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A Novel Experimental Test of Truthful Bidding in Second-Price Auctions with Real Objects*

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Abstract

We present experimental evidence on bidding in second-price auctions with real objects. Our novel design, combining a second-price auction with an individual-specific binary-choice task based on the outcome of the auction, allows us to directly identify over- and under-bidding. We analyze bidding in real-object and induced-value auctions, and find significant deviations from truthful bidding in both. Overall, under-bidding is somewhat more prevalent than over-bidding; yet, the latter has a bigger magnitude, especially with induced values. At the individual level, we find no relation between the tendency to deviate from truthful bidding in induced-value vs. real-object auctions.

JEL Classification: C91; C92; D44; D81.

Keywords: Second-price Auctions; Overbidding; Consumer Surplus.

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1 Introduction

From a purely theoretical point of view, the second-price sealed-bid or "Vickrey" auction (Vickrey, 1961) is probably the most famous and easily comprehended auction format. Indeed, it is well-known that in standard private-value models with fully rational bidders, bidding one's own value is a (weakly) dominant strategy. This theoretical prediction holds irrespective of the number of bidders, their risk attitudes, the shape of their values' distribution or whether the values are correlated. Moreover, this prediction continues to hold also under non-standard (risk) preferences such as regret aversion (Filiz-Ozbay and Ozbay, 2007) or ambiguity aversion (Chen *et al.*, 2007), and even under some departures from full rationality (e.g., Crawford and Iriberri, 2007; Gagnon-Bartsch *et al.*, 2021).

The experimental evidence, however, does not seem to support this theoretical prediction. Indeed, several studies have found that participants tend to deviate from the dominant, "truthful" strategy of bidding their values, with over-bidding being somewhat more common than under-bidding (Kagel *et al.*, 1987; Kagel and Levin, 1993; Harstad, 2000; Cooper and Fang, 2008; Garratt *et al.*, 2012; Flynn *et al.*, 2016; Georganas *et al.*, 2017; Rosato and Tymula, 2019).[1] Most of these studies use induced-value auctions where the "goods" being bid on are basically monetary amounts (typically in the form of vouchers redeemable for a specified amount). In this setting, identifying over-/under-bidding is rather simple, as one can just compare the participants' bids with these induced valuations.

In most real-world auctions, however, the prizes are real objects; e.g., consumer goods. While the nature of the prize does not affect the theoretical predictions, identifying over-/under-bidding is less straightforward in real-object auctions, as there are no "objective values" against which to compare bids. Moreover, if the prize is unfamiliar (e.g., a fossil) and bidders are asymmetrically informed, their values can reasonably depend on the information contained in others' bids (Rutström, 1998; List and Shogren, 1999). Furthermore, experimental evidence from Knetsch *et al.* (2001) and Lusk *et al.* (2004) suggests that with home-grown values, the endowment effect might complicate the imputation of values from bids in Vickrey auctions. Similarly, Lange and Ratan (2010) show that if bidders are expectations-based loss averse à la Kőszegi and Rabin (2006, 2007), bidding one's own value is no longer a dominant strategy.[2] Other factors that can sway participants away from truthful bidding include mental accounting, framing and reference-price effects, or limited cognitive ability; see Thaler (1985, 1999), Weaver and Frederick (2012), and Lee *et al.* (2020).[3]

[1] By contrast, experimental evidence from the strategically equivalent ascending English auction shows almost immediate convergence to the dominant strategy; see Harstad (2000). This discrepancy can be rationalized by Li (2017)'s notion of "obvious strategy-proofness". Moreover, differently from the second-price auction, the ascending auction is also a credible mechanism (Akbarpour and Li, 2020).

[2] Rosato and Tymula (2019) provide experimental evidence consistent with this prediction.

[3] Some of these factors also affect other experimental mechanisms commonly used to elicit participants' valuations for real goods, such as the the Becker-DeGroot-Marschak (henceforth, BDM) mechanism (Becker,

In this paper, we present and test a novel experimental design for identifying deviations from truthful bidding in private-value second-price auctions for real objects. Our design combines a standard second-price auction with a binary-choice task. The key innovation is that the binary-choice task is derived from the auction outcome and is specific to each participant. This enables us to define over-/under-bidding by comparing participants' bids in the auction with their valuations inferred from the binary-choice task.[4]

Consider two bidders competing in a second-price sealed-bid auction for an indivisible item. For $i \in \{1, 2\}$, let v_i and b_i denote bidder i's (private) value and bid, respectively. Bidder i wins the auction if and only if $b_i > b_j$, with $j \neq i$ (assume ties are broken randomly). The well-known dominant strategy in this auction is to bid $b_i = v_i$. Bidder i's payoff is $v_i - b_j$ if $b_i > b_j$ and 0 otherwise. If bidders follow the dominant strategy, i's payoff when winning equals

$$v_i - b_j = \underbrace{b_i - b_j}_{:=\Delta_i} \geq 0.$$

Therefore, bidder i should be indifferent between winning the auction and obtaining the item at price b_j, or receiving a monetary payment equal to Δ_i. Moreover, bidder i should strictly prefer the payment if $\Delta_i > v_i - b_j$ (and vice versa).

Leveraging this simple yet powerful intuition, our experiment links participants' decisions across two tasks. The first task is a two-bidder second-price auction for a mug. After the auction, without revealing its outcome, participants' bids are used to construct individual-specific lists of binary-choice scenarios for the second task. In this second task, participants make a series of binary choices between buying the same mug at a fixed price p_i or receiving various monetary amounts. The fixed price is chosen such that by choosing to buy the mug, a participant would (unknowingly) obtain the same surplus that s/he would obtain in the auction; i.e., $p_i = b_j$ if $b_i > b_j$ and $p_i = b_i$ otherwise. The monetary amounts are chosen from an interval centered on Δ_i.[5] By analyzing participants' switching behavior in the binary-choice task, we can identify whether they over-/under-bid in the auction. For instance, if a participant prefers buying the mug at price p_i over receiving a monetary amount larger than Δ_i, it must be that $v_i > b_i$. On the other hand, if a participant prefers a monetary amount smaller than Δ_i over buying the mug at price p_i, it means that $v_i < b_i$. Furthermore, if participants never (resp. always) choose to buy the mug at price p_i, it suggests that they

DeGroot and Marschak, 1964); see Banerji and Gupta (2014), Mazar *et al.* (2014) and Tymula *et al.* (2016).

