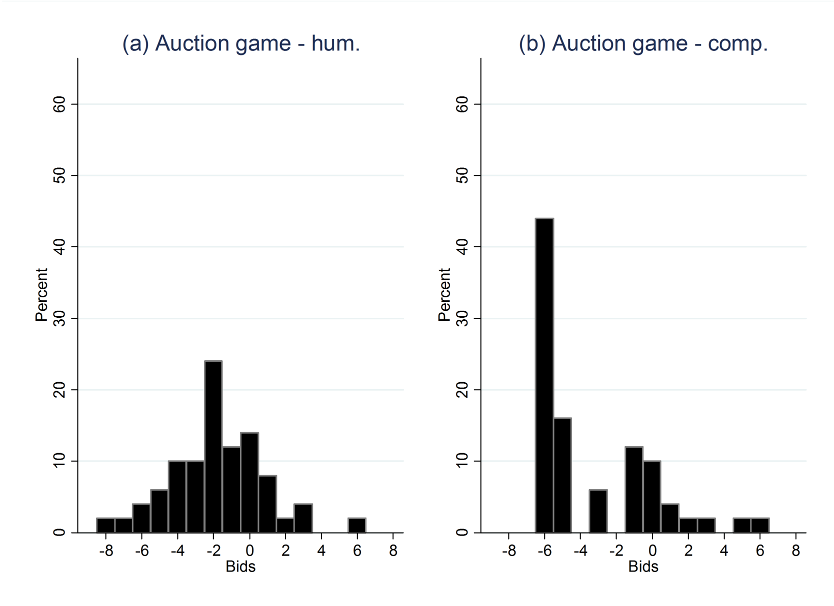

Figure 3: AH Treatment - Bids (Part I), $N = 50$.

Figures 3 and 4 report subjects' bid distributions in Part I of the AH and TH treatments. The histograms in figure 3(a) and 4(a) reflect that subjects play lower bids more often in the transformed game than they do in the auction game. Actually, the bidding behavior in the auction game to some extent gives the impression of normally distributed bids that do not reflect the equilibrium of $b_i = -8$ at all, whereas bidding behavior in the transformed game seems to at least partially reflect that the equilibrium is the lowest possible bid. For computerized opponents, figures 3(b) and 4(b) show that a larger number of subjects is able to find the best response when strategic interaction with human opponents is absent.

Table 2 distinguishes bids against human and computerized opponents for the AH and the TH treatment by category (**Total** columns and rows) and additionally shows the within-subject bid transition between the human and the computerized setting.

We first focus on the categorization of bids: For the games with human opponents, the table reveals that 39% of subjects (18 of 46) bid plausibly ($b_i \in [-8, -5]$) in the transformed game while only 12% (6 of 50) do so in the auction game (Fisher's exact test, $p = 0.001$).[11] A similar picture arises for the games with computerized opponents in which either the precise or the approximate best response is played by 54% of subjects (27 of 50) in the auction game and 80% (37 of 46) in the transformed game (Fisher's exact test, $p = 0.012$). Hence, even if subjects exactly know how their opponents react, conditioning on the event of winning still seems to be a problem at least for some subjects. All the reported results are in general robust when using the AC and the TC instead of the AH and the TH treatments, although the results for the computerized setting are slightly less

structure.

[11]All reported tests in this paper are two-sided.

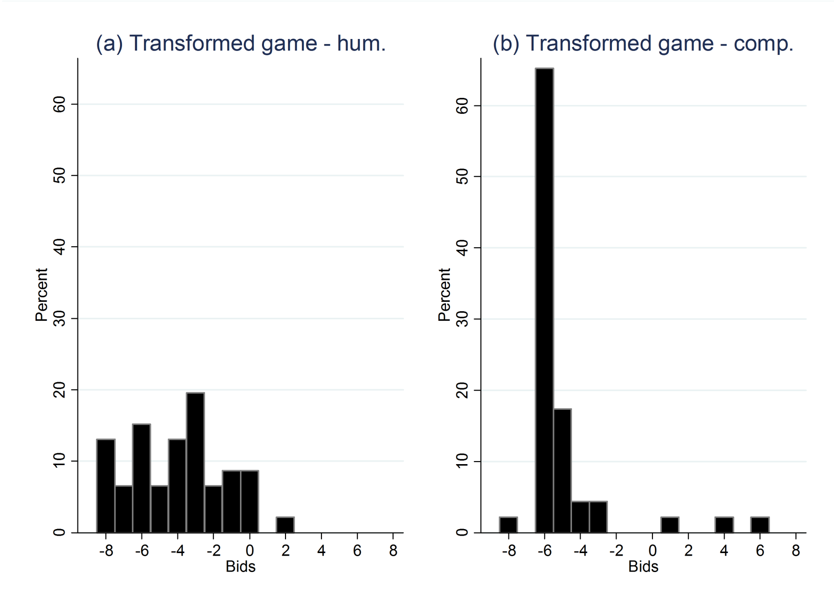

Figure 4: *TH* Treatment - Bids (Part I), $N = 46$.

significant. This might reflect that even in the computerized version of the auction game subjects already bid not too far away from the equilibrium, which makes it more difficult to improve subject's behavior.[12]

To conclude the analysis, we analyze the within-subject behavior for the two types of opponents. Table 2 gives the precise numbers by category. For clarity of exposition, the graphical illustrations with the bids against humans on the horizontal and against computers on the vertical axis are placed in appendix A.2 on page 24. Figures A.3 and A.5 show the data for the *AH* and *TH* treatment, respectively.

Two important differences are apparent. First, 19 subjects in the auction game play bids in the top-right quadrant, that is, higher than -3 against human opponents and higher than -5 against computerized opponents. This seemingly random bidding around 0 is less common in the transformed game where only 5 do this, highlighting again the detrimental effect of conditioning on equilibrium play. Second, of those 27 playing a reasonable response to the computer ($b_i \in [-5.99, -5]$), 17 (63%) subjects bid previously above -3 and thus a weakly dominated strategy in the auction game while only 30% do this in the transformed game. This suggests that beyond the ability to best respond, the conditional reasoning increases the difficulty of belief formation. In the auction setting,

[12]Comparing the games with computerized opponents, subjects' bids are lower (Wilcoxon rank sum, $p = 0.079$) and subjects' payoffs are significantly higher (Wilcoxon rank sum, $p = 0.099$). Additionally, more subjects play plausibly, $b_i \in [-5.99, -5]$, in the transformed game than in the auction game (Fisher's exact test, $p = 0.090$). Comparing the games with human opponents (part I: *ACF vs. TCF*), subjects' bids are lower (Wilcoxon rank sum, $p = 0.023$) and subjects' payoffs are higher (Wilcoxon rank sum, $p = 0.003$). Additionally, more subjects play plausibly, $b_i \in [-8, -5]$, in the transformed game than in the auction game (Fisher's exact test, $p = 0.083$). Tables 3, 4, 5, and 6 summarize subjects's behavior in the *AC* and the *TC* treatment.

Table 2: Bid transition by categories (Part I).

b_i (Comp.)	b_i (Human) $[-8]$	$[-8,-5]$	$(-5,-3]$	$(-3,8]$	**Total**
			AF treatment		
$(-5,8]$	0	0	4	19	**23**
$(-5.99,-5]$	0	1	0	8	**9**
$[-5.99]$	0	5	4	9	**18**
$(-8,-6]$	0	0	0	0	**0**
Total	**0**	**6**	**8**	**36**	50
			TF treatment		
$(-5,8]$	0	1	2	5	**8**
$(-5.99,-5]$	2	2	5	4	**13**
$[-5.99]$	4	9	4	7	**24**
$(-8,-6]$	0	0	1	0	**1**
Total	**6**	**12**	**12**	**16**	46

relatively more subjects who are in principle able to best respond seem to fail to form adequate beliefs with human opponents and best respond to them, compared to the transformed setting.[13]

> **Result 1:** For both human and computerized opponents, we find that, without conditioning, subjects bid lower and are better in avoiding the WC. Hence, we find evidence in a CVA setting with human opponents that the difficulty of conditioning on hypothetical events is one reason behind the WC.

Relatedly, we found another consequence of conditioning in the data. We can analyze whether subjects improve their behavior during the three periods they play of each game. When we test the distribution of bids for the first and the last period of each game, only 2 out of the 16 games (four games in four treatments) show significantly different results. Subjects bid closer to the equilibrium in the third compared to the first period only when the transformed game is played as first game (*TH*, p=0.001, and *TC*, p=0.067). Therefore, only without conditioning subjects are able to improve their behavior even though they do not receive feedback.[14]

[13]Table 2 also reveals that overall 36 out of 50 subjects (72%) play a weekly dominated strategy in the auction game. This provides evidence against the idea that differences in the informational structure lead to differences in behavior. It seems highly unlikely that subjects are able to understand the potential implications of higher order beliefs in the auction game but are at the same time unable to avoid a weekly dominated strategy.

[14]Our central results regarding conditional reasoning and belief formation remain in general robust to considering first or third period bids instead of mean bids, although differences are less pronounced as single period data is naturally more noisy. Appendix A.4 provides further details.

3.2 Hypothesis 2

We first analyze subjects' behavior in part I of the *AH* and the *TH* treatment. In the auction game, 61% of the winning subjects face losses with human opponents whereas only 45% do so with computerized opponents. In the transformed game, 32% of the winning subjects face losses with human opponents whereas this is only the case for 13% of subjects with computerized opponents. Again, table 1 on page 12 shows that in both games these outcomes are due to significantly lower bids when facing computerized opponents.

Referring to the idea that the informational structure and not the conditioning drives Also, subjects earn higher average payoffs when facing computerized opponents. Note that we observe differences in subjects' bidding behavior even though the best response requires a higher bid in the setting with computerized opponents than the equilibrium bid in the human opponent setting.

Judging again by the categories of table 2, in the auction setting, 6 out of 50 subjects (12%) behave plausibly with human opponents and 27 out of 50 (54%) do so with computerized opponents (McNemar's test, $p = 0.000$).[15] In the transformed game setting, 18 out of 46 subjects (39%) behave plausibly with human opponents while 37 out of 46 (80%) do so with computerized opponents (McNemar's test, $p = 0.000$). Similar results emerge when considering exact equilibrium or best response play.

