Instructions—Baseline Treatment

This is an experiment in decision-making. The University of Iowa has provided funds for this research. You can earn money based on how well you follow the instructions and on the decisions you make in the experiment. Please turn off your cell-phones, do not talk to others and do not look at their screens. These instructions are a detailed description of the procedures we will follow.

How do you earn money?

You will earn points that will be converted into dollars. You will receive 2.5 cents ($.025) for every point you earn. All earnings will be paid to you in cash at the end of the experiment.

The experiment is composed of **many periods**. In each period you will be in a pair with another person selected at random, called your **"match."** In every pair, one participant will be **red** and the other **blue**:

- If you are **red**, then you can choose to execute either **outcome Y** or **Z**:
  - By choosing to execute outcome **Y**, you earn ***8*** points and your **blue** match earns ***8*** points.
  - By choosing to execute outcome **Z**, you earn ***2*** points and your **blue** match earns ***20*** points.

- If you are **blue**, then you simply wait for **red** to make a choice.

You can expect to be **red** 50% of the periods and **blue** the other 50%.

Who will be your match in the pair?

There are twenty participants. Each participant will be assigned to a **set** composed of four persons:

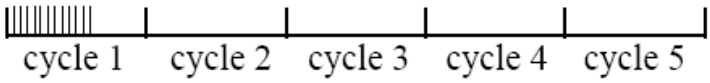
There are five sets. Your match is a person **chosen at random from your set.** The computer program selects with equal probability one of the three other persons in your set. So, there is one chance out of three that your match is any of the other three persons in your set.

Although there is a possibility that you interact with the same participant more than once, you will not know if it happens. Your match will be unknown to you because you will not see his or her experimental ID number.

In every period, after your match is selected, the computer **randomly selects** your color. In every period you have a 50% chance to be **red** and 50% chance to be **blue**. Your randomly selected match is always of a different color than yours. Hence in every set, two persons are **red** and the other two are **blue**. Since the color assignment is random, you may or may not switch color from period to period.

How many periods will the experiment last?

The experiment consists of **five cycles**. Each cycle involves many **periods** |||||| :



The number of periods in a cycle is **random** and so it is **unknown** to us. At the end of each period, the computer program randomly selects an integer number between 1 and 100. Each number is equally likely to be selected. This random number is the same for everyone in the room.
The cycle ends only if the random number selected is greater than 93. This means that:

- We never know for sure which period will be the last in a cycle.
- After each period there is a 93% chance that the cycle continues and a 7% chance that the cycle ends.
- Some cycles may be long and others may be short, but we cannot know this in advance.

The computer will select the random number in the same way a ball is drawn from a container of one-hundred balls, numbered 1 to 100. After each draw the ball is placed back into the container. Hence, the chance that a cycle will end, say, after period 25, is 7%, which is exactly the same as the chance that the cycle will end after period 1.

When a **cycle ends**, all twenty participants are divided into new sets in such a way that you will face different participants. **You will never interact with the same participants in future cycles**.

What exactly will you do in each period?

Each **period** has the following timeline:

1. You are randomly paired to a participant from your set.
2. You are randomly assigned a color (**red** or **blue**).
3. You may be called to make a choice (see below).
4. You and your match see the outcome of your choices.
5. The cycle may continue or may end.

In a moment we will explain the choices you may make in each period. The choices depend on your color, **red** or **blue**. Remember that if you are **red**, then your match is **blue** (and vice versa).

- If you are **red**, then you can select one of the following options (**Figure A**):
  - **Execute Y:** you and your match earn ***8*** points each.
  - **Execute Z:** you earn ***2*** points and your **blue** match earns ***20*** points.

- If you are **blue**, then you simply wait (**Figure B**)

Figure A: Choice screen for red

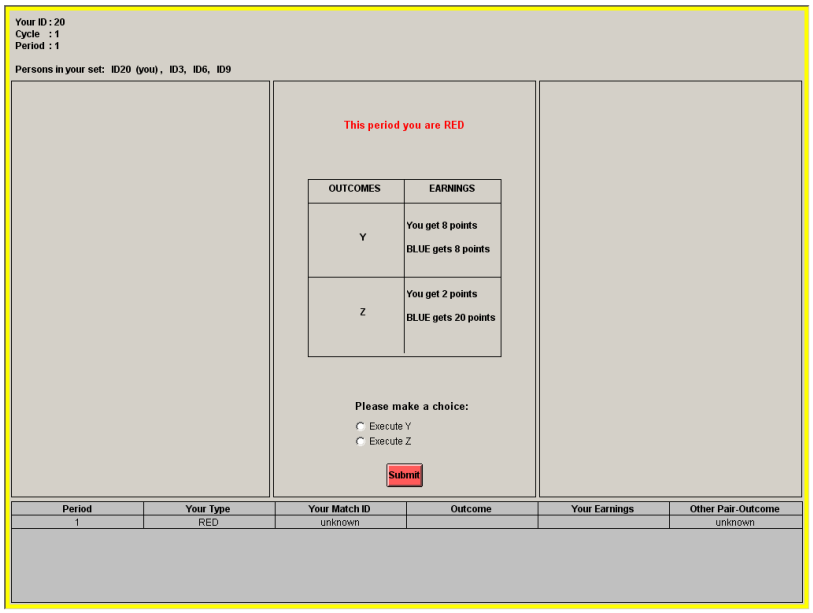
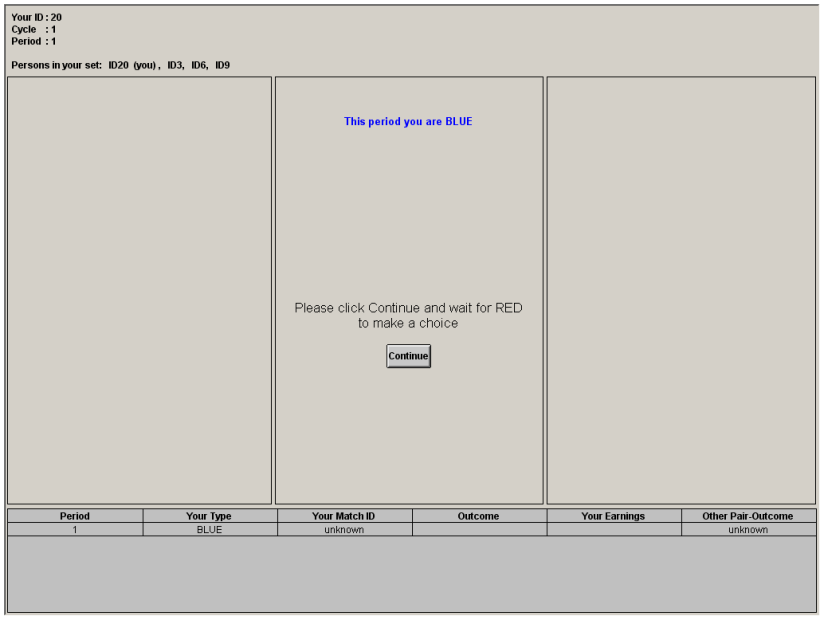


