Contests with money and time: Experimental evidence on overbidding in all-pay auctions

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Abstract: Competition for a prize frequently takes the form of dedicating time toward winning a contest. Those who spend more time become more likely to obtain the prize. We model this competition as an all-pay auction under incomplete information, and report an experiment in which expenditures and rewards are in terms of time. In the experiment, subjects must stay in the laboratory doing nothing for an initially prespecified length of time. However, they can bid, in terms of time, to leave early. The auction has an all-pay structure, so that if an individual does not submit the highest bid within her group, she must stay for the additional time that she bid. We correlate behavior in this game with behavior in an isomorphic all-pay auction played with money bids. We also consider how two measures of sophistication, the Cognitive Reflection Test (CRT) score, and performance on a probability calibration task, correlate with behavior. We find strong similarities in overall behavior between the auctions conducted with money and with time. Bidding greater than equilibrium levels is typical, and as a consequence, average earnings are negative in both auctions. Thus, the result that there is overdissipation of rent in all-pay auctions extends to competition in terms of time.

1. Introduction

Competition for prizes is a basic feature of many economic and social interactions. Firms compete to develop new products, athletes vie to win medals and cash prizes, students compete for grades, and applicants fight for jobs. Economists, beginning with Tullock (1980) have modeled these competitions as rent seeking games, in which competitors expend resources, with greater expenditures translating into a higher probability of winning the prize. An extreme case is winner-take-all competition, which can be modeled as an all-pay auction. In an all-pay auction, each of a number of competing bidders makes a bid. The player making the highest bid wins the prize, but losing players pay the amount that they bid. In a first-price all-pay auction, the winning bidder also

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pays an amount equal to her own bid.[2] Therefore, everyone participating in the game incurs a cost, making the setting well-suited to studying competition.

However, money is not the only medium of reward used in competitions. In this paper, we study competition in terms of time. In many settings, the time spent on a task translates into an advantage. The popular author Malcolm Gladwell (2008) captures the essence of this correlation with his remark that becoming a world-class expert in a domain requires 10000 hours of practice. Indeed, in many of the examples cited in the first paragraph, from competition to develop a new product, to achievement in work, school, music or athletics, the time one commits to a task is critical to achieving a high likelihood of success. This raises an important question: do individuals maintain the same strategies across different reward domains when it comes to competing in contests? This paper focuses on this question.[3]

The theory of auctions is general in the sense that the valuations and bids for items may be thought of in terms of money, effort or time, and the underlying logic of the models is the same regardless of the medium. However, the experimental research that has been conducted to date on all-pay auctions has always employed bidding in terms of money, which is the standard medium of reward in experimental studies in economics. Thus, bidding behavior in terms of money is the only setting that is well-understood. This literature has for the most part documented bidding that is more aggressive than equilibrium levels (Davis and Reilly, 1998; Potters et al., 1998[4]; Gneezy and Smorodinsky, 2006; Lugovskyy et al., 2010), and overdissipation of the available rent, in settings with complete information. Barut et al. (2002), Kaplan et al. (2002), Noussair and Silver (2006), and Hyndeman et al. (2012) also observe overbidding relative to equilibrium in environments with incomplete information. See Sheremeta (2013) and Decheneaux et al. (2015) for reviews of the literature.

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[2] There are a number of other variations, including a second price all-pay auction, in which the winner pays an amount equal to the second highest bid, and a dynamic version of the second price all-pay auction, known as the war of attrition (Maynard Smith, 1974).

[3] Some firms offer bonus time off for good performance, and a number of commentators have suggested that this form of incentive should be more common. See for example: https://www.raconteur.net/business-innovation/time-off-boost-productivity
or
https://www.forbes.com/sites/groupthink/2013/10/10/forget-vacations-and-sick-leave-a-new-way-to-give-employees-time-off/#3b033779662e

[4] This paper is an exception. Potters et al (1998) find that average bids are close to the Nash equilibrium level.

Understanding the allocation of time is also of more general interest, because individuals are required to make decisions regarding how to spend their time on a continual basis. The total amount of time available to an individual is fixed. Consequently, agents have to constantly evaluate the benefits and costs of different time allocations. Despite being of tremendous interest, only a limited number of studies in the social sciences have employed time as a source of value.

This strand of research mostly corroborates the idea that the behavior of players does not change when the medium of reward changes. Leclerc et al. (1995) in a study involving hypothetical incentives, found that individuals treat time for the most part similarly to money. They find that most individuals are risk averse over time gains and risk seeking over losses. They argue that an important difference between time and money is that money is fungible to a greater extent. Milliman and Weber (1997), in contrast, find that individuals are risk averse for both gains and losses in commuting time. Berger et al. (2012) observe no significant differences between ultimatum games where players bargain over money or time. Abdellaoui and Kemel (2014) elicit prospect theory parameters for both time and money and find less concave utility and loss aversion for time than for money. The probability function was S-shaped for both time and money. Noussair and Stoop (2015) also find that agents do not change their pattern of behavior significantly in either dictator, ultimatum, or trust games when playing in terms of time rather than money. Festjens et al. (2015) find that individuals have similar risk preferences over money and time. Doll et al. (2017) study ultimatum bargaining over waiting time, and observe that proposer behavior is similar under gain and loss framing, though responder behavior reflects a greater willingness to wait under a gain rather than a loss framing. No previous experimental studies, of which we are aware, have studied the behavior of individuals in an all-pay auction, or any other auction for that matter, in terms of time.

In the experiment reported here, we study whether participants' bidding behavior exhibits similar patterns when the effort exerted is in terms of time rather than money. To test this hypothesis, we create two different protocols. In the first protocol, called MT, subjects participate first in one monetary all-pay auction, and play one all-pay auction in terms of time thereafter. Under the second protocol, called T, participants play a one-shot time auction only. The money and time auctions are designed to be equivalent in terms of number of bidders, distribution of valuations, stakes, and gain-loss framing.

Our environment is one of incomplete information, specifically the independent private value structure introduced by Vickrey (1961). When playing in terms of money, individuals have a private monetary value for winning the item, drawn from a distribution that is common knowledge and the same for all bidders. Players then engage in a first-price all-pay auction. They submit monetary bids simultaneously. The highest bidder receives the item and every bidder pays what she bid, regardless of whether or not she won the auction.

When the auction is played in terms of time, subjects begin with an obligation to stay in a private, fully-enclosed cubicle for 30 minutes. This is a reference level of time, encouraged by the wording of the instructions to be treated like the money payoff level of 0 in the monetary auctions. During their waiting time, they are not permitted to engage in any activity except for sitting quietly. They receive a valuation, denominated in terms of minutes, for winning the auction. This valuation entitles them to leave the experiment early, by the number of minutes indicated in their valuation, if they win the auction. Each player then simultaneously submits a bid in terms of time. A bid consists of a commitment to stay for a number of minutes equal to her bid, in addition to the initial baseline of 30 minutes. The player who bids the highest receives a reduction in his required time in the laboratory by a number of minutes equal to her valuation minus her bid. All other players are required to stay an additional number of minutes equal to their bids. Thus, a player who wins the auction with a bid lower than her time exemption, gets to leave the session earlier than planned, an outcome in the domain of gains, like a bidder who won a unit for less than her valuation in a monetary auction. Bidders who bid a positive amount in the time auction but fail to win a unit must stay at their session longer than planned, putting them in the domain of losses relative to their reference point, like a bidder who pays money when they fail to win a unit in a monetary auction.

We compare bidding with equilibrium behavior, and study overall auction revenue and allocative efficiency. We then consider the relationship between cognitive ability and behavior in the auctions. We study whether bidders who display greater ability bid closer to the equilibrium levels and achieve greater earnings than other players. The Cognitive Reflection test, proposed by Frederick (2005), is employed to measure this relationship. The test has been found to correlate strongly with behavior and earnings in second-price auctions (Schneider and Porter, 2016) and asset markets (Corgnet et al., 2014; Breaban and Noussair, 2015; Bosch-Rosa et al., 2017).

Inaccurate beliefs about the relationship between a bid level and the probability that the bid is higher than the bids of all other players, might also account for overbidding. While overbidding in first-price, winner-pay auctions is consistent with risk aversion (Cox et al., 1982, 1988), Goeree et al. (2002) suggest that overbidding might result from participants' misperception of the probability of winning the auction. Armantier and Treich (2009) present evidence in support of the claim that underestimation of probabilities leads to overbidding in first-price, winner-pay auctions. Baharad and Nitzan (2008) model how the distortion of probabilistic events, encapsulated by prospect theory, can give rise to overbidding in contests. In our experiment, we implement a measurement protocol for probability calibration in auctions, and correlate the scores of individuals with their earnings, and with their deviations from equilibrium bidding.

Our results show that the general patterns in aggregate behavior are similar in auctions for money and for time. Regardless of the reward medium, bidding is on average higher than equilibrium levels and players lose money and time on average. The available rent is more than fully dissipated for both money and time. Cognitive reflection test scores are positively related to earnings in the money auction, and in some regression specifications for the time auction. A gender effect appears in that women bid more aggressively than men in the monetary auction. Thus, while the general pattern of overbidding relative to equilibrium is robust to the change in reward medium, there do appear to be some subtle differences between the way bidders approach competition over money and over time.

The paper proceeds as follows. In section two, a symmetric equilibrium bidding strategy of an all-pay auction is derived for both the monetary and the time auctions. The experimental design is described in section three. In section four, we consider the data from the all-pay auctions played using money as a medium of reward. In subsection 4.1, we report the aggregate patterns in the data. In subsection 4.2, we consider individual bidding strategies and how they correlate with our measures of sophistication. In subsection 4.3, we analyze the correlates of effective bidding. In section five, we turn our attention to the time auctions. As for the monetary auctions, the first subsection, 5.1, reviews the overall patterns in the data. 5.2 investigates correlations between bidding behavior and the sophistication measures, and 5.3, the determinants of effective bidding. In section six, we provide a comparison between the monetary and time auctions. Section seven contains some concluding remarks.

2. Model

In this section, we derive a Bayesian equilibrium for the auctions that we study in our experiment. This equilibrium serves as the benchmark against which we compare the experimental data from both conditions. The model implies that the monetary and time auctions would exhibit similar empirical patterns. Section 2.1 does so for the monetary auction, following closely the arguments of Noussair and Silver (2006), and Section 2.2 presents a similar analysis for the time auction.

As is typical in the experimental literature on auctions, we propose that individuals use a symmetric equilibrium in monotonic strategies. While there may well be asymmetric equilibria to this game, the rationale for assuming symmetry is that in the experiment, individuals are matched randomly and are in a symmetric position with no clear means of coordinating on an asymmetric equilibrium. Monotonicity is also reasonable assumption since it is natural to associate higher bids with higher values.