[4]Throughout the paper, we maintain the interpretation that valuations inferred from the binary-choice task represent the "true" valuations, and hence interpret inconsistencies between participants' bids in the auction and their behavior in the binary-choice task as evidence of over-/under-bidding. Yet, the opposite interpretation — that the bids in the second-price auction reveal the "true" valuations — is also plausible. We tend to favor the first interpretation since the binary-choice task does not feature any strategic risk and it does not require participants to engage in any form of contingent thinking. We return to this point in the concluding section of the paper.

[5]Notice that $\Delta_i = 0$ for $b_i \leq b_j$; hence, some amounts can be negative.

significantly over-bid (resp. under-bid) in the auction.

Our experimental results show that participants deviate from truthful bidding in real-objects auctions; in particular, 50% of our participants under-bid (by -\$2.21 on average), 37% of them over-bid (by \$2.34 on average), and only 13% bid truthfully.

In addition to the second-price auction and the binary-choice task for a mug, participants in our experiment also bid in a second-price auction with induced values; this allows us to investigate whether participants' bidding behavior differs between induced-value and real-object auctions. Though we found significant deviations between bids and values here too, importantly, we found no meaningful relationship between the deviations across the two types of auction, suggesting that bidders might use different bidding strategies (or heuristics) in induced-value auctions compared to auctions for real goods.

We are not the first to use real goods in experimental auctions, nor the first to compare bids in the Vickrey auction to other methods for eliciting values from experimental participants; see, for instance, Rutström (1998), List and Shogren (1999), Knetsch *et al.* (2001), Lusk *et al.* (2004), Noussair *et al.* (2004) and Frederick (2012). However, our paper differs from these previous contributions in two respects. First, prior studies have compared participants' bids in a Vickrey auction with their bids in an English auction and/or a BDM. Our paper instead compares the Vickrey auction with a binary-choice task.[6] We chose the binary-choice task over the English auction and BDM because we think the former is cognitively less demanding for participants as the price at which they can acquire the real object is fixed ex-ante. Moreover, we wanted to compare participants' bids in the Vickrey auction with their valuations elicited in a non-strategic and rather simple setting.[7] The second difference is that previous papers employ a between-participant design, thereby implicitly assuming that bids in the Vickrey auction are equal to participants' values. Instead, our within-participant design, where the binary-choice task varies across participants, allows us to test for deviations from truthful bidding in the Vickrey auction at the individual level.

A more recent paper employing a design similar to ours is Kassas *et al.* (2018). In their study, participants bid in Vickrey auctions for several real goods and, afterwards, the losing bidders participated in a secondary market where they had the opportunity to purchase any amount of one of the goods for a randomly chosen price. Hence, like in our paper, these authors can use the purchasing behavior in the secondary market to classify subjects as either "consistent" bidders, or under-/over-bidders. Nevertheless, our paper and Kassas *et al.* (2018) differ for some key design aspects, as well as for the direction of some of the

[6]In addition to eliciting valuations for real goods (Kahneman *et al.*, 1990; Andersen *et al.*, 2007), the binary-choice (or multiple price list, MPL) method has been used also to elicit discount rates (Andersen *et al.*, 2008; Coller and Williams, 1999) and risk preferences (Holt and Laury, 2002; Eckel and Grossman, 2008).

[7]While there is no strategic interaction in BDM, participants still have to submit a bid and engage in a form of contingent thinking similar to that of the Vickrey auction; this, in turn, might lead them to erroneously consider the BDM task as a strategic one.

results. With respect to the design, Kassas *et al.* (2018) had subjects bidding on 8 vegetable products, whereas subjects in our study bid on just one durable good. More importantly, because in our study the prices at which subjects can buy the good are directly linked to their bid in the auction, we can employ a stricter test for over-/under-bidding compared to Kassas *et al.* (2018). Indeed, whenever subjects in their study accept (resp. decline) to purchase the good at a price lower (resp. higher) than their bid for the same good in the Vickrey auction, they are considered "consistent" bidders. For instance, consider a participant who bid $3 and then accepts to buy the same good for $2. Such a bidder could very well have under-bid in the auction (e.g., if her valuation for the good is $4); yet, she would not be classified as an under-bidder according to Kassas *et al.* (2018). Hence, their test might underestimate the fraction of over-/under-bidders in their sample. Moreover, Kassas *et al.* (2018) only considered real-object auctions, whereas by having subjects bid also in induced-value auctions, our study allows us to explore whether there is any relation between the tendency of subjects to deviate from truthful bidding across auction types. In terms of results, Kassas *et al.* (2018) find that a significant fraction of their subjects overbid, whereas under-bidding is somewhat more prevalent in our study.

Finally, our paper is also related to the literature on "preference reversal". Originally discovered by psychologists (Lichtenstein and Slovic, 1971; 1973), the first economic analysis of this phoenomenon is due to Grether and Plott (1979).[8] In preference reversal experiments, subjects are asked to choose between two lotteries. One lottery in a pair typically has a high probability of winning a small amount of money; this is the probability bet or "P bet." The other, riskier lottery in the pair has a smaller chance of winning a larger amount of money; this is the dollar bet or "$ bet". In addition to choosing between the two bets, subjects are also asked to place a monetary value on them. The valuation question has been asked in many different ways, the most common being the BDM mechanism. A preference reversal then occurs if the preference revealed by choice is the reverse of the preference revealed by valuation; i.e., if the chosen bet is given a lower valuation than the unchosen one. In most experiments, observed preference reversals are asymmetric: subjects tend to more frequently choose the P bet and yet assign the higher price to the $ bet. Our finding that participants' bids in real-object auctions differ from their valuations — for the same object — elicited via the binary-choice task can also be seen as a form of preference reversal.[9]

The paper proceeds as follows. Section 2 describes the experimental design and the data. Section 3 presents the results. Section 4 concludes by discussing the implications of our results as well as possible directions for future research.

[8] See Slovic and Lichtenstein (1983) for a review of the early literature and Tversky and Thaler (1990) for later references.

[9] While most of the studies ask subjects to choose between, and assign monetary values to two monetary lotteries, preference reversal has also been observed with non-monetary options; see Tversky *et al.* (1988).

2 Experimental Design

The aims of our experiment are to empirically test our novel method for identifying departures from truthful bidding in the second-price auctions for *real goods* and to check whether bids in induced-value auctions predict bidding behavior in real-good auctions. To achieve these goals, we employed a within-subject design.

