Acute Stress alters Social Discounting rate among males

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Seminar in Experimental Psychology Term Project

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Context

- ❏ *Introduction and Background of Study*
- ❏ *Goal of the Study*
- ❏ *Experimental Design*
- ❏ *Behavioral Results*
- ❏ *Candidate models*
- ❏ *Model outputs and Comparison*
- ❏ *Parameter Recovery*
- ❏ *Future plan*

Introduction

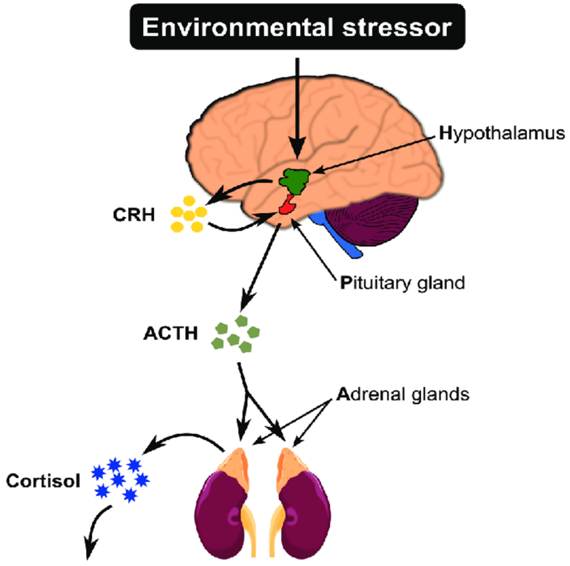

Figure 1[1]

When individuals experience a stressful situation, a biological cascade occurs in the body. We call it stress response. Among a variety of different kinds of reactions in and out of our body in response to stress, fight and flight, tend and befriend are the representing types. "Fight and flight" is deeply related to choosing whether to fight or avoid any danger or threat when we face it. On the other hand, the "tend and befriend" theory builds on the observation that some are more likely to affiliate in response to stress. Under conditions of threat, they tend to offspring to ensure their survival and affiliate with others for joint protection and comfort[2].

Besides fight or flight responses, stress research in social psychology found increased tend and befriend behavior pattern among female, which suggests increased tending and nurturing behaviors among stressed individuals.

1) Lanoix, D., & Plusquellec, P. (2013)
2) Taylor, S. E. (2012). Tend and befriend theory

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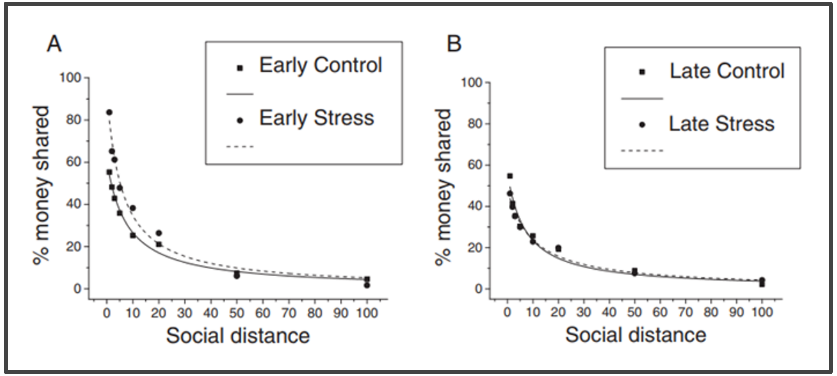


Figure 2[1]

A recent studies in social discounting suggested that the **<u>stressed males also show tend-and befriend pattern.</u>** Stressed males showed prosocial behaviors by increasing money sharing behaviors toward close others. Control group would, on average, shared about 55 percent of their endowment toward their closest friends, whereas the stressed males share upto 80 percent. This finding was replicated when they administered hydrocortisone, which elevates cortisol levels.

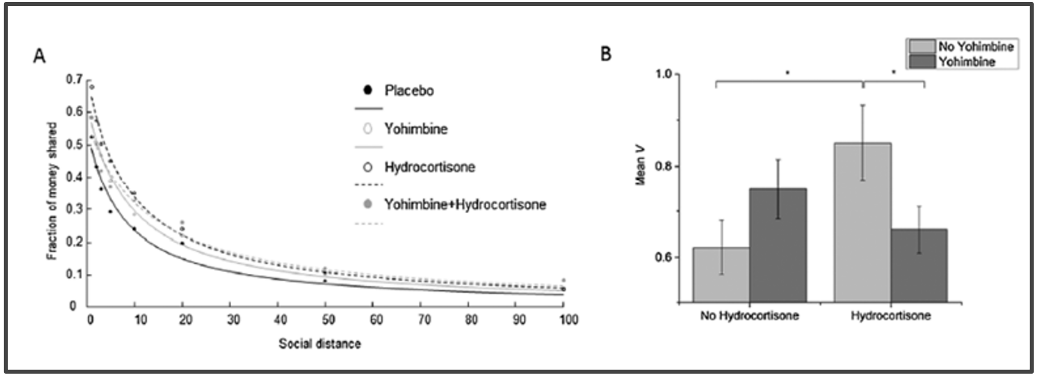


Figure 3[2]

Indeed, the pharmaceutical treatment increased money sharing behaviors among male, and the author concluded that the cortisol is a prosocial hormone. However, as seen in the graph, there seem to be a floor effect of money sharing behaviors toward distant others.

1) Margittai et al., (2015)
2)Margittai et al., (2018)

Background Study

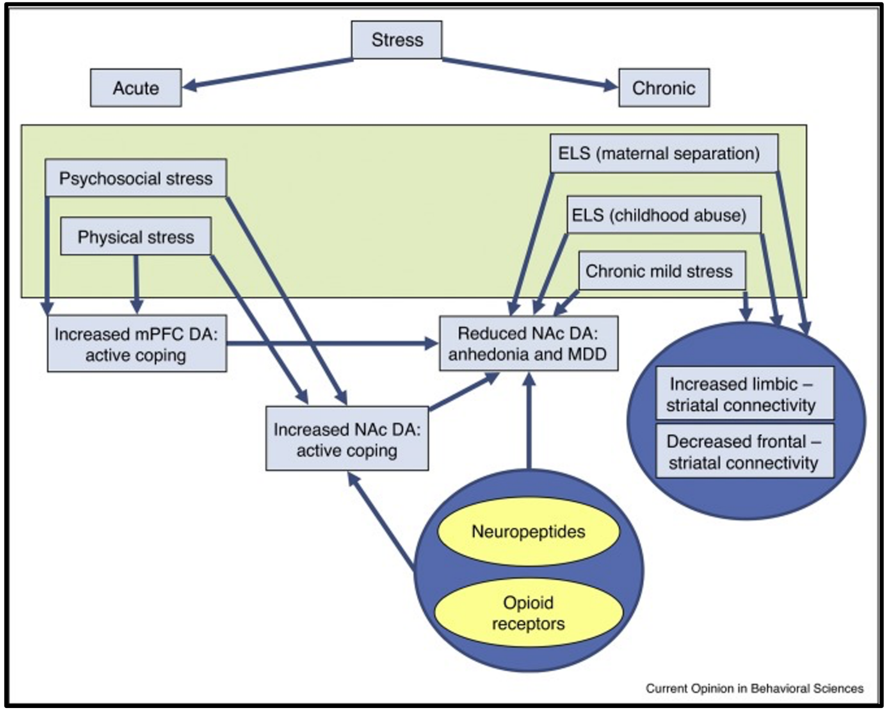


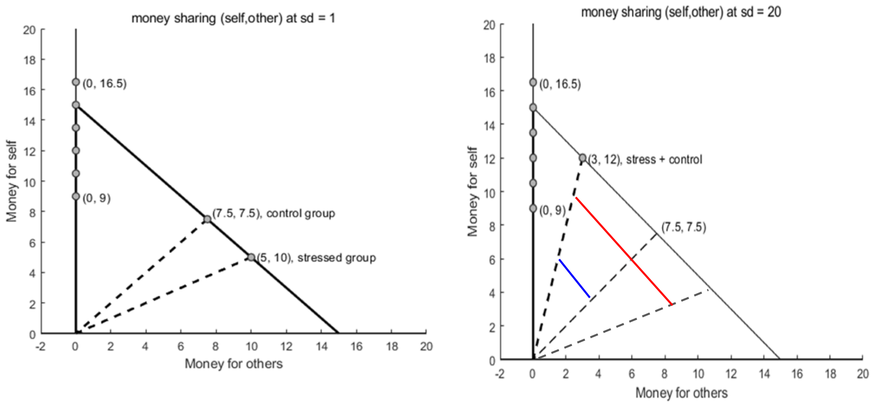
Figure 4[1]

