A Appendix: Figures and Tables

A.1 Additional Figures

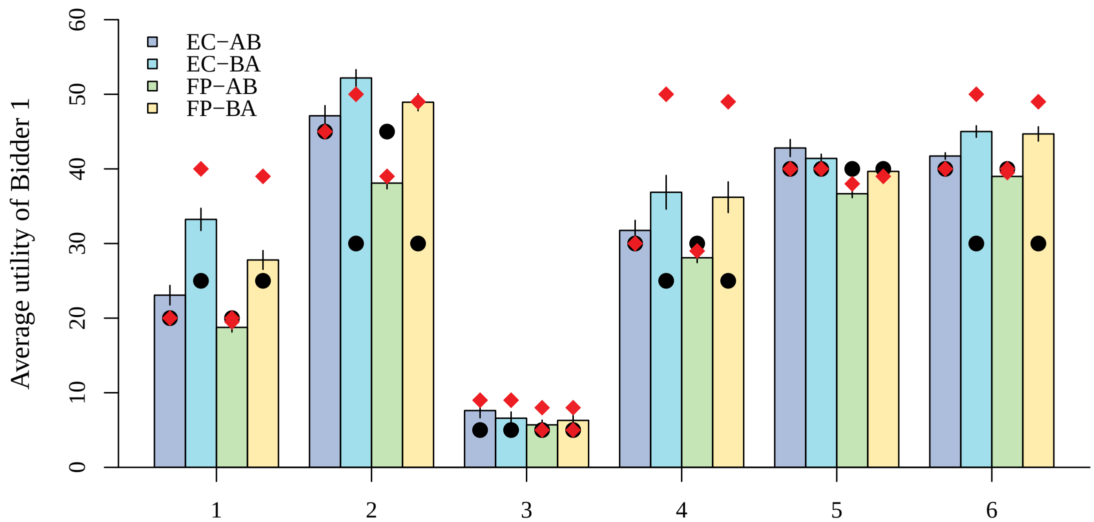


Figure A.1a: Average utility of Bidder 1 split by 6 value/budget settings. Corresponds to Figure 2.

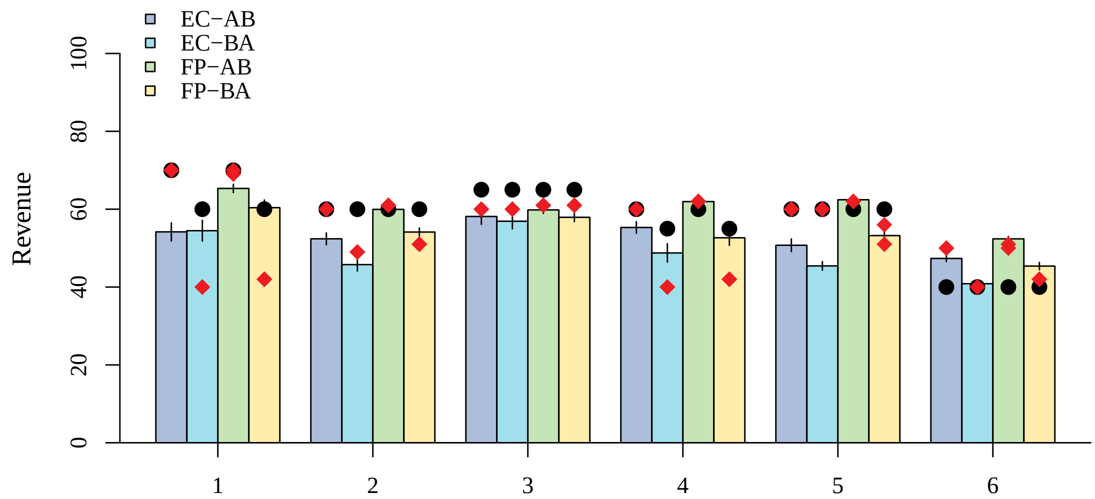


Figure A.1b: Seller's revenue split by 6 value/budget settings - repetition 1. Corresponds to Figure 2.

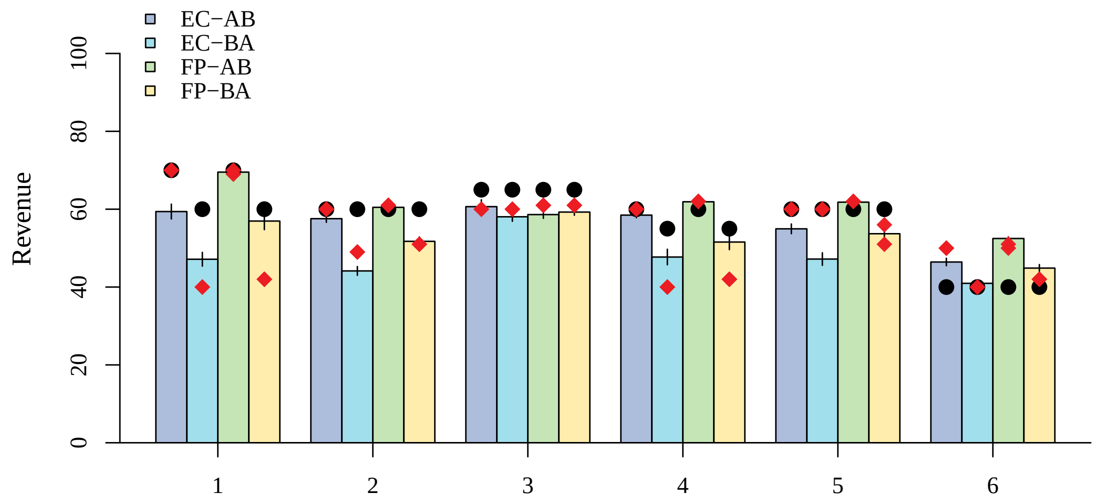


Figure A.1c: Seller's revenue split by 6 value/budget settings - repetition 2. Corresponds to Figure 2.