Each participant in our study completed two tasks: an auction task and a binary-choice task, in this order. Upon arrival, participants found $25 on their desks and were told that based on their decisions in the experiment they would be able to earn more money or lose some of this initial endowment.[10] At the beginning of the study, the instructions (see Appendix C) were presented on the screen and read aloud by the experimenter. Moreover, each participant had to answer a series of comprehension questions (see Appendix D). There were five comprehension questions, each with a backup version for those participants who did not answer correctly on the first attempt. After each question, the screen displayed the correct answers along with an explanation. If participants answered a question wrongly, they were provided with an alternative question of the same type.[11]

Each participant bid in two second-price auctions: one for a monetary voucher (induced-value auction) and one for a University of Sydney travel mug featuring university crest, vacuum insulation, and a rubberized paint finish (real-object auction). The order of the two auctions was randomized independently for each participant and, in each auction, participants were randomly paired. Voucher values were drawn randomly and independently for each individual from a uniform distribution between $0 and $20 (in $0.50 increments); they were communicated to the participants before they bid in the auction and were private knowledge, meaning that participants did not know other participants' voucher values. The voucher was redeemable for cash from the experimenter at the end of the experiment. Participants were not informed of the market value of the mug (which sold for $22.95). In both auctions, participants could submit bids from $0 to $25 in $0.50 increments. Figure 5(a) and 5(b) in Appendix A show exemplary screenshots from the auction task.

Departures from truthful bidding in the induced-value auctions can be easily inferred from the auction task. Bids over (under) the nominal value of the monetary voucher are direct evidence of over- (under-) bidding. To elicit participants' valuations for the mug independently of the auction task, and hence to identify instances of over- or under-bidding in real-object auctions, in the second task participants had to make a series of binary choices between buying the mug at a fixed price or receiving various monetary amounts. Figure 5(c) in Appendix A presents an exemplary screenshot of the binary-choice task. The prices and monetary amounts were based on the participants' bids in the auction task. Specifically, in

[10] Throughout the paper the symbol $ denotes Australian dollars (AUD).

[11] All participants answered all binary-choice task comprehension questions correctly within two attempts; 66 out of 78 participants answered all auction task comprehension questions correctly within two attempts.

all binary choices the price for the mug was always the same and equal to the price from the real-object auction that a participant bid in. Thus, if participant i was the high bidder in her auction for the mug, then p_i was equal to her opponent's bid; if instead participant i was the low bidder in her auction for the mug, then p_i was equal to her own bid. Finally, if both participants submitted the same bid, then p_i was equal to that bid. In summary, $p_i = \min\{b_i, b_j\}$ for $i \neq j$.[12] The monetary amounts for each participant i were calculated as $b_i - p_i + C_n$, $n \in \{0, 1, ..., 10\}$ with $C_0 = -\$2.50$ and $C_{n+1} - C_n = \$0.50$, for a total of 11 choice scenarios. These scenarios were presented one at a time in a randomized order; while such a randomized one-by-one presentation might increase the likelihood of participants switching multiple times between options, we chose it in order to reduce the potential occurrence of the so-called "centrality" effect; i.e., the tendency of participants to often go for the middle option in the multiple price list presentation (see Andersen *et al.*, 2006). Moreover, presenting all choices at once in one single list might not be incentive compatible (see Brown and Healy, 2018). Participants whose valuation for the mug is consistent with their bid in the auction should opt for the monetary amount (resp. buy the mug) in all scenarios where $C_n > 0$ (resp. $C_n < 0$). For $C_n = 0$, participants should be indifferent between the two options; hence, selecting either option would be consistent with their bid in the auction.

After completing both tasks, participants answered a short questionnaire (see Appendix E). The last part of the experiment was the payment. Participants' earnings were determined by only one task selected at random. If an auction was selected for payment and the participant was the winner, the participant would get the prize of this auction and pay for it a price equal to the second-highest bid; the payment was deducted from his/her initial endowment of \$25. If an auction was selected for payment and the participant was the loser, the participant kept the initial endowment. If both participants submitted the same bid, the software randomly selected the winner. If the binary-choice task was selected for payment, the software randomly selected one of the 11 decisions that the participant made in the task and realized it for payment. On average, participants earned \$32.85; in addition, 41% of participants also received a mug whose retail price was \$22.95 at the time of the experiment.

A total of 78 subjects (36 males; average age: 23) participated in the experiment, which took place at the experimental laboratory of the University of Sydney in 2019. The protocol was approved by the Human Ethics Research Committee at the University of Sydney and all participants gave informed written consent. The study was implemented using z-Tree (Fischbacher, 2007) and participants were recruited via ORSEE (Greiner, 2015).

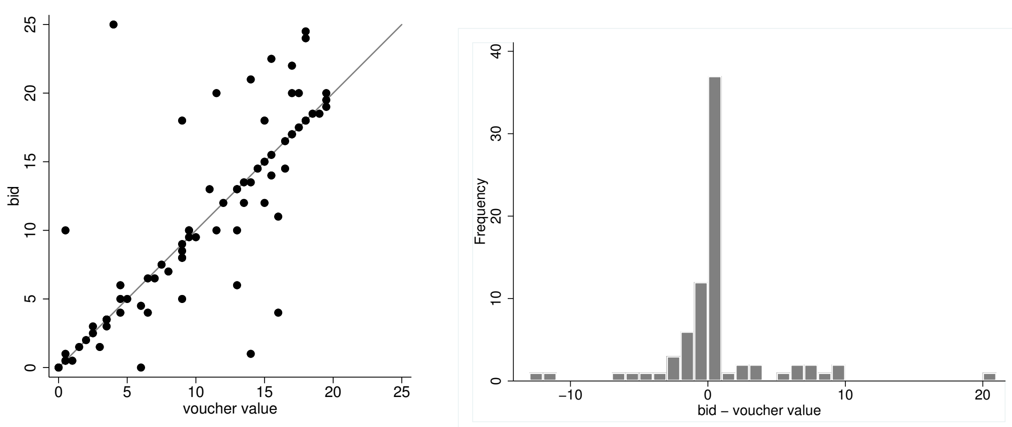
[12] Participants were not told how the price p_i was chosen.

3 Results

In this section, we report our experimental findings. We begin by separately describing the results for induced-value auctions and real-objects ones, and then discuss the relation between the two.

