Presentation of individual project for Master's thesis

Elevated state anxiety disturbs model-based decision-making under monetary loss

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Computational Clinical Science Lab

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Decision-making?

Human beings make decisions moment to moment!

Two systems of decision-making

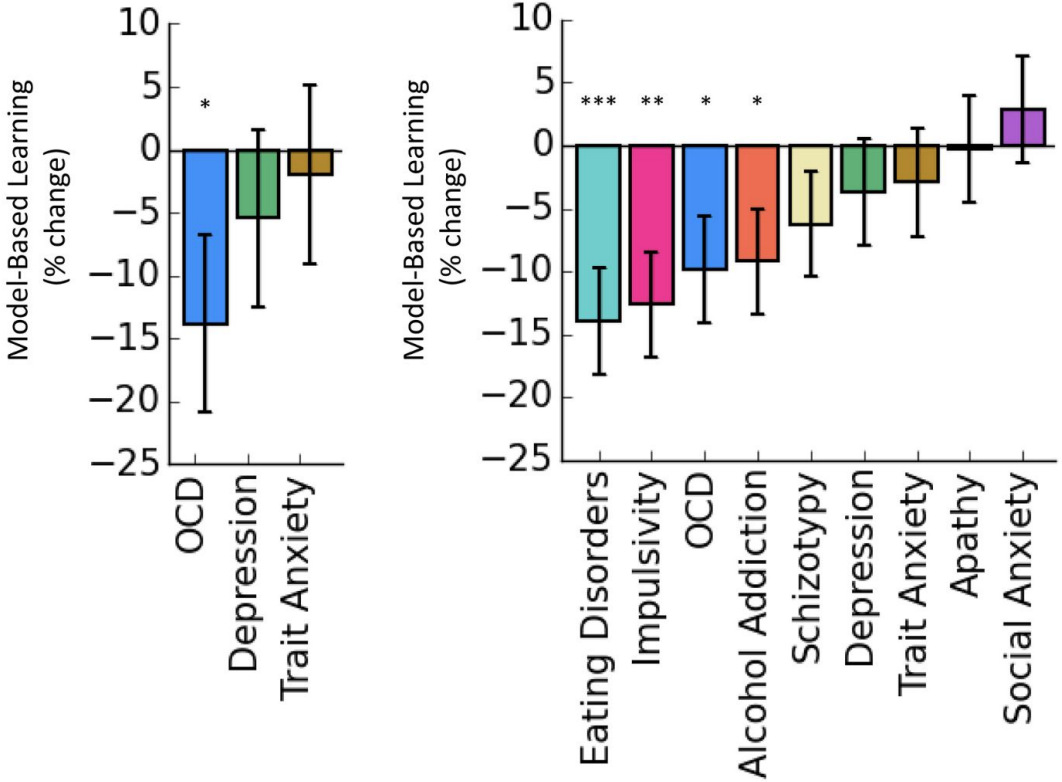
(Collins & Cockburn, 2020; Daw, 2018; Daw et al., 2005)

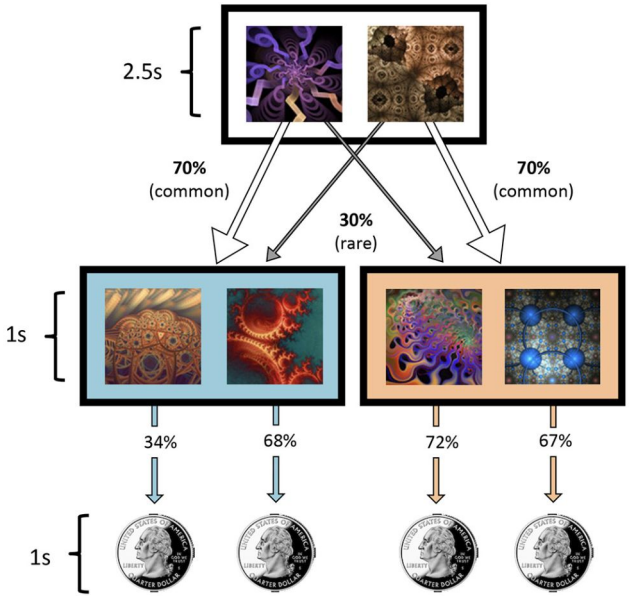
1. Model-free system:
   a. Automatic
   b. No internal structure of a task
   c. Habitual behavior

2. Model-based system:
   a. Flexible
   b. Internal structure of a task
   c. Goal-directed behavior

Necessary to adapt to a changing environment!

Model-based control and psychopathology (Gillan et al., 2016)





Multi-stage decision-making task with monetary reward

Similarities between OCD and anxiety

Psychological Medicine (2012), **42**, 1–13. © Cambridge University Press 2011
doi:10.1017/S0033291711000742

ORIGINAL ARTICLE

Is obsessive–compulsive disorder an anxiety disorder, and what, if any, are spectrum conditions? A family study perspective

In this study, to our knowledge the largest OCD family study to date, we found that anxiety disorders, related personality disorders, several (but not all) putative OCD-related conditions (Hollander *et al.* 2008) and depressive disorders were more common in persons with OCD and their first-degree relatives. Thus, using co-morbidity and familiality information, there is evidence supporting both grouping OCD with anxiety disorders, and grouping some additional conditions with OCD.