However, another recent review article suggested that the acute stress affects both mesolimbic and mesocortical pathways, amplifying the DA signalings in both pathways. This finding contradicts the findings in the Margittai et al (2015), Martittai et al., (2018) and Soutscheck et al., (2017). Unlike the previous studies that have reported increased prosocial behaviors among men, suggesting acute stress responses affect prosocial decisions, **Ironside et al (2018)** asserted that acute stress should have amplified the signalings of dopamine receptors including D2/D3 receptors, **preserving certain levels of selfishness** among males. Such conflicting findings suggest there should be additional research in the realm of social discounting related to stress response.

1) Ironside et al., (2018)

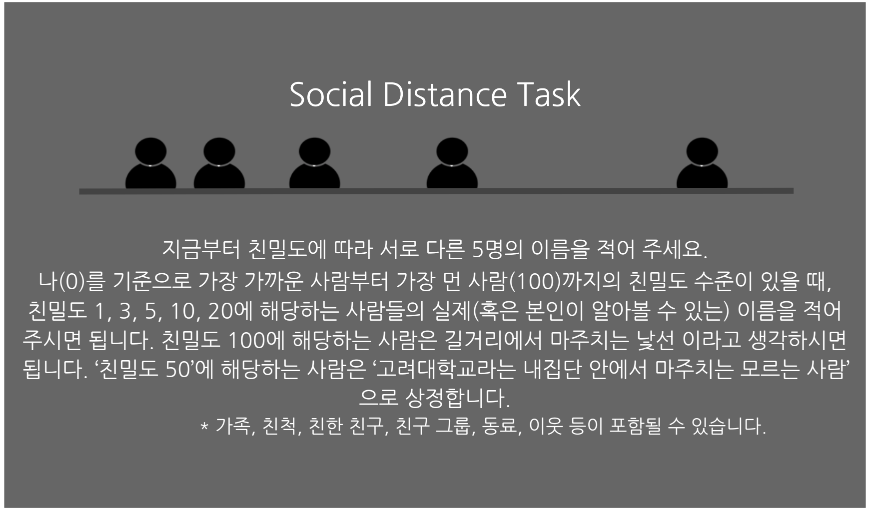
Goal of the study

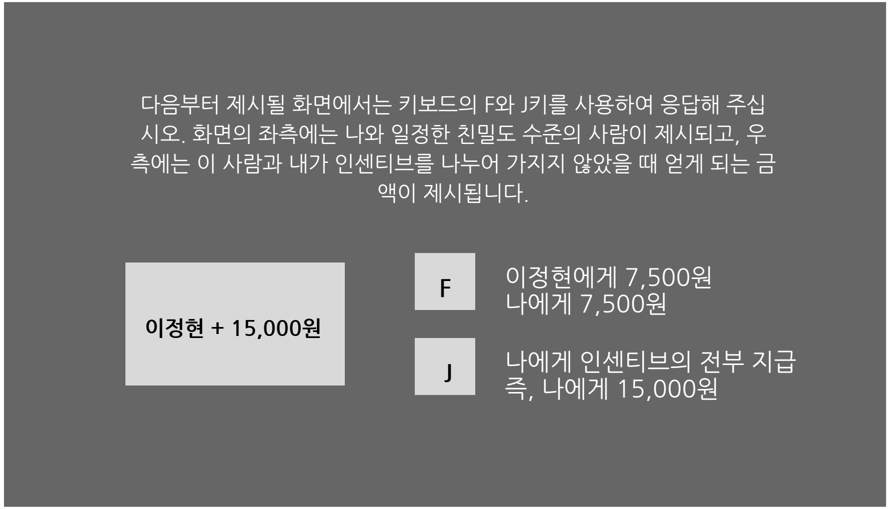
Is cortisol a prosocial hormone?



One of the major goal of the study is to check **whether the cortisol is indeed a prosocial hormone.** We focused on **whether the prosocial behaviors, would be amplified among the stress males, even toward the distant others.** The diagonal straight line represent the endowment from previous experiment. The stressed group, on average, shared more money than the control group to their closest friend as represented in the dotted line. However, the level of discounting of the other reward was greater in the stressed group (red) than the control to acquaintance (blue line). Here, we modified previous experimental design so that individuals can choose to give more money toward their distant others. If stress hormone is indeed a prosocial hormone, we should observe an increased money sharing behaviors in overall social distance.

Experimental Design



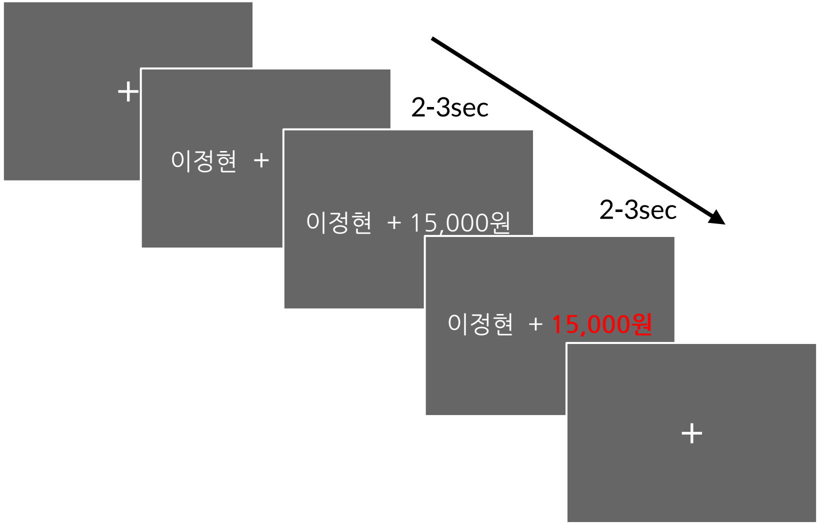


Before the main task, <u>**actual names across different social distance**</u> from participants were collected in order to ensure realistic social atmosphere. A a random person you run into on campus was set as social distance of 50 since at least one knows that he or she goes to same university with him.
Now with social distance level 50 set, the participants were made to give 5 different names of different people with social distance of 1, 3, 5, 10, and 20.

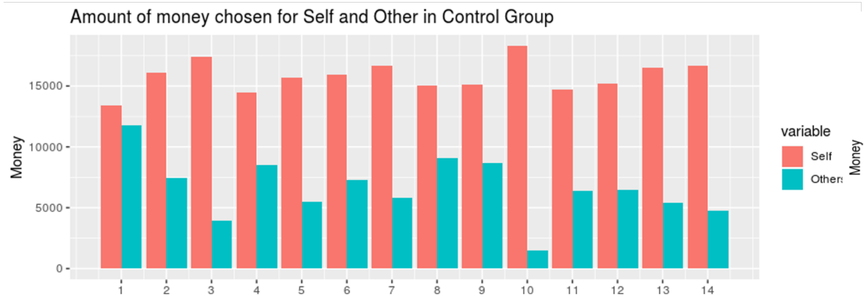
Experimental Design

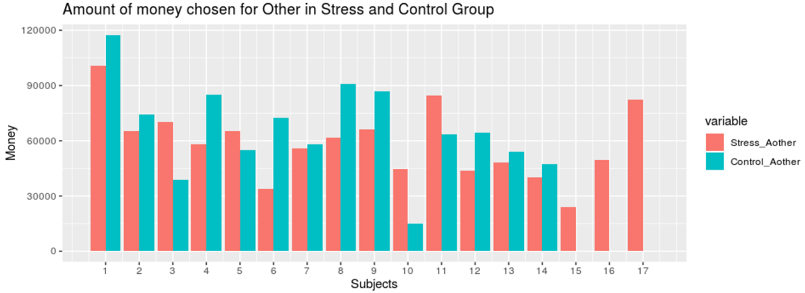
- *Subject* : Control (n=14) Stressed (17, 2 ex)
- *Trial numbers* : 144
- *Incentives* : 6 Lvs
- *Social Distance* : 1 / 3 / 5 / 10 / 20 / 50 (6 Lvs)
- *Conditions* : Equal   (7.5 for self, 7.5 for others)
  Unequal(5 for self, 10 for others)