3.1 Bidding in Induced-Value Auctions

Figure 1(a) displays participants' bids in the induced-value auctions against the monetary value of their vouchers. The bids ranged from \$0 to \$25, with an average of \$10.54 and a standard deviation of \$7.20, whereas the average value of the voucher was \$10.26 with a standard deviation of \$6.12. To investigate bidding behavior in induced-value auctions, we begin by regressing each participant's bid on the value of their voucher plus a constant; i.e., $\hat{bid} = \hat{b}_0 + \hat{b}_1 IV$.[13] Hence, estimates of $\hat{b}_1 = 1$ and $\hat{b}_0 = 0$ would indicate that, on average, participants' bids were equal to their values. Our results are broadly consistent with this value-bidding prediction, as we estimate $\hat{b}_1 = 0.95$ and $\hat{b}_0 = 0.80$ (but not significantly different from 0).



(a) bids for money voucher (b) bid deviations from voucher value

Figure 1: Bids for money voucher

However, while the data seem to support value-bidding in the aggregate, at the individual level the picture is less positive. Indeed, we find that only 31 out of 78 participants (40%) bid their voucher's value, while 27 (35%) under-bid (by an average of \$2.69), and 20 (25%) over-bid (by an average of \$4.73); see also Figure 1(b).[14] The observed fraction of value-bidding participants is in line with previous experimental findings, but we find under-bidding to be

[13]This approach is quite common in the experimental literature on auctions; see, for instance, Shogren *et al.* (2001), Cherry *et al. (2004)* and Jacquemet *et al.* (2013).

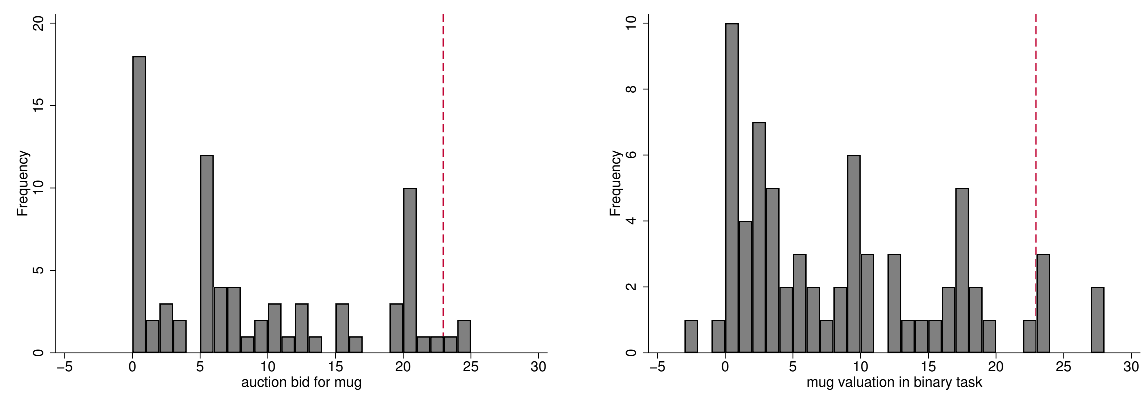
[14]There are 3 participants whose bids depart from the voucher value by more than \$11; when we remove these outliers, we observe that 19 participants over-bid (on average by \$3.87) and 25 under-bid (on average by -\$1.83).

somewhat more prevalent than over-bidding. For instance, Kagel and Levin (1993) found 27% of value-bidding, 5.7% of under-bidding and 67.2% of over-bidding. In Cooper and Fang (2008), Garratt *et al.* (2012) and Rosato and Tymula (2019) the same figures were: 44%, 16% and 40%, 21.2%, 41.3% and 37.5%, and 40%, 38% and 22%, respectively.

The observed departures from value-bidding on the individual level can hardly be explained by the participants feeling cash constrained or misunderstanding the task. Indeed, as shown in Table 3 in Appendix B, neither the difference between the bids and the voucher's value nor the absolute value of this difference are significantly related to poor task comprehension or cash constraints.

3.2 Bidding in Real-Object Auctions

Figure 2(a) illustrates bids in the auction for the mug. These bids ranged from \$0 to \$25, with an average of \$8.81 and a standard deviation of \$7.78. To assess whether participants bid truthfully, we compare the bids in the auction task with the valuations obtained from the binary-choice task. In the latter, participants made a series of choices between buying the mug at a fixed price or receiving a monetary amount that changed from trial to trial.



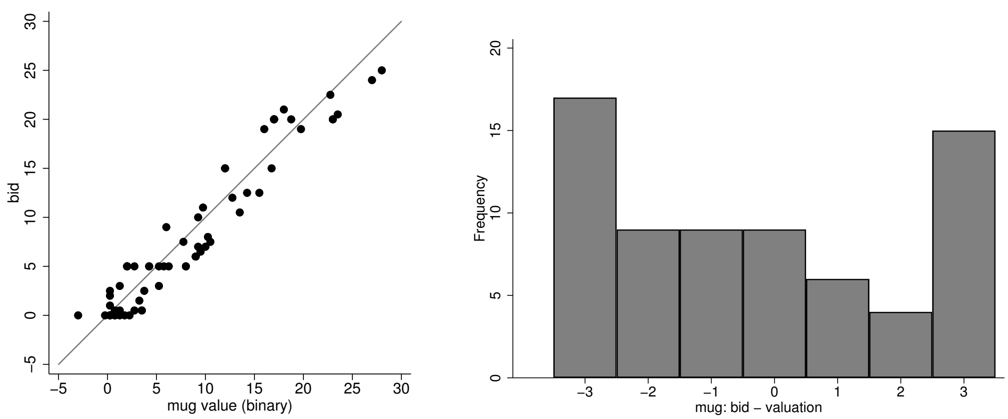
(a) auction bids

(b) binary task valuations

Figure 2: Distributions of bids and valuations for the mug. The dashed vertical line indicates the price of the mug at the time of the experiment (\$22.95).