2.1. Single unit, first price, all-pay auctions for money

Consider an all-pay auction for one item that is to be sold to the highest bidder among n competitors. Each bidder $i = \{1, \ldots, n\}$ draws a valuation for the item, v_i, independently from a uniform distribution on $[0,\bar{v}]$. Valuations are private information, but the number of players and the distribution of valuations is common knowledge.

The auction follows first price all-pay rules. Each bidder i submits a bid $b_i \geq 0$ simultaneously. The person who submits the highest bid wins the item for sale. All bidders pay their bid, regardless of whether or not they obtain the item.

The utility of player i then takes the following form:

$$\Pi_i(b_i, v_i) = \begin{cases} v_i - b_i & \text{if } b_i > b_j \ \ \forall j \neq i \\ -b_i & \text{if } \exists\, j \neq i \text{ such that } b_i < b_j \end{cases} \tag{1}$$

The first term, $v_i - b_i$, is the bidder's payoff in the event that she wins the auction. This event occurs if i submits the highest bid among all players, or in other words, if $b_i > b_j \ \forall j \neq i$. Each bidder i receives v_i in value from the item and pays b_i to acquire it. The second expression, $-b_i$, is the payoff of bidder i in the event that she is not the highest bidder, in which case she pays her bid. This outcome occurs if $\exists\, j \neq i$ such that $b_i < b_j$.

Suppose that all bidders are using a symmetric Bayesian equilibrium bidding strategy $\beta(v)$, and further assume that the equilibrium bidding strategy is monotonic so that $\beta'(v) > 0$. There is a symmetric equilibrium bidding function $\beta(v_i)$, which in the case of five bidders has the form

$$\beta(v_i) = \frac{\bar{v}(n-1)}{n}(\frac{v_i}{\bar{v}})^n. \qquad (2)$$

For the parameters of our experiment, $n = 5$, and $\bar{v} = 1000$, equation (2) becomes

$$\beta(v_i) = 800 * (\frac{v_i}{1000})^5 . \qquad (3)$$

The equilibrium expected payoff for bidder *i* is:

$$\Pi(v_i) = (\frac{1}{\bar{v}})^{n-1} * v_i^n * \frac{1}{n} . \qquad (4)$$

For our parameters, the expected payoff is:

$$\Pi(v_i) = (\frac{1}{1000})^4 * v_i^5 * \frac{1}{5} = 200 * (\frac{v_i}{1000})^5 . \qquad (5)$$

A detailed derivation is given in the appendix. The argument parallels that provided by Noussair and Silver (2006).

2.2. All-pay auction with time as a medium of reward and payment

Now consider an all-pay auction with time as a medium of reward rather than money. Before the auction takes place, each bidder has a commitment of time to the auctioneer, equal to *K* minutes. The activity during these *K* minutes has a marginal disutility, which is assumed to be constant over time.[5] In the experiment, this consists of waiting for *K* minutes in the laboratory. The valuation, v_i, drawn by each participant, represents the number of minutes that can be subtracted from the mandatory *K* minutes (allowing the participant to leave the experiment earlier) if bidder *i* wins the auction.

Each bidder simultaneously submits a positive sealed bid b_i, representing the number of minutes that she offers to remain in the laboratory, on top of the initial time *K*. The utility of player *i* is the following:

$$U_i(b_i, v_i) = \begin{cases} v_i - b_i - K & \text{if } b_i > b_j \ \forall\, i \neq j \\ -b_i - K & \text{if } \exists\, j \neq i \text{ such that } b_i < b_j \end{cases} \qquad (6)$$

[5] This constant marginal disutility can be thought of as risk neutrality in time. It means that an individual is indifferent between waiting a fixed amount of time and a random amount of time with the same expected length.

Since K is constant, it does not enter the maximization problem. As a result, the equilibrium bidding function is analogous to the case where the medium of effort is monetary:

$$\beta(v_i) = \frac{\bar{v}(n-1)}{n}\left(\frac{v_i}{\bar{v}}\right)^n. \qquad (7)$$

For the parameters used in the experiment, where there are 5 bidders, whose valuations are drawn from [0, 30], the equilibrium bidding function is:

$$\beta(v_i) = \left(\frac{1}{30}\right)^4 * \frac{4}{5} * v_i^5 \qquad (8)$$

The maximum possible bid consistent with the risk neutral Bayesian equilibrium, is $\beta(30) = 24$.

3. The experiment

3.1. General description

The sessions were conducted at the CentER experimental laboratory, at Tilburg University, The Netherlands, between 2013 and 2018. Participants were Bachelor's and Master's students at the University. The experiment had two protocols, called MT and T, and was designed to allow both within- and between-subject comparisons of auctions conducted for money and time. In each session, only one protocol was in effect. MT included one monetary auction, followed by one time auction, while T had one time auction only. Each individual participated in only one session. In both treatments, subjects also completed tasks to measure their cognitive ability and probability calibration, before the auctions took place.

In total, 15 experimental sessions were conducted, six under the MT protocol and nine under T. Ten participants were present in each session, and thus there were two auctions with five bidders conducted simultaneously.[6] On average, each session under the MT protocol lasted approximately 1 hour and 28 minutes and subjects earned an average of 21.98€[7]. Each session in the T protocol lasted approximately 1 hour and 14 minutes and participants earned on average 14.95 €. Subjects received their earnings by electronic cash transfer made on the evening of the same day as the experiment.

[6] There was one exception. In one MT session, only 5 subjects participated.

[7] On average, in the MT treatment, each participant earned 4.02€ in the CRT task,8.64€ in the probability calibration task, 4.31€ during the monetary all-pay auctions, plus a 5€ show-up fee. If losses were incurred during the monetary auctions above the initial cash balance of 30ECU, the loss would be deducted from total earnings made in other parts of the experiment. Subjects were informed of this rule at the beginning of the monetary auction. Total earnings were sent via bank transfer within 48 hours of the end of the session. Payment via bank transfer is a standard procedure at Tilburg University and was how subjects expected to be paid.

The experiment was conducted using pen and paper, and thus was not computerized. At the beginning of the session, the experimenter distributed handouts containing the instructions for the experiment. The instructions were read aloud by the experimenter before each part of the experiment. Subjects were seated in individual, private, fully-enclosed cubicles that ensured that no communication between individuals could occur during the experiment. All questions were answered privately.

3.2. The monetary auction

Under the MT protocol, one monetary auction was conducted. At the beginning of period 1, subjects received an initial cash balance of 30 ECU (Experimental Currency Units). The experimental currency was converted to Euros at a rate of 6 ECU per 1 Euro. A valuation for the item, denominated in ECU, was drawn from a discrete uniform distribution on [1, 30]. Draws were independent across bidders and between the practice period and the period that counted. Bids were made in terms of ECU and had to be greater than or equal to 0.

Bidders submitted bids for a fictitious object available for sale. They wrote their bids down on a form provided to them, which was then collected by the experimenter. All bids were submitted simultaneously in the sense that no subject could observe the choice of any other player before she submitted her bid. The instructions and forms that subjects filled out are provided in online Appendix C.

After collecting the forms and noting the winner, the experimenter returned to inform each bidder separately of whether she was successful in winning the auction. The bidder with the highest bid won the auction and received her valuation minus her bid as a payoff. All other subjects incurred a loss equal to the amount of their bid. The participants who did not win the auction did not learn the winning bid. In case of a tie, the winner was chosen by a coin flip. There was one practice auction period followed by one period that counted toward subjects' earnings.

3.3. The time auction

One time auction took place in both the MT and the T sessions. In the time auction, subjects were asked to remain in their cubicles for 30 minutes, during which time they were required to be passive. They were not allowed to use any electronic device, read, write, or communicate with other participants[8]. Subjects were given the opportunity to participate in one all-pay auction in which, if successful, they could decrease their waiting time in the laboratory from the initial 30 minutes and leave the experiment early. The wording of the instructions was intended to put winning the auction in the domain of gains and to treat 30 minutes as a reference level, in the same manner as 0 is a reference bid level in the monetary auctions. The currency used within this auction was time (in minutes).

Each participant received a "Time exemption", the term used to describe her valuation. The time exemption indicated the number of minutes that she could leave the session early if she won the auction. The time exemption for each individual was drawn independently from a discrete uniform distribution[9] on [1, 30] which was common knowledge. Players then submitted their bids in terms of minutes. The participant who bid the highest had her time exemption minus her bid subtracted from the initial 30 minutes, and the rest then had their bid added to the 30-minute baseline waiting time. That is, the winner could leave the laboratory after 30 minutes minus her time exemption plus the number of minutes that she bid. All other bidders had to stay for 30 minutes plus the number of minutes that they bid. The instructions and examples of the time auction were read aloud. They were similar to the monetary all-pay auction, but adjusted to fit the different reward medium and valuation distribution. The instructions can be found in the appendix.

A practice period was held, in which subjects did not actually have to wait. This was included to familiarize subjects with the process. This was followed by a one-shot game, which did count. After the participants placed their bids, they were informed of whether they won the auction or not, and the total amount of time they were required to wait in their cubicle. When the waiting time for an individual expired, the experimenter notified the individual that she could leave the experiment. Under both treatments, after the auctions were played, a questionnaire regarding background information was given to each participant before their waiting period began.

We tried to make as many factors as possible identical between the time and money auctions. We conducted one-shot money auctions, so that there was a comparable number of monetary and time auctions. Both were implemented in the domain of gains, with the presumed reference points

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[8] This ensured that no other utility was derived during the waiting time, as would have been the case if participants could have used their phones or laptops, for instance.

[9] The time exemptions were drawn from the interval from 1 to 30, in order to ensure that the maximum potential gain, when a subject has a time exemption of 30 and makes a bid of 0 and wins, would not result in a negative length of time that a subject would be required to spend in the laboratory.

being zero in the monetary auctions and 30 minutes in the time auctions. Our implementation of gain/loss framing is similar to that of Doll et al. (2017). The instructions emphasized 30 minutes as a reference point by indicating "The experiment consists of four (three) parts and in addition, the experiment will continue for 30 minutes after part 4 (3) of this session. For participating in all parts of the experiment, you will receive a fixed endowment of 5€. Any extra earnings gained during the experiment will be added to this sum."[10] We controlled for the stake size in the two auctions in the following manner. In the money auctions, valuations ranged from 0 – 5 Euro. In the time auctions, time reductions ranged from 0 – 30 minutes. In the laboratory in which the experiment was conducted, the advertised average payment for recruited participants is 10 Euro per hour (5 Euro per 30 minutes). Therefore, we assume that 30 minutes in the laboratory will be viewed by subjects as equivalent to 5 Euro, at least in expectation.

