Supplemental Appendix for
"An Experiment on Behavior in Queues"

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Abstract

This Supplemental Appendix explores alternative behavioral theories to explain the overselective bias under LIFO observed in our experiment. It also provides additional details about the experiment, including the instructions distributed to participants.

1 Alternative Behavioral Explanations

In addition to the ones considered in the paper, other behavioral models could potentially generate overoptimistic expectations in the LIFO game. However, we show that they fail to explain our results in the LIFO treatment quantitatively.

1.1 Selection Neglect

A vast theoretical and experimental literature documents how individuals often fail to account for selection effects that influence future payoffs.[1] Consider a subject under LIFO who

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[1]For recent examples, see Barron et al. (2024); Esponda and Vespa (2024), and references therein.

fails to account for the negative selection of items that will be offered to her in her older age. Specifically, in the second stage of the human-to-robot experiment, the expected value of a jar, conditional on being offered to a subject, is obviously lower than the unconditional one. This is because a jar with a value higher than a robot's threshold (divided by 1000), denoted as $z \in [0, 1]$, is offered to the subject only with a probability of 0.25, rather than 0.5. Neglecting to account for this adverse selection leads a subject to perceive the expected future payoff as higher than what it is. Hence, we have

$$\tilde{\theta}(z) = \frac{0.5}{2} \left[z + \frac{1}{2} (1 - z) \right].$$

In words, while the subject still understands that a jar with a value higher than the robot's threshold z is only half as likely to be offered to her, she believes that, conditional on being offered a jar, the jar always has an expected value of 0.5.

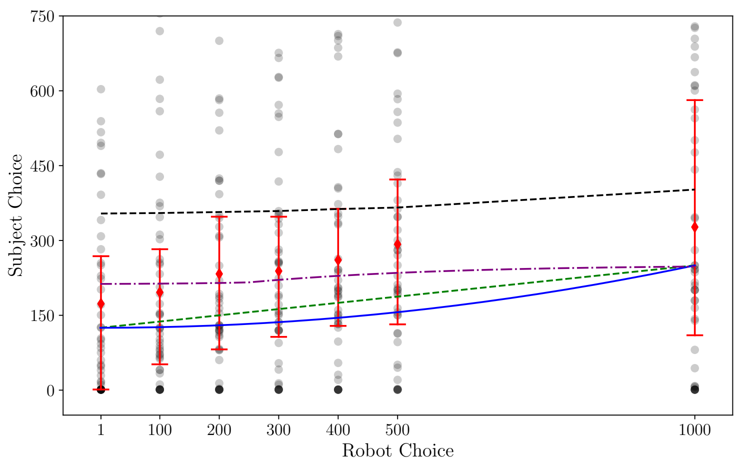


Figure 1: Selection Neglect. The black dashed line, the green dotted line, and the purple dot-dashed line represent predictions from the QRE model, selection neglect, and prospect theory, respectively. The blue solid curve indicates rational best responses. Red diamonds and segments show the observed average thresholds, with 25th to 75th percentile ranges.

In Figure 1, the green dotted line represents the choices predicted by selection neglect. As seen in the figure, these predicted choices are just above the rational ones (blue solid curve), but still notably below the observed choices. Especially when the robot's choice is near 1 or 1000, where the conditional and unconditional expected values of a jar are the same, selection neglect should not affect subjects' decision. However, the observed choices are still significantly higher than the rational benchmark.

1.2 Prospect Theory

Prospect theory postulates an asymmetry in perceived value between gains and losses relative to a reference point (Tversky and Kahneman, 1992). A Prospect theory utility function is defined as:

$$u(x;\lambda_P,r) := \begin{cases} x_0 + (x-x_0)^r & \text{if } x \geq x_0 \\ x_0 - \lambda_P(x_0-x)^r & \text{if } x < x_0, \end{cases}$$

where x_0 is the reference point, λ_P is the loss aversion coefficient, and r measures the risk attitude for both gains and losses relative to x_0.