Figure B: Choice screen for blue



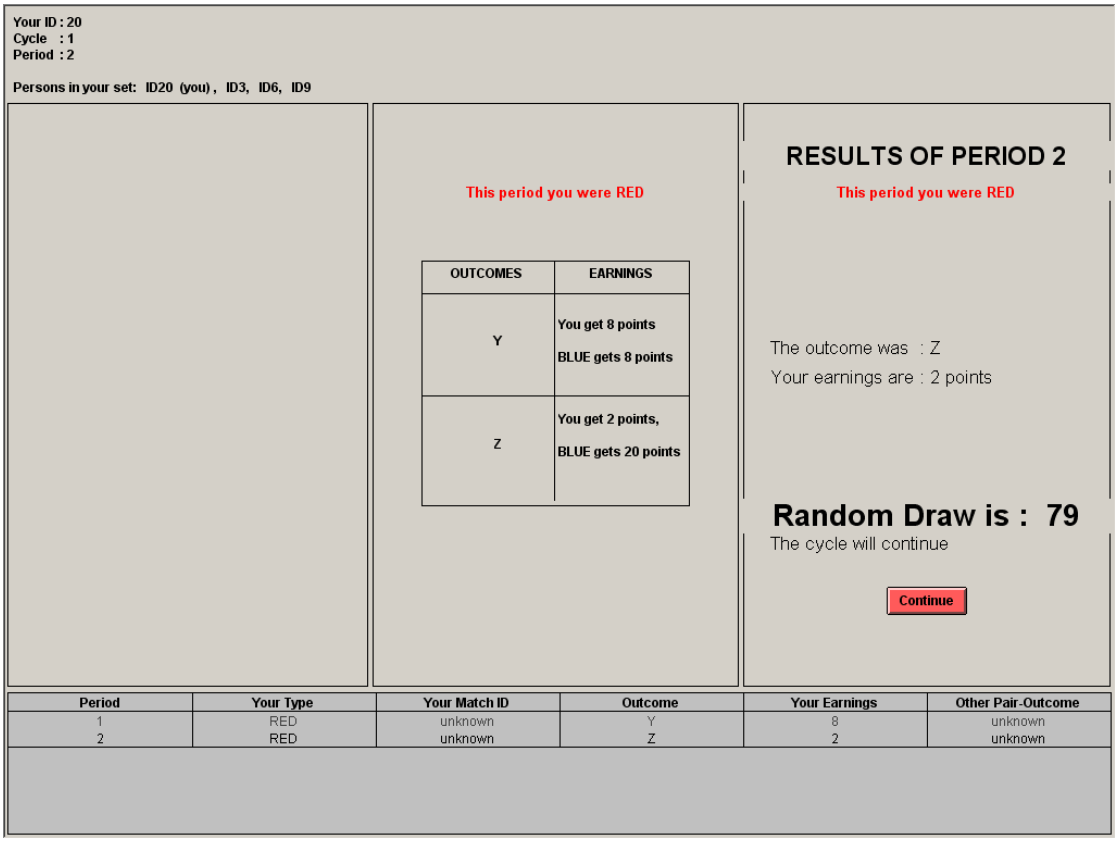
To make your choice, click the button next to the option you wish to select. You may change your mind at any time prior to clicking the "Submit" button. You are free to make any choice you like in each period.

Before making your choices, you can also review outcomes in previous periods of the cycle by looking at the **"**Summary of Results" table at the bottom of the screen. It shows your past colors and outcomes.

After all participants in your set have made their choice, the results for the period will appear on your screen:

The results screen (**Figure C**) will display your earnings in points for the period. You can see if the outcome was **Y** or **Z**. The table in the lower part of the screen shows a **"**Summary of Results" for previous periods. Each line includes: period number, your color for the period, and the outcome **Y** or **Z**. The column "Your Earnings" displays the points you have earned. **Recall that your match this period may be a different person than your match in the previous period.** Please write the results on your record sheet under the appropriate headings.

Figure C: Screen for the results of the period:



Reminder on the duration of the experiment

There will be five cycles of unknown duration. The duration of each cycle will be random. At the end of each period, the computer program will randomly select an integer number between 1 and 100, and show it on your screen (Figure C).

- If this random number is 1, 2, …, or 93, then the cycle will continue.
- If this random number is 94, 95, …, or 100, then the cycle will end.

Therefore, **after any period** there is always a 93% chance that the cycle will **continue.** This implies that, no matter what period you have reached, the **expected number of additional periods is about 13.** The number of past periods does not influence the chance that a cycle will end because the random procedure is exactly the same in every period.

When a cycle ends, you will be notified in a new screen. The rules in each cycle are the same but you interact with different persons in each cycle. After each cycle, new sets of persons will be formed. **You will never interact with another participant for more than one cycle.**

Final Comments

- Do not talk to others and do not look at their screens.
- In every period you have a 50% chance to be **red** and 50% chance to be **blue**.
- If you are **red**, then you can choose to execute either outcome **Y** or **Z**. If you are **blue**, then you simply wait. Earned points will be redeemed for dollars.
- Your match is a random person in your set. You have one chance out of three of being matched with the same person in two consecutive periods.
- Independently of the period reached, there is a 93% chance of an additional period in the cycle, and a 7% chance that the cycle ends.
- The rules are the same in all five cycles. After a cycle, you will never interact with the same participants.

Questions?

Now is time for questions. Do you have any questions before we begin the experiment?