3.4. Probability Calibration

Under both the MT and T protocols, we elicited a measure of how well subjects were calibrated about the probability that a given bid would win the auction. In the MT treatment, participants were required to write the probability that a person would win a monetary auction if she submitted the following bids: 2, 4, 6,…, 28 ECU. They had to express their answer as a percentage between 0% and 100%, inclusive. The estimates were incentivized using a quadratic scoring rule (Brier 1950; Nyarko and Schotter, 2002; Rey-Biel, 2009) that is incentive compatible[11]. The payoff function was the following:

$$\Pi = \max \{0, 10 - 45 * (P_t - P_a)^2\} \tag{9}$$

where P_t stands for the indicated probability of winning the auction and P_a represents the actual probability. The maximum of the two terms in the expression is taken in order to ensure non-negative payoffs. The subject could win a maximum amount of 10€ and a minimum of 0€. The actual probabilities, to which the guesses were compared, were estimated with a probit regression

[10] In the first three sessions run under T protocol, the instructions placed somewhat less emphasis on the reference point of 30 minutes. Nevertheless, the fact that the data is similar in these sessions to the other six sessions, leads us to believe that our goal of inducing the intended reference point was achieved in both cases.

[11] The quadratic scoring rule (QSR) assumes that respondents are risk neutral (Starmer, 2000). Adjustments to QSR procedures which account for risk aversion have been proposed by Offerman et al. (2009) and Anderson et al. (2010). These methods have been shown to reduce bias, but not to significantly increase accuracy (Trautman and Kuilen, 2011).

conducted on the data from the first session. Subjects were not informed about their performance on this task until the experiment ended. One randomly chosen decision in this task counted toward a participant's earnings.

3.5. Cognitive Reflection Test

At the beginning of each session, we also evaluated subjects' willingness/ability to reflect on a decision problem. In both MT and T, we administered the Cognitive Reflection Test (CRT) popularized by Frederick (2005). Each question in the test has an intuitive, though erroneous, answer. However, if the respondent reflects on the problem, the solution is straightforward. This test is widely used in experimental economics (Brañas-Garza et al., 2016).

Individuals who register to participate in experiments are likely to have taken part in more than one experiment, and thus may have been exposed to the CRT previously. In order to account for the possibility, the standard questions were modified while preserving their underlying logic[12]. Specifically, we asked the following three questions:

- A shirt and a hat cost 5.50 € in total. The shirt costs 5 € more than the hat. How much does the hat cost? (correct answer: 25 cents; intuitive erroneous answer: 50 cents)
- If it takes 3 people 3 hours to assemble 3 bicycles, how long would it take 90 people to assemble 90 bicycles? (correct answer: 3 hours; intuitive erroneous answer: 90 hours)
- The forest of North Carolina is home to a colony of wild rabbits. Every year, the colony doubles in size. If it takes 24 years for the colony to reach 100.000 rabbits, how long would it take for the colony to reach half of that number? (correct answer: 23 years; intuitive erroneous answer: 12 years)

Individuals received either 1 or 2 Euro for each correct answer depending on the session.

3.6. Sequence of activity in each session

Figure 1 illustrates the timing of events in each of the two protocols. The MT protocol consisted of 4 parts, and the timing is illustrated in the upper half of Figure 1. In the first part, subjects were

[12] Each individual was asked if they had encountered any of the CRT questions previously. 42% of the participants reported that they have seen similar questions before. Nevertheless, 34% of the subjects who answered 0 or 1 question out of three correctly, reported that they had already seen the test before. Brañas-Garza et al (2015), in a meta-study, find no significant difference in performance on the CRT test between respondents who have seen the test before and those who have not.

asked to answer the questionnaire for the CRT test. In part two, after we carefully explained the design of a monetary all-pay auction and provided some examples, the probability calibration measurement protocol was implemented. It was emphasized that their predictions would not influence payoffs within the actual auctions played (and vice-versa). One prediction, which would be drawn randomly at the end of the experiment, would determine the participant's payoff in part two. In part three, there was the monetary auction: one period of practice that did not count toward participants' earnings, followed by an auction that did count. Finally, one time auction was conducted, and constituted part four of the session in the MT protocol.

The T protocol consisted of three parts. The sequence of events is shown in the lower panel of Figure 1. The session began by asking the participants to fill in the questionnaire for the CRT test. In part 2, the instructions for the time auction were read. The probability calibration task was then administered, with the elicitation of probabilities in terms of time rather than money. Participants were required to write down the probability that they believed that a person would win the auction if she submitted the following bids: 2, 4, 6 ,…, 28 ECU. The answer had to be expressed as a percentage between 0% and 100%. Part 3 of the session consisted of one all-pay auction, in which the medium of reward was time, prior to which a practice period was played that did not count toward earnings.

The MT Protocol

Part 1: CRT Questionnaire	Part 2: Eliciting Beliefs	Part 3: Monetary All-Pay Auction	Part 4: Time All-Pay Auction

The T Protocol

Part 1: CRT Questionnaire	Part 2: Eliciting Beliefs	Part 3: Time All-Pay Auction

Figure 1. Timing of activity under the two protocols

In the analysis that constitutes the rest of the paper, the benchmark model is the symmetric Bayesian equilibrium to the game. This is our prediction, against which the data from the experiment are compared. Because the model applies equally to time and money, we also maintain the null hypothesis that there would be no difference between auctions for money and for time. The prediction also has a rationale in prior experimental work. There is evidence from prior research with other paradigms that there would be no difference between money and time (Leclerc et al., 1995; Milliman and Weber, 1997; Berger et al. (2012); Festjens et al., 2015; Noussair and Stoop (2015)).

4. Results for the monetary All-pay Auction

4.1. Overall bidding behavior and earnings

Figure 2 shows the relationship between valuations, observed bids, and Bayesian equilibrium bids, pooled across participants and sessions. In the figure, the horizontal axis indicates the valuation of an individual. The vertical axis indicates the observed bids submitted and the Risk Neutral Bayesian Equilibrium (RNBE) bids. The figure suggests that on average, overbidding occurs relative to the equilibrium. A *t*-test of the hypothesis that $b = b_{RBNE}$, where b is the observed bid and b_{RBNE} is the equilibrium bid, rejects the null hypothesis of equality (p = 0.047). One consequence of this overbidding is that participants' earnings are lower than predicted. Summary statistics of bidders' earnings compared to equilibrium levels are presented in Table 1. The data show that the average participant lost money during the monetary auctions. Those who lost more than their endowment had their losses deducted from their earnings accumulated in other tasks and their show up fee.

The table also displays the average allocative efficiency observed in the auctions, as well as the percentage of auctions in which an efficient allocation, the awarding of the unit to the bidder with the highest valuation, occurs. The average efficiency is 63.4%, and the percentage of auctions that are efficient is 27.27%. This incidence of efficiency is lower than that typically observed in winner-pay, first price auctions[13]. The low efficiency levels are likely in part due to the fact that each bidder participated in only one auction, and thus there was no opportunity for learning.[14]

[13]See for example Cox et al. (1988), who report an efficiency of approximately 98% in first-price winner-pay sealed bid auctions.

[14] In other research we have conducted in which participants bid in 15 consecutive all-pay monetary auctions, the average efficiency is 81% and the percentage of auctions that are efficient is 46%.

Table 1. Average earnings and efficiency in the monetary auction

Earnings (in ECU)	-4.00
Efficiency	63.4%
% of Auctions that are efficient	27.27%
Bid-RNBE, b - b_{RBNE} (in ECU)	2.88
Abs |Bid-RNBE|, |b - b_{RBNE}|(in ECU)	7.81
AV. (Bid-RNBE) >0 b - b_{RBNE} | $b > b_{RBNE}$ (in ECU)	8.64

Note: The data consist of 11 monetary auctions in the MT treatment. Earnings are net of initial endowment. Efficiency is the valuation of the winning bidder divided by highest valuation among bidders in his group. The third row is the percentage of instances in which the bidder with the highest valuation is awarded the item. Bid-RNBE is the difference between the actual bid and the risk neutral Bayesian equilibrium bid. Abs (Bid-RNBE) is the absolute difference between the actual bid and the risk neutral Bayesian equilibrium bid. Av(Bid-RNBE) >0 indicates the average overbid.

4.2. Bidding behavior at individual level

Figure 2 illustrates the heterogeneity of behavior among the participants in the monetary auctions. The incidence of two common bidding rules is given in Table 2. The first is a rule of bidding zero, regardless of one's valuation. Strictly speaking, zero bidding is a requirement that $b_i(v_i) = 0$. However, we allow a small amount of flexibility in our classification, and we include $b_i(v_i) = 1$ within the category. Bidding zero is quite common, and it is the strategy employed by 47% of bidders. Zero bidding is less common for bidders with high valuations than for those with low ones. Zero bidding represents a strategy that almost always leads to a zero payoff.[15]

The figure also shows that submitting a bid equal to one's valuation is also common. We call this *diagonal* bidding, and it is defined as $b_i(v_i) = v_i$, though for purpose of classification we consider $b_i(v_i)$ ε [v_i - 3, v_i + 3] to fall into the category. 27% of the participants in the monetary auction are classified as diagonal bidders. Diagonal bidding is a poor strategy that is guaranteed to yield a payoff of either zero, in the event one's bid is the highest in the group, or negative if it is not the highest. The diagonal bidding phenomenon is common both for low and high valuations.

[15] There is a very small probability of a strictly positive payoff if all bidders bid 0, and the tie is resolved in one's favor. There is no possibility of losing money when one bids zero.