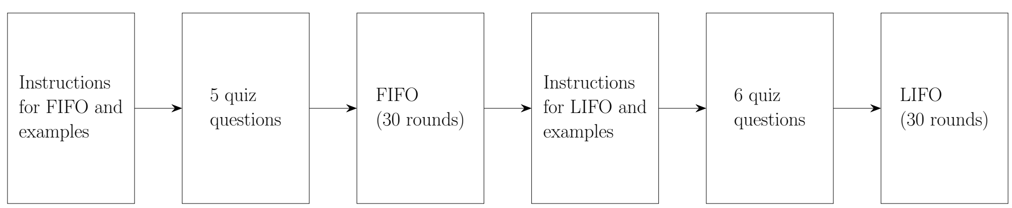
A subject is risk-loving for outcomes above the reference point, preferring higher uncertain payoffs in the second period. We set the reference point at $x_0 = 250.25$, calculated as the expected value of a jar multiplied by the probability of compatibility $p = 0.5$. We estimate the parameter values as $\lambda_P = 142$ and $r = 0.1$.[2] However, the estimates differ significantly from those in Tversky and Kahneman (1992), where $\lambda_P = 2.25$ and $r = 0.88$. Also, especially for higher robot's choices, the predicted thresholds using these estimates, represented by the purple dot-dashed line in Figure 1, are only slightly higher than the rational choices.

[2] λ_P and r are estimated as follows: A prospect-theory subject's expected utility from a second jar when the robot's choice is $z \in [0,1]$ is $U(z;\lambda_P,r) := \frac{1}{1000}(\sum_{x<1000\times z} p \times u(x;\lambda_P,r) + \sum_{x\geq 1000\times z} p(1-p)\times u(x;\lambda_P,r))$. Then, the certainty equivalent is $CE(z;\lambda_P,r) := u^{-1}(U(z;\lambda_P,r);\lambda_P,r)$. Given the data $\{z_i,\hat{\theta}_i\}_{i=1}^N$, the estimates of λ^P and r minimize $\sum_{i=1}^N(\hat{\theta}_i - CE(z_i;\lambda_P,r))^2$.

2 Detailed Description of the Experiments

The experiment described in Sections 3 and 4 of the paper involved 60 subjects over three sessions at Washington University in St. Louis in November 2022. We employed a within-subjects design, with each subject engaging in both FIFO and LIFO reduced-form games. Each session involved 18 to 22 subjects, lasted about 75 minutes, and comprised 30 rounds of the FIFO treatment followed by 30 rounds of the LIFO treatment. Subjects received 100 tokens upfront at the beginning of each round in each treatment. Items, represented as jars, contained a random number of tokens between 1 and 1000. Subjects accumulated tokens across the 60 rounds and were paid in cash at the end with a conversion rate of $1 for every 650 tokens. The average payment was $24.6, in addition to a $5 show-up fee. At the beginning of each treatment, we delivered the experimental instructions in both digital and printed formats. Subjects then went through illustrative examples of potential scenarios, followed by a quiz to further their learning of the environment. In particular, the subjects were alerted about their mistakes and were asked to review the instructions until all their answers were correct.

The timeline is as follows:



For the human-to-robot experiment presented in Section 5, we recruited 47 additional subjects and held three sessions. In each session, subjects made seven threshold choices per round (each associated with one robot's choice) across five rounds, totaling 35 threshold choices per subject. Subjects accumulated tokens throughout the 35 rounds and were compensated in cash at the end, with 600 tokens equaling 1 U.S. dollar. Each session lasted approximately 45 minutes.

3 Experiment Instructions

You will be participating in a decision-making experiment. All interactions will take place through the computer. The experiment will last about 90 minutes.

Your earnings will depend on your decisions as well as the decisions of other participants and chance. Therefore, it is important for you to understand the following instructions well.

