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An experimental study of a continuous Japanese-English auction for the wallet game*

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Abstract

This paper reports results from a laboratory experiment on a continuous Japanese-English auction in a common-value 'wallet game'. The main objective is to test whether bidders follow the equilibrium bidding strategy predicted by theory. We find systematic deviations from equilibrium behaviour: instead of bidding according to the Nash equilibrium, subjects appear to rely on *expected value* (EV) bidding. As a consequence, observed auction prices are higher than the theoretical benchmark, and the winner's curse occurs in a substantial fraction of auctions. We analyse bidding behaviour in detail and discuss the implications of our findings.

Keywords: Japanese-English auction (JEA), Wallet game, Continuous bids, Winner's curse, Expected value bidding.

JEL Classification Numbers: C72, C91, C92, D63, D83.

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1 INTRODUCTION

Milgrom and Weber (1982) analysed equilibria in a particular version of the English auction, the so-called Japanese-English auction (henceforth, continuous JEA), in which the price increases continuously and interested bidders must depress a button as long as they are prepared to buy the good for sale at the posted price; the auction ends when all but one bidder release the button. Later, Klemperer (1998) focused on a common value auction, popularly known as the "wallet game", as a special case of the general model (an affiliated value model which nests the private and common value models) studied by Milgrom and Weber (1982), and illustrated the equilibrium of the wallet game.

From an experimental viewpoint, Avery and Kagel (1997) ran an experiment on a second-price auction based on the wallet game. Following this seminal paper by Avery and Kagel (1997), Isaac *et al.* (2005) (in a private value context) and Gonçalves and Hey (2011) (in a common value context) have looked at the role of discrete bidding in auctions. Cox and James (2012) studied centipede games with a clock-format Dutch auction, motivated by earlier experimental work on small changes in the representation or institutional details of strategically similar auction environments (Cox *et al.* 1983). To the best of our knowledge, there has not been any experimental study so far on continuous JEA with the wallet game.

With this backdrop, this paper aims at testing, experimentally, bidding behavior in a continuous JEA. In order to carry out this analysis, our experimental design is firmly grounded on the underlying theoretical model of a wallet game with two values in each wallet (signals). We assume a discrete signal distribution (where bidders can only have a 'high' or a 'low' signal). We implemented this treatment as the standard continuous JEA.

As is now well-known in the literature, the equilibrium for the continuous JEA tells us at which price each individual bidder drops; this (symmetric) bid function is given by twice the value of the signal.

It is worth mentioning here that Gonçalves and Ray (2017, 2024) analysed JEA with discrete (rather than continuous) bid levels, and characterised equilibrium in that setup, which is of substantially different nature. Note also that the JEA - both continuous and discrete - is in essence a first-price auction (see, for instance, Menezes and Monteiro 2005): the auction ends at a price level such that all but one bidder have dropped out and this is the price paid by the winner.[1] However, in the literature, the JEA is often referred to as a second-price auction, but it is important to note that it is a *second-price auction by design.* (see, for instance, the example of three bidders in Haeringer 2017).

[1] In case of a tie, that is, two (or more) bidders active at a price level but inactive at the next available price level, this logic still holds: the winner is determined randomly among all the active bidders and the final price is the price level at which they were active.

Earlier literature in (common value) experimental auctions (see Kagel and Levin 2002, for an overview) has pointed out that bidders typically use rules of thumb or heuristics to make their bid choices. In the continuous JEA based on the wallet game, given their signals, bidders may make use of the signal distribution to calculate the expected value of the good and bid accordingly (expected value bidding, as defined by Avery and Kagel 1997), although this is not an equilibrium strategy (Gonçalves and Hey 2011).

Our findings in this paper suggest that bidding in the continuous JEA does not follow the equilibrium bidding prediction. Instead, bidders appear to follow *expected value* bidding strategies, which are not Nash equilibria, although they could be rationalised as *cursed equilibria* (Eyster and Rabin 2005). This is fully consistent with previous experimental results from the continuous JEA as presented by Gonçalves and Hey (2011).

We find that, consistently with previous research on the continuous JEA (Avery and Kagel 1997; Gonçalves and Hey 2011), observed auction prices in our experiment are higher than theoretically expected prices which implies significant overbidding, resulting in the winner's curse for a significant percentage of auctions (whereby the auction winner receives negative profits).

2 THEORY

Our underlying theoretical framework is that of the 'wallet game' (Klemperer 1998), where two symmetric risk-neutral bidders $i \in \{1, 2\}$ compete (typically, in a common value auction setup) for the purchase of a single good (for example, the combined amount inside bidders' wallets), whose value, $\tilde{V}$, is common but *ex ante* unknown to both bidders. In our game, the common value of the good depends on two signals (for example, the amounts in each bidder's wallet) and is given by $\tilde{V} = X_1 + X_2$. Signals are extracted randomly from the following discrete signal distribution:

$$X_i = \begin{cases} x \text{ with probability } p \\ X \text{ with probability } 1 - p \end{cases} \tag{1}$$

where X is a high signal and x is a low signal. In other words (in the 'wallet' example), each bidder knows exactly the amount in one's own wallet, but has to bid for the combined amount of both wallets, which is *ex ante* unknown.

We use a specific common value auction with the above two-person (bidder) game, as proposed by Milgrom and Weber (1982) which is known as the continuous JEA. Based on the rules of this specific type of English auction, bidders are gathered in a room, and are told to depress a button if they are interested in the item for sale. The price, publicly posted on an electronic display, is raised continuously. Whoever is depressing the button at a given price level is actively bidding in the auction. If a bidder wants to drop out of the auction, all he has to do is release the button. The auction ends when only one bidder is active, who will pay a price equal to the drop-out price of the penultimate bidder.

In the continuous JEA, a bid function is effectively each individual bidder's drop-out price. The symmetric equilibrium for the continuous JEA is given by the bid function $b_i^*(x_i) = E\left[\tilde{V}\middle| X_i = x_i; X_j = x_i\right] = 2x_i,\ i,j = 1,2,\ i \neq j$. This result has been derived by Avery and Kagel (1997) and by Klemperer (1998).[2]

This equilibrium has several important properties. First, it is an *ex post* equilibrium and there is no *ex post* regret, in the sense that even after learning the other bidder's signal, no bidder will regret having bid how they actually did (Avery and Kagel 1997). Second, profits are always positive for the winner, who in turn is always the high-signal bidder.

