# The Effects of Social Context and Acute Stress on Decision-Making Under Uncertainty

Oriel FeldmanHall[a], Candace M. Raio[a], Jennifer T. Kubota[d,e], Morgan G. Seiler[a], Elizabeth A. Phelps[a,b,c]
[a]Department of Psychology, New York University, New York NY 10003
[b]Center for Neural Science, New York University, New York NY 10003
[c]Nathan Kline Institute, Orangeburg, NY 10962
[d] Department of Psychology, University of Chicago, Chicago, IL 60637
[e]The Center for the Study of Race, Politics, and Culture, University of Chicago, Chicago, IL 60637

## SUPPLEMENTAL INFORMATION

**Verbal Instructions for Lottery and Trust Games.** "You will be playing a game for real money that you can take home. I am now giving you an additional $20. This $10 is for game 1, and this $10 is for game 2. If at any time you find that this is something that you do not wish to participate in for any reason, you are of course free to leave whether we have started the game or not. You will still be paid the $15. In one of the games you are about to play, you will play in pairs with another player. Each pair is made up of a Player 1 and a Player 2. You will be playing as Player 1 today. Whatever amount Player 1 (you) decide to share with Player 2 will be quadrupled when it is passed on to Player 2. Player 2 then has the option to split this quadrupled amount with you, or keep all of it to himself. For example, lets say you decide to share $6 with your partner. This will then be quadrupled to $24. Your partner then has the option to either split that $24 with you, in which case you will both get $12, or to keep it all, leaving you with nothing and keeping $24 for himself. You will be playing with people that we have previously interviewed, photographed, and recorded their responses. You will be playing 36 trials of this game, which means you will play with 36 different partners. However, only one trial of this game will be realized and paid out to both you and your partner. In other words, a computer will randomly select a trial to pay you out. We will then match the partner on that trial with their actual response, so if your partner decided to split the $24 with you, you will each receive $12, and you will walk away with an additional $12 today and your partner will be mailed $12. This will be explained in more detail when you read the instructions on the task."

"The other game you will be playing today will not involve another player, but will be a lottery. Again you will make decisions about playing gambles in which you can win or lose money. One of these gambles will be randomly picked, and you will be paid out if you won the lottery, or you will have to give up some of the additional $10 I just gave you if you lost the gamble. For example, lets say you gamble $6 of the $10 given to you. In one scenario there is the chance to win, double your money, and take home $12. In the other scenario you will lose your investment of $6. Once you start the game there will be more detailed instructions."

**Regression Analysis.** Although we speculated that stress would have specific effects on how feedback is incorporated in decision-making under uncertainty in the social versus non-social domains, we first ran an initial regression that included all parameters (i.e. feedback, condition, and game). For this initial regression model, lagged feedback (on the previous trial t-1) was coded such that 1 denotes a 'reciprocate' in the Trust game or 'win' in the Lottery game, -1 denotes a 'defect' in the Trust game or a 'loss' in the Lottery game, and 0 denotes a trial in which the participant chose not to gamble or trust; condition was coded as -1 for Control and 1 for Stress; and game was coded as -1 for Lottery and 1 for Trust. We then fit participants' choices to gamble or trust as a function of feedback X game X condition. Thus, within-subjects factors were intercept, main effects of feedback, game, condition, and their interactions. Estimates are reported at the group level. Results reveal that while there was a main effect of feedback and game, and interactive effects of feedback x game and game x condition, there was no three-way interaction among condition, feedback, and game (Table S1). Because our main interest is how feedback is incorporated into social versus non-social decision-making under stress, we fit the choice data in separate regressions for each condition to explore the simple effect of feedback within each condition (see manuscript).

| TABLE S1 | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *3.79 (0.27)* | *<0.001* |
| | Feedback | *-0.39 (0.12)** | *0.001* |
| | Game | *-0.24 (.039)** | *<0.001* |
| | Condition | *-0.02 (0.27)* | *0.95* |
| | Feedback X Game | *0.10 (0.05)** | *<0.04* |
| | Feedback X Condition | *0.00 (0.12)* | *0.97* |
| | Game x Condition | *-0.29 (0.04)** | *<0.001* |
| | Feedback X Game X Condition | *-0.04 (0.05)* | *0.44* |

*Significance at the 0.05 level

**Table S1 | Choice Behavior**: Linear regression coefficients of decisions of uncertainty (to trust or gamble between $0 and $10 on each trial) indicating influence of outcome of previous trial (feedback: t-1), condition (control, stress), game (Lottery, Trust), and their interactive effects.