During the experiment, you will collect **tokens**. At the end of the experiment, your tokens will be converted into dollars at the exchange rate of $1 per 650 tokens. In addition, you will receive a $5 show-up fee. You will be paid privately in cash at the end of the experiment.

All instructions and descriptions in this experiment are **factually accurate**. According to the policy of this lab, at no point will we attempt to deceive you in any way.

You must remain silent and pay full attention during the experiment. If you have a question or need assistance of any kind, please **raise your hand**. An instructor will come to you, and you may then ask your question privately.

Now, please **silence your cell phone and put it away**.

If you break these rules, we may ask you to leave.

The experiment has two parts: A and B. For each part, you will first read the instructions. Next, you will see some illustrative examples of how the events may unfold. Next, you will be given a quiz to make sure you understood the instructions. Finally, you will make your decisions. You will be provided with the instructions for Part B after you finish Part A.

Agenda

- Part A

    1. Instructions
    2. Examples
    3. Quiz
    4. Decision Making

- Part B

    1. Instructions
    2. Examples
    3. Quiz
    4. Decision Making

Overview of Part A

Part A has 30 rounds.

At the beginning of each round, you are randomly paired with another participant in this room, which we will call your "counterpart" in the round. You and your counterpart will each make a decision. Based on those decisions and random events, one of you may receive a jar of tokens in the round.

In each round, the computer will generate one or two jars with a random number of tokens. The number of tokens is equally likely to be any integer between 1 and 1000. For example, each jar has a 1/1000 chance of having 1 token, a 1/1000 chance of having 2 tokens, and so on. The number of tokens in each jar is independent of the number of tokens in the other jar.

At the end of the round, you will receive 100 tokens. In addition, if you receive a jar in the round, you will receive the tokens that are in that jar. For example, if you do not receive a jar, you will receive 100 tokens in the round. If you receive a jar that has 340 tokens, you will receive $100 + 340 = 440$ tokens in that round.

The next section describes the sequence of events which will determine whether you receive a jar in the round.

Sequence of Events in Each Round (see FlowChart)

- First, you and your counterpart each selects a **minimum acceptable value** for a jar, which is an integer between 1 and 1000. Note that you do not know your counterpart's selection when you are making the decision, and vice versa. Suppose you choose $\boldsymbol{X}$ and your counterpart chooses $\boldsymbol{Y}$.

- Next, the computer randomly chooses either you or your counterpart to be the **active player** with a 50% chance each.

- If you are **not** chosen as the **active player**, you do not receive any jar in this round.

- If you are chosen as the **active player**, whether you receive a jar or not is determined in two stages as follows.

- First stage:

  - The computer generates Jar 1 with a random number of tokens. Recall that the number of tokens is equally likely to be any integer between 1 and 1000.
  - If the number of tokens in Jar 1 is at least as big as your minimum acceptable value $\boldsymbol{X}$, then **one** fair coin will be tossed to determine if you receive Jar 1 or not.
  - If the coin lands on Heads (with a 50% chance), you receive Jar 1, and the round ends (there is no second stage).
  - Otherwise (i.e., if either the number of tokens in Jar 1 is smaller than $\boldsymbol{X}$ **or** the coin landed on Tails), you do not receive Jar 1, Jar 1 vanishes, and the round proceeds to the second stage.

- Second stage:

  - The computer generates Jar 2 with a random number of tokens. The number of tokens is also equally likely to be any integer between 1 and 1000 and is independent of the number of tokens in Jar 1.
  - Then, **one** fair coin will be tossed.
    - If the coin lands on Heads (with a 50% chance), you receive Jar 2 and the round ends.