3 EXPERIMENT

The experimental design is based on the Klemperer (1998) wallet game as discussed above. We used the following signal distribution for our experiment:

$$X_i = \begin{cases} x = 30 \text{ with probability } \frac{1}{2} \\ X = 80 \text{ with probability } \frac{1}{2} \end{cases} \tag{2}$$

In our experiment, the bidders whose signals are drawn from this signal distribution, participated in a continuous JEA, as described in the previous section. In the experiment, subjects are endowed with a number of tokens in their wallets ('signals'), which can be either 30 (x) or 80 (X), which is private information, and are bidding for the sum of the two wallets ($\tilde{V}$). The total value of the two wallets together can be 60, 110 or 160.

With this probability distribution, one can find the (expected) equilibrium price. In equilibrium, bidders stay active until $b_i^*(x_i) = 2x_i,\ i = 1,2$. Given the signal distribution, this implies that both bidders will be active until a price of $2 \times 30 = 60$ with probability $\frac{1}{4}$, one will be active until a price of $2 \times 30 = 60$ and the other would stay active until a price of $2 \times 80 = 160$ with probability $\frac{1}{2}$ (but in this case the auction ends at a price of 60), and, finally, both will be active until a price of $2 \times 80 = 160$ with probability $\frac{1}{4}$. Therefore, the (expected) equilibrium price is $E[P] = 85$.

At the beginning of each round of our experiment, first every subject receives her signal. The auctioneer begins at a price equal to zero, which then increases in increments of 1, with a potential

[2] Milgrom and Weber (1982) have derived the symmetric equilibrium in a general model; Klemperer (1998) has applied it to the wallet game.

maximum value of 200 tokens.[3] The only decision that subjects have to make is to decide at which price they want to drop out from the auction. Once a subject drops out at price p, the other bidder wins the auction and receives a net payoff equal to $\tilde{V} - p$.

3.1 Procedure

The experiment took place at the Lancaster Experimental Economics Lab (LExEL). The participants were mostly undergraduate students from the Lancaster University, from various fields of studies and were invited using the ORSEE recruitment system (Greiner, 2004).

In our study we applied a between-subjects experimental design and we have data from 4 sessions; each session consisted of 12 subjects, with one matching group (consisting of 12 subjects) in each session. Each subject participated in only one treatment. As the groups remain fixed during the experiment, each matching group represents an independent observation. In total, thus 48 subjects (58% females) participated.

In each session, a matching protocol was implemented. In each of 20 auction rounds within a session, all 12 participants were randomly matched in pairs, forming 6 groups (that is, six auctions were taking place simultaneously). At the end of each auction round, participants were re-matched. This random matching protocol was implemented, following the common practice, in order to create an environment as close as possible to a one-shot interaction between subjects. In addition, there was no way for a participant to identify the opponent with whom they were matched, in an effort to eliminate any potential reputation effects.

The overview of the experimental sessions is summarised in Table 1 below.

Price Mechanism	Sessions	Subjects per Session	Rounds	Total Subjects
Continuous	4	12	20	48

Table 1: Experimental Design

Upon arrival to the lab, participants were randomly allocated to computer terminals. Each received a set of printed experimental instructions. After the instructions phase, the participants were asked to complete a comprehension questionnaire (see the Appendix) to confirm that there was no confusion regarding the game, the matching procedure, the auction mechanism and the payoffs. When the subjects had completed the questionnaire, we made sure that they had all the answers correct. The experiment did not proceed until every subject had the correct answers to these questions. Subjects

[3] In a sense, by assuming unit increments we are implementing a discrete but 'almost continuous' JEA, where increments are equal to the smallest possible integer. Following Gonçalves and Ray (2024), the large number of bid levels that results from unit increments make it extremely difficult for bidders to compute equilibrium partition strategies.

could not communicate with each other, nor could they observe the choices of other participants during the experiment.

Effort was made to use neutral language in the instructions for the experiment, to avoid any potential connotations. Each pair of subjects was described as "you and your counterpart". Note also that we used a neutral terminology and avoided using any term that may have some other connotations, such as, "your opponent" or "your partner". Subjects were not given identifying information about their counterparts in any round to avoid any subject-specific reputation that may develop across the rounds.

All sessions followed identical protocol. Full instructions (including the questionnaire) for the experiment are in the Appendix.

At the end of each round, all subjects received feedback on whether they won the auction or not, the way they won (whether the other bidder dropped out or if the computer determined the winner), the value of the two wallets in that round, as well as their own and their counterpart's payoff. There was a limit of 120 seconds for the first 10 auction rounds to submit a decision, which was reduced to 90 seconds for the last 10 rounds. Subjects knew that if they do not provide a decision before the end of this time limit, it will be assumed that they dropped out of the auction. This happened in only 5 occasions in different sessions.

After 20 rounds, the experimental session ended and the subjects were privately paid, according to their point earnings. In this experiment, we used an exchange rate of 1 : 1 (£1 per point).[4]

Overbidding could lead to negative payoffs for subjects, so an initial endowment of £6 was provided to all participants to ensure that they would not go bankrupt. The fact that negative payoffs could happen during the experiment was sufficiently explained in the instructions and several examples were used to describe to subjects the way overbidding could lead to negative payments. The comprehension questionnaire, along with three practice rounds before the beginning of the actual experiment, provided evidence that there was no confusion among the subjects regarding the task at hand. Subjects got paid the sum of their payoffs from 10 randomly drawn rounds plus the show fee and the initial endowment. The payments were made in private and in cash, directly after the end of the experiment.

The experiment was computerised and the experimental software was custom developed using the Python programming language. The experiment lasted approximately 50 minutes and subjects earned on average £11.50 including a £2 show-up fee which is higher than usual student-jobs for ($18-20$ years old) in the UK that offer about £10 (about $13) per hour currently.

[4] Due to the 1 : 1 exchange rate, no rounding of payments was needed; subjects were paid exactly what they had earned. This keeps the connection between real incentives and the incentives stated in the instructions, which is perhaps lost in many experiments using rounding.