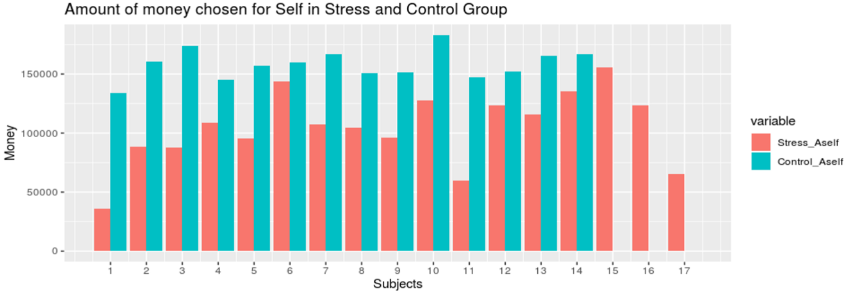
SD	**Split**		**Non-Split** (A_self)
	Unequal /	**Equal**	
1	5,000 (A_defaut)	7,500 (A_default)	16,500
3			15,000
5			13,500
10	10,000 (A_other)	7,500 (A_other)	12,000
20			10,500
50			9,000



Behavioral Results

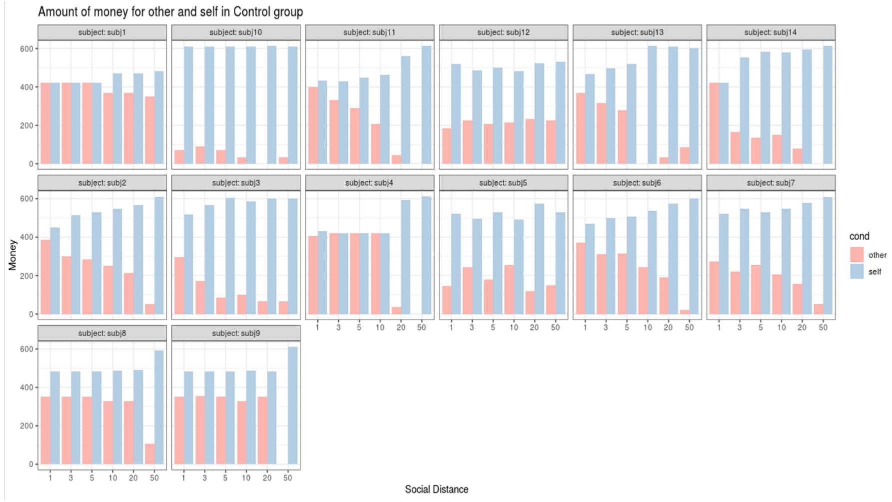


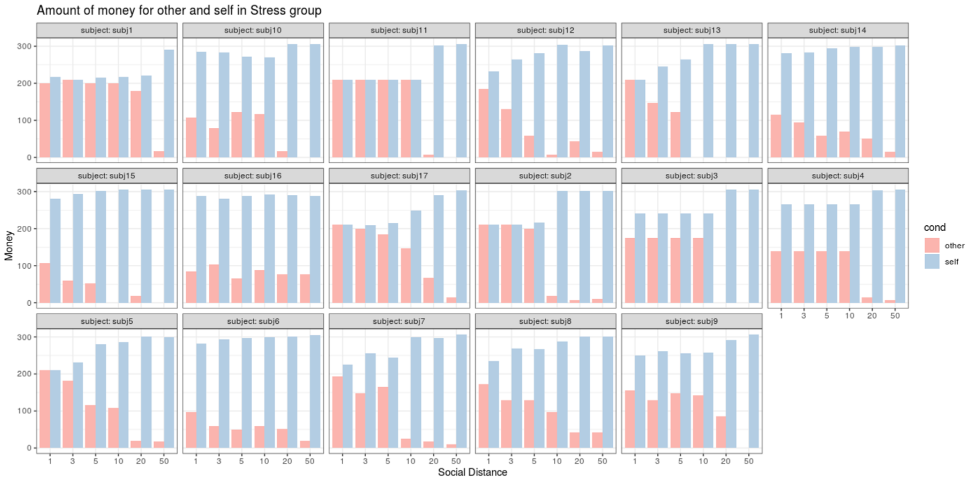




Behavioral results indicate choices for self and other for each subject across conditions. It is assumable that **people became less selfish when they are stressed out** from the graph right below because control group definitely gave out more for themselves. Also, from the behavioral plots, we decided to extract 2 subjects out of 19 subjects from stress group. So the total number of subejcts used for the analysis is 14 for control and 17 for the stress group.

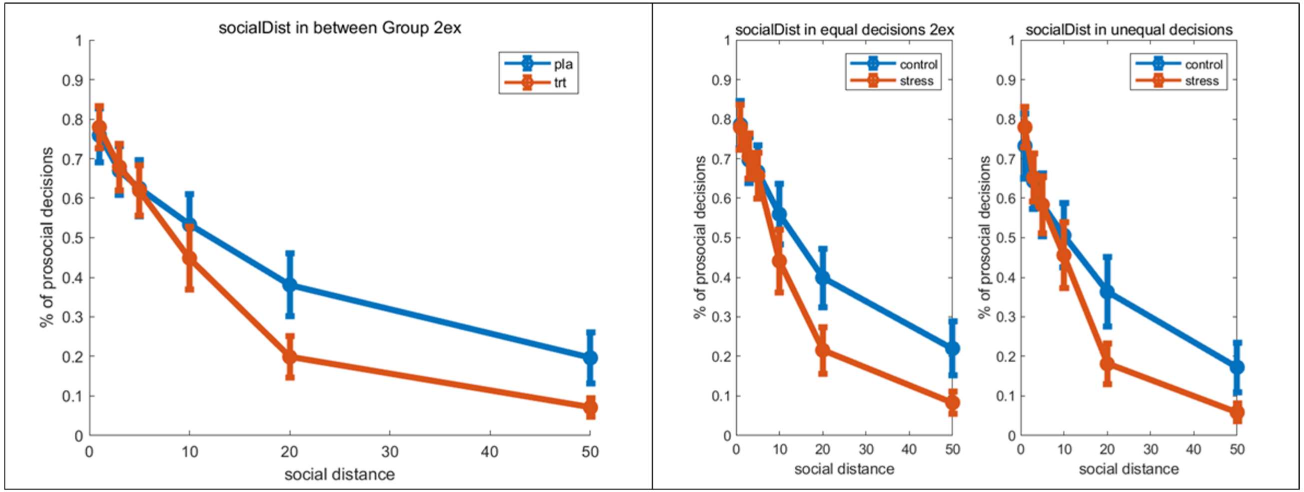
Acute Stress alters Social Discounting rate among males





These are individual plots of money chosen for other and self in control group across social distance.
So the x-axis is social distance, from 1 to 50. Subject 11, 2, 6, and 7 from the control group seem to show an expectable pattern in splitting money behavior as they minimized the amount of money splitted to the distant others, compared to the close others.
Also, visual plots helped us in detecting an outlier subject. For instance, if you look at subject 12, this data is very very likely to be troublesome when fitting.
During this term project, we did not take this outlier due to the small sample size, but we further plan to try modeling without these outliers.

Group Level Behavioral Results



And here we plotted group difference in means for splitting behavior for others across social distance. Going against the finding from previous study, we observed different steepness in relationship between social distance and split behavior. To put it bold, <u>**stressed individuals were actually less likely to split for distant others compared to the non-stressed ones**</u>.
The pattern remained same across equal and unequal conditions of splitting money as indicated in the right graph.