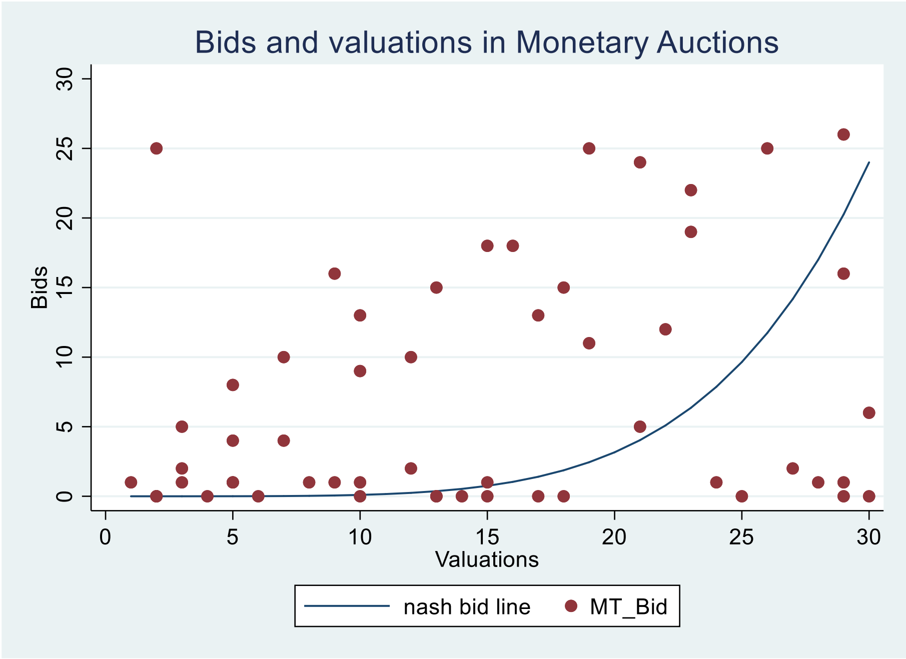

Figure 2. The relationship between bids and valuations in the monetary auctions

We now consider which factors correlate with the use of each of these two strategies. Table 2 shows the percentage of individuals using each strategy that have a number of other characteristics. The numbers beginning in the second row of the table are the percentages of individuals that use each strategy who exhibit a characteristic, rather than the percentage of individuals with a given characteristic who use the strategy. The table shows that those who use a diagonal bidding strategy tend to be females and those who are zero bidders are more likely to be male. Zero bidders are more likely to have high CRT scores and to be well-calibrated than diagonal bidders are. Diagonal bidders also earn less and deviate more from equilibrium than zero bidders.

Table 2. Bidding strategies, gender, cognitive ability and earnings

	Zero bidders	Diagonal bidders	Other strategies
Percentage using strategy overall	47% 26	27% 15	26% 14
Percentage using strategy who are male	58% 11	26% 5	18% 3
Percentage using strategy who have CRT=2,3	58% 22	18% 7	24% 9
Percentage using strategy who are well-calibrated[16]	50% 16	31% 10	19% 6
Average CRT	2.53	1.46	1.16
Average Earnings	29.57	24.60	21.78
Absolute deviation from RNBE $\|b - b_{RBNE}\|$	4.17	11.60	10.52

4.3. Correlates of effective bidding

We use two different notions of the effectiveness of bidding strategies. The first is to say that an effective strategy is one that is close to the equilibrium level. The second criterion is to define an effective strategy as one that yields high earnings. Table 3 below shows which factors correlate with both criteria: with Absolute Bid Deviation of bid from equilibrium, $|b - b_{RBNE}|$, and with earnings. The data in Table 3 show that better probability calibration or higher CRT score is not correlated with bidding closer to equilibrium, nor with higher earnings. Males in our sample bid less than females, and earn more on average in the monetary auction.

To further analyze whether individual probability miscalibration and cognitive abilities correlate with bids and earnings, when controlling for other variables, we conduct robust OLS regressions, using cognitive ability and probability miscalibration as independent variables. The deviation $(b - b_{RBNE})$, or absolute deviation $|b - b_{RBNE}|$, from the RNBE, as well as average earnings, are the dependent variables. The estimation results are reported in Table 4. They show that individuals' CRT scores are positively related to earnings and lower bids. They also reveal no

[16] We consider subjects to be well-calibrated if their accuracy in the probability calibration task was better than the average accuracy level. In our data, 39.6% of the subjects (57 out of the total of 144) are well calibrated. Therefore, the distribution of performance in the task was skewed.

relationship between bidding behavior and probability miscalibration. Males bid closer to equilibrium levels than females, controlling for miscalibration levels and CRT scores.

Table 3. Cross tabulation of correlations of subject characteristics and bidding outcomes in the monetary auction

	Absolute Bid Deviation	Earnings	Abs. probability miscalibration	Probability Miscalibration	Male	High ability (CRT=2|3)
Absolute Bid Deviation	1					
Earnings	-0.34***	1				
Abs. Probability Miscalibration	-0.03	-0.19	1			
Probability Miscalibration	-0.04	-0.07	-0.32***	1		
Male	-0.31**	0.30**	-0.18	0.08	1	
High ability (CRT=2,3)	-0.11	0.04	0.11	-0.14	0.15	1

Note: Absolute Bid Deviation is calculated as $|b\text{-}\tilde{b}|$, where b is the actual bid and $\tilde{b}$ is the Bayesian equilibrium bid. Probability Miscalibration is calculated as $avg\left(\frac{\gamma-\tilde{\gamma}}{\tilde{\gamma}}\right)$, where γ is the actual probability and $\tilde{\gamma}$ is the submitted probability. This measure captures whether there is underestimation or overestimation on average; Absolute Probability Miscalibration is calculated as $avg\left|\frac{\gamma-\tilde{\gamma}}{\tilde{\gamma}}\right|$ and it captures the magnitude of the miscalibration.

Table 4. Determinants of overbidding, differences from equilibrium, and earnings

(a) Absolute difference between bid and RBNE, $|b - b_{RBNE}|$

	(1)	(2)	(3)	(4)
	$\|b - b_{RBNE}\|$	**$\|b - b_{RBNE}\|$**	**$\|b - b_{RBNE}\|$**	**$\|b - b_{RBNE}\|$**
CRT	-1.50	-0.97		-1.04
	(-1.46)	(-0.95)		(-1.07)
Abs. Probability Miscalibration	-0.29	-2.08	-2.63	
	(-0.08)	(-0.55)	(-0.74)	
Male		-4.37	-4.95	-4.10
		(-2.17**)	(-2.61)**	(-2.08)**
Constant	10.97	12.18	10.65	11.34
	(4.71)***	(5.32)***	(5.21)***	(5.32)***
Observations	55	55	55	55
R-squared	4.3%	11.2%	9.5%	10.7%

Note: The dependent variable is the absolute difference between the observed bid and Bayesian equilibrium bid for each individual. Abs. Probability Miscalibration is the absolute difference between the probability of winning with a certain bid as indicated by a participant and the actual probability, averaged over all 14 questions. OLS regression, t-statistic based on robust s.e. in parenthesis; */**/*** indicates statistical significance at 10%, 5% and 1% level, respectively *(b) Earnings*

	(1)	(2)	(3)	(4)
	Earnings	**Earnings**	**Earnings**	**Earnings**
CRT	2.27	1.93		1.78
	(2.26)**	(1.95)*		(1.89)*
Absolute Probability Miscalibration	-5.23	-4.08	-3.00	
	(-1.53)	(-1.15)	(-0.91)	
Male		2.81	3.97	3.34
		(1.35)	(1.87)*	(1.64)
Constant	23.88	23.11	26.15	21.47
	(10.91)***	(9.90)***	(13.48)***	(9.49)***
Observations	55	55	55	55
R-squared	11.6%	14.2%	8.0%	12.5%

Note: The dependent variable is a bidder's earnings in the monetary auction. OLS regression, t-statistic based on robust s.e. in parentheses; */**/*** indicates statistical significance at 10%, 5% and 1% level, respectively.

(c) Deviation of bid from the RNBE, $b - b_{RBNE}$

	(1)	(2)	(3)	(4)
	$b - b_{RBNE}$	**$b - b_{RBNE}$**	**$b - b_{RBNE}$**	**$b - b_{RBNE}$**
CRT	-2.97	-2.84		-2.88
	(-2.20)**	(-2.00)**		(-2.15)**
Probability Miscalibration	0.64	0.79	2.05	
	(0.16)	(0.20)	(0.52)	
Male		-1.12	-2.71	-1.06
		(-0.42)	(-1.05)	(-0.39)
Constant	9.00	9.14	4.17	9.07
	(3.20)***	(3.18)***	(2.22)**	(3.07)***
Observations	55	55	55	55
R-squared	9%	9.2%	2%	9.1%

Note: The dependent variable is the difference between a player's bid and the Risk Neutral Bayesian equilibrium bid. Probability Miscalibration is the difference between the probability of winning with a certain bid as indicated by a participant and the actual probability, averaged over all 14 questions in the calibration protocol. OLS regression, t-statistic based on robust s.e. in parenthesis; */**/*** indicates statistical significance at 10%, 5% and 1% level, respectively.

Our findings regarding behavior and outcomes in the monetary auctions are summarized as result 1.

Result 1: In the auctions where money is the medium of reward, bidding exceeds the risk-neutral Bayesian equilibrium levels on average. There is overdissipation of the available rent, and average earnings of bidders are negative. Those players who are more sophisticated, as measured by CRT scores, bid lower and receive greater earnings. Males bid lower than females.

5. Results for the time all-pay auction

5.1. Overall bidding behavior and earnings

The average observed efficiency and earnings in the time auctions under both the T and MT protocols is given in Table 5, along with average bidding behavior relative to equilibrium. The table shows that average bidder earnings are negative in the time auctions, as in the monetary auctions. The average efficiency, as well as the percentage of auctions that result in an efficient outcome, is higher in the time than in the monetary auctions, suggesting that there is less heterogeneity in bidding strategies in the time auctions (in Section 6, however, we shall show that this difference is not significant). The table shows that the extent of overbidding, in terms of the average overbid compared to the equilibrium level, is similar to the levels observed in the monetary auctions. We test whether such overbidding, b - $b_{RBNE,}$ is significantly different from zero and we conclude that there is significant overbidding in both the MT protocol (p = 0.0004) and the T protocol (p = 0.0007). All of the statistics are very similar under the two protocols, reinforcing the idea that prior participation in a monetary auction had no material effect on behavior in the time auction.

Table 5. Summary Statistics for the time auction in both T and MT

	Time all-pay auction (T treatment)	**Time all-pay auction (MT treatment)**
	Mean	Mean
Earnings (in minutes)	-3.86	-3.07
Efficiency	79%	81.3%
% of Auctions that are efficient	44%	54%
Bid-RNBE (in minutes)	3.45	3.47
Abs |Bid-RNBE| (in minutes)	6.83	5.01
Av. Minutes Waited	33.86	33.07
AV. (Bid-RNBE) >0	8.18	6.66

Note: Earnings are net of initial waiting time, so that for example, an individual who is required to wait 32 minutes has earnings of -2 minutes. Efficiency is the valuation (time exemption) of the winning bidder divided by highest valuation among bidders in his group. Bid-RNBE is the difference between the actual bid and the risk neutral Bayesian equilibrium bid. Abs (Bid-RNBE) is the absolute difference between the actual bid and the risk neutral Bayesian equilibrium bid. Av(Bid-RNBE) >0 indicates the average overbid.

5.2. Bidding behavior at individual level

We now consider the bidding strategies employed in the time auction. Figure 3 plots the relationship between valuation and bid for the time auction played under both protocols.[17] The overall pattern in bidding behavior appears to be similar in MT and T. A substantial fraction of individuals bid zero, while many bid greater than the equilibrium level, often close to their valuations. The overall impression is that behavior is similar to that in the monetary auction.