3.2 Hypotheses

The theoretical predictions we set out to (experimentally) test are related to (i) auction prices, (ii) overbidding and the winner's curse and (iii) bidding strategies. Following the theoretical notions presented earlier, we formulate our own hypotheses, some of which are already confirmed in the existing literature.

In our continuous JEA, bidders obtain their signals from the probability distribution shown in the Equation (2). Assuming the bidders play their Nash equilibrium strategies, the expected auction price should be equal to $E\left[P^{T1}\right] = 85$, as explained earlier. Hence, our first hypothesis is:

Hypothesis 1 Final auction price should be on average equal to 85.

With respect to overbidding and the winner's curse, we expect this should not be observed in our treatment (when bidders play their equilibrium strategies). Thus,

Hypothesis 2 Bidders are not expected to make negative profits (in equilibrium).

Finally, regarding bidding strategies, the expectation is that in our experiment, both bidders follow their equilibrium bid function $b_i^*(x_i) = 2x_i$, $i = 1, 2$.

Hypothesis 3 Bidders are expected to play equilibrium bid strategies.

In the following section, we present a descriptive analysis of our results from the experimental sessions.

4 ANALYSIS

We present the results on several issues and thereby test our hypotheses.

4.1 Prices

First, Figure 1 below displays expected and observed average prices in our experiment.

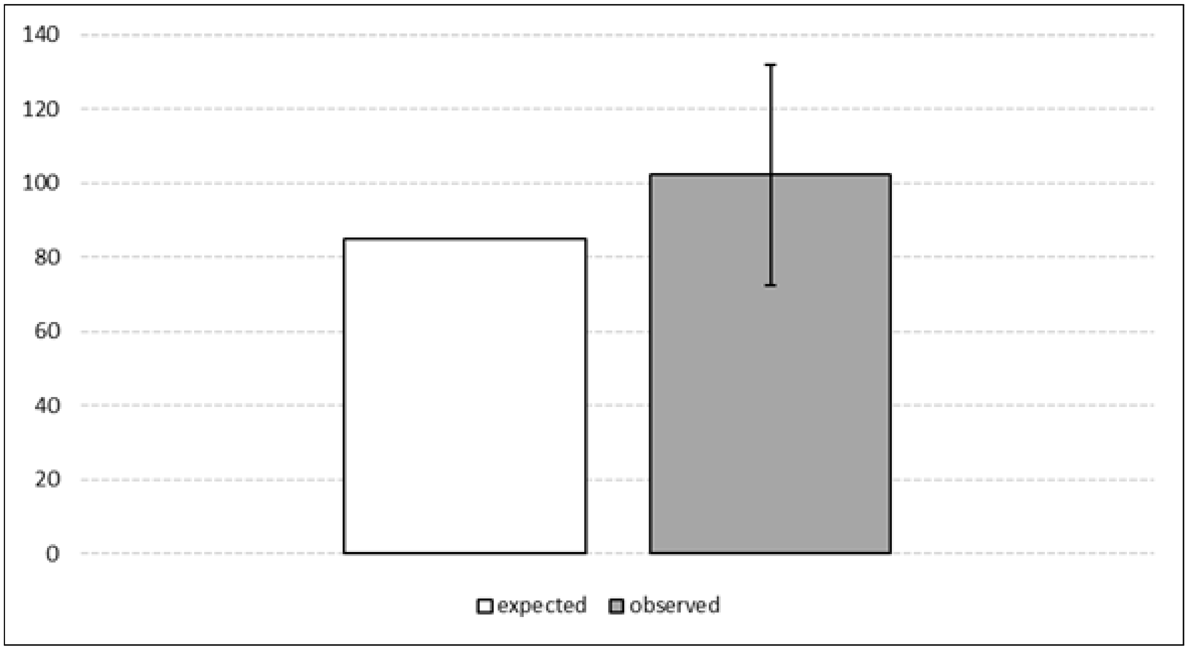


Figure 1: Expected and Observed Average Price

As it is obvious from Figure 1 above, there was significant overbidding. Table 2 below provides a more detailed overview of outcomes.

Signal Pair	Frequency	Average Price	% with −ve Profits
30 − 30	116	82.35	84%
30 − 80	236	94.33	18%
80 − 80	128	135.20	6%
Total	480	102.33	31%

Table 2: Prices and Profits for Signal Pairs

From Table 2, we find, for each auction, when both signals were low (30 − 30), the prices are noticeably high.

Figure 2 below shows how prices evolved over time. In our experiment, there does not appear to exist any noticeable time-effect (e.g., associated with learning): average prices per round appear to follow the average value of the good. Similarly, prices are higher than expected in most rounds.

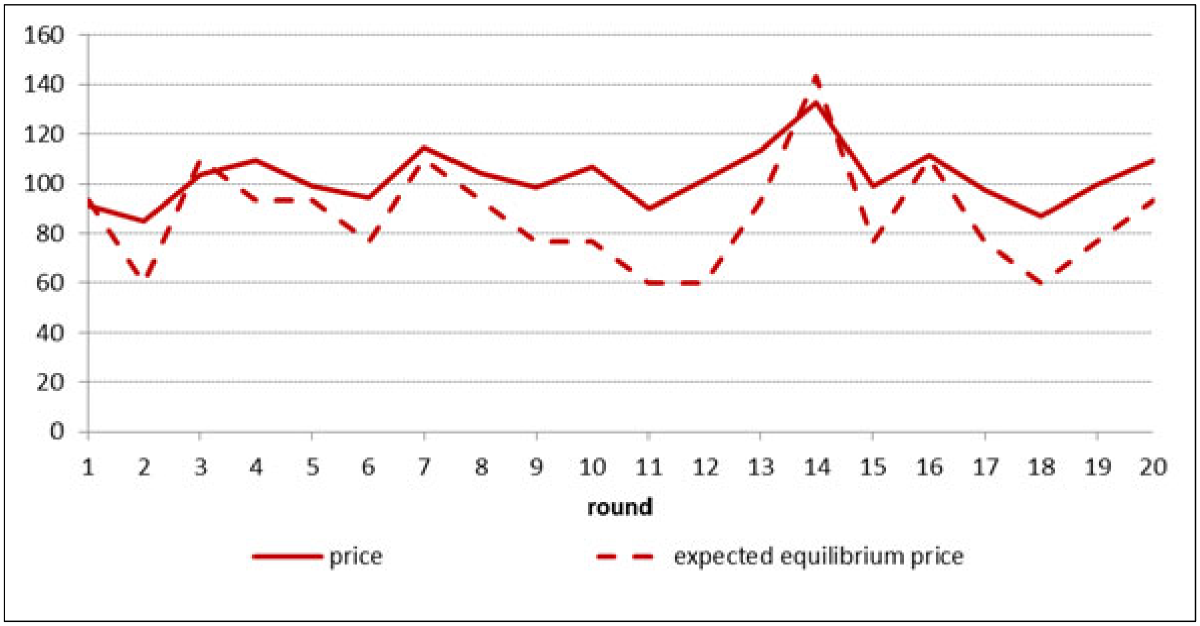


Figure 2: Average and Expected Prices in Rounds

These results allow us to conclude with the following claim regarding our Hypothesis 1.