(Bienvenu et al., 2012)

Cogn Ther Res (2010) 34:168–176
DOI 10.1007/s10608-009-9239-9

ORIGINAL ARTICLE

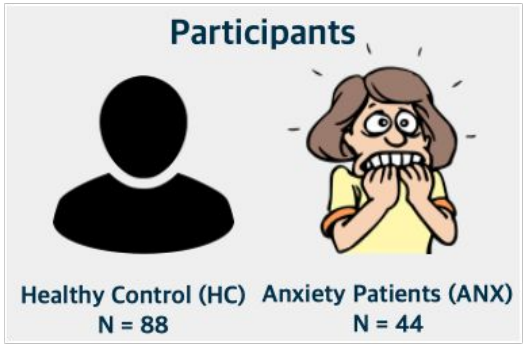
Do Symptoms of Generalized Anxiety and Obsessive-Compulsive Disorder Share Cognitive Processes?

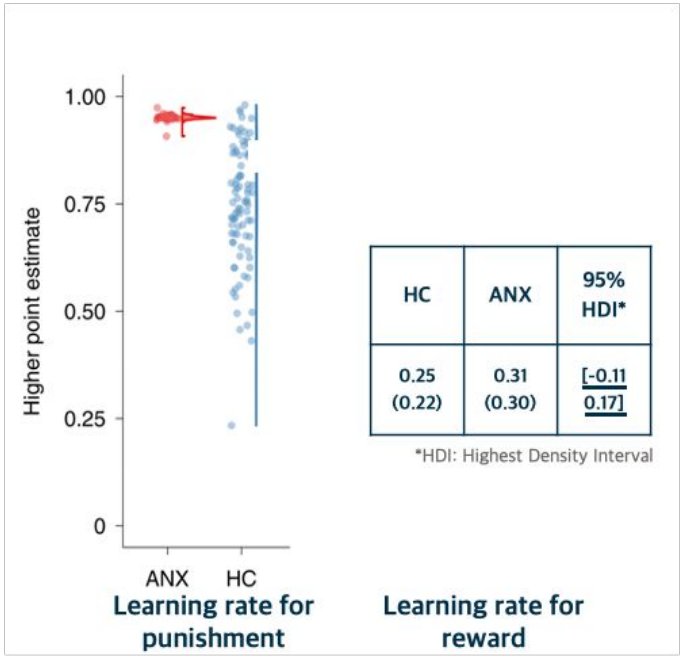
This study used a dimensional approach to examine the specificity between cognitive processes and symptoms of GAD and OCD. Results generally supported predictions as (a) all of the cognitive processes shared stronger relations with GAD and OCD symptoms compared to depressive symptoms and (b) the four predicted cognitive processes [intolerance of uncertainty (IU), negative problem orientation (NPO), perfectionism/certainty (PC), responsibility/threat estimation (RT)] shared comparable relations with both GAD and OCD symptoms. Contrary to expectations, however, IU was the only cognitive process to significantly predict both GAD and OCD symptoms when controlling for the other cognitive processes and general distress.

(Fergus & Wu, 2009)

Background

Decision-making in anxiety patients (Aylward et al., 2019)





Aberrant decision-making in anxiety patients might be dependent on the context!

Research gap

Context, model-based control, and anxiety

Hypothesis I

Regardless of the context, model-based control is not associated with anxiety level.

Hypothesis II

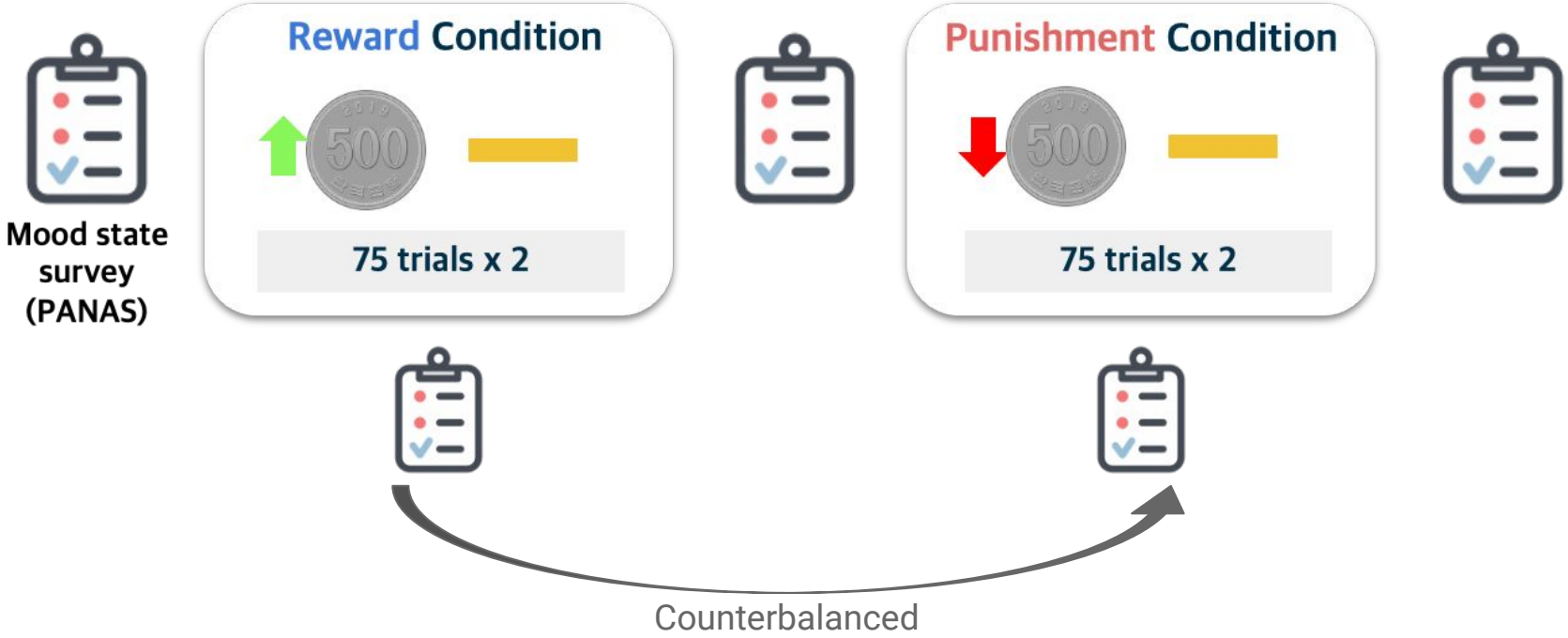
Depending on the context, model-based control might be deficient in highly anxious people.

