

A Continuous Dilemma, Daniel Friedman and Ryan Oprea, Web Appendix

Online Appendix B: Additional Mathematical Details

B.1 Discrete Time Predictions

To predict mutual cooperation in Grid- n , we can just set $\tau = 1/n$, ignoring the subtle distinctions between discrete time and continuous time with reaction lags. Alternatively, we can translate Radner's discrete time results directly into our setting. His payoff parameters a, b, c in our notation are respectively $y, x - y, 10 - y$, and his trigger strategies C_j are our cutoff strategies $K(j/n)$. Radner's equation (16) shows that $\hat{L} = \frac{a+b-c}{T} = \frac{x+y-10}{n}$ is the maximum loss of $K(1)$ against $K(j/n)$ for any $j = 0, \dots, n$, relative to the ex post best response. Note that substituting $1/n = \tau$ in \hat{L} yields exactly the same expression for ϵ as in the paragraph preceding equation (3).

We now seek a bound on the first cutoff period j_L , and check whether $s_L \approx j_L/n$. Let F be the (discrete) uniform distribution over the $n - j_L$ cutoff times $\{j/n : j = j_L, \dots, n-1, n\}$. The expected payoff for waiting until the end (i.e., playing strategy $K(n/n) = K(1)$) is

$$\pi(1|F) = 10 - [(10 - 0)\frac{n - j_L - 1}{n - j_L} + (10 - y)(n - j_L)/2]/n, \quad (11)$$

because it earns $(1/n)$ times 10 in every subperiod until the other player cuts off cooperation, at which point it earns 0 instead of 10 (in each realization except $j = n$) and thereafter earns y instead of 10 (on average in half of the $(n - j_L)$ realizations). Against the same uniform distribution, strategy $K(j_L/n)$ obtains payoff

$$\pi(j_L/n|F) = 10 - [(10 - x)\frac{n - j_L - 1}{n - j_L} + (10 - y)(n - j_L - 1 + \frac{1}{n - j_L})]/n, \quad (12)$$

because, except in one realization ($j = j_L$, when it earns y), this strategy earns the temptation payoff x instead of 10 in one period, and it always earns the punishment payoff y instead of 10 in period $j_L + 1$ and after.

One obtains j_L by equating (11) to (12) and solving. Straightforward algebra yields

$$x\frac{n - j_L - 1}{n - j_L} = (10 - y)([n - j_L]/2 - 1 + \frac{1}{n - j_L}). \quad (13)$$

Using the approximations, valid for large $n - j_L$, that $\frac{n-j_L-1}{n-j_L} \approx 1$ and $[n - j_L]/2 - 1 + \frac{1}{n-j_L} \approx [n - j_L]/2$, we can solve (13) to obtain $j_L \approx n - \frac{2x}{10-y}$ and $s_L = j_L/n \approx 1 - \frac{2x}{10-y}/n$. The last expression is exactly the same as the continuous time expression (3) when $\tau = 1/n$.

B.2 Predictions when $s_L \leq 0$

The expressions obtained so far are valid if $s_L \geq 0$ in (3). When $s_L \leq 0$, the expressions can be extended mechanically by treating s_L in (3) as a latent variable, observed as 0 when the expression is negative. The effect on (4) turns out to be simple—one just truncates (4) below at zero. To confirm this, note that in the present case the distribution F is a specific mixture of $U[0, 1]$ and the degenerate (Heaviside) distribution at 0. The mixture weight on the uniform distribution is $w = \frac{10-y}{2x\tau} < 1$ since that is the fraction of the line segment $[s_L, 1]$ that lies above zero when $s_L < 0$ in (3). Hence $F(y) = 1 - w + wy$. Applying (10), we solve $z = F(m)$ to obtain $m = \frac{z+w-1}{w} = \frac{w-1/\sqrt{2}}{w} = 1 - 1/(\sqrt{2}w) = 1 - \frac{\sqrt{2}x\tau}{10-y}$ when this expression is positive, and otherwise $m = 0$.