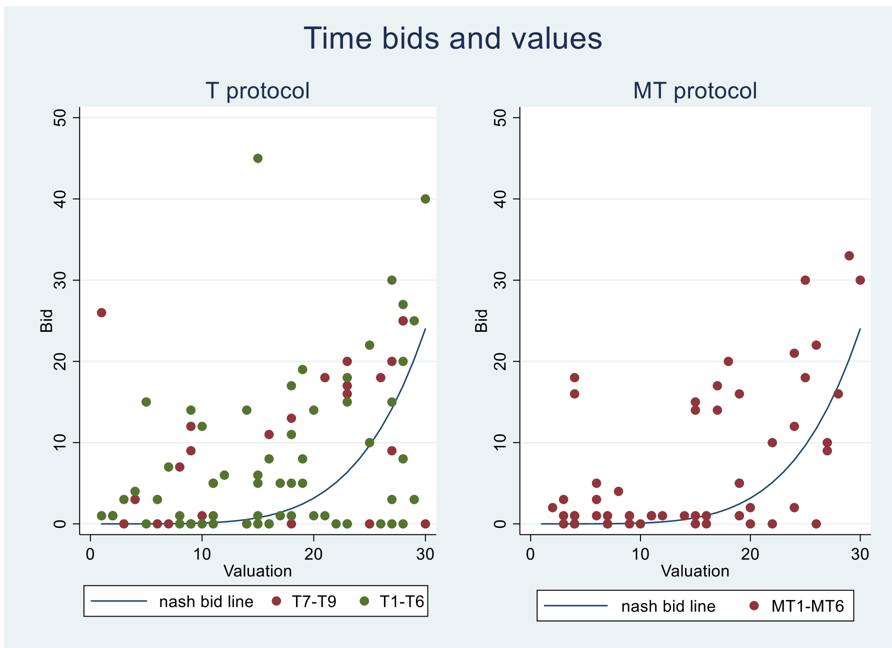

Figure 3. Bidding behavior in all time auctions in the T (left panel) and MT (right panel) protocols

Tables 6a and 6b document some correlates of bidding behavior and earnings in the time auction. The table reveals that those who bid farther from equilibrium receive lower earnings. Unlike in the monetary auctions, probability miscalibration is correlated with earnings, with better calibrated bidders earning more. There is no consistent relationship between gender or CRT scores with other variables. The correlations are similar in MT and T, again indicating that behavior is

[17] The T protocol data is shown in the left panel. There is no difference in bidding behavior between the first 6 sessions (shown with green dots) and the last 3 sessions we ran (shown with red dots). The difference between the two groups of sessions is that in the last 3 sessions, we made the reference point of 30 minutes more salient, following the techniques of Doll et al. (2017). All time auctions in the MT sessions followed the same procedures as the time auctions in these last three T sessions.

very similar under the two protocols, so that bidding patterns are not greatly affected by behavior in a prior monetary auction.

Table 6a. Correlations between key variables in the time auction under the T protocol

	Absolute Bid Deviation	Earnings	Absolute Probability Miscalibration	Probability Miscalibration	Male	High Ability (CRT=2,3)
Absolute Bid Deviation	1					
Av. Earnings	-0.35***	1				
Absolute Probability Miscalibration	-0.007	-0.17*	1			
Probability Miscalibration	0.10	-0.18*	-0.02	1		
Male	-0.11	0.09	0.09	-0.10	1	
High Ability (CRT=2, 3)	-0.10	0.03	-0.12	-0.09	0.08	1

Table 6b. Correlations between key variables in the time auction played under the MT protocol[18]

	Absolute Bid Deviation	Earnings	Male	High Ability (CRT=2, 3)
Absolute Bid Deviation	1			
Av. Earnings	-0.37***	1		
Male	-002	0.25*	1	
High Ability (CRT=2, 3)	-0.21	0.22*	0.11	1

5.3. Correlates of Effective Strategies

We now consider whether some player characteristics are predictive of bidding closer to equilibrium, bidding lower, or earning greater payoffs. The results for the T protocol, on which we place greater weight in the interpretation of our results because they are free of any potential hysteresis effects, are shown in Table 7. The analogous estimates for the MT protocol and for the

[18] The probability calibration data are not included in table 6b, because in the MT protocol, the calibration was conducted for the monetary auction, and not for the time auction.

pooled data from the time auctions in MT and T are omitted here for space considerations, and are given in Appendix B. The regressions presented in Table 7 indicate that CRT score and gender are not correlates of bids or earnings in the time auction. The only significant variable is the tendency for positively miscalibrated subjects to bid higher. The estimates for the MT protocol and the pooled data reported in the appendix also show that men bid lower than women, and those with high CRT scores bid lower and closer to equilibrium.

Table 7. OLS Results – Time auction (treatment T)

(a) Absolute deviation from RBNE bid, $|b - b_{RBNE}|$

	(1)	(2)	(3)	(4)
	|b– b_{RBNE}|	**|b– b_{RBNE}|**	**|b– b_{RBNE}|**	**|b– b_{RBNE}|**
CRT	-0.64	-0.58		-0.45
	(-1.21)	(-1.03)		(-0.82)
Absolute Probability	-2.50	-2.03	-1.33	
Miscalibration	(-1.00)	(-0.80)	(-0.56)	
Male		-2.13	-2.23	-2.26
		(-1.37)	(-1.47)	(-1.49)
Constant	9.04	9.77	8.49	8.77
	(5.76)***	(6.02)***	(5.65)***	(6.76)***
Observations	89	89	89	89
R-squared	1.6%	3.8%	2.9%	3.2%

Note: Dependent variable: Absolute difference between the risk neutral Bayesian Nash equilibrium and observed bid in the time auction. Each individual participant is the unit of observation. Absolute Probability Miscalibration is the absolute difference between the probability of winning with a certain bid indicated by the participants in the calibration task and the actual probability, averaged across all 14 probability levels. OLS regression, t-value based on robust s.e. in parenthesis; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

(b) Earnings

	(1)	(2)	(3)	(4)
	Earnings	**Earnings**	**Earnings**	**Earnings**
CRT	-0.22	-0.31		-0.02
	(-0.35)	(-0.47)		(-0.04)
Absolute Probability	-3.91	-4.51	-4.13	
Miscalibration	(-1.36)	(-1.58)	(-1.51)	
Male		2.71	2.65	2.43
		(1.65)	(1.66)	(1.49)
Constant	28.14	27.20	26.51	24.98
	(13.97)***	(13.12)***	(16.15)***	(16.02)***
Observations	89	89	89	89
R-squared	1.8%	4.9%	4.7%	2.5%

Note: The dependent variable is a bidder's earnings in the time auction. OLS regression, t-statistic based on robust s.e. in parentheses; */**/*** indicates statistical significance at 10%, 5% and 1% level, respectively.

(c) Deviation of bid from the RNBE, $b - b_{RBNE}$

	(1)	(2)	(3)	(4)
	b– b_RBNE	**b– b_RBNE**	**b– b_RBNE**	**b– b_RBNE**
CRT	0.008	0.04		-0.02
	(0.01)	(0.06)		(-0.03)
Probability Miscalibration	4.10	3.63	3.62	
	(2.14)**	(1.93)*	(1.92)*	
Male		-2.71	-2.71	-3.07
		(-1.37)	(-1.39)	(-1.56)
Constant	3.61	4.86	4.95	5.01
	(2.08)**	(2.46)**	(3.15)***	(2.54)**
Observations	89	89	89	89
R-squared	2.8%	4.9%	4.9%	2.7%

Note: The dependent variable is the difference between a player's bid and the Risk Neutral Bayesian equilibrium bid in the time auction. Probability Miscalibration is the level of miscalibration as measured by the difference between the probability of winning with a certain bid as indicated by a participant and the actual probability, averaged over all 14 questions. OLS regression, t-statistic based on robust s.e. in parenthesis; */**/*** indicates statistical significance at 10%, 5% and 1% level, respectively.

Our findings regarding outcomes in the time auctions are collected as our result 2.

Result 2: In the time auction, bidding exceeds risk-neutral Bayesian equilibrium levels on average. There is overdissipation of the available rent. Positively miscalibrated individuals overbid more. There is some evidence that individuals with higher CRT scores bid closer to equilibrium and achieve higher earnings.

6. Comparison between contests for money and time

In this section, we compare bidding behavior between the auctions for time and money. We consider the data from both the T and MT protocols. They are treated as distinct comparisons. Comparison between the money and the time auctions in MT are conducted within-subject. The money auctions and the time auctions in the T protocol are compared between-subject.

In the monetary auction, individuals bid above the equilibrium on average by 2.87 units, compared to 3.45 units in the time auction in T and 3.47 units in the time auction in MT. Thus, the average extent of overbidding is nearly identical for money and time. We test whether the distribution of deviations from the equilibrium, b- b_{RBNE}, in the monetary auction in MT and the time auction in treatment T, are significantly different. This comparison is important because individuals have a comparable degree of prior experience in the two situations, and there is no possibility for hysteresis effects to arise. We observe no significant difference (Prob > |z| = 0.98, N_1=55, N_2=89, MWU). This measure of overbidding is also not significantly different in the time auction played in the MT treatment when compared with the monetary auction in MT (Prob > |z| =0.81, N=55, MW Signed Rank test). In order to check for the effect of prior experience in a monetary auction on the time auction bids, we also compare the overbidding behavior between the time auction in the T treatment, which is played with no previous experience other than the practice auction, and time auction in the MT treatment, which is played after the monetary auction. There is no significant difference in average deviation from equilibrium between the two auctions (Prob > |z| =0.76, N_1=89, N_2=55, MWU).

In terms of absolute difference from the equilibrium, $|b - b_{RBNE}|$, we also observe that money and time produce similar outcomes. The average absolute deviation from equilibrium in the monetary auction is 7.81 units compared to 6.83 units in the time auction in T and 5.01 units in the time auction in MT. We perform a Mann-Whitney test to compare the distribution of these data and we find no significant differences between the money auction in MT and the time auction in T (Prob > |z| =0.61, N_1=55, N_2=89, MWU), between the money and time auctions in MT (Prob > |z| =0.12, N=55, MW Signed Rank test) or the time auction in MT and the time auction in T (Prob > |z| =0.11, N_1=55, N_2=89, MWU).