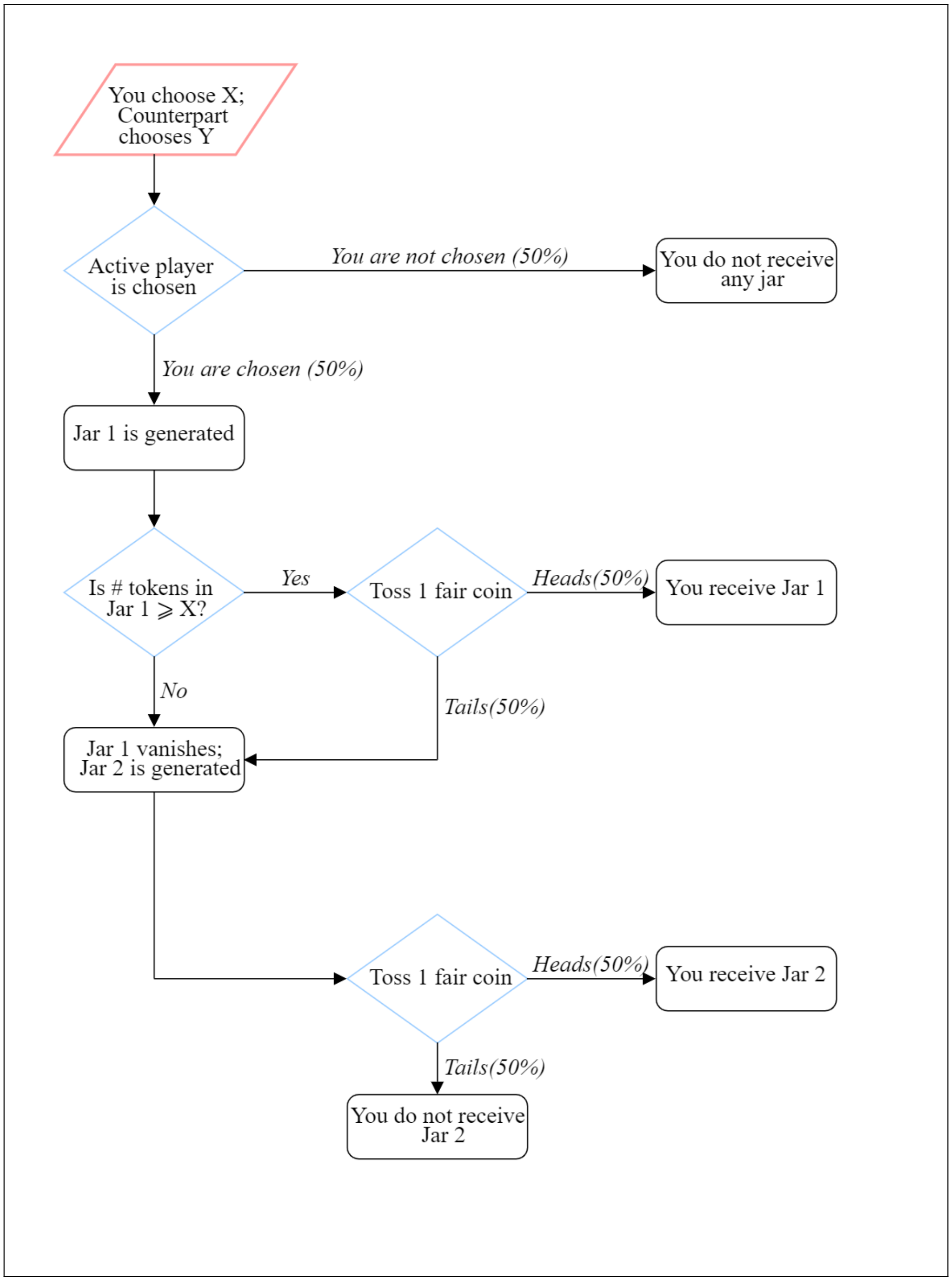
* If the coin lands on Tails (with a 50% chance), you do not receive Jar 2 and the round ends.

End of a Round

At the end of each round, the tokens you received in that round are displayed on the screen. Recall that you will be randomly paired with a newly selected counterpart in the next round.