Claim 1 *Hypothesis* 1 *is rejected as the observed price is higher than the equilibrium price.*

4.2 Overbidding

Table 2 suggests that overbidding and winner's curse were clearly present in our experiment. It was observed mainly when both signals were low.

Following the data presented in Table 2, Figure 3 below displays the percentage of auctions that yielded negative profits for the winner, for each auction round. In the top half of Figure 3, we display these percentages for $30-30$ pairs,[5] while in the bottom half, we present for $80-30$ pairs.

[5] In the top half of Figure 3 there are some gaps. This is because in auction rounds 6, 13 and 17, there were no auctions with $30-30$ signal pairs.

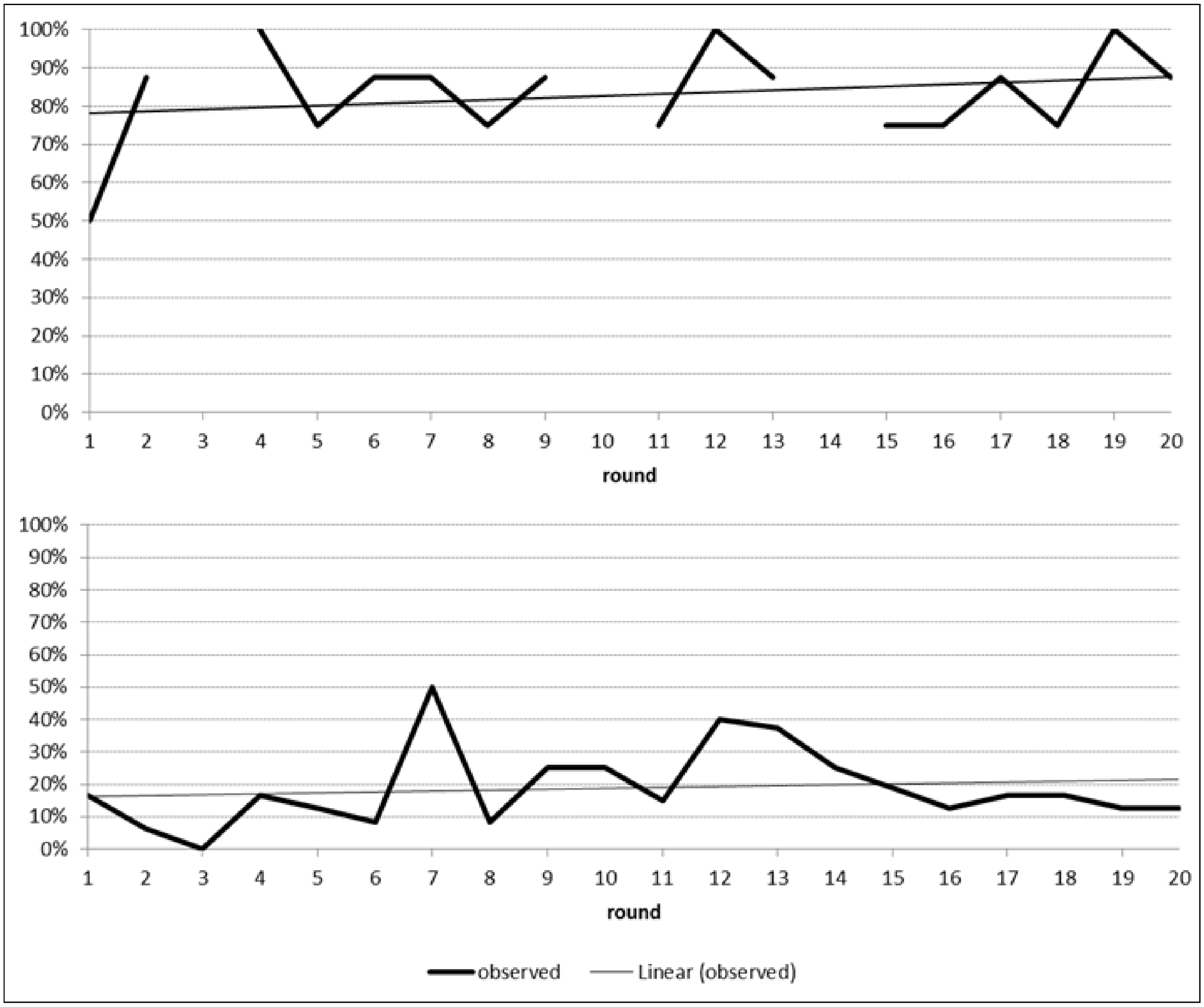


Figure 3: Percentage of Auctions with −ve profits for $30-30$ (Top) and $80-30$ (Bottom) Pairs

From Figure 3, we note a couple of points. First, these percentages are almost always positive for any round. Second, these percentages appear to increase over time.

Figure 4 below displays percentage of bidders with negative cumulative profits in each round. Interestingly, by the end of the experiment, bidders registered negative cumulative profits even more noticeably. Therefore, overbidding had a more pronounced (negative) effects on bidders' payoffs.