It remains unclear because previous literature…

- Mostly investigated model-based control with reward but not punishment
- Did not focus on the relationship between anxiety and model-based control

Design

Model-based control in reward and punishment



Hypotheses

01. Replication: in punishment condition, anxiety level will be positively associated with the second-stage learning rate (Aylwards et al., 2019).

02. Replication: in reward condition, anxiety level will not be associated with model-based control (Gillan et al., 2016).

03. In punishment condition, anxiety level will be negatively associated with model-based control.

Method

Participants and surveys

Participants

- **Non-clinical population**
  - Not medicated
  - No psychiatric treatment within 1-year
- **Age: 18-35 (mean: 23.09)**
- **Participants: 48**

Survey

Demographics

- Age
- Sex
- Years of education

Compulsivity

- Impulsivity
  - **BIS-11**
- Obsession & Compulsivity
  - **Y-BOCS-SC**

Depression

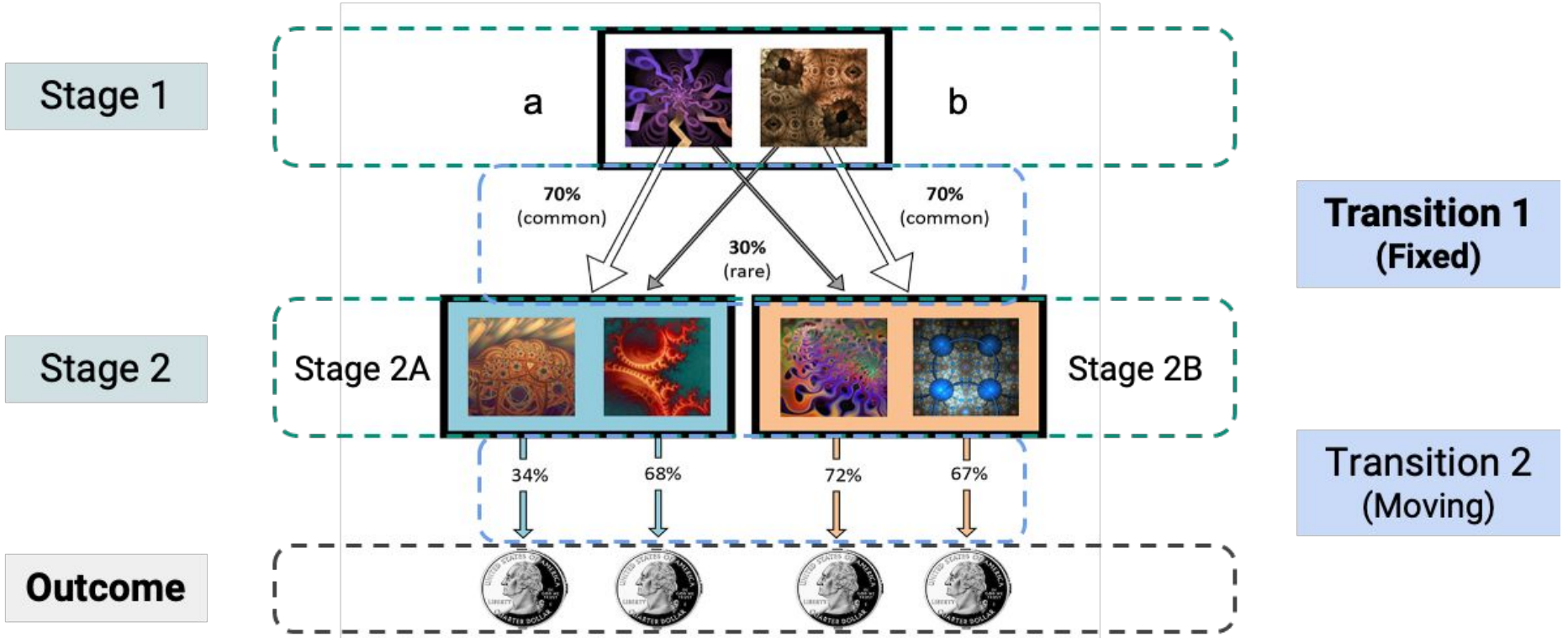
- Depressive symptoms
  - **K-BDI-2**
- Emotion regulation
  - **CERQ**

Anxiety

- State & Trait anxiety
  - **STAI-Y**

Method

Task: multi-stage, two-step task (Gillan et al., 2016)



To learn more: Daw, N. D., Gershman, S. J., Seymour, B., Dayan, P. & Dolan, R. J. Model-Based Influences on Humans' Choices and Striatal Prediction Errors. *Neuron* **69**, 1204–1215 (2011).