On the other hand, $s_L \leq 0$ overstretches the idea of equilibrium in ND distributions, because in this case, $K(0)$ (never cooperating) yields a higher expected payoff than $K(1)$ (fulltime conditional cooperation). We might therefore make the convention of predicting no cooperation in this case, which is potentially relevant for Grid-8 when $x = 18$ and for Grid-4 and Grid-2 with all parameter values. However, it turns out that this convention and the convention in the previous paragraph yield the same numerical predictions in all cases we study.

Parameters	Block 1	First Half	Second Half	Block 8
One-Shot				
Easy	0.000	0.000	0.000	0.000
Mixa	0.000	0.000	0.000	0.000
Mixb	0.000	0.000	0.000	0.000
Hard	0.000	0.000	0.000	0.000
Grid-8				
Easy	0.000	0.125	0.75	0.75
Mixa	0.125	0.125	0.5	0.5
Mixb	0.125	0.000	0.000	0.000
Hard	0.000	0.000	0.000	0.000
Continuous				
Easy	0.767	0.839	0.930	0.919
Mixa	0.336	0.763	0.889	0.883
Mixb	0.275	0.859	0.900	0.917
Hard	0.521	0.692	0.805	0.794

Table 6: One-Shot, Grid-8 and Continuous

n	Block 1	Block 2	Block 3
2	0.000	0.000	0.000
4	0.500	0.250	0.000
8	0.375	0.250	0.500
15	0.367	0.80	0.733
30	0.633	0.85	0.717
60	0.550	0.808	0.875

Table 7: Grid-n

Online Appendix C: Behavior Over Periods

In this appendix we report statistics on mutual cooperation rates across stationary repetitions.

Table 6 Lists median cooperation rates for One-Shot, Grid-8 and Continuous treatments and all parameters in the first and final 4-period blocks and the first and second half of periods. Results reveal that rates of cooperation increase over time in Continuous, doubling in some treatments. The same is true in Grid-8 for Easy and Mix-a parameters though median cooperation drops to zero quickly in Mix-b and Hard. Cooperation never rises above a median rate of zero in One-Shot.

Table 7 displays cooperation rates for each value of n for each of the three 12 period blocks. Recall, each value of n is observed twice during each of these blocks in varying orders across session. Within-subject variation of n generates relatively noisy results within each block, particularly in Block 1. By Block 2 there is a general trend towards higher rates of cooperation as n increases and the ordering becomes quite firm by Block 3. In the body paper we attempt to improve precision

by pooling Blocks 2 and 3.

Online Appendix D: Instructions to Subjects

The following is the instructions from Continuous sessions. Grid and One-Shot instructions carefully match Continuous ones, deviating only where necessary, and are available upon request.

Instructions (C)

Welcome. This is an experiment in the economics of decision-making. If you pay close attention to these instructions, you can earn a significant amount of money that will be paid to you in cash at the end of the experiment.

The Basic Idea

A	10, 10	0, 14
B	14, 0	6, 6
	a	b

In each of several periods you will be randomly matched with a counterpart, a person in this room. Each period you will choose one of two actions: “A” or “B”. Your counterpart will choose “a” or “b”.