To infer a participant's valuation for the mug from the binary-choice task, we arrange the 11 choice scenarios in increasing order according to the amounts C_n. Rational participants would choose to buy the mug at the fixed price when $C_n < 0$ and then would switch to preferring the monetary amount for $C_n \geq 0$; denote this "switching" scenario by $\hat{n}$. For each participant i, we can then infer that, for the last scenario in which they selected the mug, it must hold that $v_i - p_i \geq b_i - p_i + C_{\hat{n}-1}$; similarly, for the first scenario in which they selected the monetary amount, it must hold that $v_i - p_i \leq b_i - p_i + C_{\hat{n}}$. Thus, the participant's valuation for the mug must lie in the interval $[b_i + C_{\hat{n}-1}, b_i + C_{\hat{n}}]$. In order to estimate the participant's valuation for the mug, we take the midpoint of this interval; i.e., $v_i = b_i + (C_{\hat{n}} + C_{\hat{n}-1})/2$.[15] With this formula, from the binary-choice task we can recover the valuations of the 37 participants who switched only once between buying the mug and receiving the monetary amount. For the 32 participants who never switched, while we cannot pin down their valuation for the mug, we can identify whether they under- or over-bid. For instance, if they never chose the mug in the binary-choice task, it means that they over-bid in the auction; by contrast, if they always chose the mug, it means that they under-bid. Moreover, we can obtain upper and lower bounds on the mug valuations of these participants by using their auction bid + \$3 (resp. -\$3) if they always (resp. never) selected the mug.[16]

Valuations for the mug inferred from the binary choice task for participants who switched once or never are displayed in Figure 2(b). On average, these participants' valuations are equal to \$8.53 (with a standard deviation of \$7.75), which is not statistically different from their auction bids (\$8.23 average with a standard deviation of \$7.75). Notice also that two participants bid \$0 in the auction for the mug and then never chose to buy the mug in the binary-choice task; hence, their inferred valuations for the mug are negative ($-$\$0.25 and $-$\$3, respectively).[17]



(a) mug bids and valuations

(b) mug bid deviations

Figure 3: Relationship between bids and valuations for the mug

Nevertheless, Figure 3 shows that, as for the induced-value auctions, many participants depart from truthful bidding in real-object auctions as well. Because the monetary options in the binary choice task increased in \$0.50 increments, whenever the gap between the inferred values and the auction bids is within \$0.25, we interpret it as evidence of participants'

[15]For other methods that address the issue of interval responses, see Andersen *et al.* (2006).

[16]9 participants out of 78 (11.5%) switched more than once; hence, they are excluded from the analysis that follows. As argued by Charness *et al.* (2013), multiple switch points are not unusual in binary-choice experiments and various methods have been proposed to address them; see, for instance, Andersen *et al.* (2006), Engel and Kirchkamp (2019) and Yu *et al.* (2021).

[17]If we restrict attention to participants who switched only once in the binary-choice task, we find that their mug valuations are slightly higher than their auction bids (\$5.59 vs. \$5.19, two-sided p=0.07).

behavior being consistent across the two tasks. Overall, 25 participants over-bid for the mug (on average by \$2.34), 35 under-bid (on average by -\$2.21), and 9 bid rationality (that is within +/-\$0.25 from their valuation inferred from the binary choice task).[18] Hence, as for the induced-value auctions, we find under-bidding to be more common than over-bidding.

3.2.1 Winners vs. Losers

In the binary-choice task, some participants saw their own auction bid as the fixed price for the mug. This group consists of those participants who either lost or tied with their opponent in the auction for the mug. For these participants, $b_i - p_i = 0$ and their monetary amounts always range from -\$2.50 to \$2.50. Overall, 52.56% of the participants are in this category.[19] One might therefore wonder whether seeing their own previous bid as the price in the binary-choice task could have affected the decision process of these participants. Yet, as Table 1 shows, deviations between the two tasks were similar (χ^2's $p = 0.423$) for "losers" (who faced a fixed price equal to their bid) and "winners" (who faced a fixed price lower than their bid).

Table 1: Over-, under-, and rational bidders by whether their price is equal to their bid

	price≠bid	price=bid	
overbid	14	11	25
rational	3	6	9
underbid	15	20	35
total	32	37	69

3.3 Induced-Value vs. Real-Object Auctions

As we have shown in the previous sections, in our study participants deviated from truthful bidding in both real-object and induced-value auctions. Moreover, in each auction type, under-bidding is somewhat more common than over-bidding. In this section, we investigate whether participants' bidding behavior is correlated across the two types of auction.

Table 2 reports how many participants over-bid, bid truthfully, and under-bid for the mug (rows) and the money voucher (columns).[20] There is no significant association between these categories across auction type (Fisher's exact $p = 0.970$; χ^2's $p = 0.963$). For example, of the 16 participants who over-bid with induced values, only 7 over-bid for the mug as well, which is

[18] If we exclude the participants who never switched, 10 participants over-bid (by \$1.35 on average), 18 participants under-bid (by -\$1.47 on average), and 9 participants bid rationally.

[19] When we drop the participants who switched more than once in the binary-choice task, this percentage increases to 53.62%.

[20] The 9 participants with multiples switching points in the binary-choice task are excluded from this table.

Table 2: Relationship between overbidding for money (in columns) and mug (in rows) for all participants who switched once or never

	money			
	overbid	rational	underbid	total
overbid	7	11	7	25
rational	2	4	3	9
underbid	7	16	12	35
total	16	31	22	69

the same number of participants who under-bid for it. In other words, participants who over-bid in induced-value auctions were equally likely to over-bid or under-bid in real-object ones.

Next, we compare the size of the deviations from truthful bidding across the two types of auction. If participants' bidding behavior is similar across auctions, we would expect that those who over-bid more for the money voucher also over-bid more for the mug. Figure 4 suggests that there is no such positive correlation. We confirm this intuition by regressing the amount of mis-bidding (either over- or under-bidding) in the real-object auctions on the amount of mis-bidding in the induced-value one using a Tobit model; see Table 4 in Appendix B. We find no association in the tendency to mis-bid across different auction types despite the data in both auctions coming from the same individuals and the same experimental session.[21] Hence, we conclude that there is no significant relationship between how participants bid in induced-value auctions versus real-object ones.

Could the lack of any meaningful relation between the two types of auction be due to the fact that their environments are somewhat different? After all, real-object auctions entail a loss of control in the sense that bidders' values are home-grown rather than randomly assigned. For instance, the support and distribution of values are commonly known in induced-value auctions. Moreover, participants might be uncertain about their value for the mug, especially if they are not familiar with it; or, their values could be correlated. Yet, we do not think that these potential concerns would undermine the implications of our study. Indeed, as long as values are private, truthful bidding remains a (weakly) dominant strategy in the Vickrey auction even if the values are correlated and/or their supports are asymmetric (or unknown). Therefore, we think that our results hint at the possibility that bidders might be using different bidding strategies (or heuristics) in induced-value auctions compared to auctions for real goods.

[21]The relationship remains insignificant even when censoring deviations from truthful bidding in the induced-value auctions.