Maybe not surprisingly, there is strong evidence that the removed strategic uncertainty and the removed need to form beliefs in the computerized setting has an impact on bidding behavior. However, the within-subject analysis of the *AH* treatment in figure A.3 and table 2 suggests that strategic uncertainty alone is unable to explain the differences between settings. In this treatment, 27 out of 50 subjects approximately best respond once they are confronted with computerized opponents. Out of 27 subjects that approximately best respond to the computer opponent, a majority of 17 people (63%) bid more than -3, a weakly dominated strategy. Therefore, despite the apparent ability to best respond, subjects face problems of belief formation that go beyond strategic uncertainty.

With help of the *AC* treatment, we can corroborate for the auction game the observed differences between human and computerized opponents in that it also holds between-subject and without preceeding games. Table 3 provides summary statistics for the *AC* treatment and shows – on the diagonal – that participants bid significantly lower values and make significantly higher profits with computerized opponents (Bid averages: -1.80 vs. -2.83, payoff averages: -0.56 vs. -0.12). The Wilcoxon rank sum tests yield significant differences (Bids, $p = 0.022$; payoffs, $p = 0.033$). Additionally, a Fisher's exact test on the categories supports this finding ($p = 0.001$).

With help of the *TC* treatment, we also can corroborate our results for the transformed games. Table 5 provides the respective summary statistics for the *TC* treatment. Subjects

[15] The McNemar's test performs a similar test for binary categories as the Fisher's exact test does and is additionally appropriate for matched data.

Table 3: Summary Statistics - *AH* & *AC* Treatments

Means (Std. deviation)		*AH* Auction game	*AC* Auction game	Wilcoxon rank sum p-value
Human opp.	Bids	–1.80	–2.60	0.171
		(2.63)	(4.13)	
	Payoffs	–0.56	–0.55	0.254
		(1.55)	(2.43)	
Comp. opp.	Bids	–3.37	–2.83	0.524
		(3.30)	(3.65)	
	Payoffs	0.17	–0.12	0.825
		(1.53)	(1.99)	
Wilcoxon test (within treatment)	Bids	0.000	0.670	
p-value	Payoffs	0.001	0.061	

Notes: The last column reports two-sided p-values of Wilcoxon rank sum tests that evaluates whether the distribution of bids and payoffs is different between treatments. The last rows report two-sided p-values of Wilcoxon signed rank tests that evaluate whether the distribution of bids and payoffs is different within-subject between the human and the computerized setting.

bid lower values but do not make higher profits with computerized opponents (Bid averages: -4.00 vs. -4.18, payoff averages: 0.55 vs. 0.37). Additionally, unlike in the auction setting, differences are not significant (Bids, $p = 0.323$; payoffs, $p = 0.434$). As outlined before, the difference in the equilibrium predictions between the human and the computerized setting biases, however, against finding a difference between treatments. Hence, it is more appropriate to analyze whether plausible play increases in the computerized setting. This is clearly the case: 18 out of 46 subjects (table 2) play plausible in the human setting, whereas 27 out of 42 subjects (table 6) do so in the computerized setting (Fisher's exact test, $p = 0.001$).

Result 2(a): In support of Hypothesis 2(a), we find that belief formation and strategic uncertainty provide additional obstacles for avoiding the WC both in the auction and in the transformed game. However, strategic uncertainty alone is not to be able to explain our results, a more general problem of belief formation seems to be present in the data.[16]

[16] An alternative explanation for the difference between the games with human and computerized opponents might be the following: Subjects actually have complex beliefs about their opponent in the human setting. But because of the complexity of their beliefs, they are unable to best respond to these beliefs even so they are able to best respond to simpler beliefs in the computer setting. We think that this explanation is, however, highly unlikely for two main reasons. First, even if a player is unable to exactly best respond to his complex beliefs, he should avoid bidding above -3 because he therefore only has to best respond to the degenerated belief as if all opponents make the highest bid this player considers possible in his beliefs. But many subjects show that they are at least able to best respond to this more simple type of beliefs. Second, more generally, it seems questionable that subjects have complex beliefs even so they do not understand the game sufficiently to best respond. Then it is unclear how they should have come to these beliefs in the first place.

The AC treatment allows us to further investigate the consequence of a more subtle manipulation of the beliefs, namely the help of having played against computer opponents before. Indeed, 61% of subjects winning the auction game with human opponents face losses in the AH treatment while only 51% of subjects do so in the AC treatment. Table 3 shows that bids and payoffs differ in the expected direction in the auction game with human opponents between these treatments, but this difference is not significant ($p = 0.171$).

Table 4: Bid transition by categories (Part I).

	b_i (Human)				
b_i (Comp.)	[-8]	$[-8, -5]$	$(-5, -3]$	$(-3, 8]$	**Total**
			AH treatment		
$(-5, 8]$	0	0	4	19	**23**
$(-5.99, -5]$	0	1	0	8	**9**
$[-5.99]$	0	5	4	9	**18**
$(-8, -6]$	0	0	0	0	**0**
Total	**0**	**6**	**8**	**36**	50
			AC treatment		
$(-5, 8]$	0	4	1	19	**24**
$(-5.99, -5]$	0	3	4	0	**7**
$[-5.99]$	0	8	2	2	**12**
$(-8, -6]$	1	0	0	0	**1**
Total	**1**	**15**	**7**	**21**	44

Judging the bids by categories as illustrated in the **Total** raws of table 4, it can be seen that bids below -3 are significantly more likely when the auction game with human opponents is played after the setting with computerized opponents (Fisher's exact test, $p = 0.025$).

The within-subject analysis gives a particularly illuminating illustration of these differences. Figure A.4 and table 4 show that as well in this treatment numerous subjects place bids seemingly randomly around 0 in the top-right quadrant, just like in the AH treatment (figure A.3). More interestingly, of the 19 approximately best responding subjects, only 2 bid higher than -3 when facing human opponents. Recall that in AF, out of 27 that play a best response against computer opponents, 17 bid higher than -3 when facing human opponents. Therefore, pairing the ability to best respond with a little help in the belief formation has a strong influence on the expected payoff of the bids placed against human opponents.

Result 2(b): An effect in line with Hypothesis 2(b) is still observed: Although the observed difference in average bids is not significant, playing against computerized opponents first leads to significantly more plausible play against computerized opponents.

Table 5: Summary Statistics - *TH* & *TC* Treatments

Means (Std. deviation)		*TH* Transf. game	*TC* Transf. game	Wilcoxon rank sum p-value
Human opp.	Bids	–4.00	–4.64	0.173
		(2.61)	(2.88)	
	Payoffs	0.55	0.82	0.116
		(1.37)	(1.56)	
Comp. opp.	Bids	–5.00	–4.18	0.135
		(2.53)	(2.90)	
	Payoffs	0.81	0.37	0.301
		(1.56)	(2.11)	
Wilcoxon test (within treatment)	Bids	0.020	0.308	
p-value	Payoffs	0.184	0.082	

Notes: The last column reports two-sided p-values of Wilcoxon rank sum tests that evaluates whether the distribution of bids and payoffs is different between treatments. The last rows report two-sided p-values of Wilcoxon signed rank tests that evaluate whether the distribution of bids and payoffs is different within-subject between the human and the computerized setting.

Finally, the fourth treatment *TC* allows us to show that the effect in result 2(b) is not due to the learning of conditioning during the preceding play against the computer. Table 5 shows that the absolute difference in bids between the *TH* and the *TC* treatment is 0.64 with a p-value of 0.173, very similar to the *Auction* treatments.[17] The changes in the transition between computer and human opponents (figure A.6 and table 6) are analogue to the *Auction* treatments.

4 Conclusion

In this paper, we transform a common-value first price auction in a way that subjects do not need to condition on winning. The experimental implementation of the standard auction and the transformed auction allows us to investigate the consequences that the cognitive activity of conditioning on hypothetical events have for the bidding behavior. In line with results of Charness and Levin (2009) and Ivanov et al. (2010) on the difficulty of conditioning, we find that subjects are significantly more able to avoid the winner's curse in the transformed game.

[17]Due to the overall lower bidding in the *Transformed* treatments, there is no significant difference between categories as depicted in Table 6 (Fisher's exact test, $p = 0.212$). If we, however, only consider those subjects who at least approximately best respond ($b_i \in [-5.99, -5]$) in the computerized setting, more subjects play plausible against human opponents in the *TC* than in the *TH* treatment (Fisher's exact test, $p = 0.052$).

Table 6: Bid transition by categories (Part I).

b_i (Comp.)	b_i (Human) [−8]	(−8, −5]	(−5, −3]	(−3, 8]	Total
		TH treatment			
(−5, 8]	0	1	2	5	**8**
(−5.99, −5]	2	2	5	4	**13**
[−5.99]	4	9	4	7	**24**
(−8, −6]	0	0	1	0	**1**
Total	**6**	**12**	**12**	**16**	46
		TC treatment			
(−5, 8]	0	3	4	7	**14**
(−5.99, −5]	1	10	0	0	**11**
[−5.99]	3	6	5	2	**16**
(−8, −6]	0	1	0	0	**1**
Total	**4**	**20**	**9**	**9**	42

In contrast to the previous literature, the transformation allows us to manipulate conditioning in the context of human subject interaction. Using naïve, computerized opponents, we are able to additionally study the role of belief-formation. We find that subjects are significantly more able to avoid the winner's curse when playing against a computerized opponent whose bidding strategy is known or when playing against humans after such an interaction with computerized opponents. Overall, we find that both cognitive activities are important obstacles on subjects' way to avoid the winner's curse.

Applications of the kind of transformation we are possible in other games. In the strategic voting literature, players are conditioning on being pivotal in a jury decision. Using a computer experiment, Esponda and Vespa (2014) find that the cognitive difficulty of this operation might stand in the way of strategic voting. An experiment based on a transformation of the kind presented here can verify these results in the original voting situation with human opponents.

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A Appendix

In this appendix, we first provide additional figures. Afterwards, some considerations regarding equilibrium play at the boundaries of the signal space are made. Then, different learning patters across treatments are discussed. Finally, we present the translated instructions for the *AH* treatment. In general, instructions were based on those of Kagel and Levin (1986), although large modifications had to be made to capture our specific experimental design. Additionally, *Frequently Asked Questions* that were orally presented to subjects after explaining the auction game (Part I) and after explaining the transformed game (Part II) are outlined after the Instructions.