Recall that we will convert the sum of your tokens across all rounds into cash at the exchange rate of $1 per 650 tokens.

FlowChart



You choose X; Counterpart chooses Y
Active player is chosen
You are not chosen (50%)
You do not receive any jar
You are chosen (50%)
Jar 1 is generated
Is # tokens in Jar 1 ⩾ X?
Yes
Toss 1 fair coin
Heads(50%)
You receive Jar 1
No
Tails(50%)
Jar 1 vanishes; Jar 2 is generated
Toss 1 fair coin
Heads(50%)
You receive Jar 2
Tails(50%)
You do not receive Jar 2

Overview of Part B

Part B has 30 rounds.

At the beginning of each round, you are randomly paired with another participant in this room, which we will call your "counterpart" in the round. You and your counterpart will each make a decision. Based on those decisions and random events, one of you may receive a jar of tokens in the round.

In each round, the computer will generate one or two jars with a random number of tokens. The number of tokens is equally likely to be any integer between 1 and 1000. For example, each jar has a 1/1000 chance of having 1 token, a 1/1000 chance of having 2 tokens, and so on. The number of tokens in each jar is independent of the number of tokens in the other jar.

At the end of the round, you will receive 100 tokens. In addition, if you receive a jar in the round, you will receive the tokens that are in that jar. For example, if you do not receive a jar, you will receive 100 tokens in the round. If you receive a jar that has 340 tokens, you will receive $100 + 340 = 440$ tokens in that round.

The next section describes the sequence of events which will determine whether you receive a jar in the round.

Sequence of Events in Each Round (see FlowChart)

- First, you and your counterpart each selects a **minimum acceptable value** for a jar, which is an integer between 1 and 1000. Note that you do not know your counterpart's selection when you are making the decision, and vice versa. Suppose you choose $\boldsymbol{X}$ and your counterpart chooses $\boldsymbol{Y}$.

- Next, the computer randomly chooses either you or your counterpart to be the **active player** with a 50% chance each.

- If you are **not** chosen as the **active player**, you do not receive any jar in this round.

- If you are chosen as the **active player**, whether you receive a jar or not is determined in two stages as follows.

- First stage:

  - The computer generates Jar 1 with a random number of tokens. Recall that the number of tokens is equally likely to be any integer between 1 and 1000.

  - If the number of tokens in Jar 1 is at least as big as your minimum acceptable value $\boldsymbol{X}$, then **one** fair coin will be tossed to determine if you receive Jar 1 or not.

  - If the coin lands on Heads (with a 50% chance), you receive Jar 1, and the round ends (there is no second stage).

  - Otherwise (i.e., if either the number of tokens in Jar 1 is smaller than $\boldsymbol{X}$ **or** the coin landed on Tails), you do not receive Jar 1, Jar 1 vanishes, and the round proceeds to the second stage.

- Second stage:

  - The computer generates Jar 2 with a random number of tokens. The number of tokens is also equally likely to be any integer between 1 and 1000 and is independent of the number of tokens in Jar 1. Starting here, the environment is different than it was in Part A.

  - If the number of tokens in Jar 2 is at least as big as your counterpart's minimum acceptable value $\boldsymbol{Y}$, then **two** fair coins will be tossed.

    - If both coins land on Heads (with a 25% chance), you receive Jar 2 and the round ends.
    - Otherwise (i.e., the coins land on Heads-Tails, Tails-Heads, or Tails-Tails, which happens with a 75% chance), you do not receive Jar 2. Since your counterpart is inactive, they cannot receive the jar either. Jar 2 vanishes, and the round ends.