Candidate Models

Research Report

Social Discounting

Bryan Jones and Howard Rachlin

Inspired from paper by Jones and Rachlin, 2006, we decided to modify **delay discounting model** to fit to our study. As intertemporal delay discounting task comes along with k, which is the constant measuring degree of discounting, Jones and Rachlin came up with the constant measuring degree of social discounting. Citing from the paper, self-control in terms of delay discounting and altruism may have common origins.

As one can discount the amount of reward intertemporally, one can also discount over social distance in order to make choices in accord with the interests of a relatively larger social group with which they have common interests. To put it simple, **social discounting rate would be interpreted as discount across social distance because the one with smaller social distance from you is highly likely to share common interests**.

Jones & Rachlin, (2006)

Candidate Models

p(split) ∝ SV_other – SV_self

	SV_{self}	SV_{other}
Model 1	$A_{self} - A_{default}$	$\frac{\beta_{other} * A_{other}}{1+D}$
Model 2	$A_{self} - A_{default}$	$\frac{A_{other}}{1+\beta_{other} * D}$
Model 3	$\beta_{self}(A_{self} - A_{default})$	$\frac{\beta_{other} * A_{other}}{1+D}$
Model 4_2	$A_{self}\beta_{self}$	$\frac{A_{self}\beta_{self}}{1+D+A_{self}\beta_{self}}$

Reward level

- ***p(split)***: the probability of an individual splitting money, calculated by the discrepancy between subjective value for other and self
- ***A_self***: Amount of money for self
- ***A_default***: Amount of default money self can take
- ***A_other***: Amount of money for others
- ***β***: Sensitivity towards self reward

Candidate Models

p(split) ∝ SV_other – SV_self

	SV_{self}	SV_{other}
Model 5	$\frac{A_{self}}{1+k*D}$	$\frac{A_{other}+A_{default}}{1+k*D}$
Model 6	A_{self}	$\frac{A_{other}}{1+k*D}$
Model 6__default	A_{self}	$\frac{A_{other}+A_{default}}{1+k*D}$
Model 7	$\beta_{self}*A_{self}$	$\frac{\beta_{other}A_{other}+\beta_{self}A_{default}}{1+k*D}$

	SV_{self}	SV_{other}
Model 8	$\omega * A_{self}$	$(1-\omega)\frac{A_{other}+A_{default}}{1+k*D}$
Model 9	$\omega * A_{self}$	$(1-\omega)\frac{A_{other}-A_{default}}{1+k*D}$
Model 10	$\omega * A_{self}$	$\frac{(1-\omega)A_{other}+\omega A_{default}}{1+k*D}$

From model 1 to 7, ***p(split)*** was calculated with softmax function with the inverse temperature **τ.** Model 8, 9, and 10 were calculated with weighted sum where ***ω*** represents weight for sensitivity towards self amount of reward.

Candidate Models

p(split) ∝ SV_other - SV_self

	SV_{self}	SV_{other}
Model 11	A_{self}^{-1}	A_{other}^{-kD}
Model 12	$(\beta * A_{self})$	$((1-\beta_{self})A_{other})^{-kD}$
Model 13	$(\beta * A_{self})$	$(\beta * A_{default} + ((1-\beta)A_{other})^{-kd}$
Model 14	$\beta(A_{self} - A_{default})$	$(A_{other} * (1-\beta))^{-kD}$

From model 11 to 14, the models were formulated based on the exponential function of delay discounting model.

In overall, our winning models were **model 6_default, 12, and 14**.

For the sampling, total of **4 chains** with **4,000 iterations**, and **2,000 warm-ups** were applied.

Candidate Models

p(choice) ∝ SV_other - SV_self

Model 6_default

$$SV_{net} = \frac{A_{other} + A_{default}}{1 + \boxed{k} * D} - A_{self}$$

Social Discounting Rate

Model 12

$$SV_{net} = ((1 - \boxed{\beta_{self}})A_{other})^{\boxed{-k}D} - (\boxed{\beta} * A_{self})$$

Sensitivity to reward for self

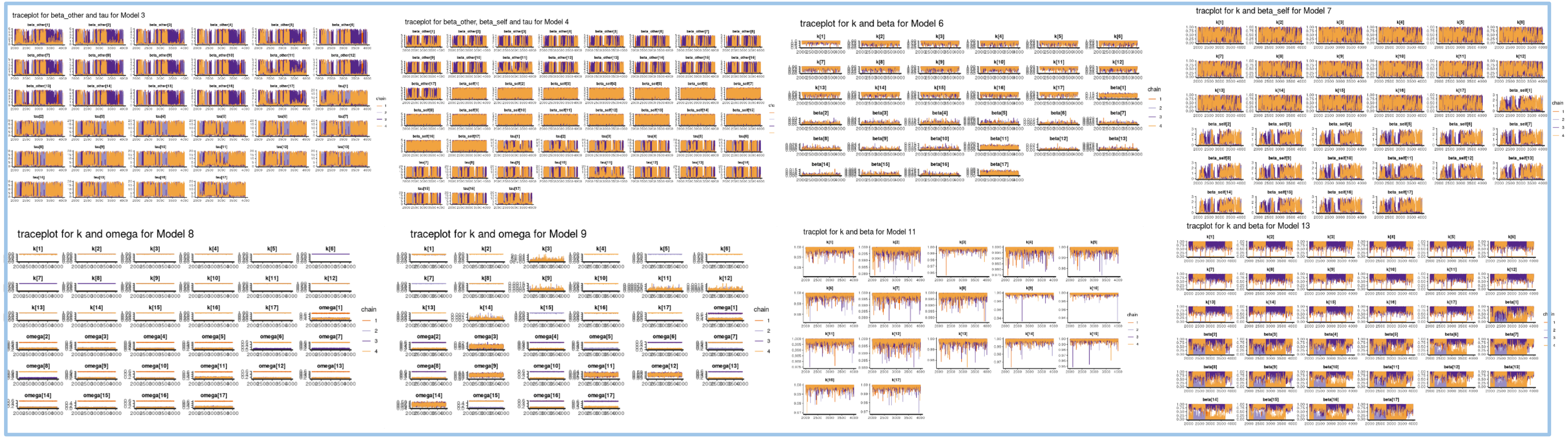
Model 14

$$SV_{net} = (A_{other}(1 - \boxed{\beta}))^{\boxed{-k}D} - \boxed{\beta}(A_{self} - A_{default})$$

These were the winning models for the term project. We tried a few models, and derived these three to be those of the most meaningful models.

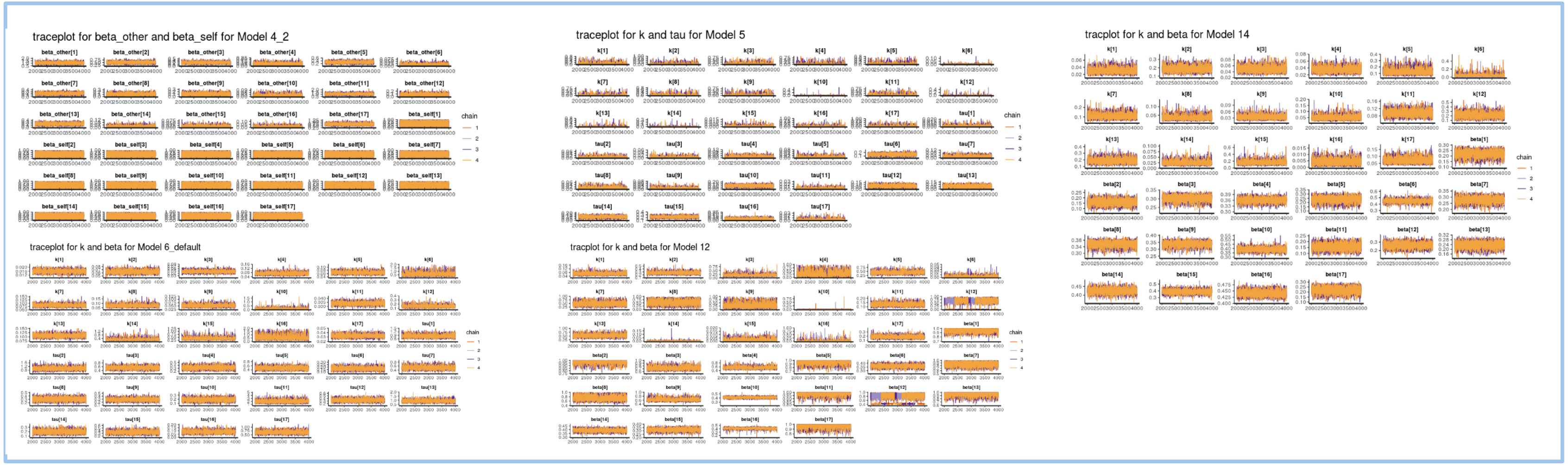
- ***k*** and ***β*** are the main individual parameters for the models, and for the hyperbolic function in Model 6_default, **τ** was estimated as inverse temperature.
- Left part of the right-hand side counts subjective value for other, while the right part counts that for self.