A.1 Figures: Histograms - *AC* and *TC*

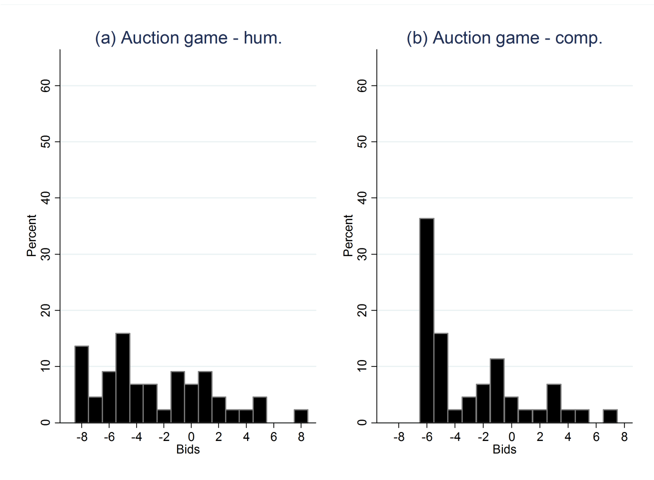


Figure A.1: *AC* Treatment - Bids (Part I)

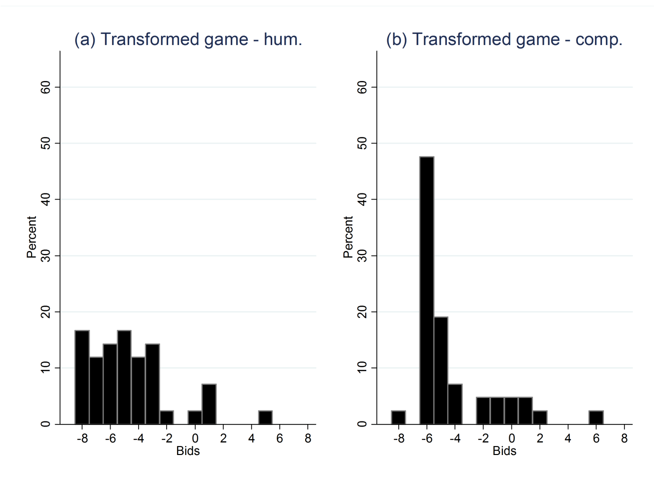


Figure A.2: *TC* Treatment - Bids (Part I)

A.2 Figures: Bid transitions

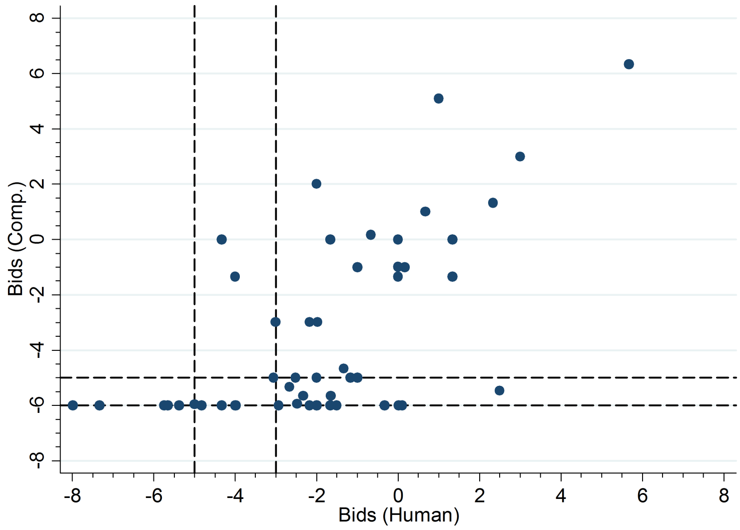


Figure A.3: *AH* Treatment - Bid transition (Part I), $N = 50$.

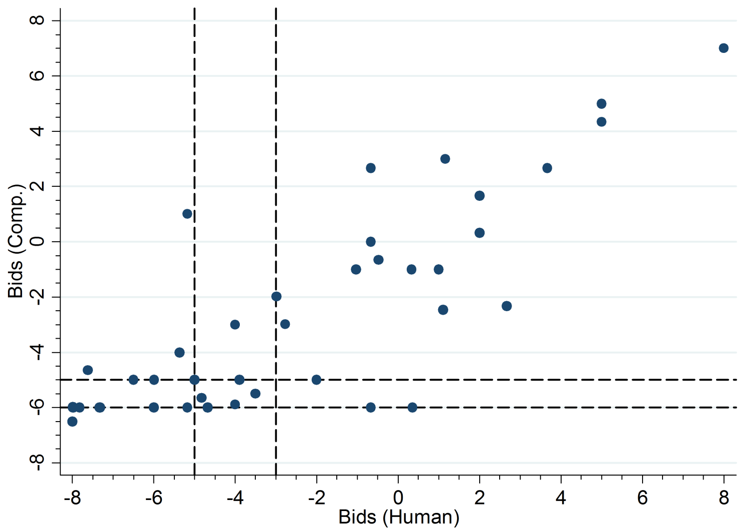


Figure A.4: *AC* Treatment - Bid transition (Part I), $N = 44$.

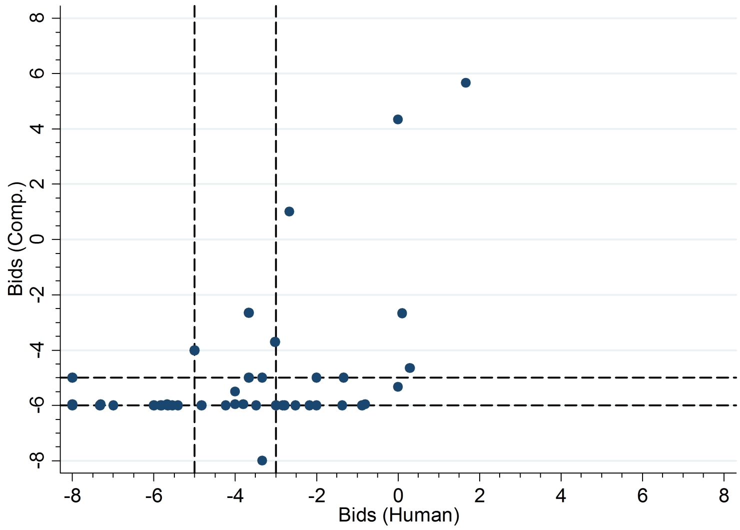


Figure A.5: *TH* Treatment - Bid transition (Part I), $N = 46$

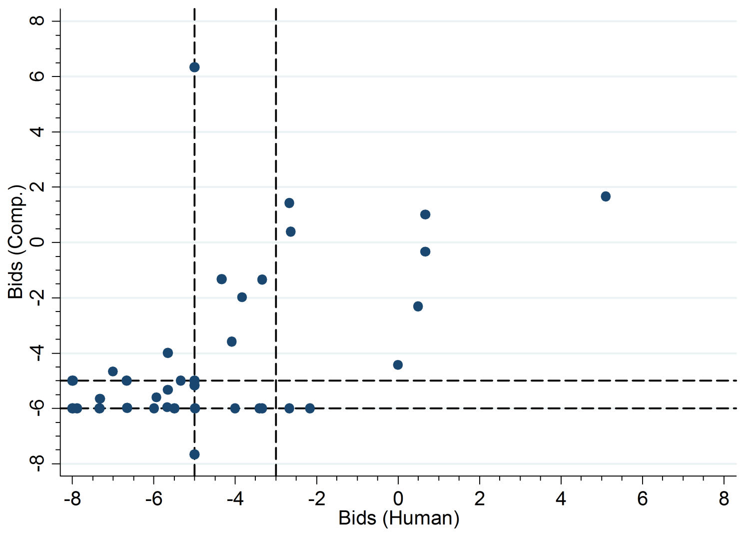


Figure A.6: *TC* Treatment - Bid transition (Part I), $N = 42$.

A.3 Equilibrium at the boundaries

In the main text, equilibrium considerations regarding the auction game do not take into account that subjects receiving a signal close to 25 or 225 can infer the commodity's real value. This might not only influence those subjects' strategies that receive signals close to 25 or 225, but it could in principle also influence those subjects' strategies that receive signals well within the interval. In the following, we will, however, outline why this influence vanishes very quickly and why $b_i = -8$ remains the equilibrium strategy for all realizations of the commodity's value that occur in the experiment. We start with the lower boundary: In order to analyze how subjects' strategy at the boundary influence subjects' strategy for central-value signals, we consider five player types. Player 5 receives a signal $x^5 \in [46, 54)$. His strategy might be influenced by his potential opponent with the lower signal: player 4, who receives the signal $x^4 = x^5 - 6, x^4 \in [40, 46)$. But player 4's strategy might of course be influenced by player 3 ($x^3 = x^4 - 6, x^3 \in [34, 40)$) whose strategy might be influenced by player 2 ($x^2 = x^3 - 6, x^2 \in [28, 34)$) and finally also by player 1 ($x^1 = x^2 - 6, x^1 \in [22, 28)$).

Player 1 receives a signal $x^1 \in [22, 28)$ from which he can infer that the commodity's real value is above his own signal. For this reason, player 1 cannot make any profits from underbidding by -8. Instead player 1 tries to overbid[18] player 2. But importantly, player 1 bids at most $b^1 = +3$ because otherwise he would lose money because of overbidding the commodity's value $x^1 + 3$. Hence, in equilibrium, player 2 will bid $b^2 \geq -3.01$ because any bid below would provide player 1 with an overbidding incentive that would lead player 2 to adjust his bid upwards. Additionally, player 2 cannot bid more than $b^2 = 0$ because higher bids would lead to negative expected payoffs. Because of these incentives of player 2, in equilibrium, player 3 can ensure himself an expected payoff of at least $Eu_i = 1.495$ by bidding $b^3 = -5.99$. If player 3 follows this strategy, player 2 cannot gain money by winning the auction, and, hence, player 2 will not overbid the player 3 and bids $b^2 = -3$ to avoid losses. This, however, provides an incentive for player 3 to bid less than -5.99, which in turn provides an incentive for player 2 to overbid the third player and these overbidding incentives only fully vanish when player 3 bids -5.99 again. Because of this circular incentive structure, in equilibrium, player 2 and player 3 will mix strategies. We do not fully characterize the exact mixed strategy equilibrium here, because it is sufficient for our purpose to show that players will not bid in certain intervals.[19]

As outlined before, for player 2, strategies above 0 cannot be part of an equilibrium. Hence player 3 can ensure himself a payoff of at least $Eu_i = 1.495$ by bidding -5.99. Importantly, strategies that are part of a mixed strategy equilibrium must lead to a higher

[18]More precisely, due to the rule we implement concerning equal bids, overbidding in this context means that player 1 only has to bid exactly player 2's absolute bid in order win the auction.