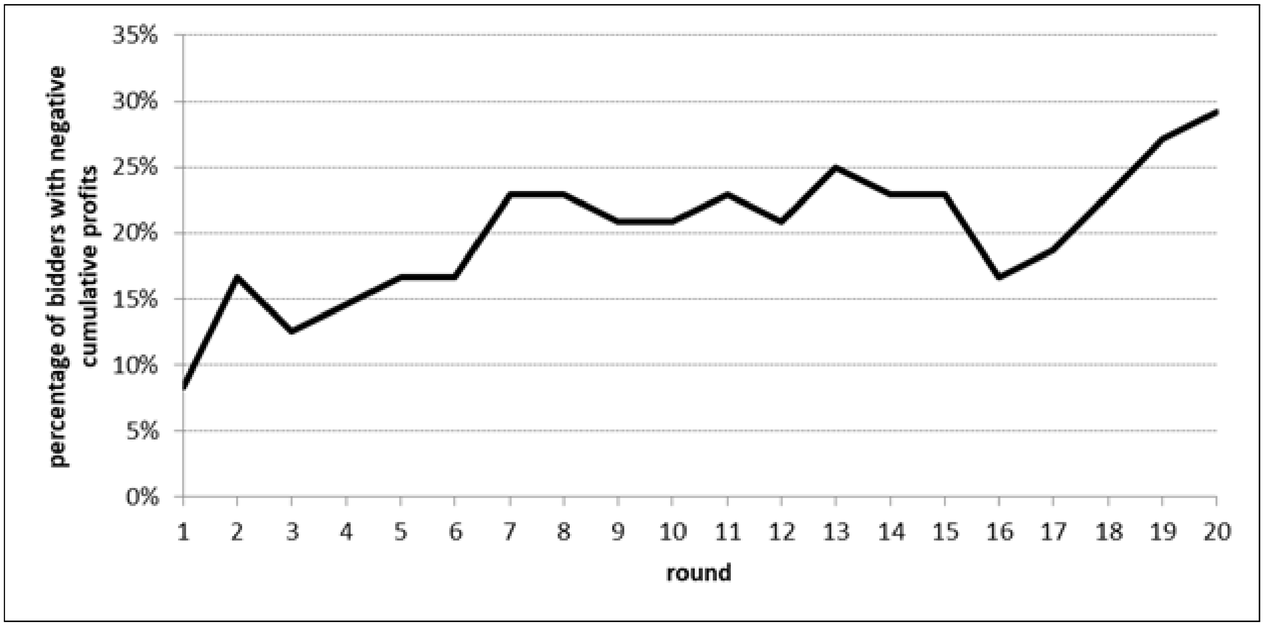


Figure 4: Percentage of Bidders with −ve Cumulative Profits in Rounds

Therefore, the hypothesis that the bidders do not make negative profits fails in a substantial part. We conclude this subsection with the following claim regarding our Hypothesis 2.

Claim 2 *Hypothesis* 2 *is rejected as there is overbidding and negative profits are observed.*

4.3 Strategy

Results in the previous subsections seem to suggest that bidders were not playing equilibrium strategies. Theoretically, the (Nash) equilibrium bidding strategy is $b_i^*(x_i) = 2x_i$. A possible alternative, put forward by Avery and Kagel (1997) and Gonçalves and Hey (2011), is *expected value* (EV) bidding: a bidder's strategy could be to stay active until the price reaches $b_i^{EV}(x_i) = x_i + \bar{x}$, where $\bar{x}$ is the expected value of the opponent's signal. In our case, $\bar{x} = 0.5(30 + 80) = 55$. Although this strategy is not an equilibrium strategy, it can be rationalised as a cursed equilibrium (Eyster and Rabin 2005).

In other words, expected value bidding may be observed in a cursed equilibrium in which bidders, with probability $\chi = 1$ (fully cursed equilibrium) behave as if their opponent's bid does not convey valuable information.[6]

Based on these two possible alternatives, namely, Nash and EV bidding, we have adopted the following rule of thumb: for winning bidders, a strategy explains individual behavior if it prescribes a bidding limit higher than (or equal to) the observed final price.

[6] See Gonçalves and Hey (2011) for a thorough discussion of the relation between expected value bidding and the cursed equilibrium.

More concretely, because there are unit increments in our experiment, we assume that a particular strategy explains behavior if the strategy's bidding limit is higher than (or equal to) the observed final price minus one. For example, a bidder with a signal of 30, wins the auction at a price of 61. We assume that this is consistent with Nash bidding because the Nash bidding limit is $2 \times 30 = 60$ and the auction ended at the next available price: 61.

For losing bidders, behavior is explained by a particular strategy if the observed final price is 'sufficiently close' to the strategy's bidding limit, and we define 'sufficiently close' to be a difference of 10 or less (in absolute value). In other words, we assume that a particular strategy explains observed behavior when losing bidders have underbid or overbid slightly with respect to the strategy's bidding limit. This allows for the possibility of there being small bidding errors (with respect to a possible theoretical bidding limit).

We have then applied this rule of thumb to all 960 individual observations (that is, for 48 individuals, playing 20 auctions each) and identified all the instances in which observed behavior is consistent with either Nash or EV bidding (or none of the two). Table 3 shows that Nash bidding behavior was more frequent than EV bidding behavior: looking at the distribution across individuals, half of them (median) display Nash-consistent behavior in 10 (out of 20) auctions and EV-consistent behavior in only 9.5 (out of 20).

Frequency	1st Quartile	Median	Mean	3rd Quartile
#Auctions Nash-Consistent	8	10	10.2	12.5
#Auctions EV-Consistent	7	9.5	9.4	11
%Auctions Won with Nash	67%	80%	77%	89%
%Auctions Won with EV	64%	80%	74%	88%
%Auctions Lost with Nash	11%	21%	26%	37%
%Auctions Lost with EV	0%	12%	20%	26%

Table 3: Distribution of Various Indicators for Participants (20 Auctions Each)

Table 3 shows how often individual bidders' behaviour is consistent with Nash equilibrium or expected-value (EV) bidding. On average, Nash bidding fits the data slightly better than EV bidding, with the median bidder exhibiting Nash-consistent behaviour in 10 out of 20 auctions, compared to 9.5 for EV bidding.

Naturally, an important question is whether consistency with a given explanatory theory depends on whether a bidder won or lost a particular auction. Both for winning and losing bidders, Table 3 shows that Nash bidding is more consistent with observed bidding behavior than EV, and the difference between the two is larger for the case of losing bidders. However, although it fares better relative to

EV, Nash bidding does not emerge, in absolute terms, as a strategy that losing bidders use often: half of all bidders appear to use it in only 21% of all the auctions they lost.