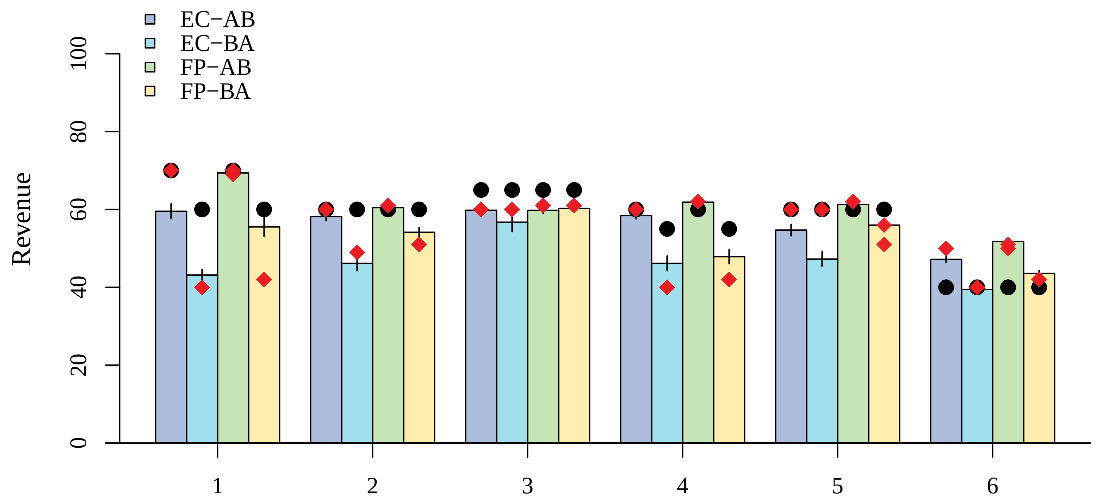


Figure A.1d: Seller's revenue split by 6 value/budget settings - repetition 3. Corresponds to Figure 2.

A.2 Correlation between empirical and predicted revenues

A.2.1 Simple Regression

The following table shows the estimates from a regression of theoretical and naively predicted revenues on the emprirically observed ones.

	Revenue			
	(1)	(2)	(3)	(4)
Theory Prediction	0.53***		0.36***	0.33***
	(0.03)		(0.05)	(0.04)
Naive Prediction		0.52***	0.28***	0.27***
		(0.02)	(0.03)	(0.04)
FP Auction				0.40
				(1.83)
Theory Prediction × FPSB Auction				0.05
				(0.07)
FP Auction × Naive Prediction				0.04
				(0.06)
Constant	25.46***	23.95***	18.69***	18.39***
	(1.66)	(1.04)	(1.15)	(1.26)
Observations	1,584	1,584	1,584	1,584
R^2	0.28	0.24	0.32	0.40
Adjusted R^2	0.28	0.24	0.31	0.39

Two-way (Subject 1 & Subject 2) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table A.2.1: Correlation between empirical and predicted revenues.

A.2.2 Finite Mixture Model (All Observations)

To analyze the heterogeneity of in the previous regression, we repeat Specification (3) in a finite mixture model framework. We use the standard version of the model. Assume that y is the dependent variable (a vector of empirical revenues), and x is the set of predictors (vectors of rational and naive revenue predictions). Assuming that the observation can be clustered in two groups, the regression model is defined by

$$y|x \sim \pi_1 N(\beta_1^T x, \sigma_1^2) + \pi_2 N(\beta_2^T x, \sigma_2^2),$$

where pi_i, β_i, σ_i are the parameters. Using the expectation minimization algorithm, each observation is assigned to one of the two clusters by computing the posterior probabilities π_i for each given observation. The procedure is iteratively repeated to maximize these probabilities. Intuitively, this procedure splits one regression into two models where coefficients come from two separate Gaussian distributions.

	Cluster 1	Cluster 2
Theory Prediction	1.06^{***}	0.15^{***}
	(0.05)	(0.04)
Naive Prediction	-0.13^{***}	0.39^{***}
	(0.03)	(0.04)
Constant	3.84^{***}	21.82^{***}
	(1.46)	(1.73)
Cluster Share	0.27	0.73
Obs.	424	1160

Two-way (Subject 1 & Subject 2) standard-errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Table A.2.2: Parameters for heterogeneous clusters from finite mixture model estimation.

Varying the amount of possible clusters does not fundamentally change the relative ratios of subject best described by the theoretical prediction. We therefore present here the simplest possible FMM specification with $k = 2$ clusters. A more complex model with $k = 4$ maximizes the model's goodness of fit according to BIC but does not change the conclusion from the results section.

A.2.3 Finite Mixture Model (repetition 1)

	Cluster 1	Cluster 2
Theory Prediction	-0.11^{*}	1.01^{***}
	(0.06)	(0.03)
Naive Prediction	0.47^{***}	-0.07^{***}
	(0.07)	(0.02)
Constant	30.93^{***}	3.41^{***}
	(3.21)	(1.25)
Cluster Share	0.72	0.28
Obs.	386	142

Two-way (Subject 1 & Subject 2) standard-errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Table A.2.3: Parameters for heterogeneous clusters from finite mixture model estimation (repetition 1 only).

A.2.4 Finite Mixture Model (repetition 3)

	Cluster 1	Cluster 2
Theory Prediction	1.03^{***}	0.34^{***}
	(0.01)	(0.06)
Naive Prediction	-0.04^{***}	0.32^{***}
	(0.01)	(0.06)
Constant	0.83^{*}	16.40^{***}
	(0.46)	(2.99)
Cluster Share	0.31	0.69
Obs.	149	379

Two-way (Subject 1 & Subject 2) standard-errors in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1

Table A.2.4: Parameters for heterogeneous clusters from finite mixture model estimation (repetition 3 only).

B Appendix: Equilibria derivation algorithm

This section provides a short overview over the algorithm used to derived the Nash equilibria featured in Table 1. The code was implemented in Python 3 and is available as an online appendix (https://osf.io/sgkr3/).

B.1 First Price Auction

For each experimental setting and value order do the following:

1. Second stage. Calculate the Nash equilibria of all second stage subgames that can be induced by any bidding pattern in the first stage.

- Compute normal form representation for each possible second stage budget combination and search for mutual best responses in pure strategies.
- Calculate the utility for each mutual best response.
- Whenever there is a draw, calculate the expected utility as the average payoff over all possible resolutions (the winner was determined randomly in these cases).

2. Full game. Find all subgame perfect Nash equilibria (SPNE) of the full auction using a normal form representation of the game given the outcomes computed in step 1.

- The utilities in each cell of the normal form representation are defined by the sum of the stage utilities in the first and second stage of the auction.

Additional notes. On the usage of second stage equilibria in the overall detection of equilibrium candidates.

- On the equilibrium path, support all equilibrium strategy candidates consisting of an first stage action pair and all induced second stage subgame NE.
- Off the path, use a bidder's worst second stage NE payoffs for each possible deviation.
- These two choices together ensure we find the largest possible set of candidate SPNEs.