QUIZ

1. The total number of **cycles** is _____
2. You are in period 1 of a cycle. What is the probability that the cycle will continue? _____
   How many **additional** periods do we expect? _____
3. What if you are in period 20? Probability _____ Expected additional periods _____
4. The number of **participants** in the experiment (total in the room) is_____
5. In a given **cycle**, how many participants are in your set? _____
6. In each period how many participants do you **interact** with? _____
7. Will you ever see the **ID** of your match? _____
8. Can you see how many times your match chose Y or Z in the past? _No _If **all** pay _If **I** pay (circle one)
9. Will you know at the end of the period the outcome in the **other pair from your set**? _____
10. If IDs 5, 10 & 16 are in your set this cycle, is there any chance that ID 5, 10 or 16 will be your match in future cycles? _____
11. You are BLUE and your RED match executes **Y**; how many points do you earn, respectively? _____
12. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Y.** How many dollars will you earn? _____
13. RED chooses **Z**; how many points do RED and BLUE earn? _____
14. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Z.** How many dollars will you earn? _____

Instructions—Information Provision Treatment

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  - By choosing to execute outcome **Z**, you earn ***2*** points and your **blue** match earns ***20*** points.

- If you are **blue**, then you simply wait for **red** to make a choice.

You can expect to be **red** 50% of the periods and **blue** the other 50%.

Who will be your match in the pair?

There are twenty participants. Each participant will be assigned to a **set** composed of four persons:

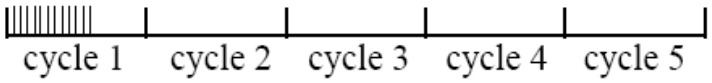
There are five sets. Your match is a person **chosen at random from your set.** The computer program selects with equal probability one of the three other persons in your set. So, there is one chance out of three that your match is any of the other three persons in your set.

Although there is a possibility that you interact with the same participant more than once, you will not know if it happens. Your match will be unknown to you because you will not see his or her experimental ID number.

In every period, after your match is selected, the computer **randomly selects** your color. In every period you have a 50% chance to be **red** and 50% chance to be **blue**. Your randomly selected match is always of a different color than yours. Hence in every set, two persons are **red** and the other two are **blue**. Since the color assignment is random, you may or may not switch color from period to period.

How many periods will the experiment last?

The experiment consists of **five cycles**. Each cycle involves many **periods** |||||| :



The number of periods in a cycle is **random** and so it is **unknown** to us. At the end of each period, the computer program randomly selects an integer number between 1 and 100. Each number is equally likely to be selected. This random number is the same for everyone in the room.
The cycle ends only if the random number selected is greater than 93. This means that:

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When a **cycle ends**, all twenty participants are divided into new sets in such a way that you will face different participants. **You will never interact with the same participants in future cycles**.

What exactly will you do in each period?

Each **period** has the following timeline:

1. You are randomly paired to a participant from your set.
2. You are randomly assigned a color (**red** or **blue**).
3. You may be called to make a choice (see below).
4. You and your match see the outcome of your choices.
5. You may have the option to make the choices public in your set (see below)
6. The cycle may continue or may end.

In a moment we will explain the choices you may make in each period. The choices depend on your color, **red** or **blue**. Remember that if you are **red**, then your match is **blue** (and vice versa).

- If you are **red**, then you can select one of the following options (**Figure A**):
    - **Execute Y:** you and your match earn ***8*** points each.
    - **Execute Z:** you earn ***2*** points and your **blue** match earns ***20*** points.

- If you are **blue**, then you simply wait (**Figure B**). After observing the results you can, at a cost of 1 point, make public in your set the choice of your **red** match. (see below)

Figure A: Choice screen for red

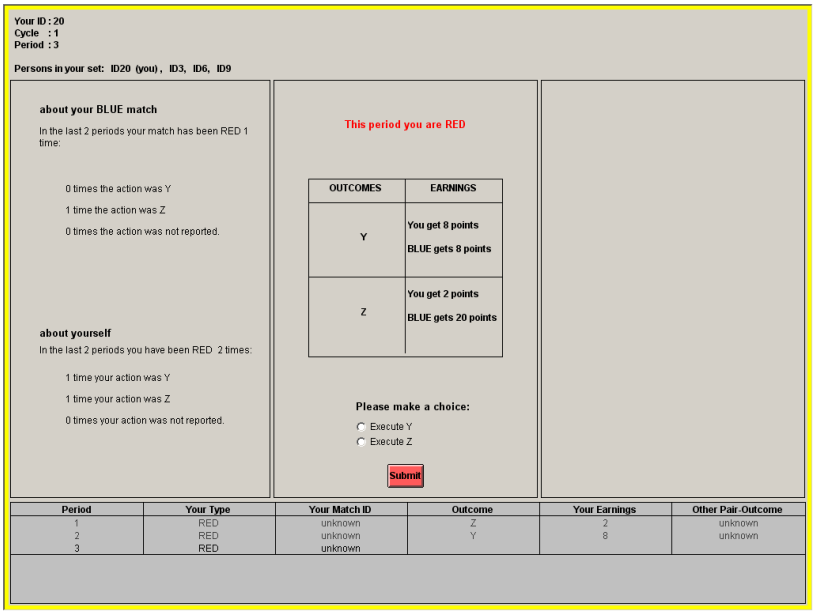
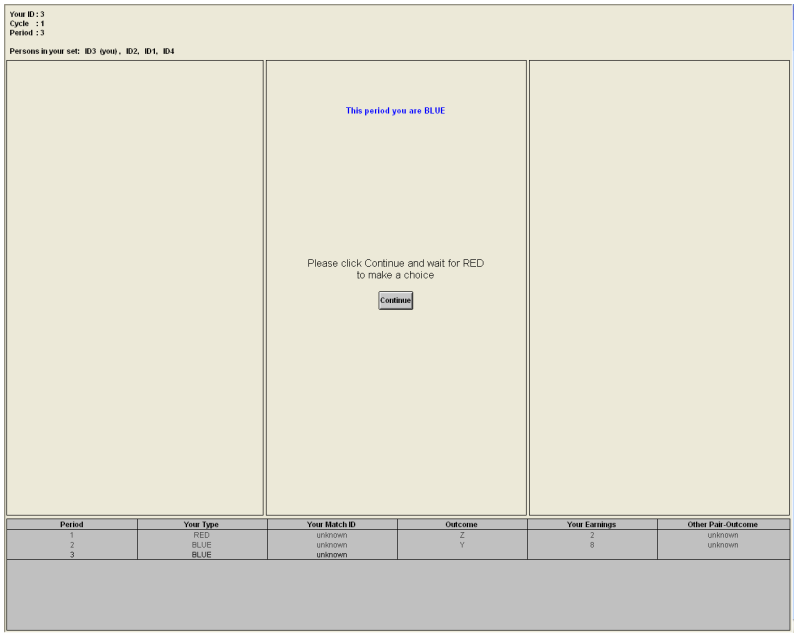


Figure B: Choice screen for blue



To make your choice, click the button next to the option you wish to select. You may change your mind at any time prior to clicking the SUBMIT button. You are free to make any choice you like in each period.