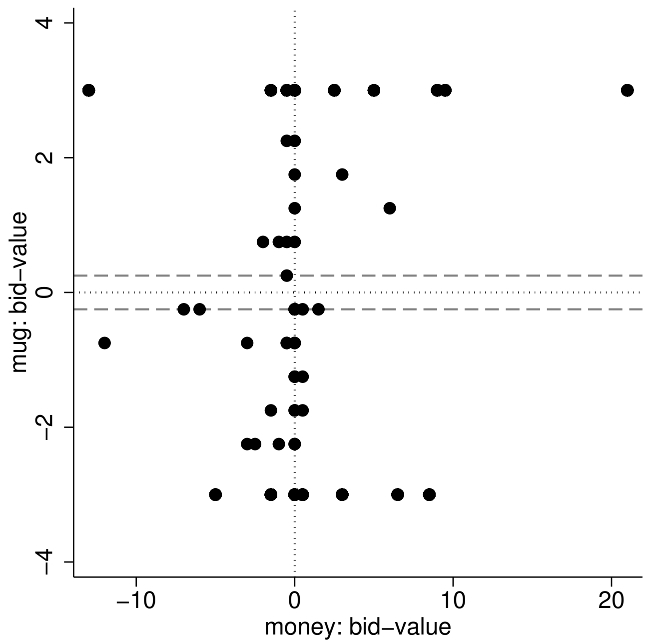


Figure 4: Relationship between mis-bidding for money and mugs. The vertical dotted line and the area between horizontal dashed lines indicate truthful bidding.

4 Discussion and Conclusion

We presented results from a laboratory experiment with a novel design aimed at testing for deviations from truthful bidding in second-price auctions with real objects. Our design, combining a standard second-price auction with an individual-specific binary-choice task, allows to directly identify over- and under-bidding. Moreover, we also compared participants' bidding behavior in real-object auctions vs. induced-value ones. We found significant deviations from truthful bidding in both types of auctions, with under-bidding being more common than over-bidding. Yet, we found no significant relationship between deviations from truthful bidding across the two types of auction, suggesting that people might bid differently in real-object auctions than in induced-value ones.

Most of the literature in experimental economics has been dominated by the use of induced values. Such a design feature allows researchers to control for otherwise unobservable confounds when studying the properties of different games and market institutions. Yet, more recently, researchers have begun to use real goods in economic experiments; e.g., food, stationary products and, especially, mugs. In these experiments, therefore, researchers are faced with the additional task of eliciting participants's home-grown values. Elicitation methods commonly employed include the second-price (or Vickrey) auction, the ascending (or English) auction, the BDM mechanism and the binary-choice format. All these methods are equivalent in principle as, under standard assumptions, they are all incentive compatible. However, there are some procedural differences which can cause the elicited values to differ across these methods. First, as participants compete against each other in Vickrey and English auctions, these two methods feature a strategic element which is absent in BDM and binary choice. Furthermore, even though strategic interaction is absent in BDM, participants might perceive it as being similar to an auction since they still have to submit bids and are exposed to some risk with respect to the item's price. For these reasons, we think that the binary-choice format is cognitively less demanding for participants and hence more apt to elicit their "intrinsic" values. Indeed, this is what we have implicitly assumed in our analysis of over-/under-bidding in real-object auctions. Under the alternative hypothesis that bids in the second-price auctions are truthful, then our results should be interpreted as evidence against the binary-choice method. In either case, our study shows that these two methods deliver different and somewhat inconsistent estimates for participants' home-grown values.

Throughout the paper, we have been deliberately agnostic about which theoretical mechanisms might explain the deviations from truthful bidding that we observe in real-object auctions. We now conclude by discussing some alternatives.

One possibility is the "joy of winning" hypothesis, which has already been put forward to explain deviations from truthful bidding in second-price auctions with induced values (see Cooper and Fang, 2008). Insofar as participants experience a boost in utility only when getting the mug in the auction but not in the binary-choice task, this hypothesis can rationalize deviations from truthful bidding in second-price auctions. Yet, one would expect such utility boost to lead to over-bidding whereas we find that most participants in our study under-bid.

As we mentioned in the introduction, our finding that participants' bids in the auction for the mug differ from their valuations elicited via the binary-choice task can also be interpreted as a form of preference reversal. Common explanations for preference reversals include nontransitive choice models (Loomes and Sugden, 1983) and risk preferences that violate the independence axiom of expected utility theory (Holt, 1986; Karni and Safra, 1987; Segal, 1988). None of these models, however, can explain deviations from truthful bidding in second-price auctions with induced values. A third option, advocated by Tversky *et al.* (1990), is a particular failure of procedural invariance, called "scale compatibility", whereby people focus their attention on the attributes that are most compatible with the response mode. In the context of the typical preference reversal experiment, scale compatibility implies that subjects attend to the monetary payoffs more when pricing the bets than when choosing between them. Hence, in the context of our study, this would imply that participants would assign a bigger monetary value to the mug in the auction task than in the binary-choice task. Indeed, we found that the average bid for the mug is slightly higher than the average valuation from the binary-choice task ($8.81 vs. $8.53), although the difference was not statistically significant.

Finally, another possibility, in light also of the differences that we observe in bidding behavior between real-object auctions and induced-value ones, is provided by models where an individual assigns different utility weights to consumption and money; e.g., reference dependence, narrow bracketing, or mental accounting. We think that a thorough investigation of these hypotheses represents a promising avenue for future research.

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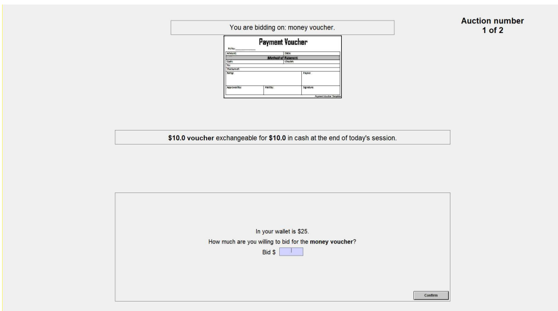
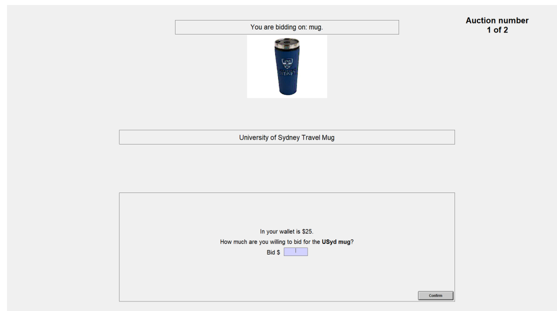
Supplementary Material

This supplementary (online) appendix contains additional figures, tables, the experimental instructions, comprehension questions, and post-experimental questionnaire.