B.2 English Auction

Game simplification

Following Benoit and Krishna, we assume that bidders do not play weakly dominated strategies. This implies that bidders bid the minimum of the valuation of the good and their remaining budget in the second stage of any auction.The outcome of the first stage of any auction therefore uniquely induces the bids, prices, and expected utilities in the second stage. When we speak about utilities in the remainder of this section, we therefore consider overall expected utilities $E(u) = E(u_1) + E(u_2)$ as the sum of Stage 1 and Stage 2 utilities.

The draws in the first auction are computed by assigning a probability of $1/n$ to the subgame in which each winner's budget is reduced by the winning bid respectively, where n is the number of drawing bidders in the first stage.

Algorithm

For each experimental setting and value, the set of SPNE is calculated via backward induction in the price of the first auction.

1. Determine the starting step. At the highest relevant price $\bar{p} = \min(b_2, V_1) + 1$ Bidder 1 will bid for the first good if this yields a higher utility than drawing Bidder 2 for $p = \min(b_2, V_1)$. If she decides to bid, then the start equilibrium price candidate is $p^* = \min(b_2, V_1) + 1$, otherwise it is $p^* = \min(b_2, V_1)$. The equilibrium candidate utilities u_1^*, u_2^* constitute the starting step of the induction algorithm.

2. Iteration Step. At each price $p \in (20, b_2]$ in decreasing order, starting from the maximum value (backward induction), determine the best responses for Bidders 1 and 2. The action space for each Bidder is $\{\text{bid}, \text{pass}\}$.

- If both Bidders bid at price p, then continue with the next lower price $p - 1$.
- If a single bidder bids at price p, then she wins the auction at this price. In this case the new equilibrium candidate is $p^* = p$. Update the equilibrium candidate utilities u_1^*, u_2^* with the induced utilities. Continue with the next lower price $p - 1$.
- If no bidder bids at price p, then both bidders draw the auction at this price. In this case the new equilibrium candidate is $p^* = p$. Update the equilibrium

candidate utilities u_1^*, u_2^* with the induced utilities. Continue with the next lower price $p-1$.

3. Equilibrium Price Definition. The equilibrium price p^* is the lowest equilibrium strategy candidate.

C Appendix: Instructions

The following pages contain instructions for the experiment. The instructions for the EC treatments are followed by the instructions for the FPSB treatments. There was no difference in instructions between orders AB and BA. All instructions were read out loud for the subjects before the experiment.

INSTRUCTIONS

This is an experiment in the economics of market decision making. The Ohio State University has provided funds for conducting this research. You may earn a considerable amount of money which will be paid to you in cash at the end of the experiment.

Please pay careful attention to the instructions. If you have any questions at any time, raise your hand.

In this experiment, you will act as bidders in a sequence of auctions. Profits will be in points which will be converted into dollars at the end of the experiment. Do not communicate with other participants during the experiment. Put your phone away and make sure it is in silent mode or turned off.

In each round:

1. Each of you will be bidding in a separate group along with two (2) other bidders. One of them will be always be controlled by the computer and the other is a randomly selected participant. After each auction, all participants will be randomly rematched into new groups.

2. In each auction, there will be two (2) items on sale. They will have different values, but these values will be the same for all three bidders in your group. Both items will be sold one after another according to the rules specified below.

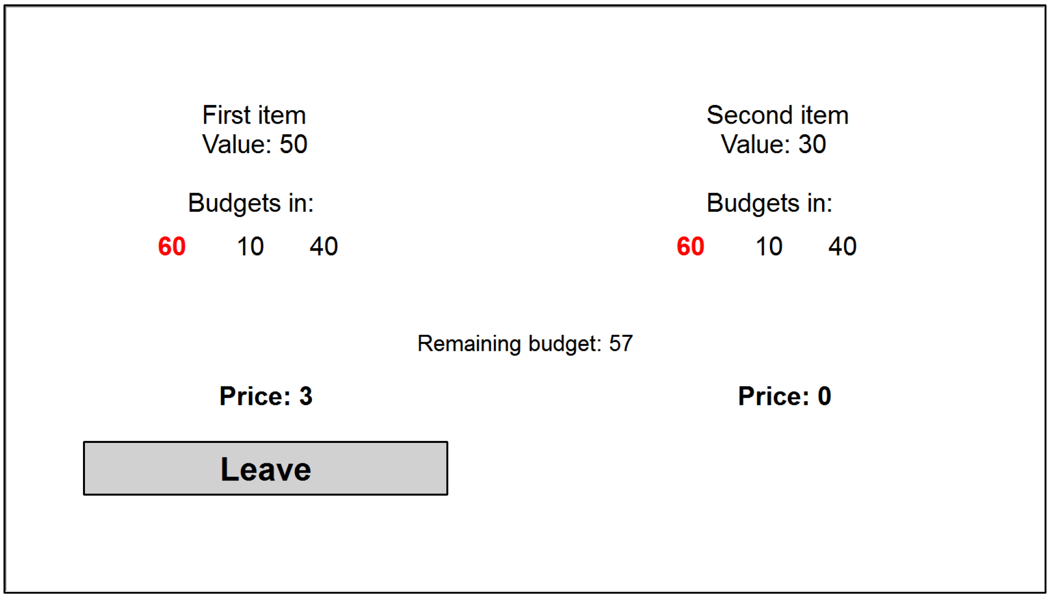
3. Item values will change in each auction.

4. Each of you will have your own bidding budget for each auction. Your budget is the maximum number of total points available to spend on the two items. You will be randomly assigned a new budget in each round. Any points left over in your budget from the previous auction have zero value in later auctions.

5. In each auction, you will know your own budget and the budgets of all bidders in your market. These budgets will differ between bidders in your auction. The computer-controlled bidder will always have the smallest budget.

6. Everything is denominated in points – the value of the item, the price paid for the item and the earnings of the high bidder for the item (item value – price paid).

7. During each auction, you will see the following information on your computer screens (see the projector screen or the picture on the next page):
   a) The values of the auctioned items (for example, 50 and 30). Your earnings if you buy the item will be equal to the value of the item less the amount you paid to get the item.
   b) For both items: budgets for the bidders that are still participating in the bidding for that item, including your own budget (in bold and red) are shown – in this example, 10, 60, and 40. For example, if you have the budget 40, you can spend up to 40 points on **either** the first and the second items, or on **both** items.
   c) A price clock for each item.
   d) Remaining budget: this shows how much budget you will have left if you buy the current auctioned item for the current price. If it reaches 0, you will no longer be permitted to bid and will be dropped from the current bidding.