In order to make earnings comparable across the monetary and time auction we treat the 30 minutes of waiting time in the time auction as the equivalent of the 0 ECU of payoff in the money auction, so that for example an individual who must wait 35 minutes in the time auction has total earnings of -5 units. The average earnings in the monetary auction are -3.8 units, compared to -3.9 units in the time auction in T and -3.1 units in the time auction in MT. We find no significant difference between the earnings in the monetary auction in MT and the time auction in T (Prob > |z| =0.93, N_1=55, N_2=89, MWU), between the monetary and the time auctions in MT (Prob > |z| =0.92, N=55, MW Signed Rank test) or between the time auction in T and the time auction in MT (Prob > |z| =0.80, N_1=89, N_2=55, MWU)

As discussed in Section 5, efficiency, at 80%, is on average 17 percentage points greater in the time auctions than in the monetary auction. However, the differences are not significant due to the high variance of efficiency in both auctions (Prob > |z| =0.126, N_1=11, N_2=29, MWU). To consider whether strategies are less heterogeneous in one of the auctions, we conduct a varianceratio test for the two auctions. We find no significant difference between the variance of $b - b_{RBNE}$ in the two types of auctions (p = 0.288).

Table 8 shows the prevalence of the types of bidding behavior introduced in Section 4, in the different auctions. Zero and diagonal bidding are observed in similar proportions in the two auctions. There is also some correlation between the strategy a given individual uses in a monetary auction and in the subsequent time auction in MT. A significant correlation between the use of a zero bidding strategy in the money auction and in the following time auction exists ($\rho = 0.30$, $p < 0.05$), though there is no similar correlation for diagonal bidding ($\rho = -0.02$, $p > 0.1$). Earnings are positively correlated in the two types of auction ($\rho = 0.26$ $p < 0.05$).

Table 8. Bidding strategies in the first monetary auction and the time auction

	Monetary all-pay auction (MT treatment, in %)	**Time all-pay auction (T treatment, in %)**	**Time all-pay auction (MT treatment, in %)**
Zero bidders	26/55 (47%)	37/89 (41%)	27/55 (49%)
Diagonal bidders	15/55 (27%)	18/89 (20%)	12/55 (21%)

Our comparison between money and time is summarized in result 3 below:

Result 3: All-pay auctions for both money and time are characterized by greater than equilibrium bidding on average and negative bidder payoffs. There is no significant difference in the extent of overbidding, departures from equilibrium bidding, efficiency, or bidder earnings, between auctions for money and time.

7. Discussion

Overbidding in all-pay auctions is a pervasive phenomenon that generalizes from money to an alternative reward medium, time. The aggregate patterns of behavior are similar in our auctions played for money and those played for time. The rent available from winning the auction is more than dissipated in both auctions. Thus, the overdisspation of rent is likely to occur not just when competition is in terms of expenditure of money, but also when it is in terms of time.

The overall similarity in terms of overbidding behavior between the auctions for money and time does conceal a number of modest differences at the level of individual behavior. A gender effect in behavior exists in the money auction though not in the time auction, with women bidding significantly higher than men in the money auction. Cognitive sophistication and accurate calibration of probabilities is related to bidding behavior and performance in both auctions, but the relationships are not overwhelmingly consistent or strong, and differ between auctions.

Typically, results from the student subjects that participate in laboratory experiments generalize well to other populations. The stakes involved in our monetary and time auctions were similar for the student participants in our experiment. However, the tradeoff between money and time might be different for other populations, such as busy professionals with high incomes, for whom time is very scarce relative to money. For such groups, the parameters used in the money and time auctions would need to be appropriately calibrated. Thus, future research could productively consider whether behavior in time auctions is similar for different demographic groups.

Some previous work, beginning with Niederle and Vesterlund (2007) would have led us to believe that men would bid more than women because of their higher level of competitiveness. In our money auctions, we observe the opposite; that men bid lower than women. Although the all pay auction is thought of as a model of competition in economic theory, it may not be viewed as a competitive situation by our participants. Our result that women bid higher than men is consistent with the previous literature on auctions (Sheremeta, 2013) and in particular with prior experiments on all-pay auctions (Ong et al., 2012; Chen et al., 2015).

An area for follow up work would be to consider whether the results are similar when expenditures are in terms of real effort. Competing in contests may involve money and time, but in some cases may also involve costly effort. A future research project could consider whether a contest in which a real effort task is conducted with the winner receiving a prize behaves similarly to the auctions that we have studied here.

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ONLINE APPENDIX

Appendix A, Bayesian equilibrium for the all-pay auctions

This appendix contains a more detailed derivation of a risk neutral Bayesian equilibrium of the monetary all-pay auction. The derivation reproduces the argument presented by Noussair and Silver (2006).

Suppose that all bidders draw a valuation v_i independently from a common distribution $F(v)$. They bid in an all-pay auction. Suppose that they follow a common equilibrium bidding strategy, $\beta_i(v_i) = \beta(v)$, for all i. We assume that the strategy is symmetric and strictly monotonic, and therefore invertible. Let $\beta^{-1}(b)$ be the inverse of $\beta(v)$. The probability that bidder i, with a bid of b_i, wins the auction, is equal to the probability that none of the n-1 other participants make a higher bid than i. Then, bidder i's expected payoff can be written as:

$$\Pi_i(b_i, v_i) = v_i * F^{n-1}(\beta^{-1}(b_i)) - b_i. \quad \text{(A1)}$$

Since v_i is distributed uniformly in the experiment on $[0, \bar{v}]$, for the experimental environment we have that

$$F(\beta^{-1}(b)) = \beta^{-1}(b) / \bar{v}. \quad \text{(A2)}$$

The expected payoff then becomes:

$$\Pi_i(b_i, v_i) = v_i * \left(\frac{\beta^{-1}(b_i)}{\bar{v}}\right)^{n-1} - b_i. \quad \text{(A3)}$$

We solve the corresponding maximization problem:

$$\frac{\partial \Pi_i(b,v)}{\partial b_i} = 0 \iff (n-1) * \frac{v_i}{\bar{v}} * \left(\frac{\beta^{-1}(b_i)}{\bar{v}}\right)^{n-2} * \frac{d\beta^{-1}(b_i)}{db_i} - 1 = 0 \quad \text{(A4)}$$

Since $\beta(v_i) = b_i$, we have that $\beta^{-1}(b_i) = v_i$, and $\frac{d\beta^{-1}(b_i)}{db_i} = \frac{1}{\beta'(v_i)}$ .Therefore,

$$\beta'(v_i) = (n-1) * \left(\frac{v_i}{\bar{v}}\right)^{n-1} \quad \text{(A5)}$$

In order to solve for the Bayesian equilibrium, we integrate the expression in (A5).

$$\beta(v_i) = \int_0^{v_i} \beta_i'(v_i)\, dv_i = \int_0^{v_i} (n-1) * \left(\frac{v_i}{\bar{v}}\right)^{n-1} dv_i = \left(\frac{1}{\bar{v}}\right)^{n-1} * \frac{n-1}{n} * v_i^n + C \quad \text{(A6)}$$

Because it is not possible to bid lower than 0 in the experiment, and bidding greater than one's value is a dominated strategy, we require that $\beta(0) = 0$. Therefore, we set $C = 0$. It follows that the equilibrium bidding function must satisfy:

$$\beta(v_i) = \left(\frac{1}{\bar{v}}\right)^{n-1} * \frac{n-1}{n} * v_i^n \quad \text{(A7)}$$

The resulting equilibrium expected payoff of bidder *i* is then:

$$\Pi_i(b_i, v_{i,}) = v_i \;*\; \left(\frac{\beta^{-1}(bi)}{\bar{v}}\right)^{n-1} - b_i$$

$$\Leftrightarrow \Pi_i(v_i) = v_i \;*\; \left(\frac{v_i}{\bar{v}}\right)^{n-1} - \beta(v_i) \Leftrightarrow \Pi(v_i)_i = v_i \;*\; \left(\frac{v_i}{\bar{v}}\right)^{n-1} - \left(\frac{1}{\bar{v}}\right)^{n-1} * \frac{n-1}{n} * v_i^n \Leftrightarrow$$

$$\Pi_i(v_i) = \left(\frac{1}{\bar{v}}\right)^{n-1} * v_i^n * \frac{1}{n} \tag{A8}$$

Appendix B: Additional regression estimates

Table B.1. OLS Results – Time auction (treatment MT)

(a) Absolute deviation from the RNBE

	(1)	(2)	(3)
	$\lvert b - b_{RBNE} \rvert$	$\lvert b - b_{RBNE} \rvert$	$\lvert b - b_{RBNE} \rvert$
CRT	-1.52		-1.61
	(-1.87)*		(-1.91)*
Male		-0.05	0.81
		(-0.03)	(0.50)
Constant	8.08	5.02	7.98
	(4.03)***	(5.05)***	(4.00)***
Observations	55	55	55
R-squared	7.4%	0.0%	7.8%

Note: dependent variable: Absolute deviation of bid from the risk neutral Bayesian equilibrium in time auction OLS regression, t-value based on robust s.e. in parenthesis; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

(b) Average earnings

	(1)	(2)	(3)
	Earnings	**Earnings**	**Earnings**
CRT	2.83		2.63
	(3.61)***		(3.02)***
Male		3.16	1.75
		(1.82)*	(1.03)
Constant	21.21	25.83	21.00
	(10.64)***	(21.03)***	(10.23)***
Observations	55	55	55
R-squared	18.8%	4.9%	20.0%

Note: dependent variable: Earnings in time auction. OLS regression, coefficient reported, t-value based on robust s.e. in parenthesis; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

(c) Deviations of bid from the RNBE

	(1)	**(2)**	**(3)**
	$b - b_{RBNE}$	**$b - b_{RBNE}$**	**$b - b_{RBNE}$**
CRT	-2.28		-2.35
	(-2.55)**		(-2.50)**
Male		-0.64	0.61
		(-0.33)	(0.32)
Constant	8.09	3.69	8.02
	(3.75)***	(3.21)***	(3.73)***
Observations	55	55	55
R-squared	12.1%	0.2%	12.2%

Note: dependent variable: Difference between an individual's bid and the risk neutral Bayesian equilibrium bid OLS regression, t-value based on robust s.e. in parentheses; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

Table B.2. OLS Results – Time auction (pooled data)

(a) Absolute deviation from RBNE bid

	(1)	(2)	(3)	(4)
	$\|b - b_{RBNE}\|$	**$\|b - b_{RBNE}\|$**	**$\|b - b_{RBNE}\|$**	**$\|b - b_{RBNE}\|$**
CRT	-0.95	-0.91		-0.83
	(-2.22)**	(-2.05)**		(-1.85)*
Absolute Probability Miscalibration	-2.24	-2.23	-1.67	
	(-1.17)	(-1.19)	(-0.92)	
Male		-1.01	-1.22	-1.01
		(-0.93)	(-1.13)	(-0.93)
Constant	8.88	6.85	7.37	8.16
	(6.84)***	(6.85)***	(6.45)***	(7.79)***
Observations	144	144	144	144
R-squared	3.07%	3.63%	1.26%	2.84%