Table 3 also shows that the pattern is consistent across quartiles. However, neither strategy explains behaviour particularly well; either strategy fails to explain a rather significant proportion of auctions for each individual bidder. While bids in auctions that participants win are largely consistent with both benchmarks, behaviour in auctions they lose is poorly explained, especially by EV bidding. Overall, Table 3 highlights substantial heterogeneity across bidders and shows that a large share of observed behaviour (driven mainly by losing bidders) cannot be accounted for by standard bidding models.

Bidding strategies may change as the experiment evolves. By observing the outcomes of their decisions, subjects may learn and adapt their strategies accordingly. We present similar data as in Table 3, over 20 rounds, in Table 4 below.

Frequency	Rounds $1-5$	Rounds $6-10$	Rounds $11-15$	Rounds $16-20$
#Auctions Nash-Consistent	23.4	24.8	25.2	24.8
#Auctions EV-Consistent	24	23.2	22.6	20.8
%Auctions Won with Nash	78%	78%	82%	72%
%Auctions Won with EV	78%	78%	73%	66%
%Auctions Lost with Nash	19%	26%	23%	32%
%Auctions Lost with EV	23%	19%	21%	21%

Table 4: Distribution of Various Indicators over Rounds (48 Participants per Round)

Table 4 above shows that Nash bidding became (slightly) more prevalent (across all 48 subjects) as time evolved, whilst EV-bidding became noticeably less prevalent: in rounds $1-5$, 23.4 (24) out of 48 bidders exhibited Nash (EV) consistent behavior, whilst in rounds $16-20$, 24.8 (20.8) did so, respectively.

Table 4 examines how consistency with Nash and expected-value (EV) bidding evolves over time. It shows a modest increase over time in the prevalence of Nash-consistent behaviour and a clearer decline in EV-consistent behaviour. This pattern is driven mainly by losing bidders: as the experiment progresses, losing bidders become more likely to behave in a way consistent with Nash bidding, while EV bidding becomes less frequent. By contrast, among winning bidders, consistency with both Nash and EV bidding declines slightly over time. Overall, Table 4 suggests limited learning towards equilibrium behaviour, concentrated primarily among bidders who lose auctions rather than those who win.

The above analysis suggests that Hypothesis 3 that individuals play Nash equilibrium in the continuous JEA , cannot be supported. We summarise these observations as our main finding of the paper.

Proposition 1 *Nash or EV bidding are particularly ill fitted to explain behavior in the continuous JEA, particularly because of the observed behavior of losing bidders.*

4.4 Regressions

In the previous subsection, by looking into the evolution of the pattern of behavior over time for winning and losing bidders, we find that both Nash and EV bidding became less frequent as time evolved for winning bidders; for losing bidders, Nash became noticeably more frequent, whilst EV became slightly less frequent. Therefore, the overall increase in bidders' adherence to Nash bidding (over time) is explained mainly by losing bidders.

In order to further understand the strategies that bidders may have been playing, we have estimated the following equation using only data for losing bidders:

$$B_{it} = \alpha_1 + \alpha_2 Signal\_80 + \sum_{k=3}^{K+3} \alpha_k X_k + \varepsilon_{it} \qquad (3)$$

where $Signal\_80$ is a dummy variable, equal to 1 when bidder i in period t receives a high signal, and where K other explanatory factors may explain bidder i's drop-out price in period t (B_{it}). As potential other explanatory factors, we consider time (which may elicit some learning), time interacted with the $Signal\_80$ dummy variable (such learning may materialise in different ways depending on the signal realisation), cumulative bidder profits (depending on their accumulated profits in previous auctions, bidders may behave differently), cumulative bidder wins (depending on the number of auctions previously won, bidders may behave differently) and a dummy variable for whether the bidder has won the previous auction round.

Table 5 presents the regression results, both when we estimate the equation with bidder fixed-effects (FE) or bidder random-effects (RE).

Independent Variables	Fixed Effects (FE)	Random Effects (RE)
	Coefficient (Std. Error)	Coefficient (Std. Error)
*Signal*_80 (dummy)	25.56*** (4.68)	26.11*** (4.64)
*Signal*_80 (dummy) x Round	1.52*** (0.32)	1.44*** (0.32)
Round	0.99** (0.46)	0.53 (0.39)
Cumulative Bidder Profits	0.019 (0.02)	−0.003 (0.02)
Cumulative Bidder Wins	−1.63* (0.96)	−0.45 (0.79)
Won Previous (dummy)	2.19 (1.86)	2.12 (1.85)
Constant	80.72*** (3.21)	83.63*** (3.41)
N	480	480
***: Significant at 1%; **: Significant at 5%; *: Significant at 10%;		

Table 5: Estimation of Losing Bidders' Strategies (Dependent Variable: Strategy)

We have carried out a Hausman test which suggests that the differences between the two models are not statistically significant.

Under Nash bidding, we should have: (i) none of the K factors is statistically significant, (ii) $\alpha_1 = 60$ and (iii) $\alpha_2 = 100$. None of these has empirical support. Clearly, as previous subsection (Tables 3 and 4) had already hinted, losing bidders were not playing Nash equilibrium strategies, and time appears to have a positive effect, but only for bidders with a high signal.

Under EV bidding, we should have: (i) none of the K factors is statistically significant, (ii) $\alpha_1 = 85$ and (iii) $\alpha_2 = 50$. First, note that the estimated α_1 is not far from (ii): $\hat{\alpha}_1^{FE} = 81$ and $\hat{\alpha}_1^{RE} = 84$. However, the estimated α_2 does differ significantly from the prediction: $\hat{\alpha}_2^{FE} = 26$ and $\hat{\alpha}_2^{RE} = 26$. As time evolves, the $\hat{\alpha}_1$ coefficient increases, although this increase is not statistically significant for the RE model (coefficient for the variable 'Round'). Therefore, under the RE model, after 20 rounds of bidding, the estimated coefficients are: $\hat{\alpha}_1^{RE} = 84$ and $\hat{\alpha}_2^{RE} = 26 + 20 \times 1.44 = 54.8$. At the 10% significance level, we cannot reject the hypothesis that (ii) and (iii) are verified under the RE model. We have carried out a similar test for the FE model: the hypothesis that (ii) and (iii) hold cannot be rejected at the 1% significance level. This provides some support to *expected value* bidding or, similarly, to the fully cursed equilibrium.