Example auction screen

8. In each round**,** items will be sold using two clock auctions, with items auctioned sequentially, one item after another.
   In each clock auction:
   a) The clock will start at the price equal to 0 points and will increase up to the value of the item.
   b) At any point in time, you can click on the **Leave** button at the bottom of your screen to exit the auction. Your budget will be faded, both in your screen and other bidders' screens.
   c) If the price reaches a bidder's budget, he/she is automatically dropped from the auction.
   d) The computer-controlled bidder (with the lowest budget) will ALWAYS stay in the bidding until its budget is depleted.
   e) The price increases at about 1 point per second.
   f) Once two of the bidders have dropped out, the remaining bidder gets the item and earns
      Profit = (item value) – (price at which the last other bidder quits)
   g) If two or more remaining bidders quit at the same time, the bidder getting the item is determined randomly at that price.
   h) If the price reaches the value of the item, all remaining bidders are dropped out. Who gets the item is determined randomly at that price. Essentially, this bidder's profit will be 0, but the budget will still decrease by the price paid.

9. If you leave the auction for the first item, you have your full budget available for the second item. If you earn the first item, you pay that price, with the remainder of your budget available to bid on the second item.

10. If you do not earn any items, or you have unused budget after both items have been sold, the remainder of your budget has zero value. That is, it's as if you are bidding on behalf of a company with a budget which if not spent will be used elsewhere. Your budget is just a limit on how much you can bid in each round.

11. At the end of the experiment, the sum of your **profits** in each auction will be displayed on the screen. Your profit is the ONLY amount that will be converted to your dollar payoff at the end of experiment.

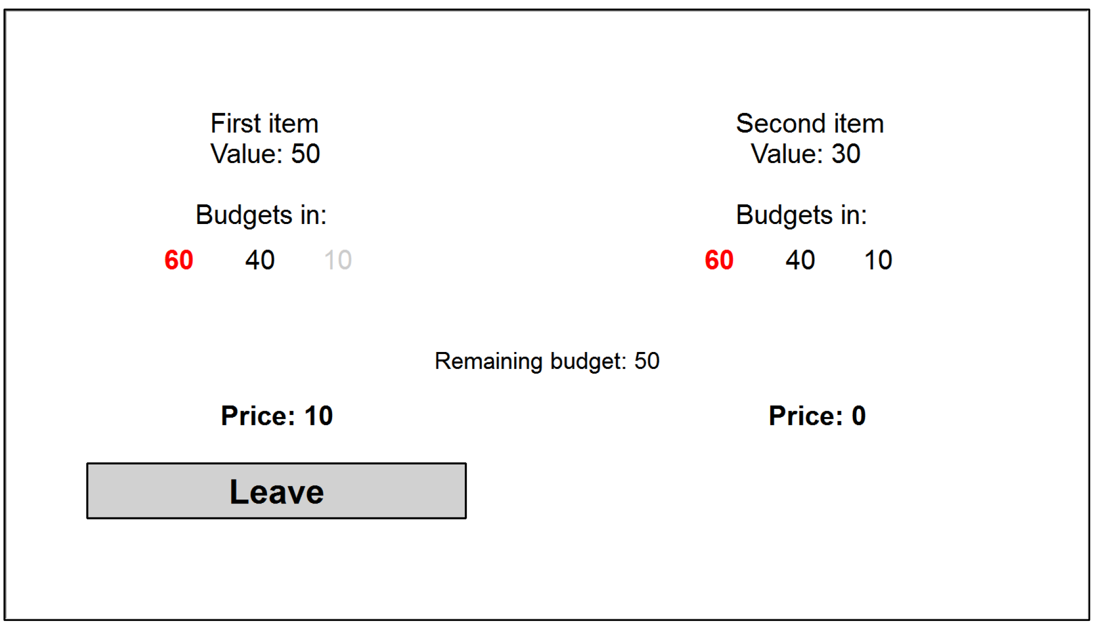
Examples and notes

Suppose there are three bidders (1, 2, 3), with budgets **10**, **40**, and **60** respectively, who participate in a market with items that have values **30** and **50**. Suppose the first item on sale has value 50, and the second one is 30.

1. In each of round, you will be **randomly** assigned a budget. You may be lucky and get a higher budget in all of them, or get other values in every new auction.

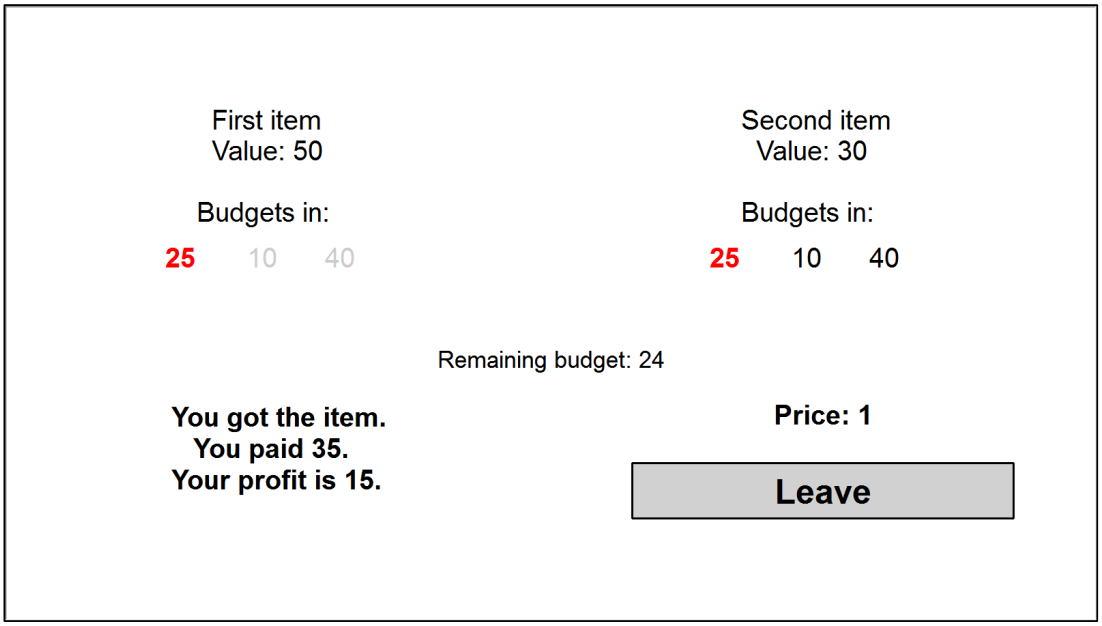
2. The price for the first item will go up from 0 to 50. Computer-controlled bidder 1 with budget 10 will be the first to drop out automatically (assuming that two other bidders did not leave the auction).

3. Suppose the price is now at 10. If any of the bidders (2 or 3) leaves the auction now, the other remaining bidder will get the item for the price at which the other one left. The profit will be 40 (the value - 50) minus that price (10). That bidder's budget for bidding on the second item will decrease by the amount paid for the first item.