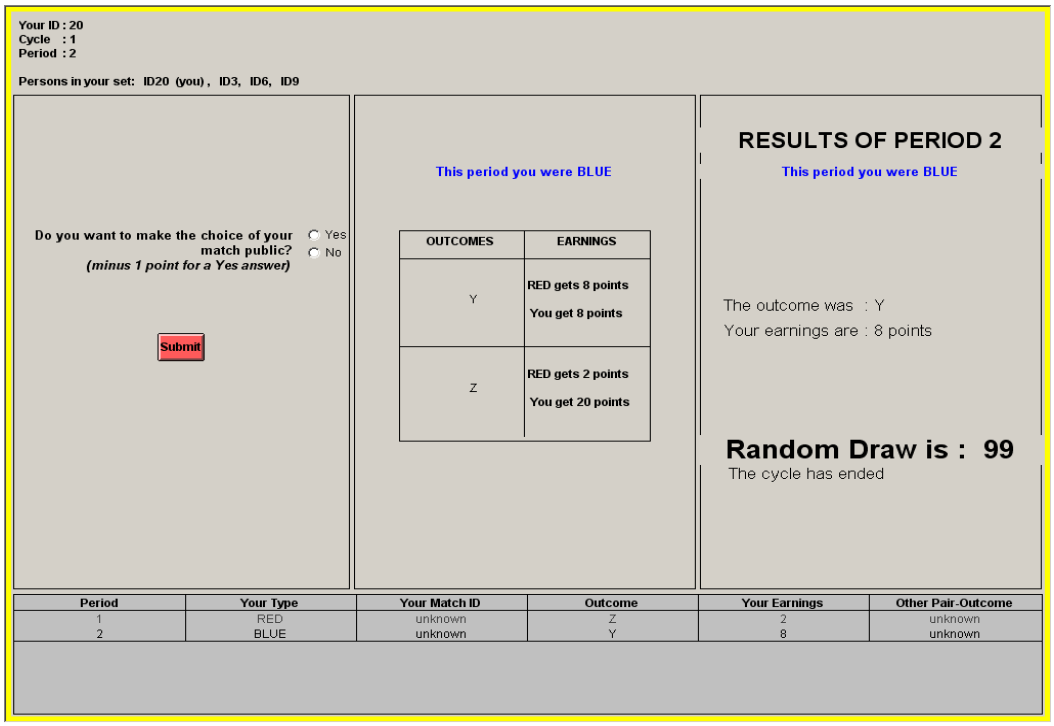
Before selecting Y or Z, **red** can observe the choices of his or her match up to the last six periods of the cycle, i.e. his or her public profile. Only the choices that were made public are in the public profile. No information is available in period 1 of the cycle. You can also observe your own public profile.

Before making your choices, you can also review outcomes in previous periods of the cycle by looking at the **"**Summary of Results" table at the bottom of the screen. It shows your past colors and outcomes.

After all participants in your set have made their choices, the results for the period will appear on your screen:

The results screen (**Figure C**) will display your earnings in points for the period. You can see if the outcome was **Y** or **Z**. The table in the lower part of the screen shows a **"**Summary of Results" for previous periods. Each line includes: period number, your color for the period, and the outcome **Y** or **Z**. The column "Your Earnings" displays the points you have earned. **Recall that your match this period may be a different person than your match in the previous period.** Please write the results on your record sheet under the appropriate headings.

Figure C: Screen for the results of the period:



On the result screen, **blue** has the option to make public the Y/Z choice of his or her **red** match. To ignore this option, select NO and click the SUBMIT button to proceed. **To make the choice public in your set**, select YES and click the SUBMIT button. By selecting YES you will pay 1 point, the public profile of your match will be updated and everyone in your set will see it.

Reminder on the duration of the experiment

There will be five cycles of unknown duration. The duration of each cycle will be random. At the end of each period, the computer program will randomly select an integer number between 1 and 100, and show it on your screen (Figure C).

- If this random number is 1, 2, …, or 93, then the cycle will continue.
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Therefore, **after any period** there is always a 93% chance that the cycle will **continue.** This implies that, no matter what period you have reached, the **expected number of additional periods is about 13**. The number of past periods does not influence the chance that a cycle will end because the random procedure is exactly the same in every period.

When a cycle ends, you will be notified in a new screen. The rules in each cycle are the same but you interact with different persons in each cycle. After each cycle, new sets of persons will be formed. **You will never interact with another participant for more than one cycle.**

Final Comments

- Do not talk to others and do not look at their screens.
- In every period you have a 50% chance to be **red** and 50% chance to be **blue**.
- If you are **red**, then you can choose to execute either outcome **Y** or **Z**. If you are **blue**, then you simply wait and then can make public in your set the choice of your match. Earned points will be redeemed for dollars.
- Your match is a random person in your set. You have one chance out of three of being matched with the same person in two consecutive periods.
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- The rules are the same in all five cycles. After a cycle, you will never interact with the same participants.

Questions?

Now is time for questions. Do you have any questions before we begin the experiment?