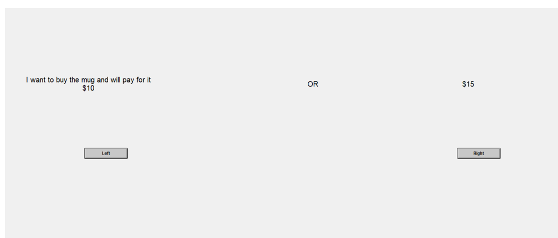
A Appendix: Figures



(a) auction for money voucher



(b) auction for travel mug



(c) binary choice

Figure 5: Screenshots from the auction and binary choice tasks.

B Appendix: Tables

Table 3: Determinants of overbidding (models 1-3) and deviations from truthful bidding (models 4-6) in auctions for the money voucher. In models 1-3, the dependent variable is the the difference between the bid for the voucher and its nominal value. In models 4-6, the dependent variable is the absolute vaue of the difference between the bid and its nominal value. *incomprehension* is the number of questions answered incorrectly in the auction task comprehension test. *cash constrained* is an indicator variable for whether participants felt cash constrained when bidding on the money voucher. Robust standard errors. $^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$.

dep. var.	$bid - value$			$\lvert bid - value \rvert$		
	(1)	(2)	(3)	(4)	(5)	(6)
incomprehension	0.205	0.231		0.380	0.399	
	(0.290)	(0.284)		(0.342)	(0.347)	
cash constrained	0.334		0.394	1.212		1.615
	(0.981)		(0.965)	(1.086)		(1.120)
male	0.406			–0.601		
	(0.813)			(0.904)		
constant	1.679***	1.898***	2.070***	–0.058	–0.137	–0.008
	(0.489)	(0.429)	(0.477)	(0.565)	(0.512)	(0.544)
R^2	–0.024	–0.001	–0.011	0.009	0.015	0.009
No. of obs	78	78	78	78	78	78

Table 4: Relationship between overbidding for mug and money voucher. The dependent variable is the difference between the bid for the mug and its valuation from the binary choice task. Tobit model censored at -3 and 3. Robust standard errors in parenthesis. $^{*}p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$.

	(1)
overbid amount money	0.151
	(0.149)
constant	–0.410
	(0.493)
No. of obs	69

C Appendix: Instructions

General You are participating in an experiment on economic decision-making and will be asked to make a number of choices. If you follow the instructions carefully, you can earn some money and goods. At the end of the experiment, you will be paid your earnings.

You are not allowed to communicate with other participants. If you have a question, raise your hand and we will gladly help you.

The study is strictly anonymous: that is, your identity and actions will not be revealed to others and the identity and actions of others will not be revealed to you.

Timeline

The study consists of the following parts:

1. Instructions for Auction task
2. Comprehension test
3. Auction task
4. Instructions for Decision task
5. Comprehension test
6. Decision task
7. Questionnaire about you and the study
8. Receipts, payment and good-bye!

Payment

Your final payment will be determined by the choices that you make in the experiment so please pay attention to your decisions. Once you make a decision and move on to the next stage you will not be allowed to go back and change your decision. So, please really pay attention to your decisions.

You have received a $25 endowment (it is in an envelope in the top left corner of the desk). You should think of this as your money. Throughout the experiment you can make more money or lose some of it. To determine your final earnings, the computer will pick one of the decision scenarios at random and your decision in that decision scenario will determine your payment.

Your final earnings = $25 (endowment) + earnings from one randomly selected decision scenario

Instructions: Auction task

You will participate in two auctions for two different products today. The outcome of one of these auctions may count towards your payment. It will never happen that your decisions in both of the auctions count towards your final payment so you should treat each auction as if it was the only auction in which you are participating.

In each auction you will be randomly paired with another bidder. You will not know who exactly you are paired with, only that this person is participating in the study at the same time as you are. The other bidder also does not know who exactly they are paired with.

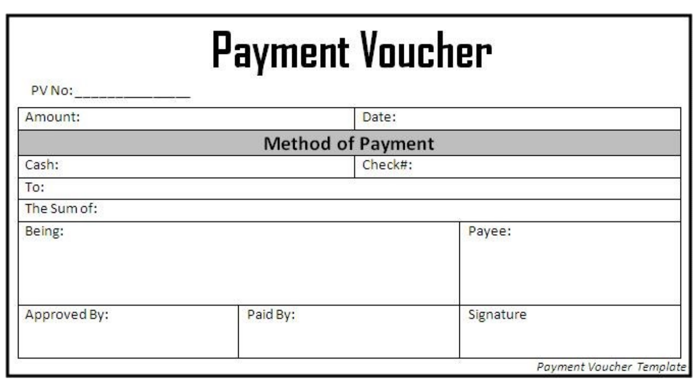
In each auction, your budget is equal to your endowment of $25 and you cannot submit a bid larger than your endowment. You can submit bids in $0.50 increments.

Products

Product 1: University of Sydney Travel Mug

Environmentally friendly double walled travel mug, featuring university crest, vacuum insulation, rubberised paint finish.

Product 2: Money voucher



Payment Voucher

PV No:____________

Amount:	Date:
Method of Payment	
Cash:	Check#:
To:	
The Sum of:	
Being:	Payee:

Approved By:	Paid By:	Signature

Payment Voucher Template

The voucher is redeemable from the experimenter at the end of this experimental session in exchange for cash.

The monetary value of the voucher that you will be bidding on will be randomly selected by the computer at the beginning of this experimental session and will stay the same throughout the experiment. It can be any monetary value between \$0 and \$20 in \$0.50 increments, with each amount being equally likely to be selected.

The voucher value is selected randomly and independently for each participant so different people in the experiment will be offered vouchers of different value. You will be informed of the exact value of your voucher but not of the values of other people's values.

Remember however that even though you do not know the exact values of other people's vouchers, you know that they are an amount between \$0 and \$20.

Earnings from the auction task

If the decision randomly selected to count towards your payment is from the auction task, your payment will be:

a) If your bid was higher than the bid of the other bidder: \$25-other'bidders bid + product

b) If your bid was lower than the bid of the other bidder: \$25

If you purchase a product, it will be a final sale. No returns, exchanges or refunds are possible.