Model outputs and Comparison



A lot of models were discarded by drawing traceplots and checking on r-hat values.
A few of them had toohigh r-hat values, and a few of them showed bad convergence.

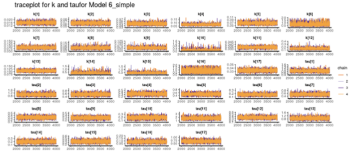
Model outputs and Comparison



Model	Model 4_2	Model 5	Model 6_default	Model 12	Model 14
LOOIC (control)	2502.6	2709.5	1899.3	2417.0	1759.5
LOOIC (stress)	3061.3	3292.4	2026.3	2511.8	1814.0

winning models

Model 6_default



Rhat	Rhat
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
1	1.00
	1.00
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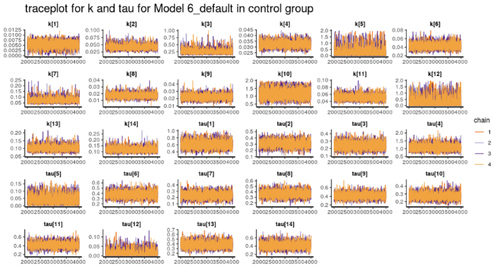
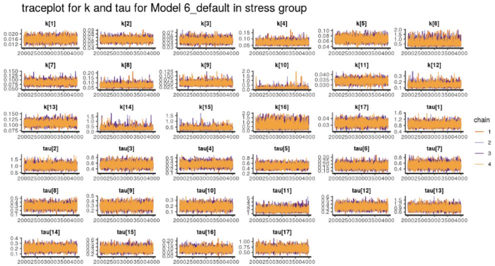
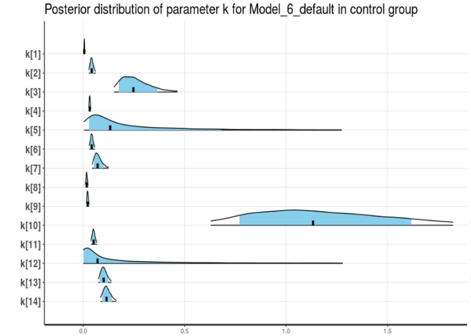
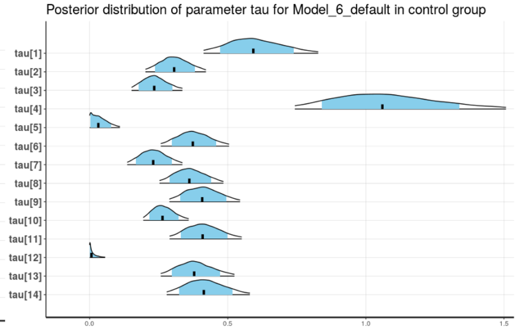
	1.00
	1.01
	1.00
	1.01



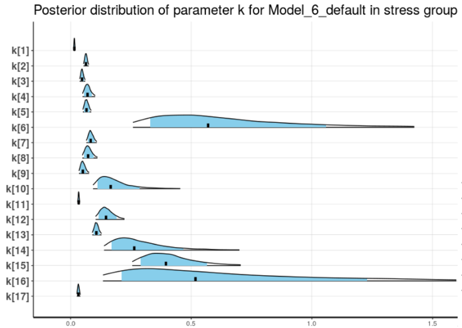


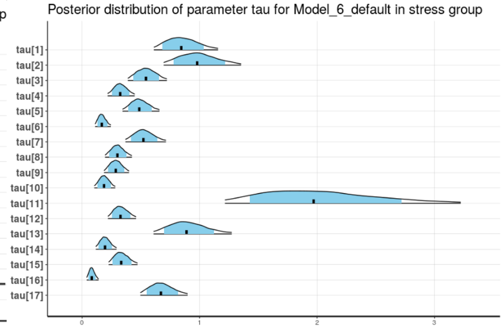
Control group





Stress Group





Model 12

Rhat	Rhat
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.19	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.06
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.00	1.00
1.18	1.00
1.00	1.00
1.00	1.00
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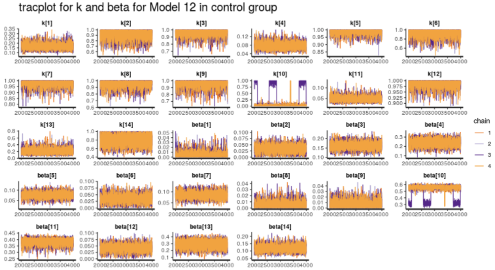
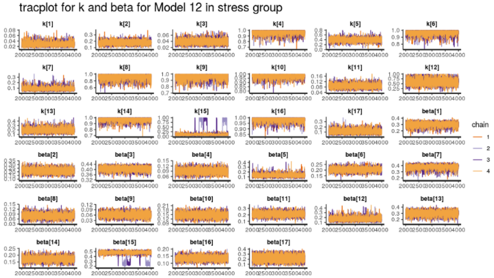
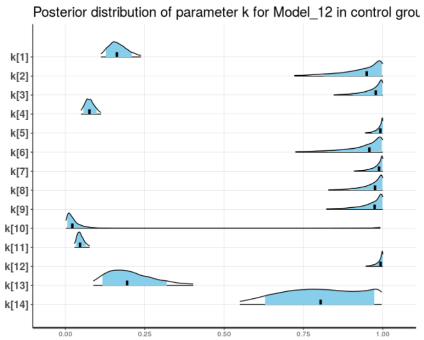
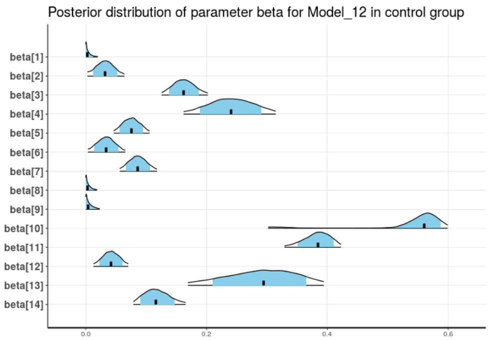
	1.00
	1.00
	1.05
	1.00
	1.00