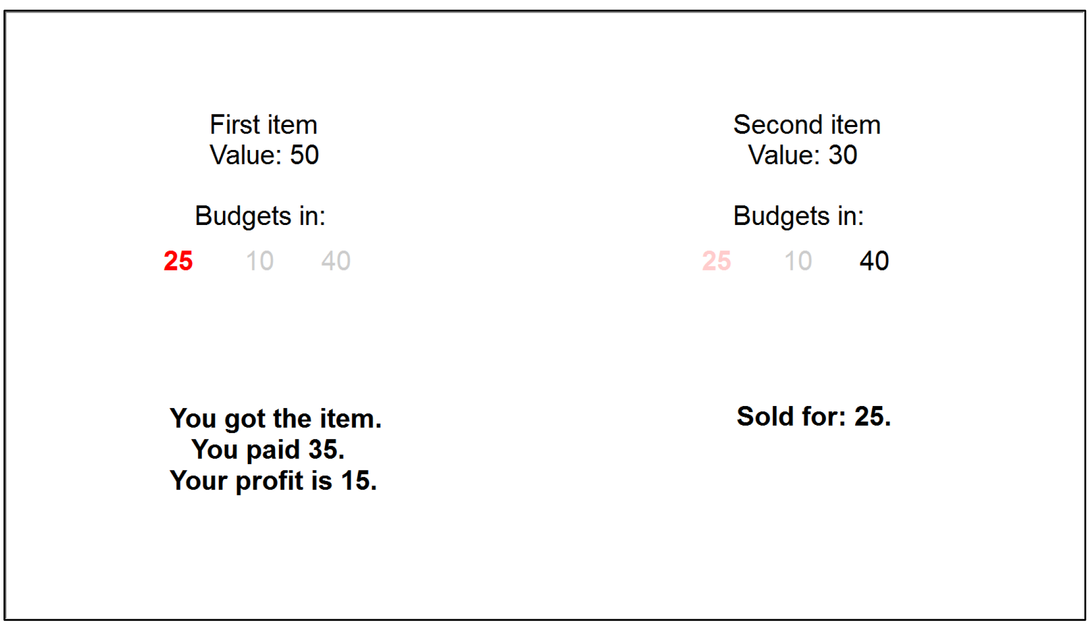


4. Examples:

    a. The auction starts with bidding on first item worth 50. Please pay attention to the screenshot below. So, bidder 1 has dropped out at 10. Suppose bidder 2 (budget of 40) leaves the auction at a price of 35. Bidder 3 gets the item and pays 35 for it for a profit of 50 - 35 = 15. Bidder 3's remaining budget will be 60 – 35 = 25 available to bid on the second item. Bidders 1 and 2 will keep their starting budgets to bid on the second item.

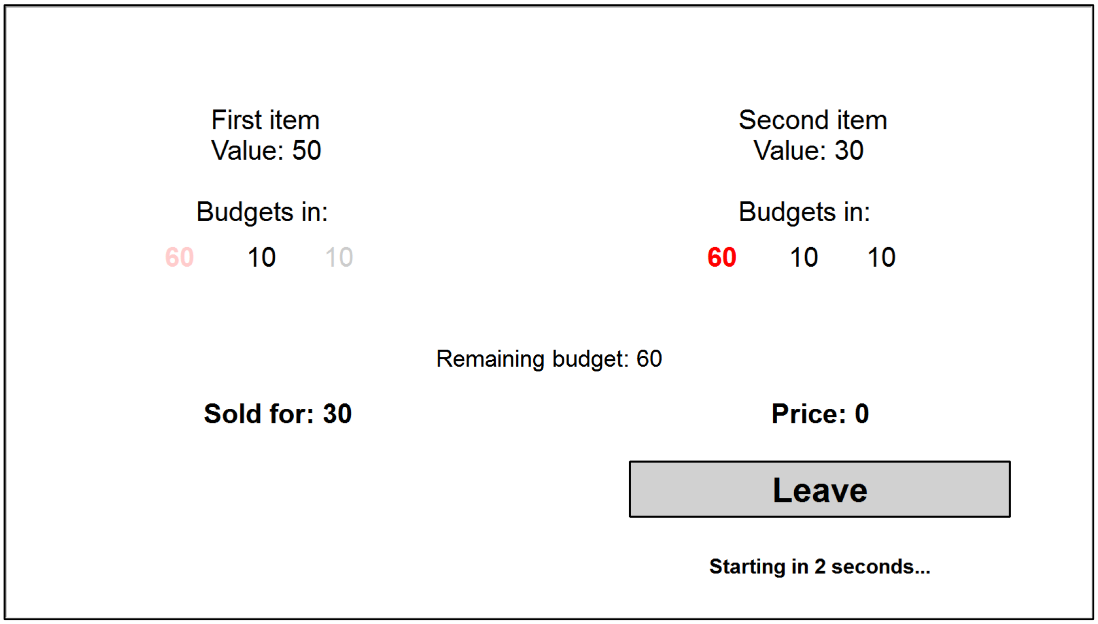


a. Now the second item (value 30) is on sale. Budgets: bidder 1 now has 10, bidder 2 has 40, bidder 3 has 25. Bidders will not keep these budgets after this item is sold so that it makes sense to bid up to their remaining budget. Bidders 1 and 3 will be dropped out automatically at 10 and 25 if they don't leave, and bidder 2 will get the item for 25. The profit will be 30 – 25 = 5. Results of the auction: bidder 2 has profit 5, bidder 3 has profit 15.