**Reinforcement-learning model**. It is also possible that multiple previous experiences shape current decisions. In other words, during either the Trust or Lottery games, a subject might compute the reinforcement schedule, and thus how much money is received through their partner reciprocating a offer or how much money is received from a gamble. If a participant uses multiple previous trials to compute their odds of getting a positive outcome (reciprocate or win), it would indicate that the participant is learning across trials. To test this, we created a reinforcement-learning model with no assumptions that provides a set of weights using the following equation:

$$Choice_t = \beta_0 + \beta_1(FB_{t-1}) + \beta_2(FB_{t-2}) + \beta_3(FB_{t-3})$$

Where $Choice_t$ is the participant's choice on the current trial, $FB_{t-1}$ is the feedback on the previous trial, $FB_{t-2}$ is the feedback on two trials back, and $FB_{t-3}$ is the feedback on three trials back. Thus, the regression gives a set of values for the recent history of feedback that best predicts current choice (Bayer and Glimcher 2005). We used separate regressions for each condition and game. The regression results revealed that only in the Control condition during the Lottery task does more than one trial back influence choice (Table S2A). In the Stress condition during gambles, only $FB_{t-1}$ significantly predicted current choice (Table S2B). In the Trust task, participants in the Control condition did not use any previous trials (Table S3A, akin to the findings in the manuscript), while those in the Stress condition used $FB_{t-1}$ when making their decision to trust (Table S3B). Effectively, the reinforcement-learning model confirms the results in the manuscript.

TABLE S2 LOTTERY

| A \| Control | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *3.68 (.46)* | *<0.001* |
| | | *-0. 72 (.31)** | *0.01* |
| $FB_{t-1}$ | | *-0.43 (0.21)** | *0.04* |
| | | *-0.19 (0.12)* | *0.11* |

| B \| Stress | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *4.34 (.43)* | *<0.001* |
| | | *-0.54 (.21)** | *0.01* |
| $FB_{t-1}$ | | *-0.22 (0.16)* | *0.18* |
| | | *0.06 (0.11)* | *0.58* |

*Significance at .05

TABLE S3 TRUST

| A \| Control | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *3.82 (0.40)* | *<0.001* |
| | | *-0.16 (0.21)* | *0.46* |
| $FB_{t-1}$ | | *0.24(0.15)* | *0.09* |
| | | *0.009 (0.13)* | *0.94* |

| B \| Stress | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *3.28 (0.37)* | *<0.001* |
| | | *-0.44 (0.14)** | *0.002* |
| $FB_{t-1}$ | | *-0.04 (0.11)* | *0.70* |
| | | *0.10 (0.09)* | *0.27* |

*Significance at .05

**Table S2 & S3 | Reinforcement Learning Model**: Linear regression coefficients of decisions to gamble and trust indicate that the feedback from one trial back is most predictive for both the Lottery and Trust choices when under stress.

**Weighted Average Learning Model**. An alternative explanation is that participants use a collection of previous experiences to shape current choice. To test this alternative model, we created a moving window that could account for the weighted average feedback received over the past three trials (Lempert, Glimcher et al. 2015). For instance, say a subject received no feedback on trial one (0), positive feedback on two (1), and positive feedback on trial three (1). This then would be coded as the feedback received for these past three trials divided by total number of trials (always three), or in this case, the equivalent of 2/3. This fraction is then entered into the regression model as the feedback on trial four. The feedback is recalculated on every trial, according to the type of feedback (or lack thereof) on the previous three trials. This assumes that the learning rate is flat throughout the task. We used the same regression model structure presented in the manuscript to determine if this feedback structure predicted choice. Results reveal that only decisions made in the non-social domain (gambles)—irrespective of whether the subject was in the control or stress manipulations—were susceptible to the aggregated feedback received over the past three trials (Table S4). In other words, while we found no effect of using feedback over the past three trials to inform the next choice during the

Trust game (all Ps>.32), there was a main effect of feedback received over the past three trials in the Lottery game (p=0.006), again illustrating the robustness of gamblers' fallacy.

TABLE S4

| Lottery | Coefficient ($\beta$) | Estimate (SE) | P value |
|---|---|---|---|
| | Intercept | *3. 72 (0.46)* | *<0.001** |
| | Feedback (average past 3 trials) | *-1.47 (0.54)* | *0.006** |
| | Condition | *0.62 (0.63)* | *0.32* |
| | Feedback X Condition | *0.72 (0.65)* | *0.27* |

*Significance at the 0.05 level

**Table S4 | Feedback for past three trials in Lottery game**: Linear regression coefficients of decisions to gamble indicating influence of outcome of previous three trials (feedback), condition (control, stress), and their interactive effects.