QUIZ

1. The total number of **cycles** is _____
2. You are in period 1 of a cycle. What is the probability that the cycle will continue? _____
   How many **additional** periods do we expect? _____
3. What if you are in period 20? Probability _____ Expected additional periods _____
4. The number of **participants** in the experiment (total in the room) is_____
5. In a given **cycle**, how many participants are in your set? _____
6. In each period how many participants do you **interact** with? _____
7. Will you ever see the **ID** of your match? _____
8. Can you see how many times your match chose Y or Z in the past? _No _If **all** pay _If **I** pay (circle one)
9. Will you know at the end of the period the outcome in the **other pair from your set**? _____
10. If IDs 5, 10 & 16 are in your set this cycle, is there any chance that ID 5, 10 or 16 will be your match in future cycles? _____
11. You are BLUE and your RED match executes **Y**; how many points do you earn? _____
12. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Y.** How many dollars will you earn? (suppose no monitoring costs) _____
13. RED chooses **Z**; how many points do RED and BLUE earn, respectively? _____
14. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Z.** How many dollars will you earn? (suppose no monitoring costs)_____

Instructions—Information Request Treatment

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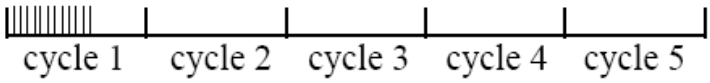

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The computer will select the random number in the same way a ball is drawn from a container of one-hundred balls, numbered 1 to 100. After each draw the ball is placed back into the container. Hence, the chance that a cycle will end, say, after period 25, is 7%, which is exactly the same as the chance that the cycle will end after period 1.

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5. The cycle may continue or may end.

In a moment we will explain the choices you may make in each period. The choices depend on your color, **red** or **blue**. Remember that if you are **red**, then your match is **blue** (and vice versa).

- If you are **red**, then you can select among the following options (**Figure A1**) :

  - **Execute Y:** you and your match earn ***8*** points each.
  - **Execute Z:** you earn ***2*** points and your **blue** match earns ***20*** points.

  Before selecting Y or Z, you have the option to pay 1 point to see the past choices of your match, up to the previous **six periods in that same cycle**.

  1. If you do not wish to see the past choices of your match, then click the button next to the option Y or Z you wish to select. Then, click the NO, SUBMIT MY Y/Z CHOICE button. You may change your mind at any time prior to clicking that button.

  2. If you wish to see the past choices of your match, then click the button: YES, SHOW ME THE INFORMATION. At this point, information will be displayed on a new screen (**Figure A2**). To make your choice Y or Z, click the button next to the option you wish to select. You may change your mind at any time prior to clicking the SUBMIT button.

  You are free to make any choice you like in each period.

- If you are **blue**, then you simply wait (**Figure B**)