[19]The strategy space in our experiment is finite because participants have to round their bids to the cent-level. But for finite strategy spaces we know that there always exists an equilibrium.

payoff than strategies that are not part of this equilibrium. Hence, bidding $b^3 \in (-5.99, -2)$ cannot be part of a mixed strategy equilibrium because it leads to lower payoffs than bidding -5.99, independent of how player 2 exactly mixes pure strategies below $b^2 = 0$. Bidding $b^3 \in [-8, -5.99)$ could in principle lead to the same payoff (or even a higher payoff) as bidding -5.99 because the commodity's real value is underbid by a larger amount. The same is true for bidding $b^3 \in [-2, -1.50]$ because player 3 might overbid player 4 with these bids. By bidding above -1.5, player 3 might still overbid player 4, but the (maximal) payoff ($Eu_i = 1.49$) resulting from these bids is lower than the payoff of bidding -5.99. Bearing these considerations in mind, player 4 could always avoid to be overbid by player 3 by bidding $b^4 = -7.49$ and ensuring himself a payoff of $Eu^4 = 2.245$. Because player 3, however, does not bid -5.99 as a pure strategy but possibly also mixes strategies over $[-8, -5.99]$ and $[-2, -1.50]$, player 4 potentially mixes strategies over $-8 \leq b^4 \leq -7.49$. Importantly, bidding above -7.49 cannot be part of an equilibrium because then payoffs are lower than $Eu^4 = 2.245$. Especially overbidding player 5 even when this player is bidding $b^5 = -8$ would only lead to an expected payoff of $Eu^4 = 2.0$. For this reason, the influence on strategies of boundary-signals ends at player 5: This player and all players with higher signals than player 5 will play -8 as a pure strategy in equilibrium because their lower-signal opponents do not have an incentive to overbid them. Or in other words, for signals above 46, bidding -8 remains the equilibrium.

Additionally, at the higher boundary of the commodity's value space, no problems occur: A player receiving the signal $x^{high} \in (222, 228]$ knows that the commodity's real value is below his own signal. Hence, he has to underbid his opponent who has a lower signal in order to earn money. But this do not lead to a change in equilibrium because if the opponent bids -8, the player with x^{high} also just bids -8 and has no incentive to deviate.

A.4 Learning

In this section, we first provide evidence that our central results regarding conditioning and belief formation remain robust when considering single periods and not the average of the three periods per game, as done in the main text. Afterwards, we additionally analyze the data from Part II of the *AH* and the *TH* treatment, as the main text only analyzes data from Part I of our treatments.

To robustness check whether our results also hold when considering single periods instead of the average of three periods is really only interesting for comparisons involving the transformed game either with human or computerized opponents when played first in the *TH* and the *TC* treatment. As outlined in the main text, only in these two games, subjects significantly improve their behavior from the first to the second period.

Regarding our results referring to the conditioning problem, we might want to test whether the comparisons between the auction and the transformed game remain valid when we abstract from the fact that subjects learn in the transformed game when this game is played as the first game of a treatment. When we compare bidding behavior and payoffs between the auction game and the transformed game with human opponents (*AH* vs. *TH*) and this time base this comparison only on the first period (to abstract from learning in the transformed game), subjects still bid significantly less (and earn significantly more) in the transformed game (Wilcoxon rank sum, bids - $p = 0.018$, payoffs - $p = 0.050$). Additionally, plausible behavior is more likely in the transformed game (Fisher's exact test, $p = 0.011$) than in the auction game. When comparing behavior between the auction and the transformed games against computerized opponents (*AC* vs. *TC*) and considering only the first period (to control for learning in the transformed game), results still have the expected direction but are not generally significant (Wilcoxon rank sum, bids - $p = 0.146$, payoffs - $p = 0.388$; Fisher's exact test, $p = 0.057$).

Regarding our results referring to the belief formation problem, we might want to check whether subjects still improve their behavior in the setting with computerized opponents compared to human opponents even if we incorporate that subjects learn in the three rounds of the transformed game with human opponents. When we compare the human and the computerized version of the transformed games in the *TH* treatment and focus on third periods (to incorporate learning in the setting with human opponents), the differences between the two settings naturally diminish and bids and payoffs are not significantly different any more (Wilcoxon rank sum, bids - $p = 0.143$, payoffs - $p = 0.871$). Importantly, we have different equilibria in both settings which biases against observing a difference in bids or payoffs. Hence, the more reliable measure is to consider whether the percentage of subjects playing plausible in both both settings change. Indeed, more subjects play plausible in the setting with computerized opponents compared to human opponents and this difference remains highly significant (McNemar's Test, $p = 0.001$). We obtain a similar result if we do the same analysis not within but between-subject (*TH* vs. *TC*), and again consider only the third period (Wilcoxon rank sum, bids - $p = 0.621$, payoffs - $p = 0.442$; Fisher's exact test, $p = 0.000$). Hence, as expected, results become slightly weaker when incorporating that subjects learn in the transformed games, but the overall pattern of the results seems to remain intact.

In the main text, our analysis was focused on Part I of the three treatments. In this section, we will additionally analyze Part II of the *AH* and the *TH* treatment. Following Charness and Levin (2009) that problems with contingent reasoning are at the origin of the WC suggests that we should observe a different learning pattern from Part I to Part II between the two treatments. If conditional reasoning is an obstacle for understanding the auction game, playing this game before the transformed game should not per se improve behavior in the transformed game. Subjects should not gain a better understanding of the transformed game via the auction game simply because most participants do not understand the auction game because of the problems with contingent reasoning and those subject who manage to avoid the WC in the auction game would most likely already play rationally in the transformed game if this is played first. Playing the transformed game first, however, might very well facilitate playing the auction game. By understanding the structure of the transformed game, a better understanding of the setting in which contingent reasoning on future events is necessary might arise. Hence, different patterns of learning behavior between the two treatments should be observed:

> ***Hypothesis 3:*** *In the AH treatment, no learning effect should be observed. Playing the transformed game after playing the auction leads to similar results than first playing the transformed game. In the TH treatment, however, a learning effect should be observed: Playing the auction game after the transformed game leads to more rational behavior than playing the auction game first.*[20]

We focus on the *AH* and the TF treatments because both treatments potentially provide a better comparison for the predicted learning effect than the *AC* and the TCF treatments. In the later treatments, subjects also first play against the computer in the second part which in principle could have an influence on playing against human opponents at very end of each treatment.[21]

[20]Our design can, however, not distinguish whether such a learning effect is driven by the fact that subjects really understand the necessity to condition on the event of winning in the WC because they played the transformed game first, or whether alternatively, subjects only learn that bidding low is a good strategy in the transformed game which they then also apply in the auction game. It is, however, noteworthy, that subjects at least do not receive any feedback about the results before the end of the experiment. Hence, they do not get any feedback on whether bidding low in the transformed game is a good strategy

[21]In general, results for the *AC* and the TCF treatment are comparable to those in the *AH* and *TH* treatment to the extent, that playing the auction games first does not help playing the transformed games, whereas playing the transformed games first helps playing the auction games. This effect is significant for human opponents, whereas for computerized opponents the effect has the right sign but is insignificant.

Table A.1: Summary Statistics - *AH* & *TH* Treatments (Part II)

Mean (Std. deviation)		*AH* Transf. game	*TH* Auction game
Human opponents	Bids	–3.66	–3.79
		(4.05)	(2.88)
	Payoffs	0.05	0.29
		(2.29)	(1.90)
Comp. opponents	Bids	-3.04	-4.48
		(3.74)	(2.66)
	Payoffs	–0.16	0.68
		(2.09)	(1.53)

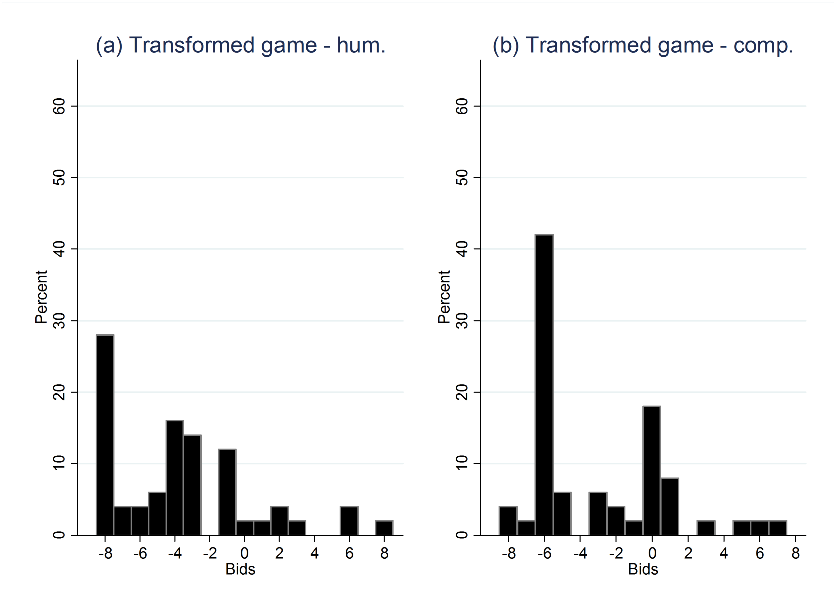


Figure A.7: *AH* Treatment - Bids (Part II), n = 50

Hence, our focus is on the *AH* and the *TH* treatment: Does playing one game first facilitates playing the other game in these treatments? Table A.1 provides the mean values for subjects' bids and payoffs for Part II of both treatments.[22] In the *AH* treatment, the transformed game was played in the second part, both with human opponents and computerized opponents. In the *TH* treatment, the auction game was played in the second part, again both with human opponents and computerized opponents. Figure A.7 and A.8 additionally show histograms of subjects' bids in the *AH* and the *TH* treatment for Part II of both treatments.

So results in the *AH* and the *TH* treatment are in general in line with our learning hypothesis from part I to part II. It might however, be not so clear, to what extent playing against the computer first still influences these results.