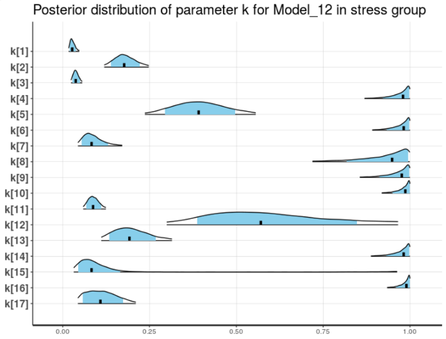


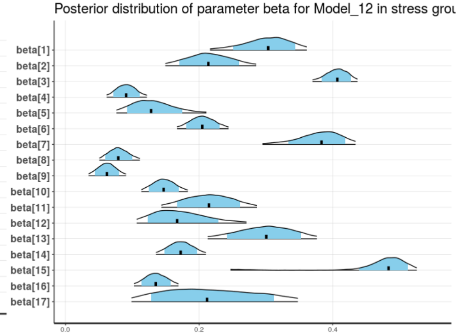
Control group





Stress Group





Model 14

Rhat	Rhat
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
1	1
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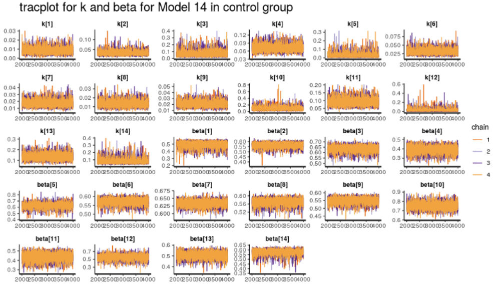
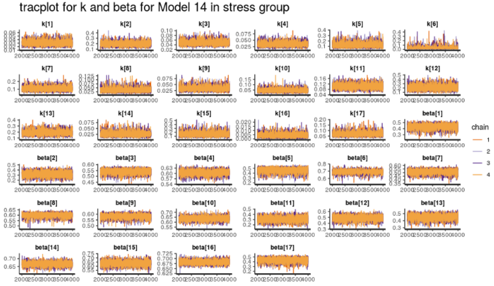
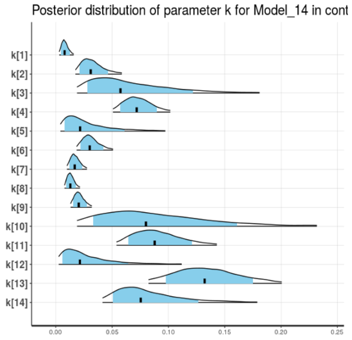
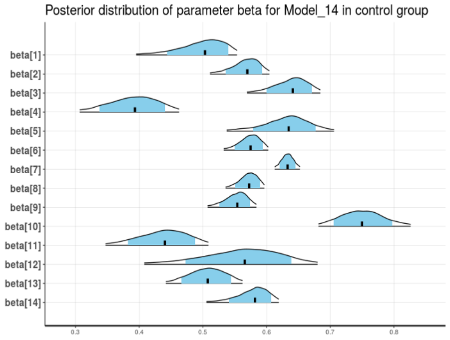
	1
	1



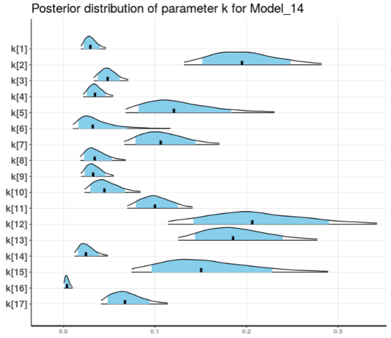


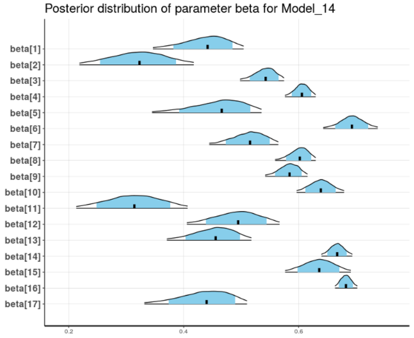
Control group



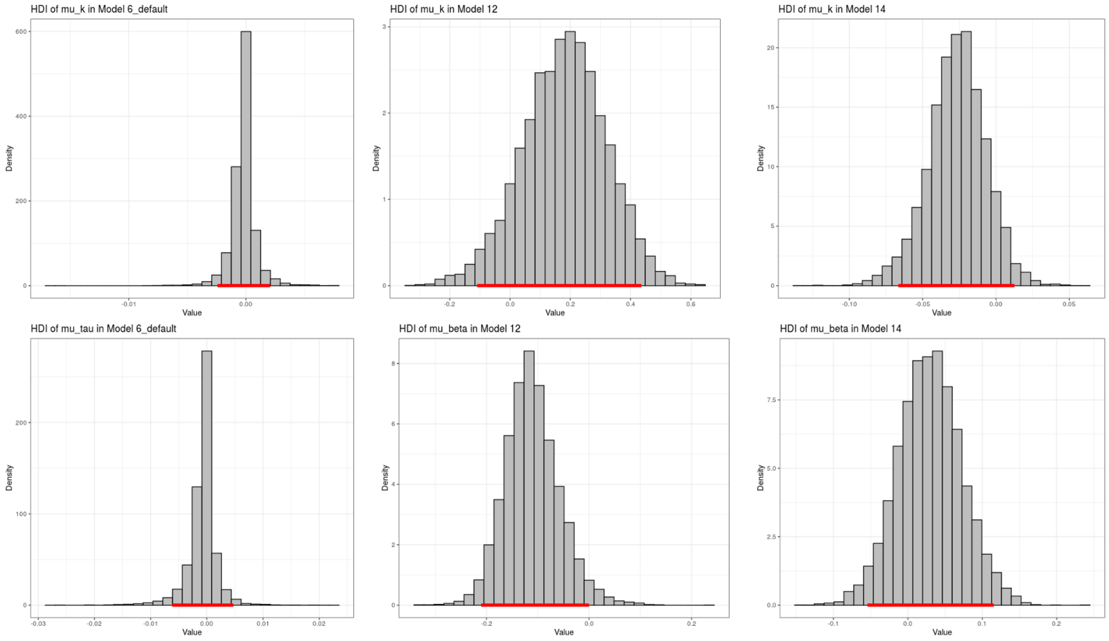


Stress Group





Group difference

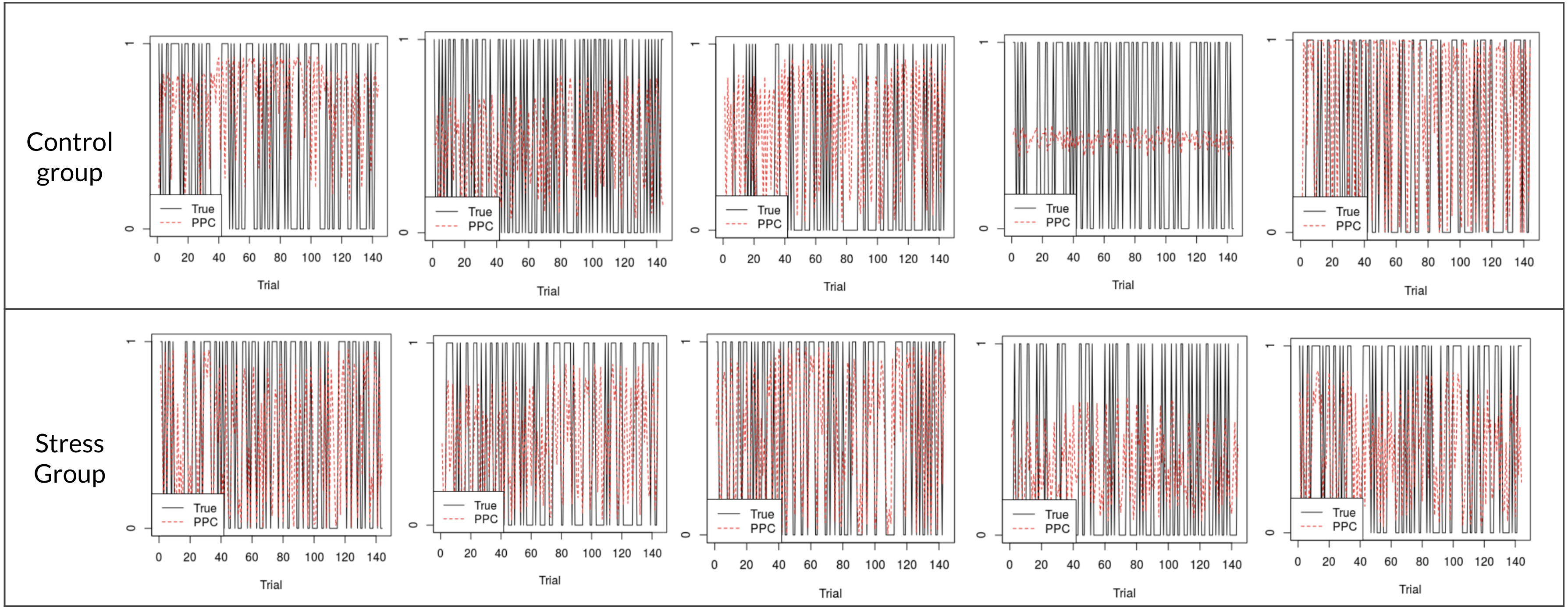


These graphs show group difference of hyperparameters in control and stress groups by getting discrepancy between each group parameters by simply subtracting the stress group from the control group across condition.