Figure A1: Choice screen for red

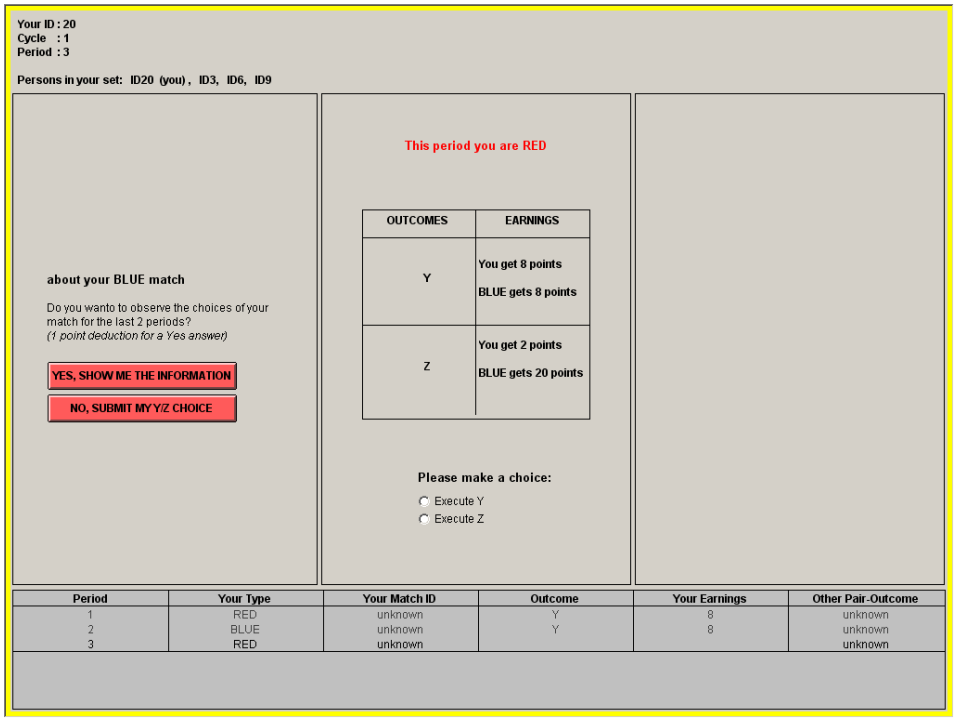


Figure A2: Choice screen for red after requesting information

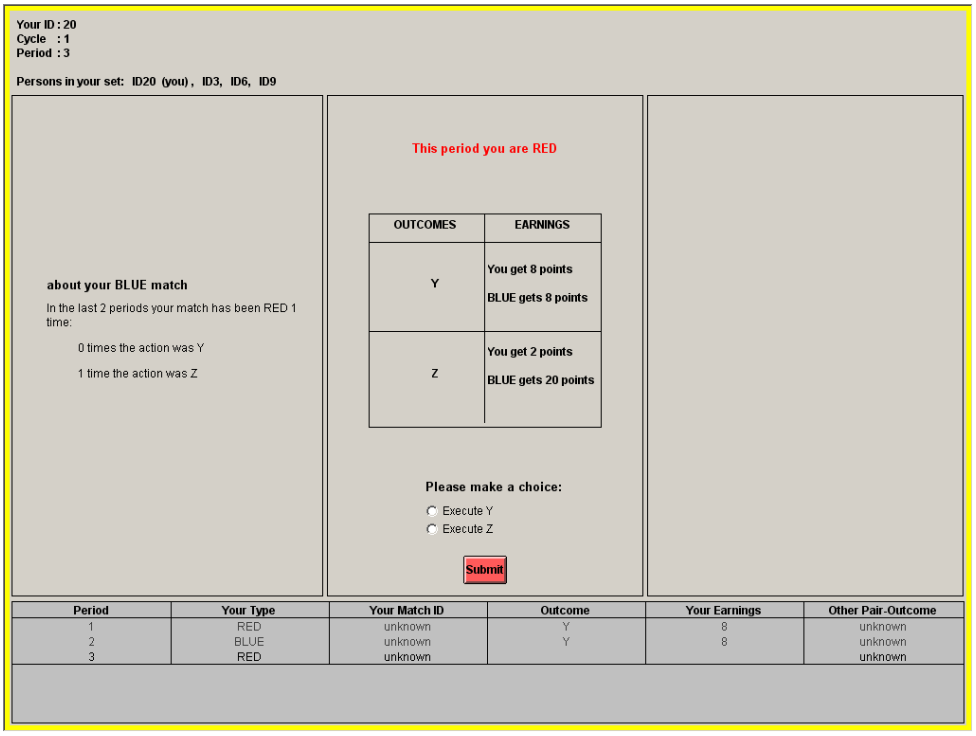
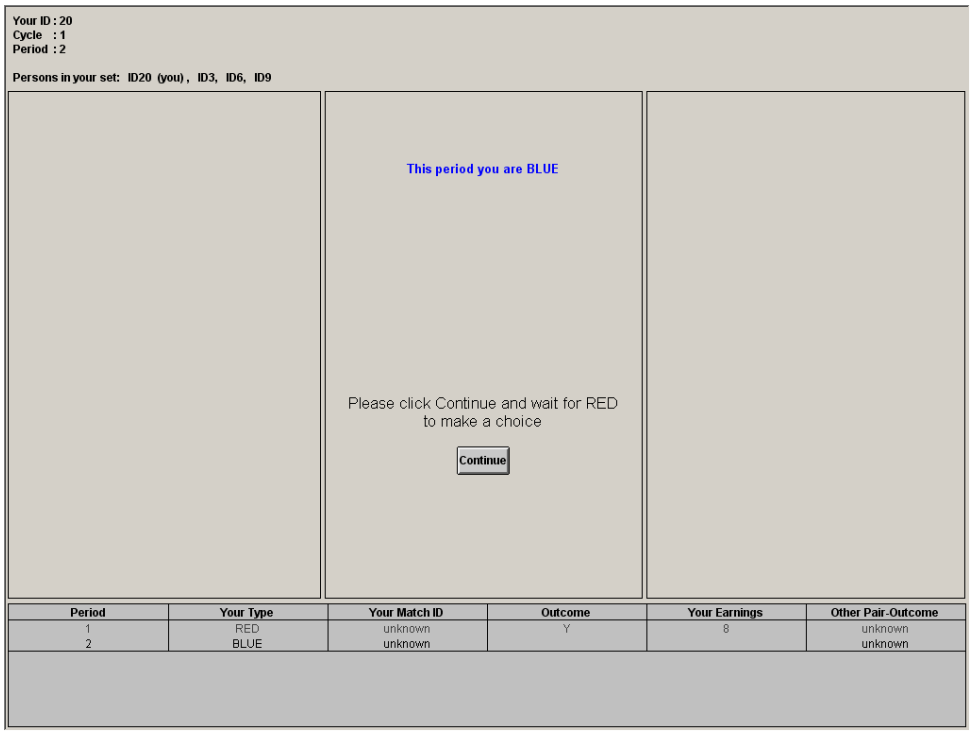


Figure B: Choice screen for blue

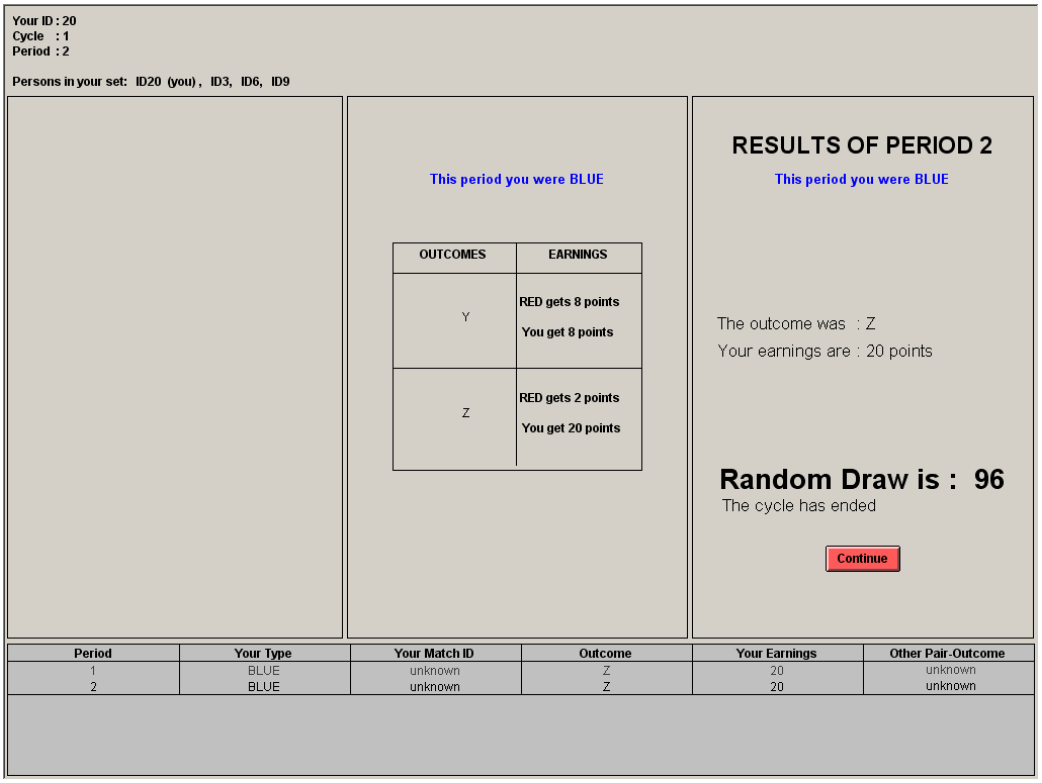


Before making your choices, you can also review outcomes in previous periods of the cycle by looking at the **"**Summary of Results" table at the bottom of the screen. It shows your past colors and outcomes.

After all participants in your set have made their choices, the results for the period will appear on your screen:

The results screen (**Figure C**) will display your earnings in points for the period. You can see if the outcome was **Y** or **Z**. The table in the lower part of the screen shows a **"**Summary of Results" for previous periods. Each line includes: period number, your color for the period, and the outcome **Y** or **Z**. The column "Your Earnings" displays the points you have earned. **Recall that your match this period may be a different person than your match in the previous period.** Please write the results on your record sheet under the appropriate headings.

Figure C: Screen for the results of the period:



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- If this random number is 1, 2, …, or 93, then the cycle will continue.
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Therefore, **after any period** there is always a 93% chance that the cycle will **continue.** This implies that, no matter what period you have reached, the **expected number of additional periods is about 13**. The number of past periods does not influence the chance that a cycle will end because the random procedure is exactly the same in every period.