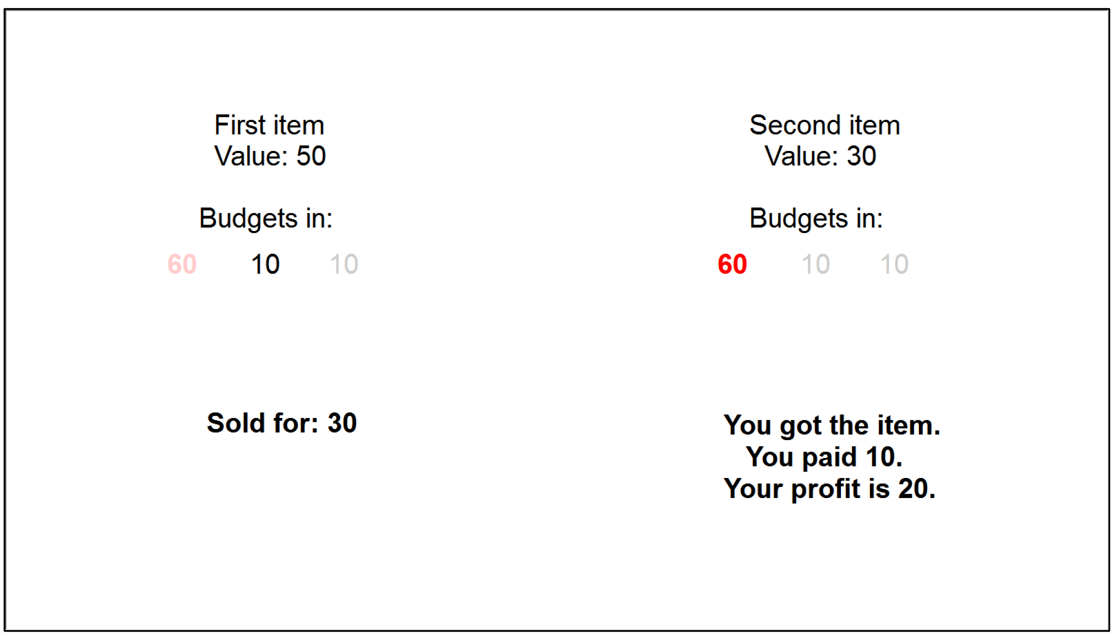


5. Now consider a different scenario. Again, the price is at 10, so bidder 1 is again gone. The price starts to increase and now bidder 3 (budget of 60) leaves the auction at 30.

   a. Bidder 3 (budget of 60) leaves the auction at 30. Bidder 2 will pay 30 and will get a profit of 50 – 30 = 20. The remaining budget will be 40 – 30 = 10. Bidder 3 will keep the budget of 60.



b. Bidder 1 has 10, bidder 2 has 10, bidder 3 has 60. It should be clear that bidder 3 is winning the auction. The price, if everyone stays in, will be 10. The profit will be 30 – 10 = 20. Results: bidder 2 has profit 20, bidder 3 has profit 20.



6. What if they click "Leave now" at the same time? The item will be assigned to one of them randomly and the price at which they left will be paid.

7. As you can see, there are multiple outcomes depending on every bidder's choice. Getting an item by itself does not give you any value, profit is the only thing that matters for your payoff.

SUMMARY:

You are participating in an auction for two items with two other bidders. One of them (with the lowest budget) is controlled by the computer and always bids up to the full budget. You have a limited budget. The two items are sold in order: first item 1 on the left, then item 2 on the right. In the auction, the price clocks go up 1 point per second. You can leave any bidding at any time. Once there is only one bidder left, he/she gets the item and the clock stops. Your profit is item's value minus the price at which the clock stopped.

If you have any questions, please raise your hand and ask the experimenter now.

First we will run a practice auction with two items for sale that will be unpaid.

After the practice session, you will have an opportunity to ask questions again. After any remaining questions, we will start the 18 paid rounds.

Again, you will be paid for the sum of your profits in all of the 18 paid rounds, which will be converted to dollars at a rate of $1 = 50 points at the end of the experiment.

INSTRUCTIONS

This is an experiment in the economics of market decision making. The Ohio State University has provided funds for conducting this research. You may earn a considerable amount of money which will be paid to you in cash at the end of the experiment.

Please pay careful attention to the instructions. If you have any questions at any time, raise your hand.

In this experiment, you will act as bidders in a sequence of auctions. Profits will be in points which will be converted into dollars at the end of the experiment. Do not communicate with other participants during the experiment. Put your phone away and make sure it is in silent mode or turned off.

In each round:

1. Each of you will be bidding in a separate group along with two (2) other bidders. One of them will be always be controlled by the computer and the other is a randomly selected participant. After each auction, all participants will be randomly rematched into new groups.

2. In each auction, there will be two (2) items on sale. They will have different values, but these values will be the same for all three bidders in your group. Both items will be sold one after another according to the rules specified below.

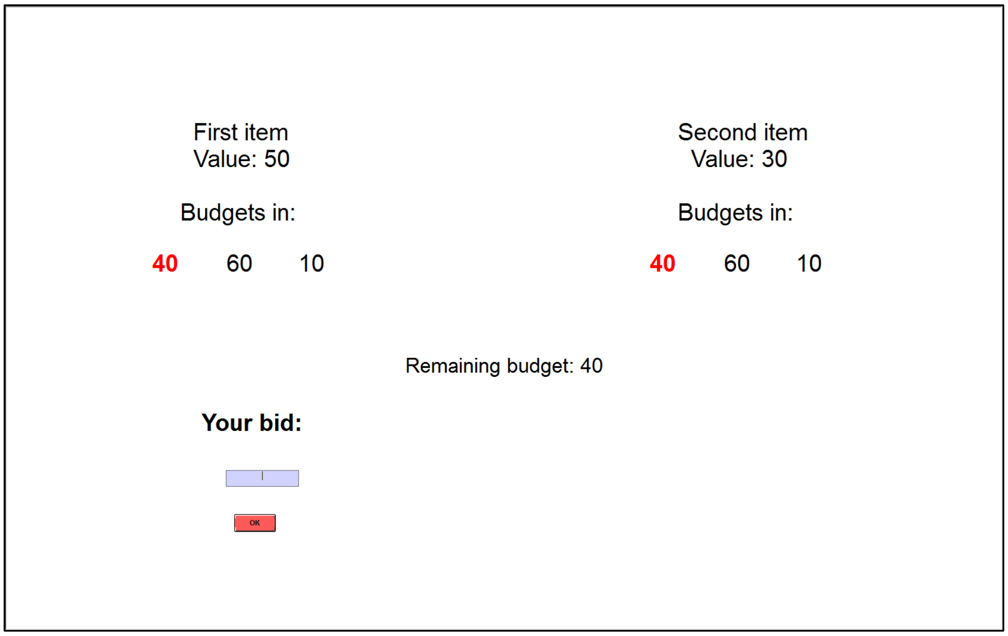
3. Item values will change in each auction.

4. Each of you will have your own bidding budget for each auction. Your budget is the maximum number of total points available to spend on the two items. You will be randomly assigned a new budget in each round. Any points left over in your budget from the previous auction have zero value in later auctions.

5. In each auction, you will know your own budget and the budgets of all bidders in your market. These budgets will differ between bidders in your auction. The computer-controlled bidder will always have the smallest budget.

6. Everything is denominated in points – the value of the item, the price paid for the item and the earnings of the high bidder for the item (item value – price paid).