Analysis

1. Behavioral analysis
2. Computational modeling analysis
3. Correlation analysis

Result

Data exclusion

Exclusion criteria

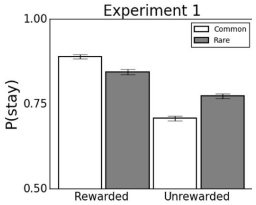
1. Low reward sensitivity (e.g., P(win|common rewarded) < 0.5)) (Otto et al., 2013)
2. Same first stage response in over 95% trials (Gillan et al., 2016)
3. Different experiment parameters (Experiment II)

	Experiment I	Experiment II	Experiment III
Participated	12	4	32
Excluded 1.	1	0	5
Excluded 2.	1	2	3
Total	10	2	24

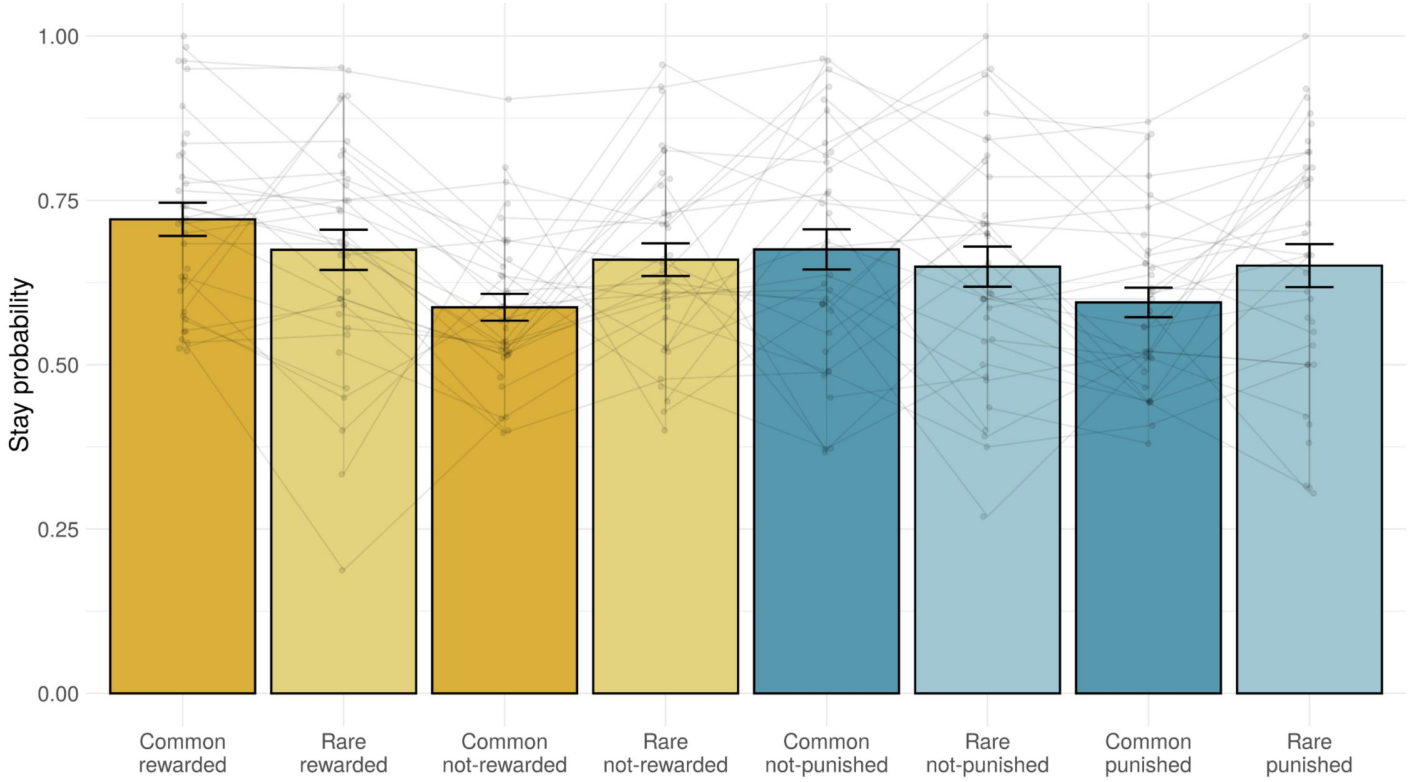
N = 34 (male: 16)

Result

Behavioral analysis: stay probability



(Gillan et al., 2016)



Result

Computational modeling

(Ahn et al., 2017)

- **Hierarchical Bayesian analysis**
- Three reinforcement-learning models:
  - *7 parameters (original)*
    - 6 parameters + lambda (= eligibility trace)
  - *6 parameters*
    - 4 parameters but two learning rates and two inverse temperatures (for each stage)
  - *4 parameters*
    - One learning rate and one inverse temperature + perseverance + model-based weight

Result

Computational modeling

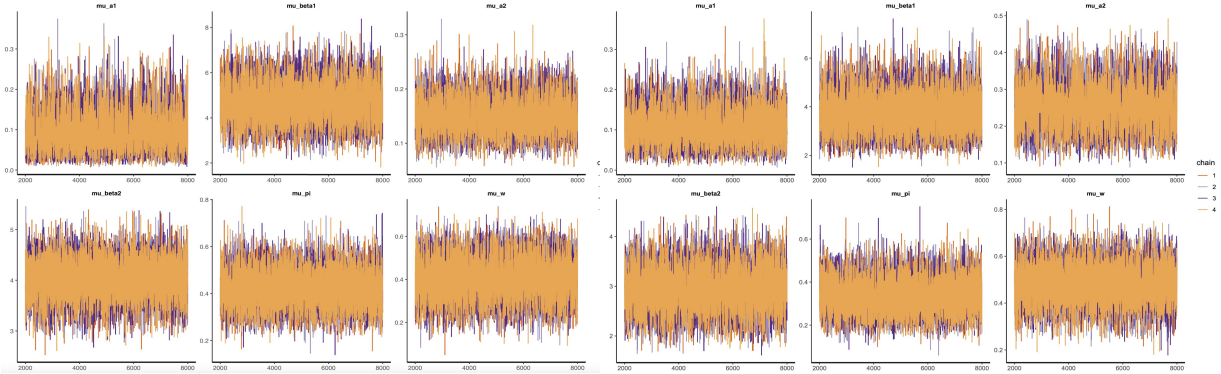
Model Comparison

Domain	Model	LOOIC
rew	ts_par7	11692.57
pun	ts_par7	11741.06
rew	ts_par6	11681.12
pun	ts_par6	11736.47
rew	ts_par4	11790.17
pun	ts_par4	11824.87