[22]We omit the non-parametric tests shown in Table 1 because for the analysis we would like to perform in this section mainly tests comparing results in Part I with results in Part II are necessary.

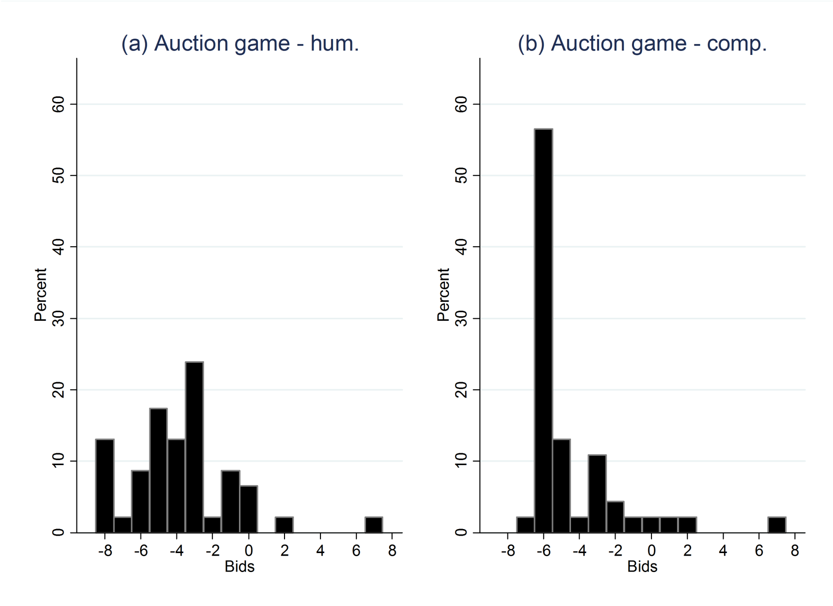


Figure A.8: *TH* Treatment - Bids (Part II), n = 46

For the *TH* treatment, we hypothesized that we might observe a learning effect. We will look at the setting with human opponents first: When the auction game is played after the transformed game (*TH* treatment), only 28% of those subjects who win the game face losses, whereas 61% of those subjects face losses when the auction is played first (*AH* treatment). In line with this observation, bids in auction game are lower in *TH* treatment (Figure A.8(a)) than in the *AH* treatment (Figue 3(a)), whereas payoffs are higher (Mean values - bids: -3.79 vs. -1.80; payoffs $+0.29$ vs. -0.56).[23] Hence, there is clear evidence that playing the transformed game in the *TH* treatment before the auction game helps subjects to avoid the WC in the auction game. Because of learning, we also do not observe the treatment effect between the two games within-subject in the *TH* treatment: Bids and payoffs are roughly the same between the transformed and the auction game in this treatment (Mean values - bids: -4.00 vs. -3.79; payoffs: 0.55 vs. 0.29).[24]

Do we also observe this learning effect for the setting with computerized opponents? When the auction game is played after both transformed games (*TH* treatment), only 22% of those subjects who win the game face losses, whereas 45% of those subjects face losses when the auction game is played in Part I (of the *AH* treatment). In line with this observation, bids in auction game (with computerized opponents) are lower in *TH* treatment (Figure A.8(b)) than in the *AH* treatment (Figure 3(b)), whereas payoffs are higher (Mean values - bids: -4.48 vs. -3.37; payoffs $+0.68$ vs. $+0.17$). Hence, it again looks like that subjects behave slightly more rationally when they play the transformed

[23]Wilcoxon rank sum test - bids: two-sided $p = 0.000$; payoffs: two-sided $p = 0.002$. Fisher's exact test based on plausible play - two-sided p-value $= 0.025$.

[24]Wilcoxon signed rank test - bids: two-sided $p = 0.814$; payoffs: two-sided $p = 0.833$. Additionally, a McNemar's test (two-sided: $p = 0.6072$) based on plausible play reveals no significant difference.

game first compared with the situation when this is not the case. Statistical support, however, provides only partial support for this this impression.[25] Additionally, unlike in the case of human opponents, the learning effect seems not to be strong enough to totally prevent a treatment effect also within-subject.[26] Hence, there is some evidence for a learning effect also in the *TH* treatment, but this learning effect seems to be weaker than in the setting with human opponents. In the *TH* treatment, the auction game with computerized opponents was played as the last game. Potentially, exhaustion or confusion because of all the different games played before might have been highest at the end of the experiment, diminishing the learning effect. At least, subjects behave less rational than expected in the very last game of the *TH* treatment.

For the *AH* treatment, we hypothesized above that subjects should not benefit from playing the auction game first in playing the transformed game second. We will first analyze the setting with human opponents: When the transformed game is played after the auction game (*AH* treatment), 47% of those subjects who win the game face losses, whereas 32% of those subjects face losses when the transformed game is played first (*TH* treatment). Additionally, bids in the transformed game are even slightly higher in *AH* treatment (Figure A.7(a)) than in the *TH* treatment(Figure 4(a)), whereas payoffs are lower (mean values - bids: -3.66 vs. -4.00; payoffs $+0.05$ vs. $+0.55$). Differences, however, are small and not statistical significant.[27][28] In any case, subjects do not seem to learn how to avoid the WC in the transformed game from playing the auction game first. Because subjects do not learn in the *AH* treatment, we also observe the treatment effect between the two games within-subject in this treatment: Bids are higher in the auction game compared to the transformed game, whereas payoffs are lower (mean values - bids: -1.80

[25]Wilcoxon rank sum test - bids: two sided $p = 0.076$; payoffs: two sided $p = 0.054$. But: Fisher's exact test based on plausible play - two sided: $p = 0.301$.

[26]Again, the statistical analysis is fairly inconclusive. A Wilcoxon signed rank test just reveals no significant difference (bids: two-sided $p = 0.101$; payoffs: two-sided $p = 0.371$) within-subject between the transformed and the auction game (with computerized opponents), but a McNemar's test based on plausible play reveals such a difference with marginal significance (two-sided p-value $= 0.065$).

[27]Wilcoxon rank sum test: Bids - two-sided $p = 0.848$; payoffs - two-sided $p = 0.293$. Additionally, a Fisher's exact test based on plausible play supports this finding (two-sided $p = 0.834$).

[28]Difference additionally remain statistically insignificant (with the exception of payoffs) when only comparing bids and payoffs for the last of the three periods (and not mean values for all three periods) and hence controlling for the learning which takes place in the transformed game when played first in the *TH* treatment: Wilcoxon rank sum test: bids (last period) - two-sided $p = 0.306$; payoffs (last period) - two-sided $p = 0.061$. Additionally, a Fisher's exact test using (last period) bids smaller or equal -5 as a classification criterion for plausible behavior supports this finding (two-sided $p = 0.209$). In the *AH* treatment, one might argue that there is a different kind of learning effect in the sense that subjects do not perform better in the transformed game than subjects in the *TH* treatment, but at least these subjects do not have to learn over the three periods of the game (as in the *TH* treatment) because the auction game was played before. Importantly, however, differences between treatments in the transformed game are also not significant when comparing first round behavior which potentially speaks against this different kind of learning: Wilcoxon rank sum test: bids (first period) - two-sided $p = 0.274$; payoffs (first period) - two-sided $p = 0.652$. Additionally, a Fisher's exact test using (first period) bids smaller or equal -5 as a classification criterion for plausible behavior supports this finding (two-sided $p = 0.302$).

vs. -3.66; payoffs: -0.56 vs. $+0.05$)[29]

How does the behavior in the games with computerized opponents evolve in the *AH* treatment? When the transformed game is played after both auction games (*AH* treatment), 43% of those subjects who win the game face losses, whereas only 13% of those subjects face losses in the transformed game in Part I of the *TH* treatment. In line with this observation, bids in transformed game (with computerized opponents) are higher in *AH* treatment (Figure A.7(b)) than in the *TH* treatment (Figure 4(b)), whereas payoffs are lower (Mean values - bids: -3.04 vs. -5.00; payoffs -0.16 vs. $+0.81$)[30] Hence, in the setting with computerized opponents, we do not only not observe a learning effect, but subjects in the *AH* treatment even perform slightly worse than in the *TH* treatment. For this reason, we also do not observe the treatment effect between the two games within-subject in the *AH* treatment: Bids and payoffs are fairly similar in the auction game compared to the transformed game (mean values - bids: -3.37 vs. -3.04; payoffs: $+0.17$ vs. -0.16).[31]

As in the *TH* treatment, learning behavior seems to be slightly different between the setting with human opponents and computerized opponents also in the *AH* treatment. Our - admittedly - speculative explanation why this is the case is the following: As in the *AH* treatment, the transformed game with computerized opponents was played as the last game. First of all, subjects might already be slightly exhausted at this point of the experiment. In addition, when solving this game they might at least consider two other games as a reference: the transformed game with human opponents and the auction game with computerized opponents. Considering both games might have lead to some confusion of at least some subjects, leading e.g. to the very high frequency of zero bids in the transformed game with computerized opponents (imitating the computer's strategy - Figure A.7(b)). At least, as in the *TH* treatment, we also observe in *Auction treatment* that subjects behave less rational than expected in the very last game of the experiment. Overall:

> ***Result 3:*** In the setting with human opponents, we observe a learning effect as hypothesized: Playing the transformed game first facilitates playing the auction game, whereas the reverse is not true. With computerized opponents, a similar but weaker learning effect is observed in the *TH* treatment. Overall, however, rationality levels in the last game of both treatments are lower than expected. Exhaustion or increased confusion might be responsible for this result.

[29] Wilcoxon signed rank tests: bids - two-sided $p = 0.000$; payoffs - two-sided $p = 0.003$. This result is also supported by a McNemar's test (two-sided $p = 0.002$) based on plausible behavior.

[30] Wilcoxon rank sum test: bids - two-sided $p = 0.033$; payoffs - two-sided $p = 0.007$. Fisher's exact test based on plausible play - two-sided $p = 0.001$.

[31] Wilcoxon signed rank test: bids - two-sided $p = 0.980$; payoffs - two-sided $p = 0.205$. McNemar's based on plausible play - two-sided $p = 0.549$.

A.5 Figures: Individual Data

For completeness, Figures A.9, A.10, A.11, and A.12 provide individual bids for all 12 periods of the experiment for all subjects of the three treatments. These figures support the evidence presented so far that subjects only improve their behavior in the transformed game when this game is played in Part I of the experiment.