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Final Comments

- Do not talk to others and do not look at their screens.
- In every period you have a 50% chance to be **red** and 50% chance to be **blue**.
- If you are **red**, then you can choose to see the history of choices of your match and then choose to execute either outcome **Y** or **Z**. If you are **blue**, then you simply wait. Earned points will be redeemed for dollars.
- Your match is a random person in your set. You have one chance out of three of being matched with the same person in two consecutive periods.
- Independently of the period reached, there is a 93% chance of an additional period in the cycle, and a 7% chance that the cycle ends.
- The rules are the same in all five cycles. After a cycle, you will never interact with the same participants.

Questions?

Now is time for questions. Do you have any questions before we begin the experiment?

QUIZ

1. The total number of **cycles** is _____
2. You are in period 1 of a cycle. What is the probability that the cycle will continue? _____
   How many **additional** periods do we expect? _____
3. What if you are in period 20? Probability _____ Expected additional periods _____
4. The number of **participants** in the experiment (total in the room) is_____
5. In a given **cycle**, how many participants are in your set? _____
6. In each period how many participants do you **interact** with? _____
7. Will you ever see the **ID** of your match? _____
8. Can you see how many times your match chose Y or Z in the past? _No _If **all** pay _If **I** pay (circle one)
9. Will you know at the end of the period the outcome in the **other pair from your set**? _____
10. If IDs 5, 10 & 16 are in your set this cycle, is there any chance that ID 5, 10 or 16 will be your match in future cycles? _____
11. You are BLUE and your RED match executes **Y**; how many points do you earn? _____
12. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Y.** How many dollars will you earn? (suppose no monitoring costs)_____
13. RED chooses **Z**; how many points do RED and BLUE earn, respectively? _____
14. Suppose the experiment lasts 70 periods, you are RED half of the periods, BLUE half of the periods, and everybody always chooses **Z.** How many dollars will you earn? (suppose no monitoring costs)_____

ID ____ DATE ___________

RECORD SHEET

Cycle	Period	Your color	Your Choice Blue: -- Red: Y, Z	Outcome	Your period earnings	Cumulative earnings

RECORD SHEET CONTINUED

Cycle	Period	Your color	Your Choice Blue: -- Red: Y, Z	Outcome	Your period earnings	Cumulative earnings

Appendix B: Existence of cooperative equilibrium

Not for Publication

This Appendix is based on the Online Appendix to Camera and Casari (2014). There are four identical players. In each period they are matched in pairs, with uniform probability of selection. In each pair, one player is a seller and the other is a buyer. Seller and buyer are equally likely states for an individual, i.e., the individual is a seller with probability $\alpha = \frac{1}{2}$.

Two outcomes are possible in a match: defection Y, and cooperation Z. In what follows we will say that if the seller chooses Z in a matched pair, then his opponent "consumes" and the seller "produces." For an individual, let $u = 20$ be the stage game payoff from consuming and $-c = d = 2$ the stage game payoff from producing (the seller chooses Z). Set $a = 8$, as the stage game payoff from defection (the seller choose Y).Period payoffs are geometrically discounted at rate $\beta = 0.93$. Payoffs and continuation payoffs in the game are given by expected lifetime utilities.

Equilibrium payoffs

Consider a social norm based on grim trigger. It has a rule for cooperation: a seller must always choose Z. It has also a rule for punishment: If a defection is observed, then Y is selected forever after. Suppose an equilibrium exists based on this social norm. The payoff of the representative player is denoted

$$V = \frac{(1-\alpha)u - \alpha c}{1-\beta}. \tag{1}$$

This is simply the present value of the stream of expected period payoffs, which are time-invariant in equilibrium. To discuss existence of equilibrium we now present individual optimality conditions in and out of equilibrium.

In equilibrium cooperation is a best response for a seller if

$$-c + \beta V \geq a + \beta v_2. \tag{2}$$

The left-hand-side denotes the payoff from cooperating when everyone has always cooperated up to that point. The right-hand-side from defecting when everyone has always cooperated up to that point. The notation v_2 denotes the off-equilibrium continuation payoff in the group where two players have seen a defection and follow the rule of punishment of the social norm (as a seller, choose Y). Since $V > v_2$ for (2) to hold, we rewrite it as

$$\beta \geq \beta_L := \frac{a+c}{V - v_2}.$$

Out of equilibrium payoffs

Consider out of equilibrium actions when everyone follows the social norm. Out of equilibrium we have at least two defectors. Let v_4 denote the continuation payoff for any player in a group with four defectors (everyone defects as a seller). Since both sellers will defect we have

$$v_4 = \frac{a}{1-\beta} \tag{3}$$

and so we call v_4 the **defection** payoff.

Now consider the case where a defection has just taken place for the first time. So there are only two defectors. For concreteness, let player x observe a defection for the first time in period $t-1$. She believes that everyone has played cooperation up to that point. player x may be the one who defected, or her opponent, denoted y. Suppose that everyone will behave according to the social norm from now on. Next period t there will be two defectors (players x and y) and two cooperators (players in the other match who observed nothing).

The continuation payoff for player x at the start of period t is

$$v_2 = \tfrac{1}{3}(a + \beta v_2) + \tfrac{2}{3}[(1-\alpha)(u + \beta\tfrac{v_4+v_3}{2}) + \alpha(a + \beta\tfrac{v_2+v_3}{2})]. \tag{4}$$

To see why note that with probability $\frac{1}{3}$ player x meets again player y (a defector), and with probability $\frac{2}{3}$ player x meets a cooperator.

- If x meets y once again, a is the period payoff, and since no one else observed a defection next period $t+1$ there will still be two defectors. So the discounted continuation payoff is βv_2.
- If x someone other than y, then this player is a cooperator.
  - If x is a seller (with probability $\alpha = \frac{1}{2}$), then x defects and earns a. The defection is seen by her opponent but the continuation payoffs depends also on what happens in the other match. This is because the other pair is also composed of a defector (player y) and a cooperator. If player y is a seller, then he defects (seen by her opponent). Hence, next period we have four defectors (v_4 is the payoff). If, instead, player y is a buyer, then there is no defection in the other match and the following period we have three defectors (v_3 is the payoff). Since y is a seller with probability $\frac{1}{2}$, then a defection occurs the other match with that probability.
  - If x is a buyer (with probability $1-\alpha = \frac{1}{2}$), then he earns u. Again, the continuation payoff depends on events in the other match and, since x does not defect, we cannot have more than three defectors next period. With probability $\frac{1}{2}$ there are three defectors and there are two, otherwise.