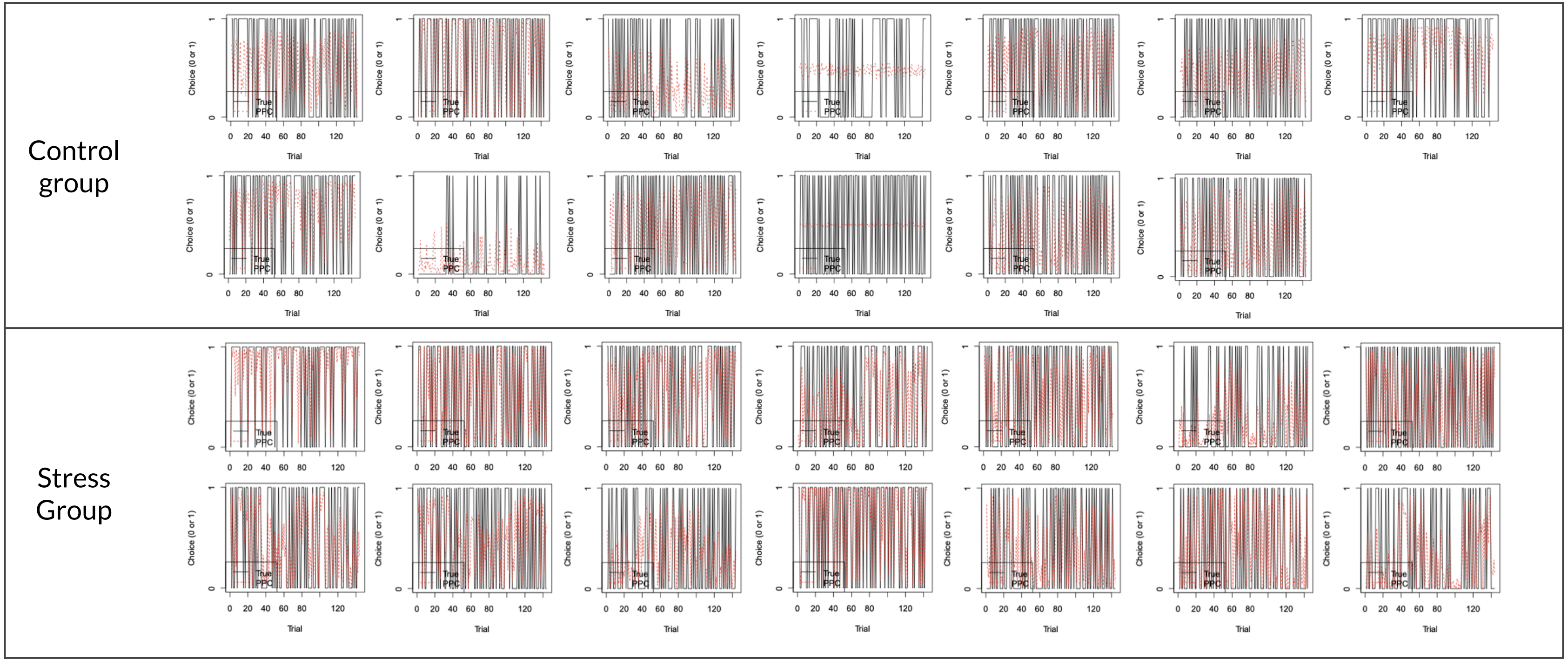
And HDI result is indicated with red line, and there seems to be **no credible difference between the two groups** since all the results include 0 in the highest density interval.

But in the mu_beta in model 12, the HDI does not include 0 and **this may suggest a differences in sensitivities to self-reward between two groups.**

Posterior Probability Check for Model 6_default



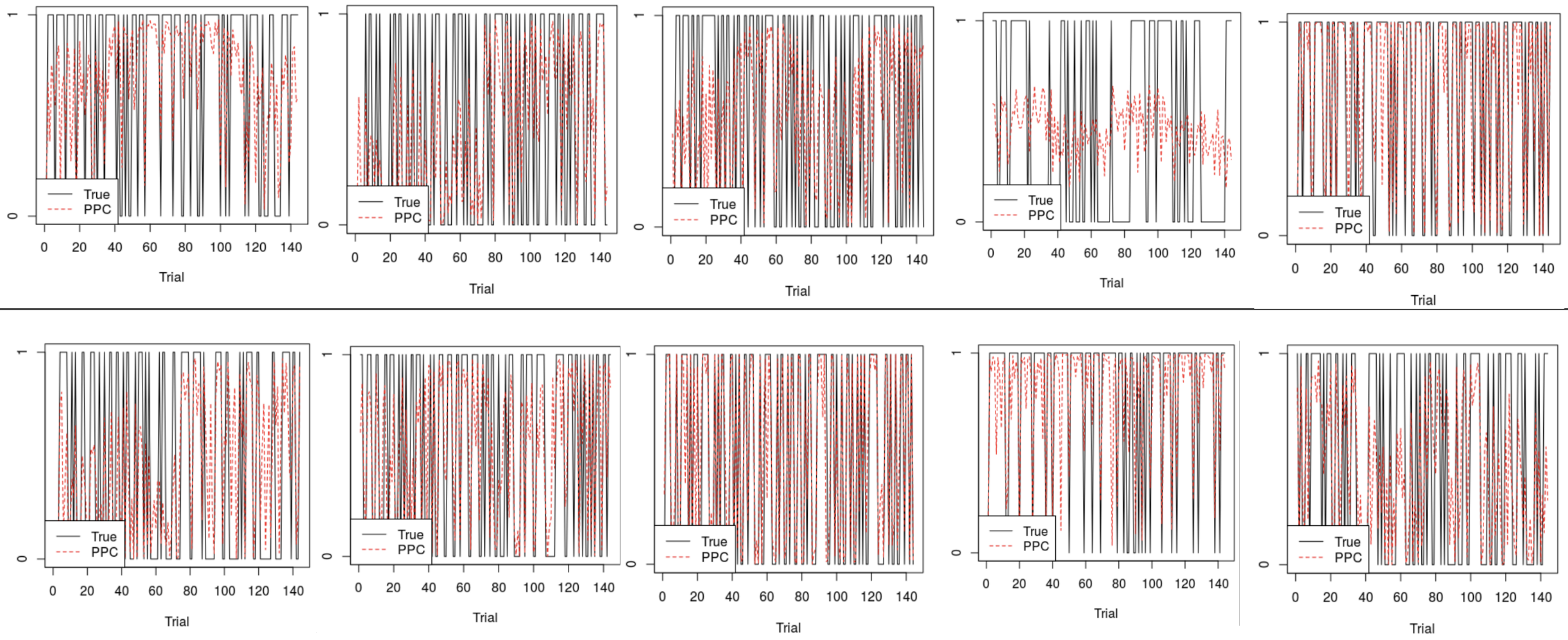
Posterior Probability Check for Model 12