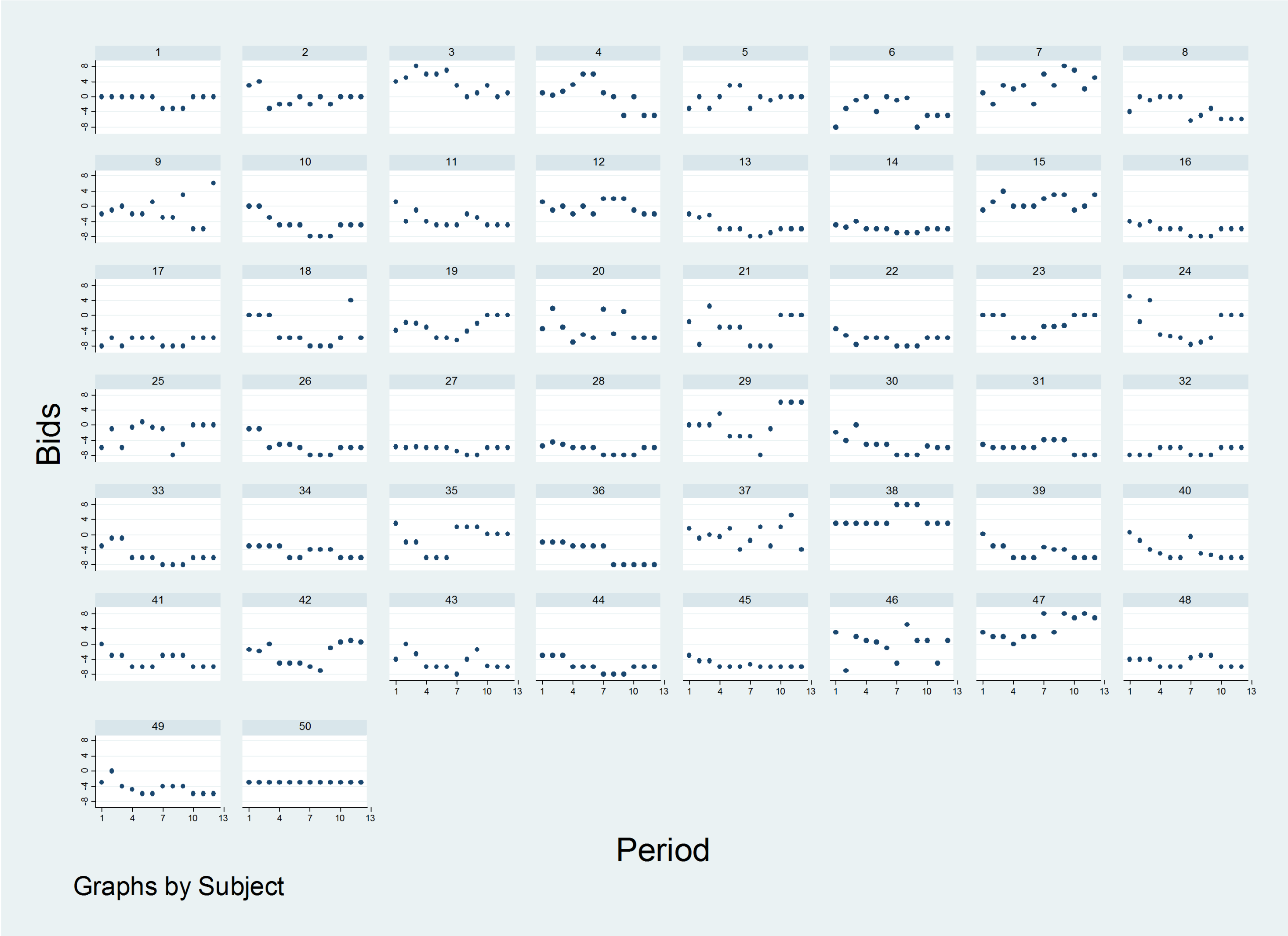


Figure A.9: Each Subjects' Behavior in the AF treatment (3 periods per game)

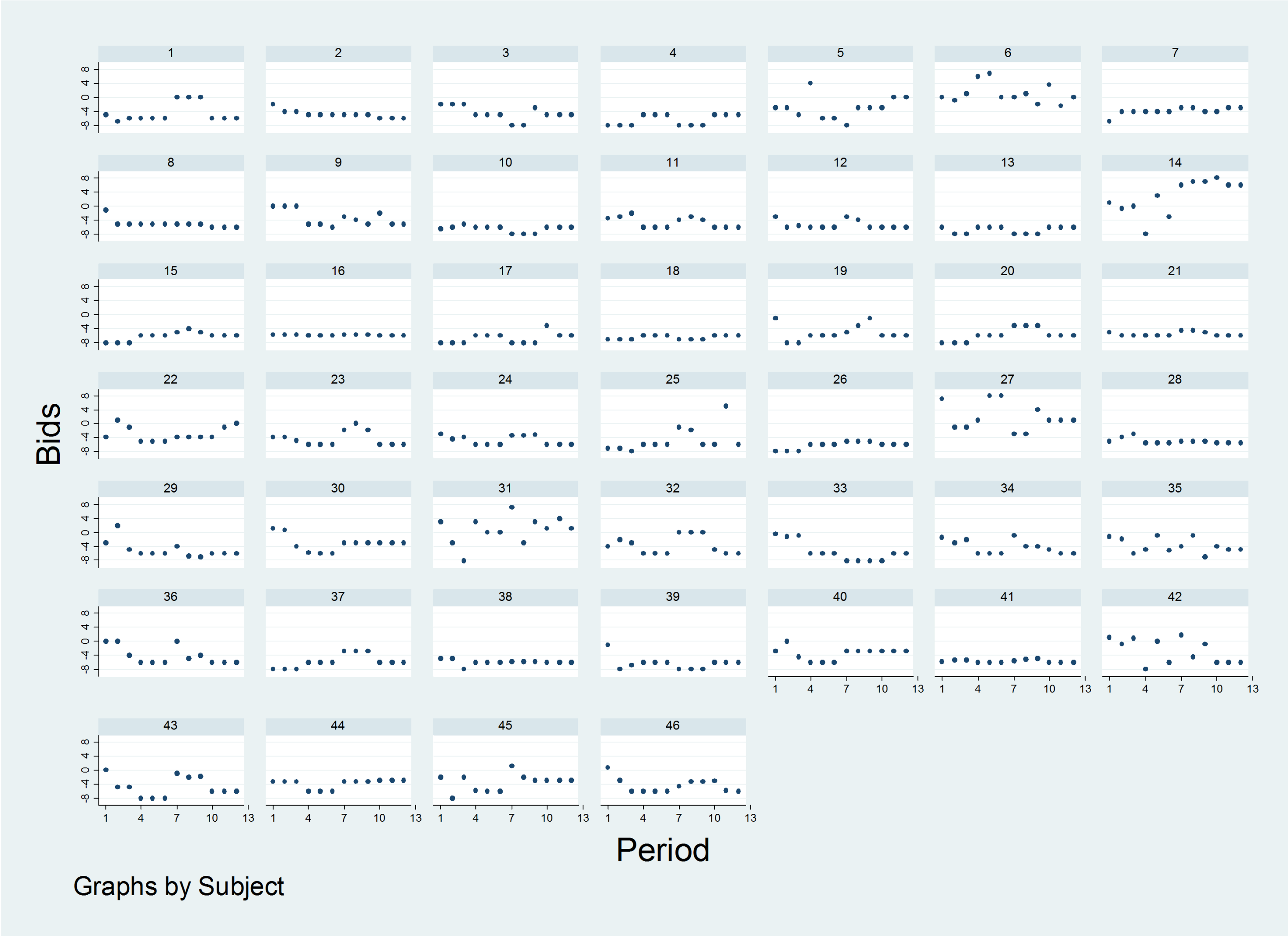


Figure A.10: Each Subjects' Behavior in the TF treatment (3 periods per game)