Note: dependent variable: Absolute difference between the risk neutral Bayesian Nash equilibrium and observed bid in the time auction. Each individual participant is the unit of observation. Absolute Probability Miscalibration is the absolute difference between the probability of winning with a certain bid indicated by the participants in the calibration task and the actual probability, averaged across all 14 probability levels. OLS regression, t-value based on robust s.e. in parenthesis; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

(b) Earnings

	(1)	(2)	(3)	(4)
	Earnings	**Earnings**	**Earnings**	**Earnings**
CRT	0.87	0.77		0.83
	(1.71)*	(1.46)		(1.59)
Absolute Probability	-1.60	-1.60	-2.08	
Miscalibration	(-0.75)	(-0.76)	(-1.00)	
Male		2.33	2.50	2.33
		(1.91)*	(2.09)**	(1.91)
Constant	25.45	24.62	26.20	23.84
	(15.73)***	(14.64)***	(19.57)***	(19.58)***
Observations	144	144	144	144
R-squared	2.44%	4.92%	3.50%	4.58%

Note: dependent variable: Earnings in time auction. OLS regression, coefficient reported, t-value based on robust s.e. in parenthesis; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

(c) Deviation of bid from the RNBE

	(1)	(2)	(3)	(4)
	Bid-RNBE	**Bid-RNBE**	**Bid-RNBE**	**Bid-RNBE**
CRT	-0.70	-0.62		-0.68
	(-1.13)	(-0.98)		(-1.08)
Probability	2.04	1.98	2.17	
Miscalibration	(1.35)	(1.35)	(1.46)	
Male		-1.96	-2.10	-2.00
		(-1.41)	(-1.54)	(-1.43)
Constant	4.97	5.68	4.58	5.63
	(3.52)***	(3.84)***	(4.45)***	(3.84)***
Observations	144	144	144	144
R-squared	1.93%	3.27%	2.57%	2.50%

Note: dependent variable: Difference between an individual's bid and the risk neutral Bayesian equilibrium bid OLS regression, t-value based on robust s.e. in parentheses; */**/*** stands for statistical significance at 10%, 5% and 1% level, respectively.

Appendix C: Instructions

Instructions for the MT protocol:

Instructions

Session: _______; ID participant:_______ ANR:_____________

Welcome everybody!

You are about to participate in an experiment in the economics of decision-making. The experiment consists of four parts and in addition, the experiment will continue for 30 minutes after part 4 of this session. For participating in all parts of the experiment, you will receive a fixed endowment of 5€. Any extra earnings gained during the experiment will be added to this sum. The total earnings will be paid in cash at the end of the experiment. In the **first** part you will be required to answer a few questions. Each question responded correctly will bring you 2€. The **second** part will consist of estimating probabilities of winning in an auction where currency is the method of transaction. The **third** part consists of participating in the actual auction. The **fourth** part consists of participating in a similar auction but where the method of transaction is minutes and as mentioned, after that remaining in the lab for 30 minutes.

After completing each part, we will distribute the instructions for the following part. Also, any form of communication with other participants is prohibited. Any questions should be directed towards the experimenters. Any deviation of this rule will result in direct exclusion from the experiment and loss of any return. Please turn the page to begin part 1.

Part 1

Session: _______; ID participant:_______

Please answer the following questions as well as you can.
Each question you answer correctly will increase your total earnings by 2€. You have 5 minutes to answer the questions.

QUESTION NR. 1:
A shirt and a hat cost 5.50 € in total. The shirt costs 5 € more than the hat. How much does the hat costs? ______ cents

QUESTION NR. 2:
If it takes 3 people 3 hours to assembly 3 bicycles, how long would it take 90 people to assembly 90 bicycles? _______ hours

QUESTION NR. 3:

The forest of North Carolina is home to a colony of wild rabbits. Every year, the colony doubles in size. If it takes 24 years for the colony to reach 100.000 rabbits, how long would it take for the colony to reach half of that number? ______ years

Part 2

Session: _______; ID participant:_______

Part 2 consists of some questions regarding what you think happens in the following auction. We will be playing this auction in part 3. In the auction you will be grouped with other **4** participants. The participants in your group in the practice and the real auction will be different. Identifying the participants in your group is not possible. The currency used within the auction is called “ECU”. The conversion rate is 30 ECU to 5 EURO. In the beginning of the auction you will receive an **initial endowment of 30 ECU.**

In the auction, a single unit, called “Product Y”, will be auctioned separately to each group. A Record sheet will be provided. On the Record Sheet, under the column “Product value”, a value is written. This value represents your product valuation and is an indication of the amount of ECU you can obtain if you win unit “Product Y”. The "Product Value" is chosen randomly before the experiment and independently from another player’s valuation and will be an integer **between 1** and **30**. In the auction you can submit a **positive** bid by filling in the amount in column “Bid”. The bid submitted is in terms of ECU currency. You **will pay the bid whether you win or not**. All participants will submit their bids simultaneously without having any information about the bids of other subjects. The bidder with the highest bid, within each group, will receive unit “ Product Y”. In case of a tie, the unit will be randomly assigned by a coin toss.

Calculating your earnings:

If you make the highest bid in the auction, you must write under the column "ECU won" your "Product Value" for that period; otherwise a 0 should be filled in. After the auction, you must record your earnings, which you can easily calculate by subtracting Column 3 from Column 4, in the column named "Earnings".

At the end of the experiment, your total earnings will be the sum of the earnings that you won during the auction, plus the initial endowment of 30 ECU and minus any bid you made.

Example : Suppose that your Product value is 10 and you write a bid of 8 in the column "Bid". If you win the auction by having the highest bid among all bids, you will write 10 under "ECU won".

Therefore, your earnings for that period will be equal to 10 – 8 = 2 ECU. If it happens that you didn't win the auction, you will write 0 under "ECU won" and -8 under "Earnings".

Reporting probabilities

Before we start the auction, you will be given a series of questions in which you will be asked to report the probability with which you believe a *person can win the auction, by bidding a certain amount of ECUs*. You should report a probability from 0% to 100%. Your earnings will be determined by how accurate your guesses are. The reported probability will be compared with the average probability of winning the auction in a previous session with a randomly chosen group. The reported probabilities for each bid will **not** influence any of your potential payoffs in the later stages of the experiment. Your potential earnings will be calculated using the following formula:

$$\textbf{Payoff} = \max\{ 0 ,\ 10 - 45*(P_r - P_a)^2 \},$$

where $\mathbf{P_r}$ represents the reported probabilities by you and $\mathbf{P_a}$ represents the actual probability of winning the auction

Basically, what the formula does is that it penalizes you every time your reported probability is different than the actual probability. You can obtain the most revenue when the actual probability is equal to the reported probability. The most you can get is 10 €. Let's look at an example:

Example: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids 20? If you believe that the probability of winning the auction is 38% but the actual probability is 20%, you can receive:

$$\text{Payoff} = \max\{0, 10 - 45(0.38—0.20)^2\} = 8.54\ €$$

At the end of the experiment, one of the question will be chosen at random to be paid. Depending on how accurate your prediction is for that question, you will receive the amount of Euros corresponding to that question. The formula presented above will be used to calculate the payoff. Therefore, you should respond as accurate as you can to each question, as any of the questions could prove to be the one that determines the payment.

Questionnaire

Session: _______; ID participant:_______

Question 1: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **2**? ______%

Question 2: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **4**? ______%

Question 3: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **6**? ______%

Question 4: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **8**? ______%

Question 5: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **10**? ______%

Question 6: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **12**? ______%

Question 7: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **14**? ______%

Question 8: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **16**? ______%

Question 9: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **18**? ______%

Question 10: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **20**? ______%

Question 11: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **22**? ______%

Question 12: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **24**? ______%

Question 13: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **26**? ______%

Question 14: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **28**? ______%

<u>Part 3</u>

Session: _______; ID participant:_______

In the current stage you will take part in an auction. There will be 1 practice period before the one auction that counts toward your earnings. What you lose or gain in the practice auction will not affect earnings. Please look at Record Sheet Nr. 1 and fill in your bid for the practice period. Your Endowment is 30 ECU. When the practice auction is finished, look at Record Sheet Nr. 2.

Record sheet Nr.1

Session: _______; ID participant:_______

	Product Value	Bid ECU	ECU won	Earnings
Practice				

Total Earnings = 30 ECU - _____(Bid) + _____(Product value if won or 0 if lost) =

= _________ECU

Record sheet Nr.2

Session: _______; ID participant:_______

	Product Value	Bid ECU	ECU won	Earnings
Auction				

Total Earnings = 30 ECU - _____(Bid) + _____(Product value if won or 0 if lost) =

= _________ECU

Part 4

Session: _______; ID participant:_______

In this part of the experiment everybody must wait **30** minutes in the laboratory. During the mandatory waiting time, you are not allowed to do anything. You cannot use the computer or any other device, and you cannot communicate with other participants. However, you will have the chance to decrease the waiting time and leave the laboratory earlier by participating in an auction.

In the auction you will be grouped **randomly** with other **4** participants. You will first participate in a practice round. The participants in your group in the practice and the real auction will be different. Identifying the participants in your group is not possible. The currency used within this auction are minutes.

In the auction, a single unit, called "Moment Y", will be auctioned separately to each group. A Record sheet will be provided. On the Record Sheet, under the column "Time Exemption", a value is written. This value represents your product valuation and is an indication of the number of minutes to be exempt from waiting if you win unit "Moment Y". The " Time Exemption" is chosen randomly before the experiment and independently from another player's valuation and is equally likely to be any integer **between 1** and **30**. Therefore, all the biddings and payoffs will be made using minutes.

Every period you can submit a **positive** bid by filling in the number of minutes in column "Bid". You will **pay the bid whether you win or not**. The bidder with the highest bid, within each group, will win the auction. In case of a tie, the unit will be randomly assigned by a coin toss.

If you are successful in winning the auction, the number of minutes that you win after you pay your bid, will be subtracted from the mandatory waiting time of 30 minutes and you can leave the laboratory earlier. If you are unfortunate and lose the auction, your waiting time will not be decreased. However, you will have to pay your bid by staying even longer that the mandatory time, by the number of minutes you bid.

Example 1: Suppose that your "Time exemption" is 20 minutes and you bid an amount of 11 minutes and you win the auction. Then, you will be able to decrease your mandatory waiting time by 9 minutes. (20-11= 9). In other words, you will be able to leave the experiment 9 minutes earlier than when the experiment is supposed to finish.

Example 2: Suppose that you have a “Time exemption” equal to 12 and you bid 6 minutes. However, you are not successful in winning the auction. Therefore, you will have to wait in the laboratory an additional 6 minutes after stage 3 is over.