→ ***Best: 6-parameter model***

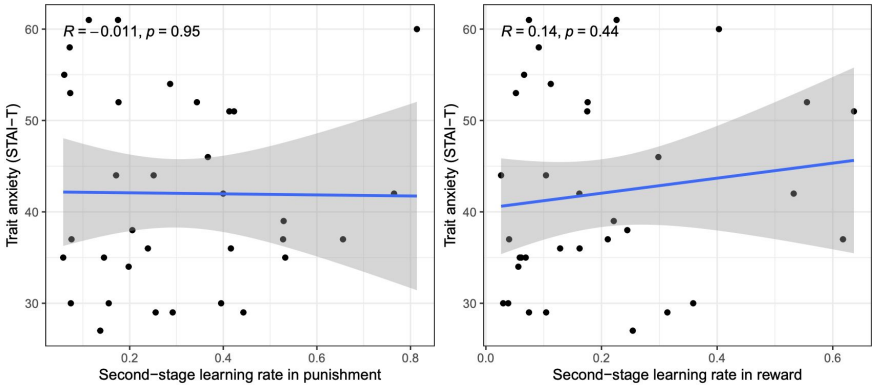
Reward

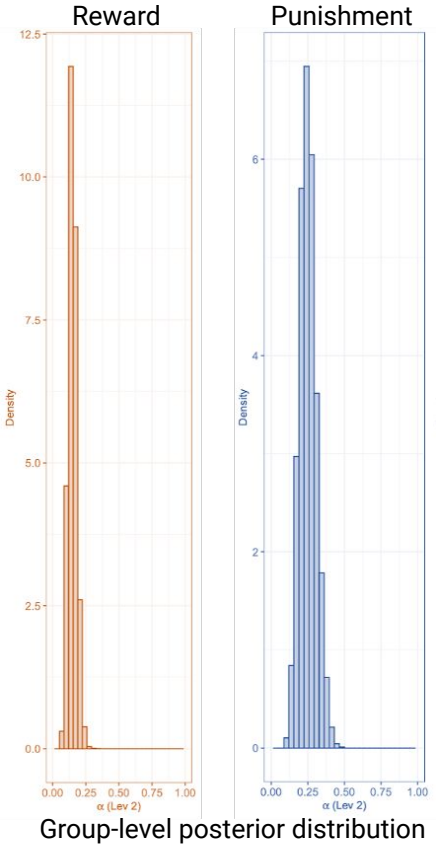
Punishment



Result: testing hyp. I

Correlation I: anxiety scores with learning rate





Group-level posterior distribution

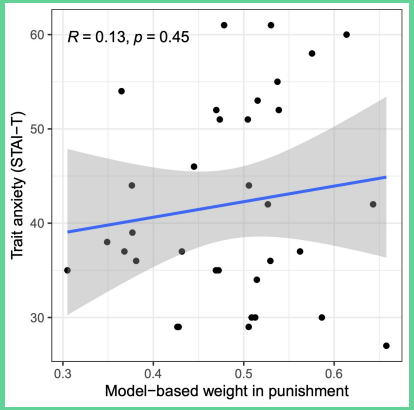
1. Anxiety level was not significantly related to learning rate in either condition.

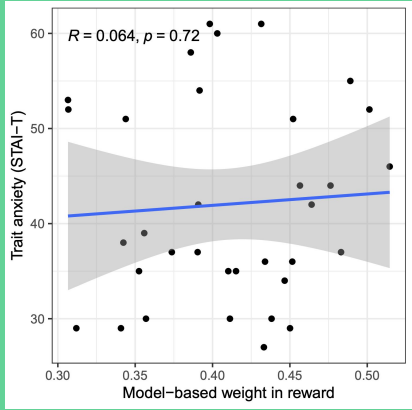
2. The mean of the group-level learning rate parameter value was greater in the punishment condition.

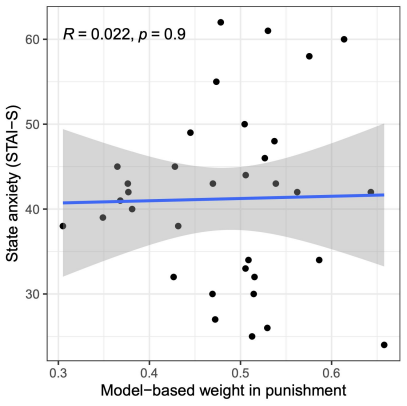
Result: testing hyp. II & III

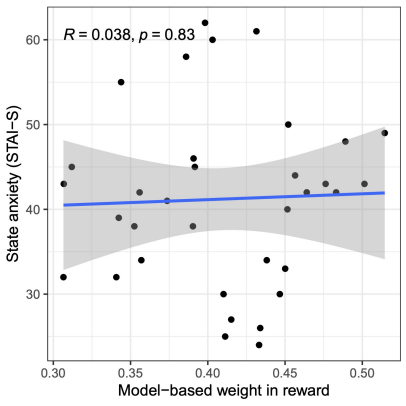
Correlation II: survey scores with model-based weight