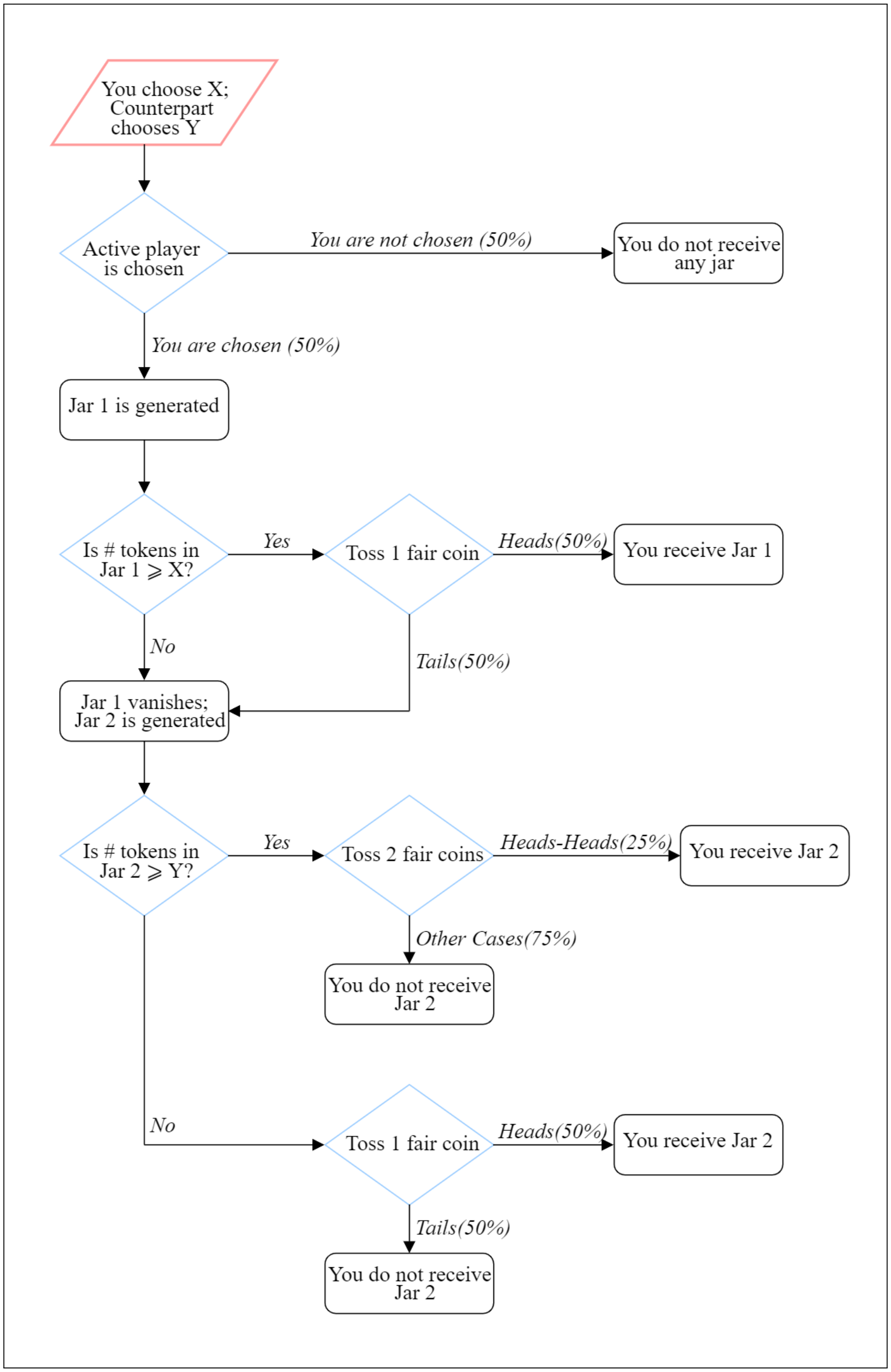
  - If the number of tokens in Jar 2 is smaller than your counterpart's minimum acceptable value $\boldsymbol{Y}$, then **one** fair coin will be tossed.
    - If the coin lands on Heads (with a 50% chance), you receive Jar 2 and the round ends.
    - If the coin lands on Tails (with a 50% chance), you do not receive Jar 2 and the round ends.