7. During each auction, you will see the following information on your computer screens (see the projector screen or the picture on the next page):
   a) The values of the auctioned items (for example, 50 and 30). Your earnings if you buy the item will be equal to the value of the item less the amount you paid to get the item.
   b) For both items: budgets for the bidders that are participating in the bidding for that item, including your own budget (in bold and red) are shown – in this example, 10, 60, and 40. For example, if you have the budget 40, you can spend up to 40 points on **either** the first and the second items, or on **both** items.
   c) A bid entry window and a button.
   d) Remaining budget: this shows your current budget.



Example auction screen

8. In each round**,** items will be sold using two auctions, with items auctioned sequentially, one item after another.
   In each auction:
   a) You enter how much you want to bid for the item and click "OK". You cannot bid more than your (remaining) budget or more than the item value.
   b) The computer-controlled bidder (with the lowest budget) will ALWAYS bid their full remaining budget for each item.
   c) After all the bids are made, the highest bidder gets the item and pays his or her bid.
   d) If the two highest bids are equal, the item will be assigned randomly.

9. If you do not get the first item, you have your full budget available for the second item. If you earn the first item, you pay that price, with the remainder of your budget available to bid on the second item.

10. If you do not earn any items, or you have unused budget after both items have been sold, the remainder of your budget has zero value. That is, it's as if you are bidding on behalf of a company with a budget which if not spent will be used elsewhere. Your budget is just a limit on how much you can bid in each round.

11. At the end of the experiment, the sum of your **profits** in each auction will be displayed on the screen. Your profit is the ONLY amount that will be converted to your dollar payoff at the end of experiment.

Examples and notes

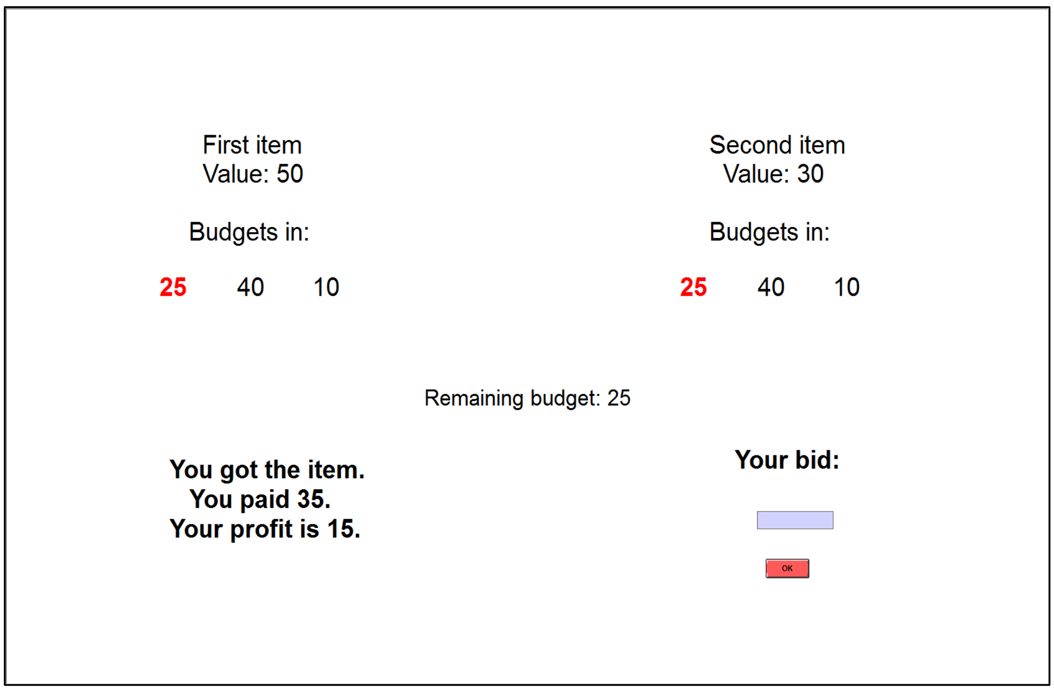
Suppose there are three bidders (1, 2, 3), with budgets **10**, **40**, and **60** respectively, who participate in a market with items that have values **30** and **50**. Suppose the first item on sale has value 50, and the second one is 30.

1. In each of round, you will be **randomly** assigned a budget. You may be lucky and get a higher budget in all of them, or get other values in every new auction.

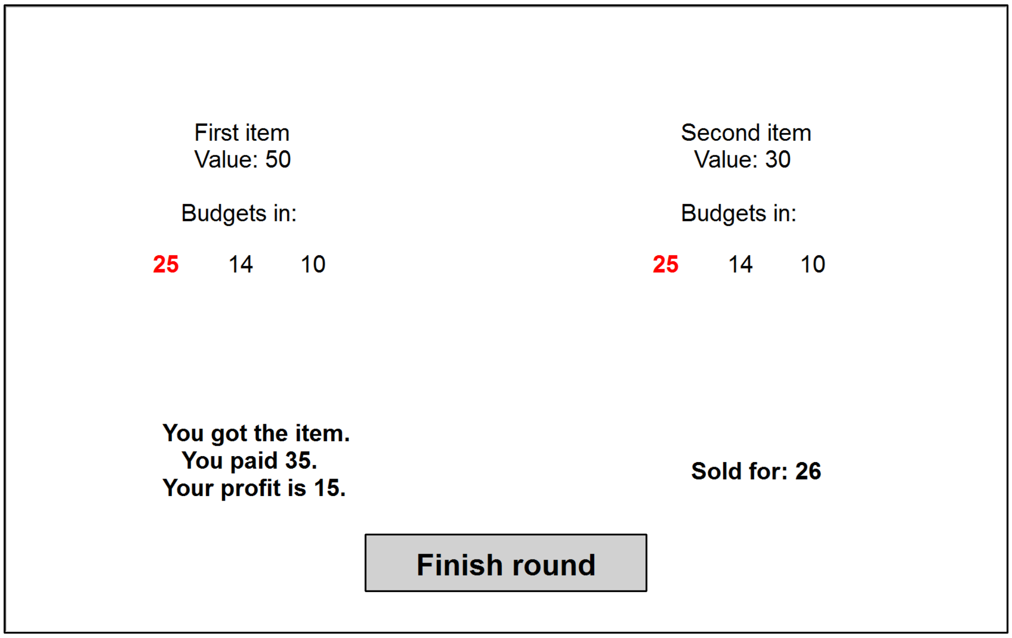
2. Computer-controlled bidder 1 with budget 10 will always bid 10.