Example 3: Let’s suppose that your “Time exemption” is 12 minutes. If you bid 14 minutes and your bid is the highest among all the other bidders, then after paying the bid (12-14= -2) you will have to wait in the laboratory an additional 2 minutes after stage 3 is over. So you will have 2 minutes added to the mandatory time.

We will first play one auction for practice. Since it is for practice only, it does not require any waiting time. Then we will play one auction that will count for the remaining time that you must stay in the laboratory. In each auction you will be grouped randomly with other **4** participants. Please look at the Record Sheet Nr. 3 and fill in the values for the practice auction. After the practice auction is finished, please have a look at Record Sheet Nr. 4.

Record sheet Nr.3

Session: _______; ID participant:_______

	Time exemption	Bid (minutes)	Minutes exempted
Practice			

Total waiting time = 30 minutes + _____(Bid) - _____(Time exemption if won or 0 if lost)=

= _________minutes

<u>Record sheet Nr.4</u>

Session: _______; ID participant:_______

	Time exemption	Bid (minutes)	Minutes exempted
Auction			

Total waiting time = 30 minutes + _____(Bid) - _____(Time exemption if won or 0 if lost)=

= _________minutes

After finishing the auction please fill in the appropriate total waiting time in Record sheet Nr. 2 and answer a few questions regarding your background. The answers will remain confidential as you will provide only your ID.

After this, the experimenter will announce when the mandatory 30 minutes period starts. Then, you must wait patiently in your chair, until the total waiting time which you must remain in laboratory (adjusted by the minutes won or lost in the auction), elapses.

Thank you for your cooperation!

<u>Background Information Sheet</u>

Session: _______; ID participant:_______

As your ID number cannot be linked to your name either by the instructor or by other participants, this information will remain anonymous. Please fill in the questionnaire or select the appropriate category by circling the answer.

1. What is your age? ____ years
2. What is your gender?

   (Female / Male)
3. What is your race?

   (White, Black, Yellow, Red, Brown)
4. What is your religion?

   (Christian / Atheist / Muslim / Buddhist / Other)
5. How many years of <u>higher</u> education you have? ___ years
6. How many siblings do you have? _____siblings
7. What is your family income per year approximately? _______ Euros

   (10.000- 15.000); (15.000 -30.000); (30.000-60.000); (60.000-100.000); higher
8. How many years of <u>higher</u> education do your parents have? _____years
9. Have you ever encountered the first 3 questions asked in Part **1** of the experiment?

   Yes /No

Instructions for the T Protocol:

Session: _______; ID participant:_______

Welcome everybody!

You are about to participate in an experiment in the economics of decision-making. The experiment consists of three parts, and the experiment will continue for 30 minutes after part 3 of this session. For participating in all parts of the experiment, you will receive a fixed endowment of 5€. Any extra earnings gained during the experiment will be added to this sum. The total earnings will be paid in cash at the end of the experiment. The experiment will consist of **three** parts. In the **first** part you will be required to answer a few questions. Each question responded correctly will bring you 2€. The **second** part consists of estimating probabilities of winning in an auction and the **third** part consists of participating in an auction.

After completing each part, we will distribute the instructions for the following part. Also, any form of communication with other participants is prohibited. Any questions should be directed towards the experimenters. Any deviation of this rule will result in direct exclusion from the experiment and loss of any return. Please turn the page to begin part 1.

Session: _______; ID participant:_______

<u>Part 1</u>

Please answer the following questions as well as you can.

Each question you answer correctly will increase your total earnings by 2€. You have 5 minutes to answer the questions.

QUESTION NR. 1:

A shirt and a hat cost 5.50 € in total. The shirt costs 5 € more than the hat. How much does the hat costs? ______ cents

QUESTION NR. 2:

If it takes 3 people 3 hours to assembly 3 bicycles, how long would it take 90 people to assembly 90 bicycles? _______ hours

QUESTION NR. 3:

The forest of North Carolina is home to a colony of wild rabbits. Every year, the colony doubles in size. If it takes 24 years for the colony to reach 100.000 rabbits, how long would it take for the colony to reach half of that number? ______ years

Part 2

Session: _______; ID participant:_______

Part 2 consists of some questions regarding what you think happens in the following game. We will be playing this game in part 3. Suppose that everybody must wait **30** minutes in the laboratory. During the mandatory waiting time, you are not allowed to do anything. You cannot use the computer or any other device, and you cannot communicate with other participants. However, you will have the chance to decrease the waiting time and leave the laboratory earlier by participating in an auction.

In the auction you will be grouped **randomly** with other **4** participants. You will first participate in a practice period. The participants in your group in the practice and the real auction will be different. Identifying the participants in your group is not possible. The currency used within this auction are minutes.

In the auction, a single unit, called "Moment Y", will be auctioned separately to each group. A Record sheet will be provided. On the Record Sheet, under the column "Time Exemption", a value is written. This value represents your product valuation and is an indication of the number of minutes to be exempt from waiting if you win unit "Moment Y". The " Time Exemption" is chosen randomly before the experiment and independently from another player's valuation and is equally likely to be any integer **between 1** and **30**. Therefore, all the biddings and payoffs will be made using minutes.

Every period you can submit a **positive** bid by filling in the number of minutes in column "Bid". You will **pay the bid whether you win or not**. The bidder with the highest bid, within each group, will win the auction. In case of a tie, the unit will be randomly assigned by a coin toss.

If you are successful in winning the auction, the number of minutes that you win after you pay your bid, will be subtracted from the mandatory waiting time of 30 minutes and you can leave the laboratory earlier. If you are unfortunate and lose the auction, your waiting time will not be decreased. However, you will have to pay your bid by staying even longer that the mandatory time, by the number of minutes you bid.

Example 1: Suppose that your "Time exemption" is 20 minutes and you bid an amount of 11 minutes and you win the auction. Then, you will be able to decrease your mandatory waiting time by 9 minutes. (20-11= 9). In other words, you will be able to leave the experiment 9 minutes earlier than when the experiment is supposed to finish.

Example 2: Suppose that you have a "Time exemption" equal to 12 and you bid 6 minutes. However, you are not successful in winning the auction. Therefore, you will have to wait in the laboratory an additional 6 minutes after stage 3 is over.

Example 3: Let's suppose that your "Time exemption" is 12 minutes. If you bid 14 minutes and your bid is the highest among all the other bidders, then after paying the bid (12-14= -2) you will have to wait in the laboratory an additional 2 minutes after stage 3 is over. So you will have 2 minutes added to the mandatory time.

Reporting Probabilities

Before we start the auction in part 3, you will complete part 2 of the experiment. In part 2, you will be given a series of questions in which you will be asked to report the probability with which you believe a person can win the auction described above, by bidding a certain number of minutes. You should report a probability from 0% to 100%. Your earnings will be determined by how accurate your guesses are. The reported probability will be compared with the average probability of winning the auction in a previous session with a randomly chosen group. The reported probabilities for each bid will **not** influence any of your potential payoffs in the later stages of the experiment. Your potential earnings will be calculated using the following formula:

$$\textbf{Payoff} = \max \{ 0 , \ 10 - 45*(P_r - P_a)^2 \} ,$$

where $\mathbf{P_r}$ represents the reported probabilities by you and $\mathbf{P_a}$ represents the actual probability of winning the auction

Basically, what the formula does is that it penalizes you every time your reported probability is different than the actual probability. You can obtain the most revenue when the actual probability is equal to the reported probability. The most you can get is 10 €. Let's look at an example:

Example: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids 5? If you guess that the probability of winning the auction is 38%, but the actual probability is 20%, you earn:

$$\text{Payoff} = \max\{0, 10 - 45*(0.38—0.20)^2\} = 8.54 €$$

At the end of the experiment, one of the questions will be chosen at random to count toward your earnings. Depending on how accurate your prediction is for that question, you will receive the number of Euros gained for answering that question. The formula presented above will be used to calculate your earnings. Therefore, you should respond as accurately as you can to each question, as any of the questions could prove to be the one that determines the payment.

Session: _______; ID participant:_______

Questionnaire

Question 1: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **2**? ______%

Question 2: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **4**? ______%

Question 3: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **6**? ______%

Question 4: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **8**? ______%

Question 5: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **10**? ______%

Question 6: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **12**? ______%

Question 7: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **14**? ______%

Question 8: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **16**? ______%

Question 9: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **18**? ______%

Question 10: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **20**? ______%

Question 11: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **22**? ______%

Question 12: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **24**? ______%

Question 13: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **26**? ______%

Question 14: Suppose an individual plays the auction presented above against 4 other people. All players' values are equally likely to be any value between 1 and 30. What are the chances that the individual wins the auction if he bids **28**? ______%

Part 3

Session: _______; ID participant:_______

Now that you have assessed the probabilities we can start the auction.

We will first play one auction for practice. Since it is for practice only, it does not require any waiting time. Then we will play one auction that will count for the remaining time that you must stay in the laboratory. In each auction you will be grouped randomly with other **4** participants. Please look at the Record Sheet Nr. 1 and fill in the values for the practice auction. After the practice auction is finished, please have a look at Record Sheet Nr. 2.

Record sheet Nr.1

Session: _______; ID participant:_______

	Time exemption	Bid (minutes)	Minutes exempted
Practice			

Total waiting time = 30 minutes + _____(Bid) - _____(Time exemption if won or 0 if lost) =

= _________minutes

Record sheet Nr.2

Session: _______; ID participant:_______

	Time exemption	Bid (minutes)	Minutes exempted
Auction			

Total waiting time = 30 minutes + _____(Bid) - _____(Time exemption if won or 0 if lost)=

= _________minutes

After finishing the auction please fill in the appropriate total waiting time in Record sheet Nr. 2 and answer a few questions regarding your background. The answers will remain confidential as you will provide only your ID.

After this, the experimenter will announce when the mandatory 30 minutes period starts. Then, you must wait patiently in your chair, until the total waiting time which you must remain in laboratory (adjusted by the minutes won or lost in the auction), elapses.

Thank you for your cooperation!

Background Information Sheet

Session: _______; ID participant:_______

As your ID number cannot be linked to your name either by the instructor or by other participants, this information will remain anonymous. Please fill in the questionnaire or select the appropriate category by circling the answer.

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   (Female / Male)
3. What is your race?

   (White, Black, Yellow, Red, Brown)
4. What is your religion?

   (Christian / Atheist / Muslim / Buddhist / Other)
5. How many years of <u>higher</u> education you have? ___ years
6. How many siblings do you have? _____siblings
7. What is your family income per year approximately? _______ Euros

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8. How many years of <u>higher</u> education do your parents have? _____years
9. Have you ever encountered the first 3 questions asked in Part **1** of the experiment?

   Yes /No