**Gender differences**. There were no significant differences for money gambled or trusted between males (n=12) and females (n=16) in the stress group (Lottery: $F(1,1)=0.22$, $p=0.64$; Trust: $F(1,1)=0.59$, $p=0.48$). Although not significant, there were small gender differences in the control group for both the Lottery ($F(1,1)=1.83$, $p=0.19$) and Trust ($F(1,1)=3.55$, $p=0.07$) tasks, such that males (n=14) gambled (mean $4.35 SD 2.39) and trusted (mean $4.54 SD 2.28) slightly more than females gambled (mean $3.12 SD 2.38) and trusted (mean $3.08 SD 1.76). We also explored whether engaging with only male Trustees may have influenced behavior differentially between male and female participants. We did not find any significant differences in the stress group between male and female participants (P=.64), or in the control group between male and female participants when trusting male Trustees (P=.07).

**Order effects.** Even though the Trust and Lottery tasks were counterbalanced, we wanted to ensure that there were no order effects across the experiment. We therefore ran an ANOVA to test whether completing the Trust or Lottery task first had an effect on how much money was gambled/trusted, while also accounting for condition (stress versus control manipulations). For the Lottery task, we found no main effect of task order (p=0.42) or interactive effect of task order X condition (p=0.46). Similar results were found for the Trust Game: no main effect of task order (p=0.36) and no interactive effect of task order x condition (p=0.50).

**Cold Pressor Task (CPT).** During the CPT, subjects randomly selected to be in the stress condition were asked to submerge their right forearm in ice water. The ice-bath was hidden from the subjects' view until they were asked to place their arm in the ice water. Once a subject's arm was submerged in the ice-bath, the experimenter would turn her eyes to her own note pad so that the subject did not feel that he or she was being watched or observed during the CPT. The same protocol was followed during the control manipulation (i.e. room temperature water). During both manipulations, the experimenter stayed in the room while the subject submerged their forearm in the water.

**Reaction times**

*Raw reaction times*. Subjects were slower to trust another player then they were to gamble, regardless of whether they were in the control or stress condition. In the control condition, subjects spent on average 3.2 seconds ±2.9 SD deciding whether to trust another, which was significantly more than the average time spent deciding to gamble: 1.4 seconds ±0.74 SD ($t(27)=3.49$, $p=0.002$). The same pattern was observed in the stress condition, as subjects spent on average 3.2 seconds ±1.6 SD deciding whether to trust another, significantly more time then deciding to gamble: 1.6 seconds ±1.2 SD ($t(27)=6.6$, $p<0.001$). There were no significant differences between groups (control v stress) in their reaction times to trust or gamble ($F(1,54)=0.49$, $p=0.75$).

*Logged reaction times*. Since reaction times were positively skewed, we log transformed reaction times. The results remain the same: subjects were slower to trust another player then they were to gamble, regardless of whether they were in the control or stress condition. In the control condition, subjects spent on average 7.8 seconds ±0.64 SD deciding whether to trust another, which was significantly more than the average time spent deciding to gamble: 7.1 seconds ±0.48 SD ($t(27)=6.39$, $p<0.001$). The same pattern was observed in the stress condition, as subjects spent on average 7.9 seconds ±0.59 SD deciding whether to trust another, significantly more time then deciding to gamble: 7.2 seconds ±0.64 SD ($t(27)=5.39$, $p<0.001$). There were no significant differences between groups (control v stress) in their reaction times to trust or gamble ($F(1,54)=0.02$, $p=0.89$). It is possible that longer reaction times when deciding to trust indicates that participants are weighing more components within the social decision-making space. Alternatively, longer reaction times when choosing to trust may reflect that participants feel more uncertainty about decisions involving others (these choices contain more perceived ambiguity) than decisions to gamble.

**Choice Rate**. An examination of choice behavior revealed that participants trusted at roughly the same rate, regardless of condition (stress, control). However, in the Lottery game, participants gambled at a higher rate under stress than they did in the control condition.

| Game | Condition | Choice rate | $\chi^2$ (p value) |
|---|---|---|---|
| **Trust** | Control | *70%* Play | *0.06 (0.81)* |
| | Stress | *70%* Play | |
| **Lottery** | Control | *67%* Play | *21.7 (<0.001)* |
| | Stress | *77%* Play | |

SUPPLEMENT REFERENCES

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