3. Examples:

    a. The auction starts with bidding on first item worth 50. Please pay attention to the screenshot below. So, bidder 1 bids 10. Suppose bidder 2 (budget of 40) makes a bid of 30 and bidder 3 bids 35. Bidder 3 gets the item and pays 35 for it for a profit of 50 - 35 = 15. Bidder 3's remaining budget will be 60 – 35 = 25 available to bid on the second item. Bidders 1 and 2 will keep their starting budgets to bid on the second item.

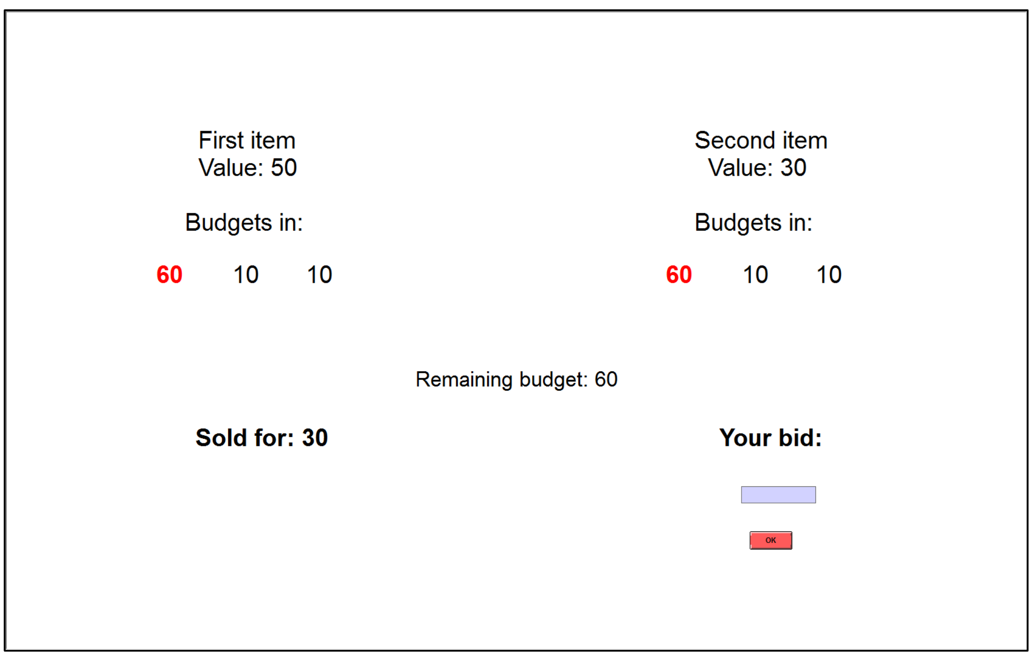


    a. Now the second item (value 30) is on sale. Budgets: bidder 1 now has 10, bidder 2 has 40, bidder 3 has 25. Bidders will not keep these budgets after this item is sold so that it makes sense to bid up to their remaining budget. Bidders 1 and 3 will bid 10 and 25, and bidder 3 can bid 26 to get the item. The profit will be 30 – 26 = 4. Results of the auction: bidder 2 has profit 4, bidder 3 has profit 15.

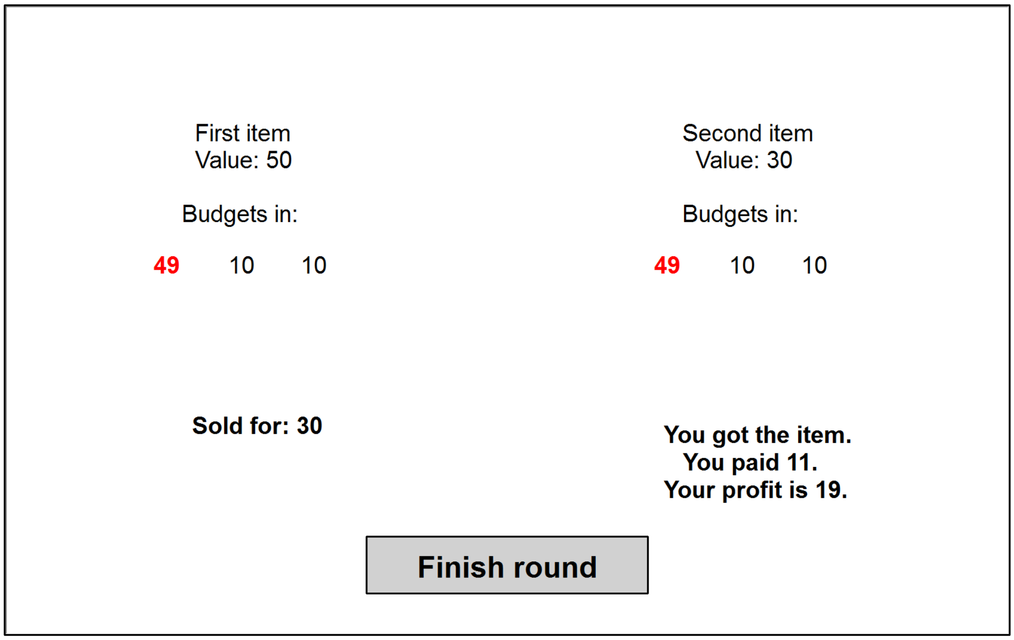


4. Now consider a different scenario. Again, bidder 1 bids 10. Suppose now bidder 3 (budget of 60) bids 25 and bidder 2 bids 30.

    a. Bidder 2 will pay 30 and will get a profit of 50 – 30 = 20. The remaining budget will be 40 – 30 = 10. Bidder 3 will keep the budget of 60.



    b. Bidder 1 has 10, bidder 2 has 10, bidder 3 has 60. It should be clear that bidder 3 is winning the auction by bidding 11. The profit will be 30 – 11 = 19. Results: bidder 2 has profit 20, bidder 3 has profit 19.



5. As you can see, there are multiple outcomes depending on every bidder's choice. Getting an item by itself does not give you any value, profit is the only thing that matters for your payoff.

SUMMARY:

You are participating in an auction for two items with two other bidders. One of them (with the lowest budget) is controlled by the computer and always bids their full budget. You have a limited budget. The two items are sold in order: first item 1 on the left, then item 2 on the right. In the auction, you can make a bid up to your remaining budget. The highest bid wins. Your profit is the item's value minus your bid, if it is the highest one.

If you have any questions, please raise your hand and ask the experimenter now.

First we will run a practice auction with two items for sale that will be unpaid.

After the practice session, you will have an opportunity to ask questions again. After any remaining questions, we will start the 18 paid rounds.

Again, you will be paid for the sum of your profits in all of the 18 paid rounds, which will be converted to dollars at a rate of $1 = 50 points at the end of the experiment.