Posterior Probability Check for Model 14

Control group

Stress Group

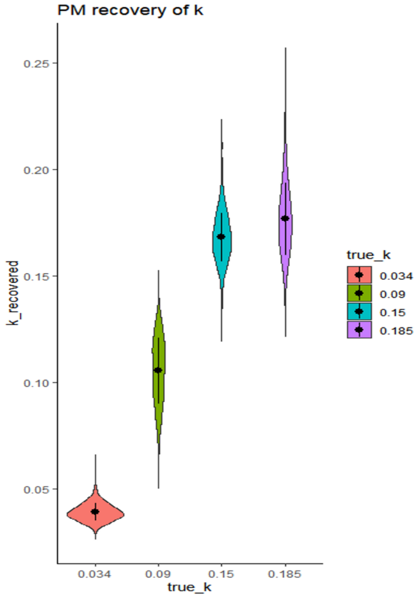


Parameter Recovery

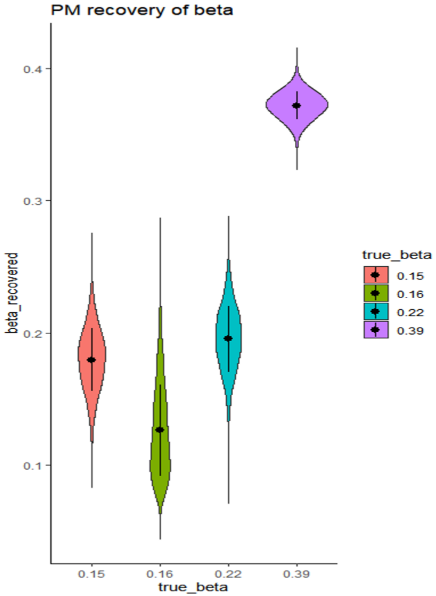
```
  for (n in 1:nrep){
    for (t in 1:numTrial) {
      ev_self  = amount_self[t]
      ev_other = (amount_default[t] + amount_other[t]) / (1 + k * social_distance[t])
      SVnet[n, t] = ev_other - ev_self

      psplit[n, t] = 1 / (1 + exp(tau*(ev_other - ev_self)))
      psplit[n, t]  = psplit[n,t] * 0.9998 + 0.0001
      fakesplit[n,t] = rbinom(n=1,size = 1, prob = psplit[n,t]) #this will give 1 or 0
    }
  }
  #return(psplit) #for returning probabilites
  return(fakesplit)
  #return(SVnet) //returning SVnet for all trials given the composition of parameters.
}
```

- Set specific values for parameters (e.g. k = 0.1, tau = 2.0)
- Compute the subjective values and plug it into a softmax function to generate probability given the condition.
- Repeat this to generate 10~100 identical artificial subjects of similar values.
- Fit again to the stan model to see whether the specific values for parameters are recovered.

PM recovery of M14



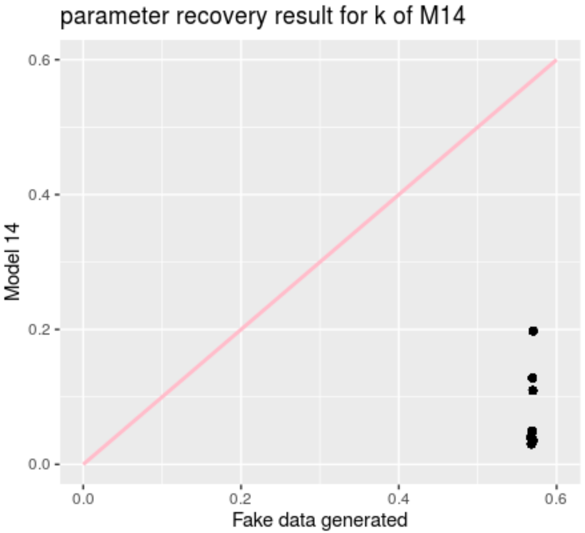
Orange
(k, beta, t) = (0.034, 0.15, 2.28)
Green
(k, beta, t) = (0.09, 0.16, 3.73)



Emerald
(k, beta, t) = (0.15, 0.22, 4.34)
Violet
(k, beta, t) = (0.185, 0.39, 1.96)

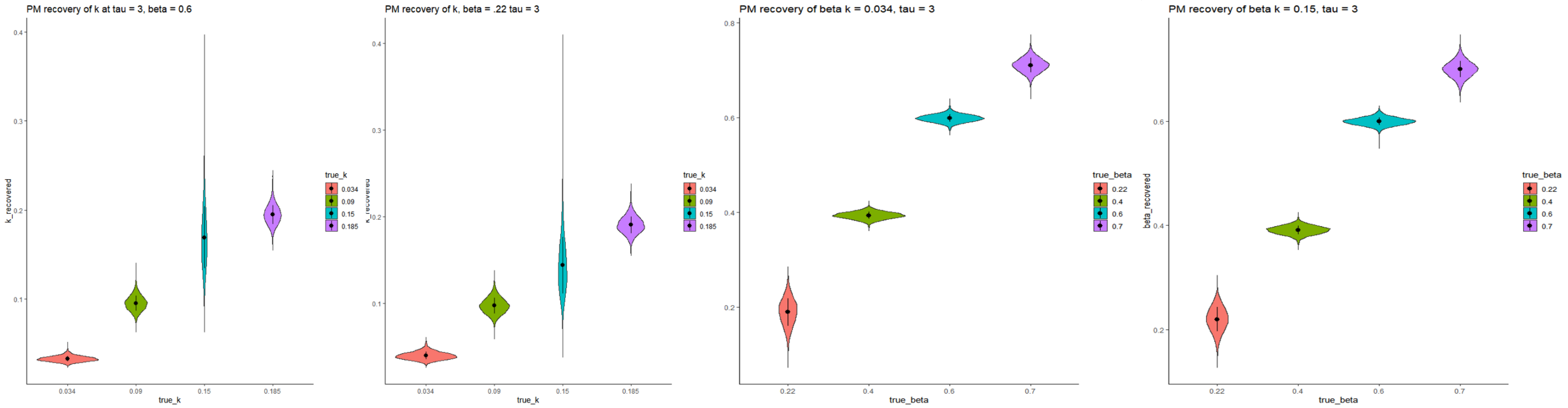
Here, we set the four individual participant's median parameter values as the true parameter and generated fake data of 10 subjects.
The violin plots show the probability density of the data at different values.
The plots are the average samples of the synthetic 10 subjects for each parameter of each subject. As seen, the parameters for each subject are failry well-recovered, especially for beta.

PM recovery of M14



However, when looking at the correlation plots of the mean values, parameters do not seem to be well recovered. Such result can be interpreted this as the issue of over-fitting and could possibly be solved with developing a more generalizing model.

PM recovery of M14 - Arbitrary true value



Unlike the last plots, we wanted to see how estimation of certain parameters can be affected by the changes in other parameters. In other words, when the true value of k is 0.05, does the different value of beta or tau affect the estimated values of k? The estimates of the parameters were reliable when one parameter was estimated with different composition of other parameters.

Summary

- Behavior data suggested possible group difference between control and stressed groups in money sharing behavior to distant others.
- Hyperbolic models and exponential models with the weighted sum were the two winning candidates out of 15 models.
- LOOIC result suggests that exponential model is the winning candidate.
- 95% HDI interval between two groups did not confirm the credible difference between the group.
- Parameter recovery results suggested the recovery of the parameters was possible in hyperbolic model whereas the weighted sum models was not.

Further Plan

- Find the optimal experimental setup.
  - given the composition of social distance, amount for self and other, what is the possible range of k, tau, and other additional parameters?

- Testing additional models
  - Inequality aversion models (Chen Qu et al., 2020)

$$SV(G, C) = \alpha G + \beta C$$

<table>
<tr><th rowspan="2">SD</th><th colspan="2">Split</th><th rowspan="2">Non-Split
(A_self)</th></tr>
<tr><th>Unequal</th><th>Equal</th></tr>
<tr><td>1</td><td rowspan="3">3,000
(A_defaut)</td><td rowspan="3">6,000
(A_default)</td><td>16,500</td></tr>
<tr><td>3</td><td>15,000</td></tr>
<tr><td>5</td><td>13,500</td></tr>
<tr><td>10</td><td rowspan="3">12,000
(A_other)</td><td rowspan="3">9,000
(A_other)</td><td>12,000</td></tr>
<tr><td>20</td><td>10,500</td></tr>
<tr><td>50</td><td>9,000</td></tr>
</table>

Reference

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