End of a Round

At the end of each round, the tokens you received in that round are displayed on the screen. Recall that you will be randomly paired with a newly selected counterpart in the next round.

Recall that we will convert the sum of your tokens across all rounds from Part A and Part B into cash at the exchange rate of $1 per 650 tokens.

FlowChart


You choose X; Counterpart chooses Y
Active player is chosen
You are not chosen (50%)
You do not receive any jar
You are chosen (50%)
Jar 1 is generated
Is # tokens in Jar 1 ⩾ X?
Yes
Toss 1 fair coin
Heads(50%)
You receive Jar 1
No
Tails(50%)
Jar 1 vanishes; Jar 2 is generated
Is # tokens in Jar 2 ⩾ Y?
Yes
Toss 2 fair coins
Heads-Heads(25%)
You receive Jar 2
Other Cases(75%)
You do not receive Jar 2
No
Toss 1 fair coin
Heads(50%)
You receive Jar 2
Tails(50%)
You do not receive Jar 2

4 Quiz

Quiz for Part A (FIFO)

1. You will be paired with the same person in all rounds.

   (A) True

   (B) False

   (C) Uncertain

2. What is the chance that you are not chosen as the inactive player in a given round?

   (A) 30%

   (B) 40%

   (C) 50%

   (D) 75%

3. Suppose that you have chosen a minimum acceptable value X equals 350, your counterpart has chosen Y equals 600, and you are selected as the active player. Suppose that the computer has randomly generated Jar 1 with 500 tokens and the first coin toss lands on Heads. How many tokens will you receive in total in this round?

   (A) 350

   (B) 500

   (C) 600

   (D) 700

4. Suppose that you have chosen a minimum acceptable value X equals 350, your counterpart has chosen Y equals 600, and you are selected as the active player. Suppose that you did not get Jar 1 in the first stage, and the computer has randomly generated Jar 2 with 500 tokens. What is the chance that you will get Jar 2?

   (A) 0%

   (B) 25%

(C) 50%

(D) 75%

5. Suppose you consider increasing your minimum acceptable value X from 350 to 800. What effect will this have on the chance that you receive Jar 2 in this round?

   (A) Increase

   (B) Stay the same

   (C) Decrease

Quiz for Part B (LIFO)

1. You will be paired with the same person in all rounds.

   (A) True

   (B) False

   (C) Uncertain

2. What is the chance that you are not chosen as the inactive player in a given round?

   (A) 30%

   (B) 40%

   (C) 50%

   (D) 75%

3. Suppose that you have chosen a minimum acceptable value X equals 350, your counterpart has chosen Y equals 600, and you are selected as the active player. Suppose that the computer has randomly generated Jar 1 with 500 tokens and the first coin toss lands on Heads. How many tokens will you receive in total in this round?

   (A) 350

   (B) 500

   (C) 600

   (D) 700

4. Suppose that you have chosen a minimum acceptable value X equals 350, your counterpart has chosen Y equals 600, and you are selected as the active player. Suppose that you did not get Jar 1 in the first stage, and the computer has randomly generated Jar 2 with 500 tokens. What is the chance that you will get Jar 2?

   (A) 0%

   (B) 25%

   (C) 50%

   (D) 75%

5. Suppose that you have chosen a minimum acceptable value X equals 350, your counterpart has chosen Y equals 600, and you are selected as the active player. Suppose that you did not win Jar 1 in the first stage, and the computer has randomly generated Jar 2 with 700 tokens. What is the chance that you will receive Jar 2?

   (A) 25%

   (B) 50%

   (C) 75%

   (D) 100%

6. Suppose that you have chosen a minimum acceptable value X equals 350. If your counterpart increases Y from 600 to 900, your chance of receiving Jar 2 __.

   (A) Increases

   (B) Stays the same

   (C) Decreases

References

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