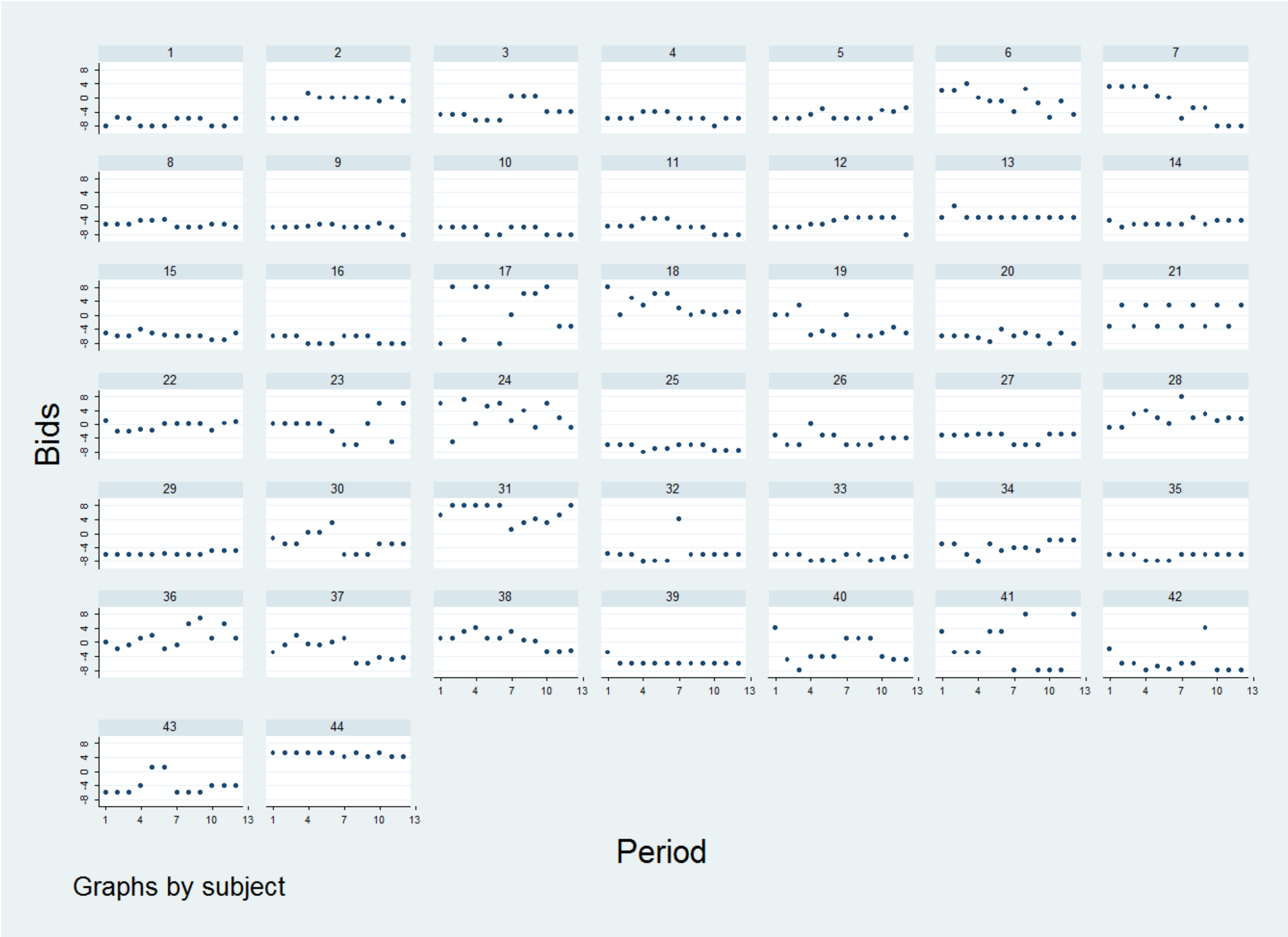


Figure A.11: Each Subjects' Behavior in the ACF treatment (3 periods per game)

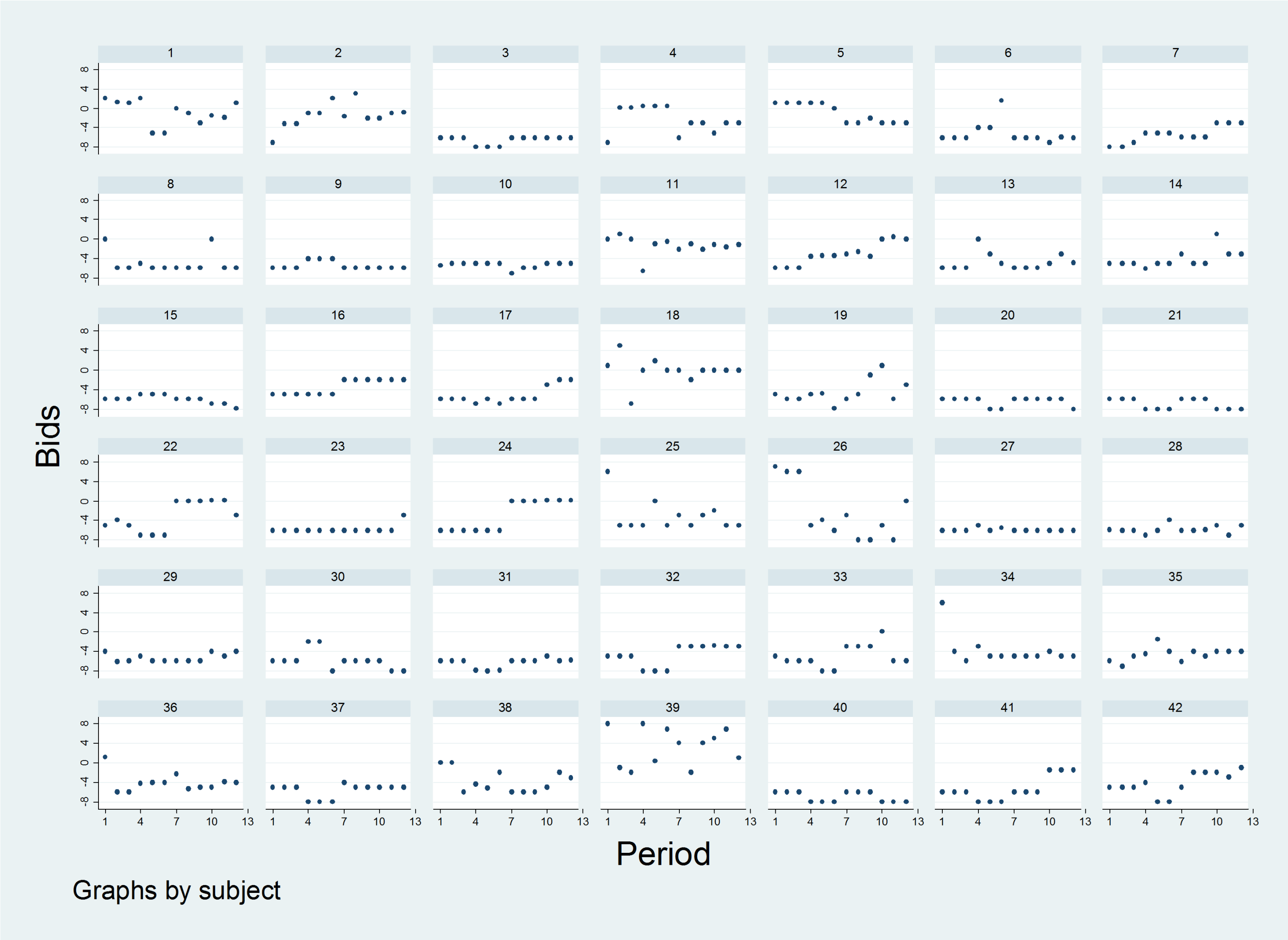


Figure A.12: Each Subjects' Behavior in the ACF treatment (3 periods per game)

A.6 Instructions: *AH* treatment

Welcome to the experiment!

Introduction

I welcome you to today's experiment. The experiment is funded by the University of Mannheim. Please follow the instructions carefully.

For participating, you first of all receive a participation fee of 4€. Additionally, you may earn a considerable amount of money. Your decisions and the decisions of other participants determine this additional amount. You will be instructed in detail how your earnings depend on your decisions and on the decisions of other participants. All that you earn is yours to keep, and will be paid to you in private, in cash, after today's session.

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

The experiment consists of three parts. For all three parts, you will receive separate instructions. You will first make your decisions for all three parts and only afterwards **at the very end** of the experiment get to know which payments resulted from your decisions. The currency used in all three parts of the experiment is called Taler. Naturally, however, you will be paid in Euro at the end of the experiment. **Two Taler will then convert to one Euro.**

If you have any questions at this point, please raise your hand.

Part I

The first part of the experiment consists of 2×3 trading periods (thus trading periods 1-3 and trading periods 4-6). These instructions describe the decision problem as it is present in trading periods 1-3. This decision problem will be slightly modified in the trading periods 4-6. You will be informed about the details of this modification at the end of trading periods 1-3.

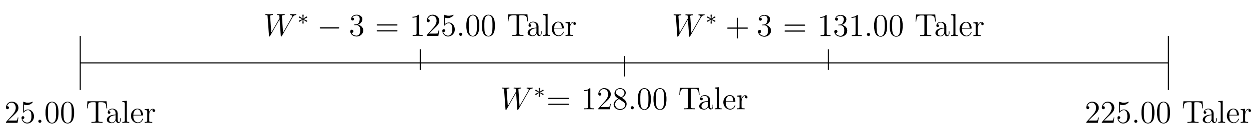
In this part of the experiment, you will act as a buyer of a fictitious commodity. In each trading period, you will have the opportunity to submit a bid for one unit of the commodity. Importantly, not only you will have this opportunity to make a bid for the commodity. In each trading period, you will be matched with another participant of this experiment. This participant will also have the opportunity to make a bid for the commodity. Importantly, you will always bid against another randomly determined participant in each trading period.

Your task is to submit bids for the commodity in competition with the other participant. The precise value of the commodity at the time you make your bids will be unknown to you. Instead, you and the other participant will receive an information signal as to the value of the item which you should find useful in determining your bid. Which kind of information you will receive, will be described below.

The value of the auctioned commodity (W^*) will alwalys be an integer and will be assigned randomly. This value can never be below 25 Taler and never be above 225 Taler. Additionally, the commodity's value W^* is randomly and independently determined from trading period to trading period. As such a high W^* in one period tells you nothing about the likely value in the next period

Private Information Signals: Although you do not know the precise value of the commodity, you and the participant who is matched with you will receive an information signal that will narrow down the range of possible values of the commodity. This information signal is either $W^* - 3$ or $W^* + 3$, where both values are equally likely. In addition, it holds that when you receive the information signal $W^* - 3$, the person who is matched to you will receive the information signal $W^* + 3$. If in contrast, you receive the information signal $W^* + 3$, the other person gets the information signal $W^* - 3$.

For example, suppose that the value of the auctioned item (which is initially unknown to you) is 128.00 Taler. Then you will either receive a) the information signal $W^* - 3 = 125.00$ Taler or b) the information signal $W^* + 3 = 131.00$. In both cases, the other person will receive the opposite information signal, in case of a) the information signal $W^* + 3 = 131.00$ and in case of b) the information signal $W^* - 3 = 125.00$ Taler. The line diagram below shows what's going on in this example.



It also holds that the commodity's value W^* is equal to the signal $-$ 3 or the signal + 3 with equal probability. The computer calculates this for you and notes it.

Your signal values are strictly private information and are not to be revealed to the other person. In addition, you will only be informed about the commodity's value W^* and the other participant's bid at the end of the whole experiment (when also the second and the third part of the experiment are completed).

It is important to note that no participant is allowed to bid less than the signal $-$ 8 and more than the signal + 8 for the commodity. Every bid between these values (including these values) is possible. Bids have at least to be rounded **to one cent**. Moreover, it holds that the participant who submits the higher bid gets the commodity and makes a profit equal to the differences between the value of the commodity and the the amount he or she bids. That is,

- Profit = W^* (128.00 Taler) – higher bid

for the higher bidding person. If this difference is negative, the winning person looses money. If you do not make the higher bid on the item, you will neither make a profit nor a loss. You will earn zero profits. If you and the other participant submit the same bid, the person who received the lower signal will get the commodity and he or she will be paid according to his or her bid.