5 REMARKS

This paper's main objective is to test experimentally how bidders behave in a common value continuous JEA. Having as our experimental treatment a continuous JEA, we find evidence of significant departures from equilibrium bidding. In the continuous JEA, bidders appear to have played a non-equilibrium strategy which has resulted in higher-than-expected prices and in the winner's curse.

Our findings in this paper, as presented in Tables 3 and 4 about losing bidders and exit behavior is similar in nature to the analysis of endogenous exit in common-value auctions in Cox *et al.* (2001), highlighting the role of beliefs and learning in determining when bidders withdraw.

Several other experimental studies have documented systematic deviations from equilibrium predictions in common value auctions. Brocas *et al.* (2017) conducted laboratory experiments examining second-price sealed bid auctions under different information structures (private information, public information, and common uncertainty). Their results revealed significant departures from Nash equilibrium predictions (winner's curse) regardless of the information structure, with subjects not differentiating private and public information and deviating from theoretical predictions with respect to all three types of information.

Similarly, Charness *et al.* (2019) demonstrated that the winner's curse persists even when valuable information regarding the (unknown) common value is public and identical to all players. By separating the two possible mechanisms that may lead to the winner's curse, Charness *et al.* (2019) find that an incorrect estimation of the (unknown) common value may be a much stronger explanatory factor for the winner's curse than the failure to incorporate in bidding strategies the information released in the event of winning.

In a parallel paper (Georgalos *et al.* 2025), in a very similar setup, we test how bidders bid when the bid levels are discrete (following the analysis presented in Gonçalves and Ray 2017, 2024) with different prior probabilities of signal realisations.

Whilst we have explored some alternative explanations for our findings for the continuous JEA, further work is necessary in order to understand bidding behavior. Perhaps bidders were following alternative strategies or alternative bidding motivations (e.g., other-regarding preferences), through which they do not participate in the auction when the prospect of winning is low (although not zero), perhaps so as to elicit some sort of reciprocal behavior from their opponents in subsequent auctions. In a way, such a strategy would trade-off an immediate loss with the possibility of a large future gain. These are likely to be the next steps in our research.

6 APPENDIX

We report the full instructions for our experiment here. All participants in all sessions have the following identical instructions.

6.1 Instructions

Welcome to this experiment and thank you for participating. Please read the following instructions carefully. From now on, please do not talk to any other participants until this session is finished. You will be given 10 minutes to read these instructions. Please read them carefully because the amount of money you earn may depend on how well you understand these instructions. If you have a question at any time, please feel free to ask the experimenter.

In this experiment, you will take part in an auction, where you will act as a buyer, in each of the successive 20 rounds. In each round, you will be randomly matched with a person (your counterpart) and you have an equal chance of being matched with any particular person present in this room. Both your identities will remain concealed throughout the session and you will have no direct contact with each other during the experiment. In each of the 20 auction rounds, there is a good for sale, which is worth V, an amount equal to the total number of tokens you and your counterpart have in your "wallet". You do not know how much V is, and hence you do not know exactly how much this good is worth (from now on, the value of the good is denoted by the total number of tokens in the two wallets put together). Your earnings for this experiment will depend on the choices you make as well as the choices made by the persons you are matched with.

Design:

In any particular round there will be the following stages:

Stage 0

You are randomly matched with another participant (your counterpart).

You and your counterpart will be informed about the total number of tokens in each wallet.

The total number of tokens in your wallet can be either 30 or 80, and similarly the total number of tokens in your counterpart's wallet can be either 30 or 80.

You know the number of tokens in your wallet; however you do not know the exact number of tokens in your counterpart's wallet, but you know that it can be either 30 or 80, with equal chances.

Thus, the total number of tokens in the two wallets together can be 60, 110 or 160.

Stage 1

In the auction, all you must do is to decide at what price you want to drop out of the auction. The decision you take will be independent, without knowing the decision of your counterpart.

The auctioneer (computer) sets an initial price equal to 0 for the two wallets put together.

The price, p, will increase in increments of 1 and the maximum price it can reach is 200 tokens.

If you decide to drop out of the auction first at a particular price p, then the auction ends. Your counterpart is the winner of the auction, the net amount he/she gets is equal to $V - p$ and you get 0.

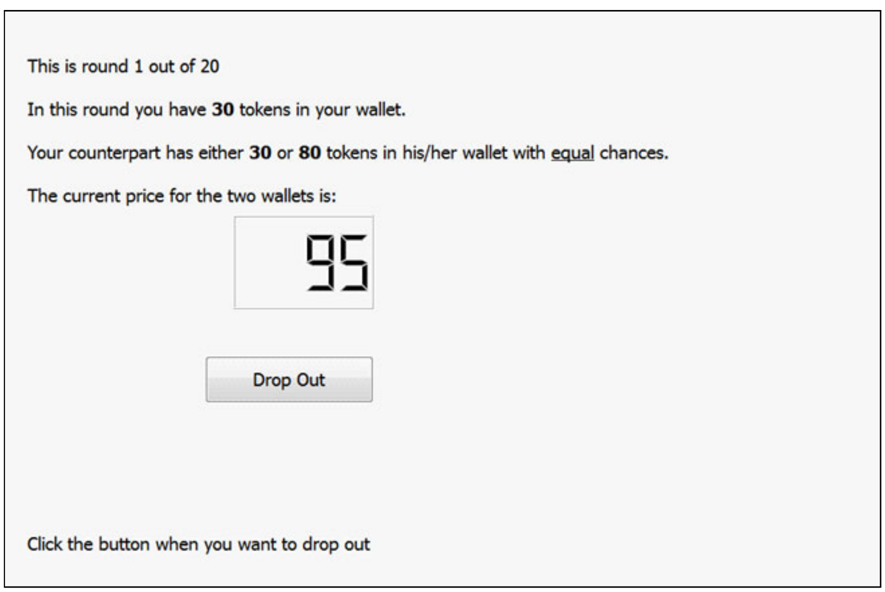
If instead your counterpart decides to drop out of the auction first at a particular price p, then the auction ends. You are the winner of the auction, the net amount you get is equal to $V - p$ and your counterpart gets 0.

If both you and your counterpart decide to drop out of the auction at exactly the same time, then the auction ends. The winner is chosen at random (with equal chances) by the computer. The net amount the winner gets is $V - p$; the one who loses gets 0.