Anxiety

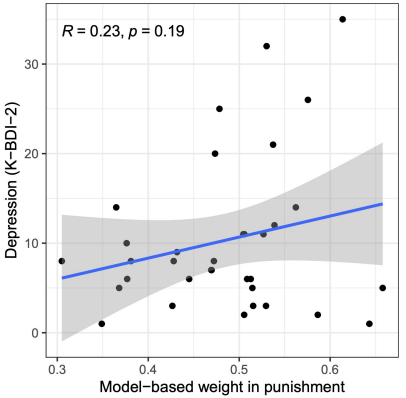


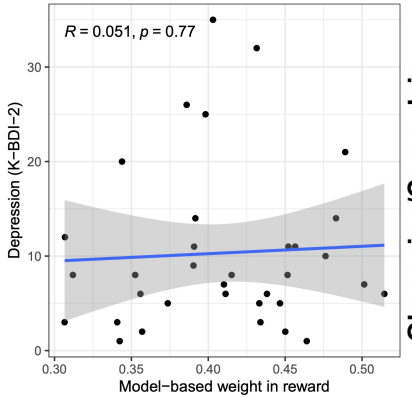




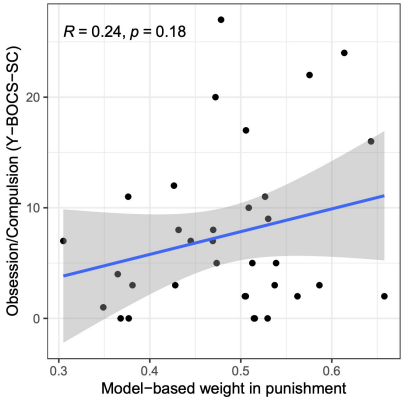


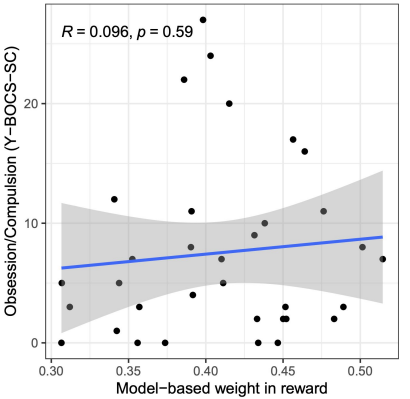
Depression





Obsession/Compulsion

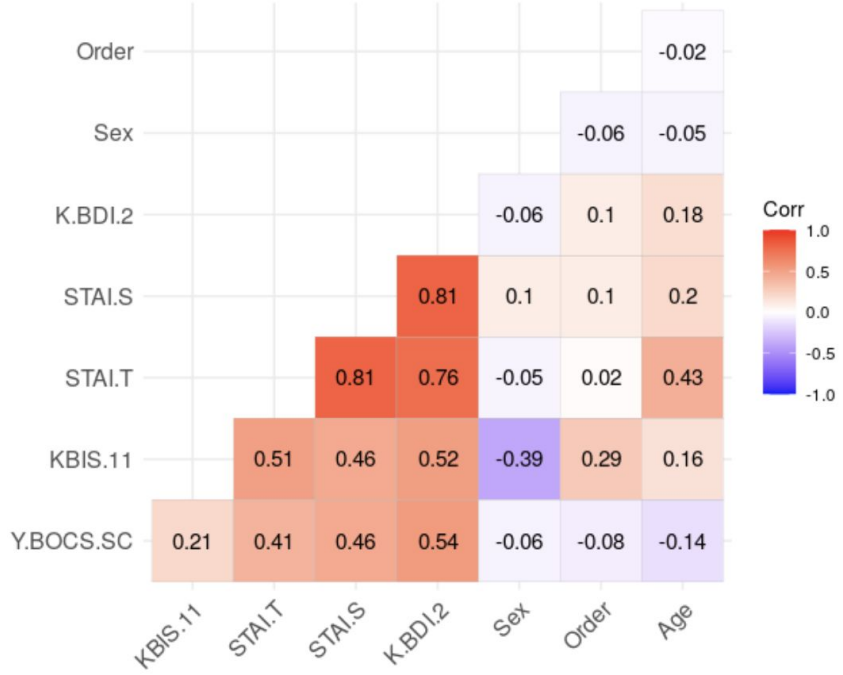




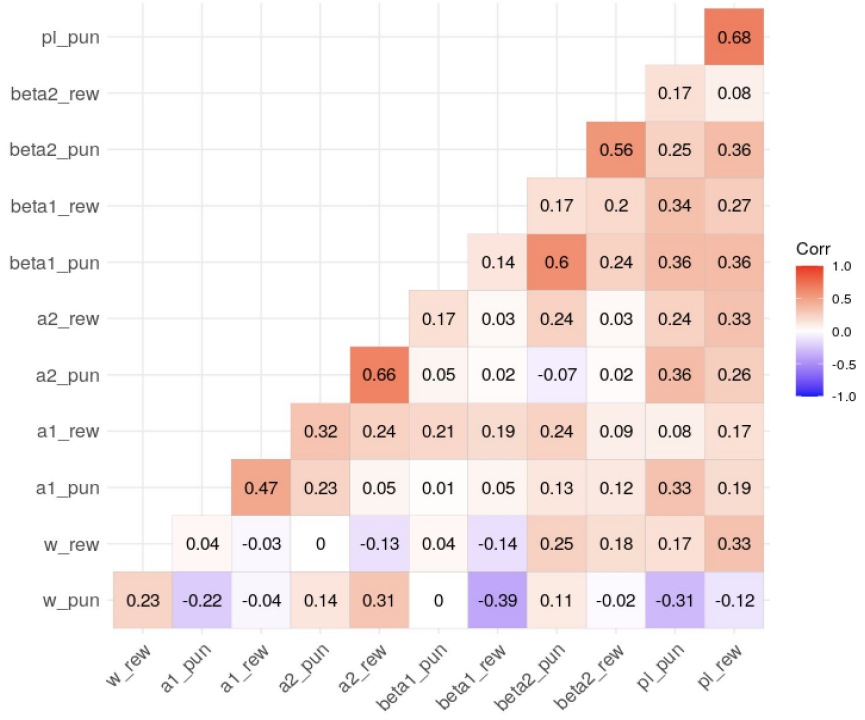
Result

Correlation III: survey scores & model parameters

Survey scores with age, order and sex



Model parameter values



Result: testing hyp. II & III

Multiple regression analysis I: state anxiety

Model *(w_pun, w_rew: model-based weight in punishment and reward, respectively)*

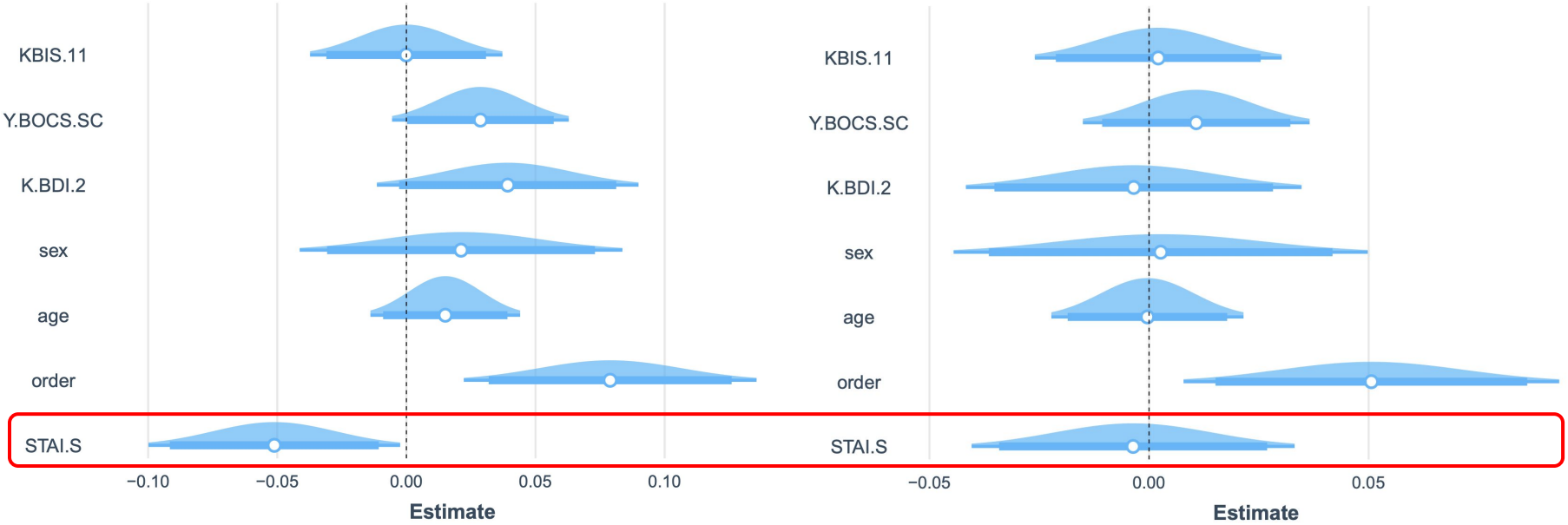
```
w_pun <- lm(w_pun~STAI.S + order + age + sex + K.BDI.2 + Y.BOCS.SC + KBIS.11
w_rew <- lm(w_rew~STAI.S + order + age + sex + K.BDI.2 + Y.BOCS.SC + KBIS.11
```

Table 1: Regression results

	Dependent variable:	
	Model-based weight in punishment	Model-based weight in reward
	(1)	(2)
STAI.S	−0.005** (0.002)	−0.0004 (0.002)
order	0.079*** (0.028)	0.051** (0.021)
age	0.004 (0.004)	−0.0001 (0.003)
sex	0.021 (0.030)	0.003 (0.023)
K.BDI.2	0.005 (0.003)	−0.0004 (0.002)
Y.BOCS.SC	0.004* (0.002)	0.001 (0.002)
KBIS.11	−0.00001 (0.002)	0.0002 (0.001)
Constant	0.476*** (0.135)	0.381*** (0.102)
Observations	34	34
R^2	0.381	0.213
Adjusted R^2	0.215	0.001
Residual Std. Error (df = 26)	0.075	0.057
F Statistic (df = 7; 26)	2.288*	1.006
Note:		*p<0.1; **p<0.05; ***p<0.01

Result: testing hyp. II & III

Regression result: coefficient values



DV: model-based weight in punishment

DV: model-based weight in reward

→ **Model-based weight was negatively associated with state anxiety scores only in the punishment condition! (Hyp. II & III)**

Result: testing hyp. II & III

Multiple regression analysis II: punishment-focused

Table 2: Regression results (with and without depression)