Example 1:

Suppose that John and Amy were paired together in an auction for a University of Sydney mug. John bid \$20 and Amy bid \$10. Here are their earnings:

John's earnings = \$25 (endowment) - \$10 (price) + mug = \$15 + mug (John had the higher bid so he gets to purchase the mug for a price equal to Amy's bid)

Amy's earnings = \$25 (Amy had the lower bid so she does not purchase the mug and keeps her \$25 endowment)

Example 2:

Suppose that John and Amy were paired together in an auction for a money voucher. Amy bid \$24 on a \$25 money voucher and John bid \$10 on a \$10 money voucher. Here are their earnings:

John's earnings = \$25 (John had the lower bid so he does not purchase the money voucher and keeps his \$25 endowment)

Amy's earnings = \$25 (endowment) - \$10 (price) + \$25 (voucher) = \$40 (Amy had the higher bid so she purchases the voucher for a price equal to John's bid)

Instructions: decision task

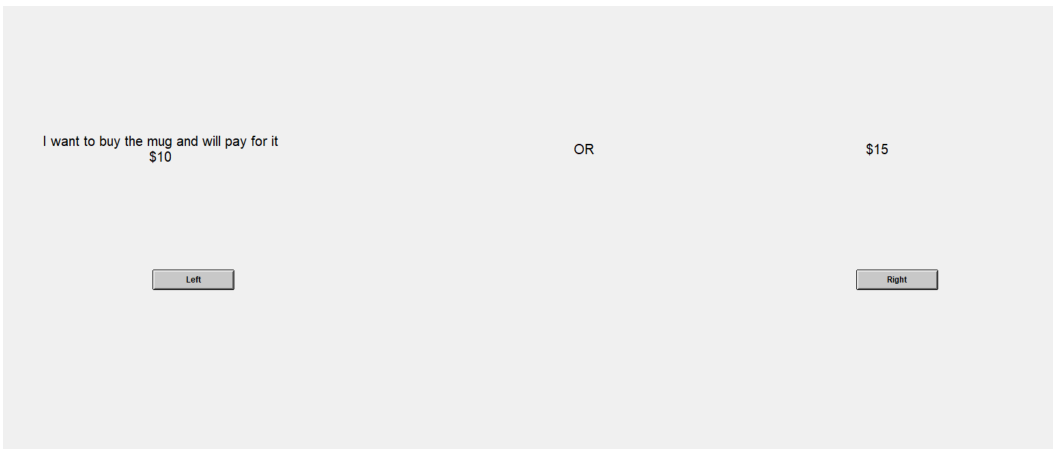
In this task, we will ask you to choose between two options (the following is just an example and you don't need to choose on this screen):

You will be able to select the option that you prefer, by clicking the corresponding button.

Example: Suppose that the following decision scenario was selected for payment (this is just an example and you don't need to choose on this screen):

If you selected left option, your earnings will be: \$25- \$10 + mug = \$15 + mug

If you selected right option, your earnings will be: \$25+\$15 = \$40



D Appendix: Comprehension questions

D.1 Comprehension questions

Question 1

Consider the following example. There are 2 participants in the auction. They are bidding on a mug and each had $25 endowment in his/her wallet. Below are the details of the auction.

Participant name	Bid
Participant1	$22
Participant2	$20

a) Who wins the auction?

- Participant1 *
- Participant2

b) How much does (s)he pay for the mug?

- $22
- $20 *

c) What are the earnings of Participant1 from this part of the experiment?

- $0 + mug
- $5 + mug *
- $22
- $25

d) What are the earnings of Participant2 from this part of the experiment?

- $0 + mug
- $5 + mug
- $22
- $25 *

Question 2

Consider the following example. There are 2 participants in the auction. They are bidding on money vouchers and each had $25 endowment in his/her wallet. Below are the details of the auction.

Participant name	Bid	Voucher value
Participant1	$12	$12
Participant2	$17	$20

a) Who wins the auction?

- Participant1
- Participant2 *

b) How much does (s)he pay for the voucher?

- $5
- $12 *
- $17
- $20

c) What are the earnings of Participant1 from this part of the experiment?

- $0 + voucher
- $13 + voucher
- $20
- $25 *

d) What are the earnings of Participant2 from this part of the experiment?

- $0 + voucher = $20
- $13 + voucher = $33 *
- $20
- $25

Question 3

Consider the following example. Participant1 had $25 endowment in his/her wallet. Below are the details of the decision task.

[a screenshot showing on the left "I want to buy the mug and I will pay for it $15 and on the right "$10"]

What are the earnings of Participant1 if (s)he selected the Left option?

- $5 + mug
- $10 + mug *
- $25
- $35

Question 4

Consider the following example. Participant1 had $25 endowment in his/her wallet. Below are the details of the decision task.

[a screenshot showing on the left "I want to buy a mug and I will pay for it $10 and on the right "$4"]

What are the earnings of Participant1 if (s)he selected the Right option?

- $15 + mug
- $10 + mug
- $4

- $29 *

Question 5 Consider the following example. Participant1 had $25 endowment in his/her wallet. Below are the details of the decision task.

[a screenshot showing on the left "I want to buy a mug and I will pay for it $10" and on the right "-$1.5"]

What are the earnings of Participant1 if (s)he selected the Right option?

- $15 + mug
- $5 + mug
- $23.5 *
- $15

E Appendix: Post-experimental questionnaire

Questionnaire

1. Age [enter numeric value]
2. Gender [select: male or female]
3. I am: [undergraduate student, graduate student, postgraduate, employee]
4. What year are you in? [select:1,2,3,4,5,6,does not apply]
5. How much did you want to buy the mug? [rate on scale from 1(did not want the item at all) to 6 (really wanted to buy)]
6. How familiar were you with the mug before participating in this study? [rate on scale from 1(I did not hear about the product before) to 6 (I know this product very well)]
7. Do you own a University mug like the one that we offered today? [yes/no]
8. What amount of money would make you indifferent between buying and not buying the mug? [free entry]
9. Please describe your bidding strategy. [free text entry]
10. Did you feel cash- constrained in the auction for the mug? (i.e., you wanted to bid more than $25) [yes/no]
11. Did you feel cash- constrained in the auction for the money voucher? (i.e., you wanted to bid more than $25) [yes/no]
12. Did you intend to buy the mug a) for own use b) as a gift c) to resell d) other?