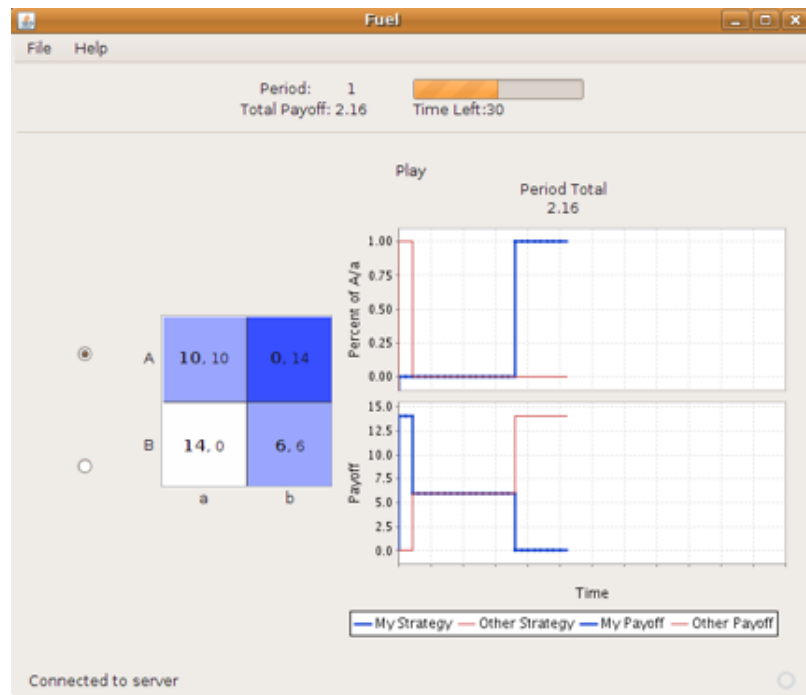
Your earnings will depend on the combination of your action and your counterpart’s action. These earnings possibilities will be represented in a matrix like the one above. Your action will determine the row of the matrix (A or B) and your counterpart’s will determine the column of the matrix (a or b). The cell corresponding to this combination of actions will determine earnings as follows. In each cell are two numbers. The first of the two numbers (shown in bold) is your earnings from this action combination. The second number is your counterpart’s earnings.

For example, in the sample matrix above, if you chose A and your counterpart a, you would earn 10 points and your counterpart 10. If instead your counterpart chose b, you would earn 0 points and your counterpart would earn 14.

When you start a new period, you will be randomly matched with a different counterpart. We do our best to ensure that you and your counterpart remain anonymous.

The payoff matrix in a new period is not always the same as in the previous period, so you should always look at it carefully at the beginning of the period.

Details on How to Play



Periods will each last 60 seconds and the clock at the top of the screen will show how much time is left. Each period, the computer will start you and your counterpart off with randomly chosen actions. At any moment during the period, you will be able to change your action by clicking the two radio buttons (or by using the arrow keys). The row corresponding to your chosen action and the column corresponding to your counterpart's action will both be highlighted in blue. You and your counterpart may change your decision as many times as you want over the course of the period.

The numbers in the payoff matrix are the period payoffs you would earn if you maintained the same action throughout the period. For instance if you played B for the entire period and your counterpart b in the example above, you would earn 6 points and your counterpart 6 points.

In each period the payoffs depend only on how much time is spent in each cell of the payoff matrix. The more time you spend in any one cell, the closer final payoffs will be to the payoffs in that cell. For example, if you played A for half of the period and B for the other half while your counterpart played b for the entire period, then your earnings would be $(1/2)0 + (1/2)6 = 3$ and your counterpart's earnings would be $(1/2)14 + (1/2)6 = 10$. This is because you spent half of the period

in the upper left cell and half the period in the lower right cell of the payoff matrix.

To the right of the payoff matrix are two graphs showing outcomes over the course of the period. The top graph shows your action (in blue) and your counterpart's action (in red) so far during the period. The graph is labeled "Percentage of A." If this is at 100% it means that at that moment you are using action A. If it is 0% it means at that moment you are using action B. The graph tracks any changes you and your counterpart make during the period.

The bottom graph shows your earnings over the course of the period in blue. On the horizontal axis is your payoff and on the vertical axis is the percentage of time elapsed. The more area below your earnings curve, the more you have earned. The red line on this graph shows the corresponding payoffs for your counterpart.

Earnings

You will be paid at the end of the experiment based on the sum of point earnings throughout the experiment. These total earnings are displayed as the Total Payoff at the top of the screen. The conversion rate from points to US dollars is written on the whiteboard.

Frequently Asked Questions

Q1. Is this some kind of psychology experiment with an agenda you haven't told us?

Answer. No. It is an economics experiment. If we do anything deceptive or don't pay you cash as described then you can complain to the campus Human Subjects Committee and we will be in serious trouble. These instructions are meant to clarify how you earn money, and our interest is in seeing how people make decisions.

Q2. If I choose the rows and my counterparty chooses the columns, does his (or her) screen look different than mine?

Answer. On his or her screen, the same choices are shown as rows. For example, if s/he chooses row B then it shows up on your screen as a choice of the b column. Of course, the payoff numbers are the same on both screens, just shown in a different format.