At the beginning of part I, each individual participant will be given a starting capital credit balance of 8 Taler. Any profit earned by you in the experiment will be added to this sum. Any losses incurred will be subtracted from this sum. At the end of this part of the experiment, all gains and losses will be add up and the net balance of these transactions will be added to your captital credit balance. You are permitted to bid in excess of your capital credit balance. Even in case of a negative captial credit balance, you are still permitted to submit bids. Should your net balance at the end of this part of the experiment be zero (or less), you will not get any payoff from this part of the experiment. But even in case you make losses in this part of the experiment, you will keep your initial show-up fee of 4€.

Summary:

1. Two participants have the opportunity to submit bids for a fictitious commodity. The exact value of the commodity W^* is unknown to you. This value will, however, always be between 25 Taler and 225 Taler. Moreover, you receive a private information signal concerning the commodity's value. This signal is either $W^* - 3$ or $W^* + 3$. The other participant will receive the other signal. No one is allowed to bid less than the signal – 8 or more than the signal + 8.

2. The higher-bidding participant gains the commodity and makes the following profit = commodity's value - higher bid.

3. Profits will be added to your initial capital starting balance. Losses will be subtracted from your initial capital starting balance. You can always submit higher bids than your capital starting balance.

4. This part of the experiment consists of two rounds with overall 6 trading periods. These instructions describe the decision problem as it occurs in the trading periods 1-3. There will be a modification of the decision problem for rounds 4-6, about which you will be informed soon.

If you have read everything, please click the "Ready" button, to start the experiment.

Modifciation of the decision problem

You have now entered all decisions for the trading periods 1-3. Now, trading periods 4-6 will follow for which the decision problem so far will be slightly modified. As up to now the task is to submit bids for a fictitious commodity. Importantly, the other participant who also has the opportunity to submit bids will be replaced by the computer. As the other participant in the trading periods 1-3, the computer will also receive a signal about the commodity's value that is opposite to your own signal. The computer then decides according to the following decision rule: ***The computer always exactly bids his information signal***. Suppose, for example, that the true value of the commodity is 128.00 Taler. If the computer receives the information signal 125.00 Taler (commodity's value − 3), the computer's bid is equal to 125.00 Taler. If the computer receives the information signal 131.00 Taler (commodity's value + 3), the computer's bid is equal to 131.00 Taler. Otherwise, everything else does not change.

If you have read everything, please click the "Ready" button, to continue with the experiment.

Part II

The second part of the experiment consists of 3 trading periods (trading periods 7-9). In this part of the experiment, you will again act as a buyer of a fictitious commodity. In each trading period, you will have the opportunity to submit a bid for one unit of the commodity. Importantly, not only you will have this opportunity to make a bid for the commodity. In each trading period, you will be matched with another participant of this experiment. This participant will also have the opportunity to make a bid for the commodity. Importantly, you will always bid against another randomly determined participant in each trading period.

Your task is to submit bids for the commodity in competition with the other participant. In general, the value of the auctioned commodity will always be an integer and will be randomly determined. This value can never be below 25 Taler and never be above 225 Taler. At the beginning of each period, you and the other participant will be informed about the commodity's value. Importantly, however, there is a slight uncertainty about the value of the commodity. This value can take two different specifications in every period. The commodity can either be worth W_1^* or W_2^*, where both values always differ by 6 Taler and W_1^* always indicates the lower value. Which of the two values really realizes depends on chance and your bid as well as the other participant's bid and will be explained to you in more detail below. Both your bid and the other participant's bid are not allowed to be lower than $W_1^* - 5$ or higher than $W_2^* + 5$. Every bid between these values (including these values) is possible. Bids have at least to be rounded **to one cent**.

To make the rules of the auction understandable, they will be explained in detail with the help of an example. Suppose that at the beginning of one period, you are informed that the commodity's value is either $W_1^* = 107.00$ Taler or $W_2^* = 113.00$ Taler. You and the other participant are not allowed to bid less than $W_1^* - 5 = 102.00$ or more than $W_2^* + 5 = 118.00$ Taler. Who gets the commodity depends on your bid and the other participant's bid. Three rules apply:

1. **Your bid is 6.00 Taler or more higher than the other participant's bid:**
   In this case, you will get the commodity for sure. With a 50 percent chance each the commodity's value then is either W_1^* (107.00 Taler) or W_2^* (113.00 Taler). Hence, your profit is:

   - Profit = W_1^* (107.00 Taler) – Your bid   or
   - Profit = W_2^* (113.00 Taler) – Your bid

   Both scenarios are equally likely and the computer will randomly choose which scenario occurs. If one of the differences is negative and this scenario occurs, you will make a loss. The other participant will be paid according to rule 2.

2. **Your bid is 6.00 Taler or more below the other participant's bid:**
   In this case, you will not get the commodity in any case and your profit is zero. The other participant will be paid according to rule 1.

3. **Your bid is less than 6.00 Taler above or less than 6.00 Taler below the other participant's bid:**
   In this case, either you or the other participant get the commodity with a 50 percent chance and the computer will make this decision. The commodity's value is in any case W_1^* (107.00 Taler). Hence, in case you get the commodity, your profit is:

   - Profit = W_1^* (107.00 Taler) – Your bid

   In this case, the other participant earns zero Taler. If on the contrary, you do not get the commodity, your profit is zero and the other participant's profit is:

   - Profit = W_1^* (107.00 Taler) – His/her bid

   In both cases, it holds for the person who gets the commodity that this person will make a loss if the difference is negative.

At the beginning of part II, each individual participant will be given a starting capital credit balance of 8 Taler. Any profit earned by you in the experiment will be added to this sum. Any losses incurred will be subtracted from this sum. At the end of this part of the experiment, all gains and losses will be add up and the net balance of these transactions will be added to your captital credit balance. You are permitted to bid in excess of your capital credit balance. Even in case of a negative captial credit balance, you are still permitted to submit bids. Should your net balance at the end of this part of the experiment be zero (or less), you will not get any payoff from this part of the experiment. But even in case you make losses in this part of the experiment, you will keep your initial show-up fee of 4€.

You will only be informed about the other participant's bid and which value of commodity actually has realized at the end of the whole experiment (when also the third part of the experiment is completed).

Summary:

1. Two participants have the opportunity to submit bids for a fictitious commodity. The value of commodity will always be between 25 Taler and 225 Taler. Because of uncertainty, the commodity's value can take two specifications W_1^* and W_2^*, where the difference between both values is always 6 Taler. No one is allowed to bid less than $W_1^* - 5$ and more than $W_2^* + 5$.

2. If one person bids at least 6.00 Taler more than the other person, this persons gets the commodity for sure and either makes the profit $= W_1^*$ − his/her bid or the profit $= W_2^*$ − his/her bid. If one person bids at least 6.00 Taler less than the the other person, this person does not get the commodity in any case and makes a profit of zero Taler. If the difference of the bids is less than 6.00 Taler, both participants get the commodity with a 50 percent chance and make the following profit $= W_1^*$ − his/her bid in this case.

3. Profits will be added to your initial capital starting balance. Losses will be subtracted from your initial capital starting balance. You can always submit higher bids than your capital starting balance.

4. This part of the experiment consists of 3 trading periods.

If you have read everything, please click the "Ready" button, to continue with the experiment.

Part III

The third part of the experiment consists of 3 trading periods (trading periods 10-12). These 3 trading periods are almost identical to the trading periods 7-9 of part II. In addition, your capital credit balance of the end of part II will be the starting capital credit balance of this part. Hence, the payoff you receive from part II and part III of the experiment will finally depend on the amount of the capital credit balance at the end of this part of the experiment. In part III of the experiment, the following modification of the decision problem of part II is implemented: As up to now the task is to submit bids for a fictitious commodity. Importantly, the other participant who also has the opportunity to submit bids will be replaced by the computer. As the other participant in the trading periods 7-9, the computer is informed about both possible values of the commodity. The computer then decides according to the following decision rule: ***The computer always exactly bids the mean value of both values of the commodity (hence*** $\frac{W_1^*+W_2^*}{2}$ ***or*** $\boldsymbol{W_1^* + 3 = W_2^* - 3}$***)***. Suppose, for example, that the true value of the commodity is either $W_1^* = 107.00$ Taler or $W_2^* = 113.00$ Taler. The computer will then bid 110.00 Taler ($\frac{107+113}{2} = 107.00 + 3.00 = 113.00 - 3.00$). Otherwise, everything else does not change.

If you have read everything, please click the “Ready” button, to continue with the experiment.

A.7 Instructions: Frequently Asked Questions

Auction game

1. *When I make my decision about which bid to submit, what kind of specific information do I have? Do I know the true value of the commodity?*
   You do not know the commodity’s value W^*. When making your decision, you only know your private information signal. You also do not know whether you received the “high” or the “low” signal. You only receive one number. With a 50 percent chance, you have received the high signal and with a 50 percent chance you have received the low signal. All this also holds correspondingly for the other participant.

2. *On what does it depend whether I get the commodity and how much do I earn should this situation arise?*
   The person who submits the higher bid gets the commodity. The profit then is: W^* – higher bid. If both bids are exactly the same (meaning bids are also the same on the cent-level), the person with the lower signal gets the commodity.

3. *Which values am I allowed to bid?*
   You are allowed to under- and overbid your personal information signal by up to

8.00 Taler. In addition, it is important that you are not only allowed to bid integers. For example, you could also bid 30.45 Taler instead of 30 Taler.

Transformed treatment

1. *When I make my decision about which bid to submit, what kind of specific information do I have? Do I know the true value of the commodity?*
   When making your decision, you know about two possible specifications of the commodity's value: W_1^* and W_2^*. Which of these values actually realizes in the end depends on your decision, the other participant's decision and chance.

2. *On what does it depend whether I get the commodity and how much do I earn should this situation arise?*
   If you at least bid 6.00 Taler more than the other person, you will get the commodity for sure. Your profit will then be W_1^* – your bid or W_2^* – your bid, with a 50 percent chance each. Conversely it holds, that if you bid at least 6.00 Taler less than the other person, you will not get the commodity and your profit will be zero. If the difference of the bids is smaller than 6.00 Taler, either you or the other participant gets the commodity with a 50 percent chance and the computer will make this decision randomly. If the computer chooses you as the winner, your profit will be W_1^* – your bid.

3. *Which values am I allowed to bid?*
   You are allowed to underbid the lower value of the commodity W_1^* by up to 5.00 Taler and overbid the higher value of the commodity W_2^* by up to 5.00 Taler. In addition, it is important that you are not only allowed to bid integers. For example, you could also bid 30.45 Taler instead of 30 Taler.