Substituting for $\alpha = 1/2$ we rearrange (4) as

$$v_2 = \tfrac{2}{3(2-\beta)}(u + 2a + \beta\tfrac{1}{2}v_4 + \beta v_3). \tag{5}$$

To calculate v_3 consider the case when, at the beginning of some date, player x is one of three defectors (i.e., players who have seen or implemented a defection Y). Suppose that everyone adopts the social norm. The payoff to player x is

$$v_3 = \tfrac{1}{3}\left[\tfrac{1}{2}(u + \beta v_3) + \tfrac{1}{2}(a + \beta v_4)\right] + \tfrac{2}{3}(a + \beta\tfrac{v_4+v_3}{2}), \tag{6}$$

because with probability $\frac{1}{3}$ player x meets a cooperator, and with probability $\frac{2}{3}$ she meets a defector.

- If player x meets a cooperator, then her period payoff depends on whether she is a seller of a buyer. Her continuation payoff depends also on this because only if she produces will the group move to the state with four defectors. Indeed, the other match has two defectors.
- If player x meets a defector. Then she always earns a but the continuation payoff depends on whether the cooperator in the other match is a buyer. If that's the case (with probability 1/2), then the group transitions to a state with four defectors. Otherwise, it will remain in a state with three defectors.

Rearranging (6) we have

$$v_3 = \frac{1}{3(2-\beta)}(u + 5a + 3\beta v_4).$$

Using the above in (4) we have

$$v_2 = \tfrac{2}{3(2-\beta)^2}\{(u + 2a)(2 - \beta) + \beta[\tfrac{(2+\beta)a}{2(1-\beta)} + \tfrac{u+5a}{3}]\}. \tag{7}$$

We can now find a condition such that defecting in equilibrium is individually sub-optimal

Lemma 1. *There exists a non-trivial interval $(\beta_L, 1)$ such that if $\beta \in (\beta_L, 1)$, then (2) holds.*

Proof of Lemma 1. Rewrite (2) as $\frac{a+c}{v_2} \leq \beta(\frac{V}{v_2} - 1)$. As $\beta \to 0$ we have $V \to \frac{u-c}{2}$ and $v_2 \to \frac{u+2a}{3}$. So, clearly, as $\beta \to 0$ then (2) is violated for any $a \geq 0$ and $c < 0$. Notice that $\frac{\partial v_2}{\partial \beta}, \frac{\partial V}{\partial \beta} > 0$. As $\beta \to 1$, we have $v_2 \to \infty$ and $V \to \infty$. It should be clear that as $\beta \to 1$ then $\frac{a+c}{v_2} \to 0$. In addition, the RHS of the inequality converges to a positive quantity since, as $\beta \to 1$, then $\frac{V}{v_2} \to \frac{u-c}{2a} > 1$, given our initial assumption. We conclude that there exists a β_L sufficiently close to one such that (2) holds for all $\beta \in (\beta_L, 1)$, with strict inequality.

Deviating out of equilibrium

Now we find conditions under which it is optimal to follow the rule of punishment after having observed a defection.

Suppose player x observes a deviation for the first time in a match with player y (it does not matter who defects). Consider now the date when player x is a seller, for the first time, after observing the defection in the match with y. This event may happen quite some time after observing the defection (role assignment is probabilistic) so it is possible that everyone else in the group has also observed the defection because y had a chance to defect. It is also possible that y never had a chance to defect, so the group still has two people who observed a defection. This scenario certainly occurs if x is a seller the period after observing the defection.

Consider the following deviation. Player x refuses to choose Y as a seller and, instead, she cooperates. She will follow the social norm for punishment afterward (one-time deviation). The rationale for this is that she can slow down the contagion to full defection, hence enjoy some payoffs u for a little longer.

This deviation is suboptimal if the group has already three defectors since no one will ever cooperate. The best-case scenario is when the group has only two defectors. Hence, consider this case by supposing that player x is a seller the period immediately after observing her first defection,

Choosing to deviate from the social norm out of equilibrium (choosing Y) is a best response if

$$a + \beta(\tfrac{1}{3}v_2 + \tfrac{2}{3}\tfrac{v_3+v_4}{2}) \geq -c + \beta(\tfrac{1}{3}v_2 + \tfrac{2}{3}\tfrac{v_2+v_3}{2}). \tag{8}$$

- Consider the LHS of (8), which is when x follows the social norm, out of equilibrium. Since player x is a seller she will defect, generating a period payoff. The continuation payoff depends on whom she meets. With probability $\frac{1}{3}$ player x meets y, the deviator met earlier. In this case the continuation payoff is v_2 since the other match has two cooperators. If, instead, player x meets a cooperator (probability $\frac{2}{3}$) then the group will have three defectors only if in the other match the defector is not a seller (with probability $\frac{1}{2}$).

- Consider the RHS of (8), which is when x does not defect today (though she should). Instead, she chooses Z today, so her period payoff is $-c$, and will choose Y forever after. Her continuation payoff depends once again on whom she meets. If she meets player y, the other defector, then next period there will be again two defectors (her and player y). This occurs with probability $\frac{1}{3}$. If, instead, player x meets a cooperator, with probability $\frac{2}{3}$ next period the group has 2 or 3 defectors depending on what happens in the other match. With probability $\frac{1}{2}$ a defection occurs in the other match (player y is a seller).

Inequality (8) can be rearranged as

$$a + c \geq \frac{\beta}{3}(v_2 - v_4). \tag{9}$$

Recalling that if it is optimal for player x to defect out of equilibrium after having observed an initial defection (i.e., when there are two defectors, including player x), then it will also be optimal to defect after having observed more than one defection (i.e., when there are more than two defectors, including player x).

Since $v_2 > v_4$ for (9) to hold, we rewrite it as

$$\beta \leq \beta_H := \frac{3(a + c)}{v_2 - v_4}.$$

Inserting $u = 20$, $-c = 2$ and $a = 8$ we numerically find $\beta_L = 0.808$ and $\beta_H = 1.2$. Hence, for the parameterization $u = 20$, $a = 8$ and $-c = 2$ if $\beta \geq 0.808$, then the grim trigger strategy is an equilibrium.