Let us illustrate this with an example: Suppose, you have 30 tokens in your wallet and let us also suppose that your counterpart has 80 tokens. You only know the number of tokens in your wallet. The auctioneer starts at a price equal to 0 and keeps increasing the price. Your counterpart decides to drop out of the auction when the price is equal to 42. Therefore you are the winner in the auction, and the net amount you get is 68 ($= V - 42$, where $V = 30 + 80 = 110$). Your counterpart gets 0.

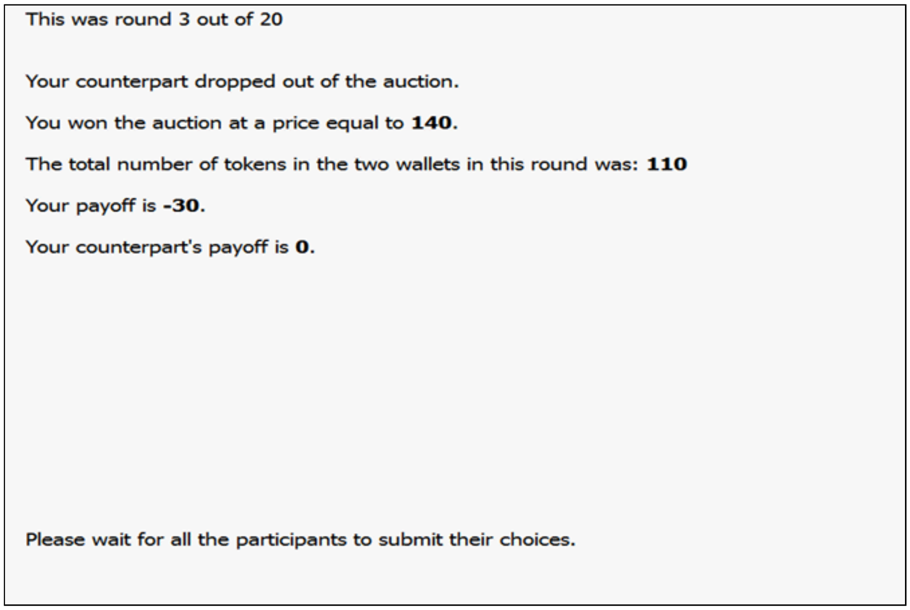
The computer screen:

The main screen of each round looks like as follows. It will mention how many tokens you have in your wallet; in the middle of the screen, the current price will be displayed and this price will increase.



At the price level that you wish to drop out of the auction, just press the button "DROP OUT".

After a few moments, the results screen (as below) will appear, which will indicate the total number of tokens in the two wallets, the winner of the auction and the net amount you and your counterpart receive.



After all the participants have read their results (15 seconds), the main screen for the next round will appear again, as shown above (first screenshot).

Payments:

For showing up on time and completing the experiment, you will earn £2. At the end of the experimental session, we will randomly select ten (out of 20) rounds. The net amounts in any round are in pence, i.e., a net amount of 40 is equivalent to 40 pence. Please note that you can also get zero or negative net amounts in a particular round. You will also receive an extra amount of £6 on top, regardless of the net amounts received in each round. For example, if out of the 20 rounds, we randomly select Rounds 3, 5, 7, 8, 11, 12, 15, 16, 18 and 20, and in those ten rounds you have earned 40, 0, 0, −11, 0, −16, 0, 121, −65 and 78, respectively, your final cash payment will be rounded off to the nearest penny: in this case, a total £9.47 (= 2+0.40+0+0−0.11+0−0.16+0+1.21−0.65+0.78+£6 = £9.47), including the show-up fee and extra money. You will be paid, individually and privately, your total earnings at that time. Please complete the receipt form which you will also find on your desk. We need these receipts for our own accounts.

Trial rounds:

There will be three trial rounds of the experiment to make sure all the participants understood the instructions. These trial rounds will not be chosen among the ten random rounds for payment. If you have any questions about the instructions or during the trial rounds, please feel free to ask the experimenter.

Questionnaire:

We will now pass around a questionnaire to make sure all the participants have understood all the instructions and how to read the points table. Please fill it out now. Do not put your name on the questionnaire. Raise your hand when finished, and the experimenter will collect it from you. If there are any mistakes in your questionnaire answers, we will go over the relevant part of the instructions with you once again. You may look again at the instructions while answering these questions.

6.2 Questionnaire

After reading the instructions you will be asked to complete this brief questionnaire, to ensure you have understood them, before starting the experiment itself. You may look again at the instructions while answering these questions. For the questions 1 -5 below, write the answers. For questions 6 - 8 below, circle either True or False.

1. Suppose you and your counterpart have 30 tokens each. You know only the number of tokens in your wallet, that is, you do not know the number of tokens in your counterpart's wallet. The auctioneer (computer) sets an initial price of 0, and the price keeps increasing. When the price reaches 72, you decide to drop out and your counterpart decides to stay. Who is the winner in the auction?

2. Consider the same situation as in question 1. What is the net amount the winner gets?

3. Suppose you have 30 tokens and your counterpart has 80 tokens. You know only the number of tokens in your wallet, that is, you do not know the number of tokens in your counterpart's wallet. The auctioneer (computer) sets an initial price of 0, and the price keeps increasing. When the price reaches 102, your counterpart decides decide to drop out and you decide to stay. Who is the winner in the auction?

4. Consider the same situation as in question 3. What is the net amount the winner gets?

5. At the end of the experiment, if out of the 20 rounds, we randomly select Rounds 2, 3, 5, 6, 7, 11, 13, 15, 16 and 19, and in those ten rounds you have got a net amount of -63, 0, 40, -10, 0, -10, 0, -60, 0 and 74 respectively, what is your final cash payment in total (in £) for the experiment?

6. You do not know the exact number of tokens in your counterpart's wallet but you know that it can be 80 with 1 out of 2 chances. True / False

7. Your counterpart is the same person in each round. True / False

8. In any publications arising from this experiment, the participants will be completely anonymous. True / False

Thank you for completing this questionnaire. Please leave this completed sheet face up on your desk. The experimenter will come round to check that you have the correct answers. If any of your answers are incorrect then the experimenter will give you some explanatory feedback.

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