	Dependent variable:	
	Model-based weight in punishment (model with depression)	Model-based weight in punishment (model without depression)
	(1)	(2)
STAI.S	−0.005** (0.002)	−0.003 (0.002)
order	0.079*** (0.028)	0.080*** (0.028)
age	0.004 (0.004)	0.005 (0.004)
sex	0.021 (0.030)	0.018 (0.031)
K.BDI.2	0.005 (0.003)	
Y.BOCS.SC	0.004* (0.002)	0.005** (0.002)
KBIS.11	−0.00001 (0.002)	0.001 (0.002)
Constant	0.476*** (0.135)	0.365*** (0.119)
Observations	34	34
R^2	0.381	0.321
Adjusted R^2	0.215	0.170
Residual Std. Error	0.075 (df = 26)	0.077 (df = 27)
F Statistic	2.288* (df = 7; 26)	2.126* (df = 6; 27)
Note:		*p<0.1; **p<0.05; ***p<0.01

>

Result: testing hyp. II & III

Multiple regression analysis III: punishment-focused

Table 3: Regression comparsion

	Dependent variable:		
	Model-based weight in punishment		
	(1)	(2)	(3)
STAI.S	−0.005** (0.002)	−0.005** (0.002)	−0.002 (0.002)
order	0.079*** (0.028)	0.079*** (0.026)	0.082*** (0.027)
age	0.004 (0.004)	0.004 (0.004)	0.005 (0.004)
sex	0.021 (0.030)	0.021 (0.026)	0.013 (0.027)
K.BDI.2	0.005 (0.003)	0.005 (0.003)	
Y.BOCS.SC	0.004* (0.002)	0.004* (0.002)	0.005** (0.002)
KBIS.11	−0.00001 (0.002)		
Constant	0.476*** (0.135)	0.475*** (0.102)	0.390*** (0.091)
Observations	34	34	34
R^2	0.381	0.381	0.318
Adjusted R^2	0.215	0.244	0.196
Residual Std. Error	0.075 (df = 26)	0.074 (df = 27)	0.076 (df = 28)
F Statistic	2.288* (df = 7; 26)	2.772** (df = 6; 27)	2.613** (df = 5; 28)
Note:			*p<0.1; **p<0.05; ***p<0.01

Result: testing hyp. II & III

Multiple regression analysis IV: trait anxiety

Model *(w_pun, w_rew: model-based weight in punishment and reward, respectively)*

```
mb_pun_anxT <- lm(w_pun~STAI.T + order + age + sex + K.BDI.2 + Y.BOCS.SC + KBIS.11
mb_rew_anxT <- lm(w_rew~STAI.T + order + age + sex + K.BDI.2 + Y.BOCS.SC + KBIS.11
```

Table 4: Regression comparsion

	Dependent variable:	
	Model-based weight in punishment	Model-based weight in reward
	(1)	(2)
STAI.T	−0.001 (0.002)	0.001 (0.002)
order	0.076** (0.030)	0.052** (0.021)
age	0.004 (0.004)	−0.001 (0.003)
sex	0.001 (0.031)	−0.0003 (0.022)
K.BDI.2	0.001 (0.003)	−0.001 (0.002)
Y.BOCS.SC	0.003 (0.002)	0.001 (0.002)
KBIS.11	−0.001 (0.002)	−0.00004 (0.001)
Constant	0.403*** (0.141)	0.375*** (0.098)
Observations	34	34
R^2	0.277	0.221
Adjusted R^2	0.082	0.011
Residual Std. Error (df = 26)	0.081	0.056
F Statistic (df = 7; 26)	1.421	1.052
Note:		*p<0.1; **p<0.05; ***p<0.01

Conclusion

Summary

Learning rate in the second-stage was greater with punishment than with reward.

Anxiety level was not associated with model-based control with reward.

State anxiety was negatively associated with model-based control in punishment, after controlling for other psychiatric symptom scores.

Limitations

- Modeling: no dissociation between *negative* and *positive* learning rate

  (i.e. only one second-stage learning rate in each condition)
- Analysis relying on self-reported measures
- Mostly correlational
- Unclear interpretation on the order effect
- Difference between state and trait anxiety

References

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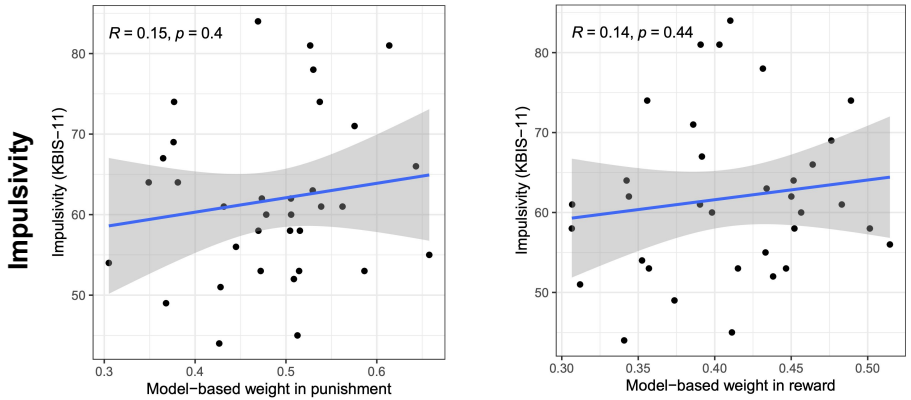
Thank you for your listening!

Supp. I Impulsivity & Model-based weight



Supp. II Data exclusion

	Pilot I	**Pilot II**	**Actual**
Duration	20.11.23-27	20.11.28	20.11.30-
# of participants	12	4	32
Differences (outcome probabilities)	- Two sets of random distributions (counterbalanced) -All initialized at **0.50**	- One set of random distributions - Initialized at **0.25, 0.75 and 0.40, 0.60**	- One set of random distributions - Initialized at **0.40, 0.45, and 0.50, 0.55**