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Acute stress reshapes third-party punishment and help decisions: Behavioral evidence and neurocomputational mechanisms

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how the brain supports learning and memory, and interactions with emotion, and how these processes develop as the brain matures from childhood through adolescence into adulthood

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2023.06.25

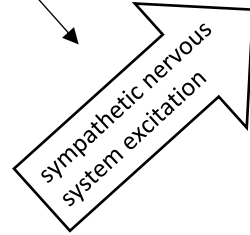
Introduction

**Unpredictable
and
Uncontrollable
events**

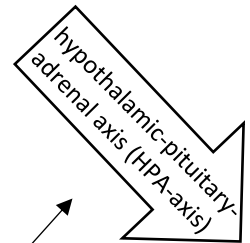


Acute Stress

fast



slow



- Moral decision
- Trust game (TG)
- Dictator game (DG)

“tend-and-befriend” ✓

Prosocial behavior

“fight or flight”

- Charitable giving
- Trust behaviors

*Prosocial behavior acts as good emotional buffer and can maintain a good social relationships to **obtain social support** and **release anxiety***

OR

*This reduced prosocial behavior can also be understood as a **“flight”** response*

Introduction

Second party decision

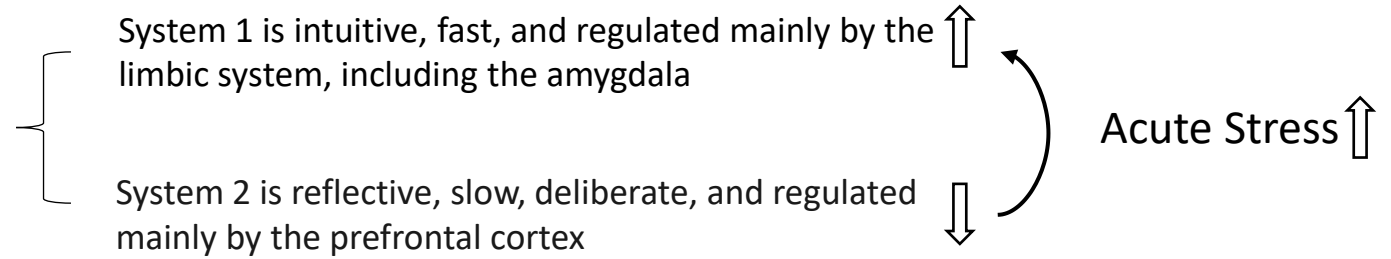
- Emotion?
- Power?
- Status?
- Justice?
- Retribution?

OR

➤ Prosocial?



The dual process theory of decision-making (Kahneman, 2013)



Third-party decision-making

Stress-sensitive neural systems, at least in part, overlap with functional brain systems and networks involved in the decision-making process during third-party responses.



Punishment?

OR

Help?

the neurocognitive mechanisms underlying the trade-off between third-party help and punishment under acute stress remain unclear

Introduction

When facing injustice, both third-party responses correlate with the **activation of fairness violations**

AI, ACC, DLPFC, amygdala and vmPFC

Enhanced ventral striatal activity is further associated with **punishing an offender** instead of helping a victim

Punishment

The TPJ, precuneus, and mid-temporal regions are more associated with an individual **preference for help** rather than punishment

rDLPFC increased more after experiencing advantageous unfairness and **engaging in help** instead of punishment

Help

Third-party
decision-making

Punishment?

OR

Help?

Acute Stress ↑

Activation of “theory of mind” (ToM) brain regions ↑

which is fundamental for becoming more other-oriented with a **preference for providing help**

Help

In value utility calculations

people rely only on intuition and habit in the allocation of some choices (eg, helping), while others (eg, punishing) are considered more carefully and deliberately.

Hypothesis:

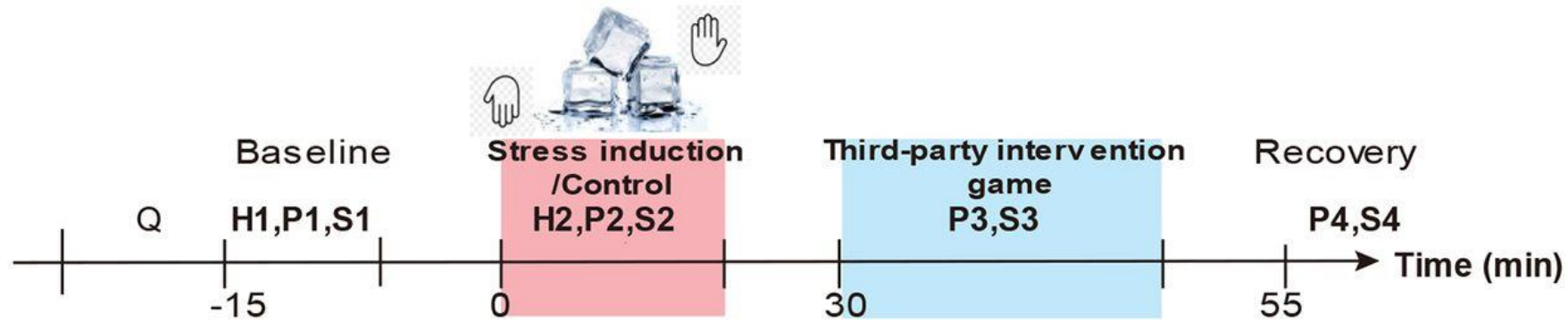
1. People under stress would prefer helping when third-party punishment and helping are in conflict because punishment is more executive control-dependent
2. expected to observe neural changes in brain functioning related to the theory of mind (eg, ACC and TPJ) and subjective value computations (eg, vmPFC and PCC)

Design

Cold pressor test (CPT)

H=Heart Rate
S=Subjective affect ratings
P=Saliva

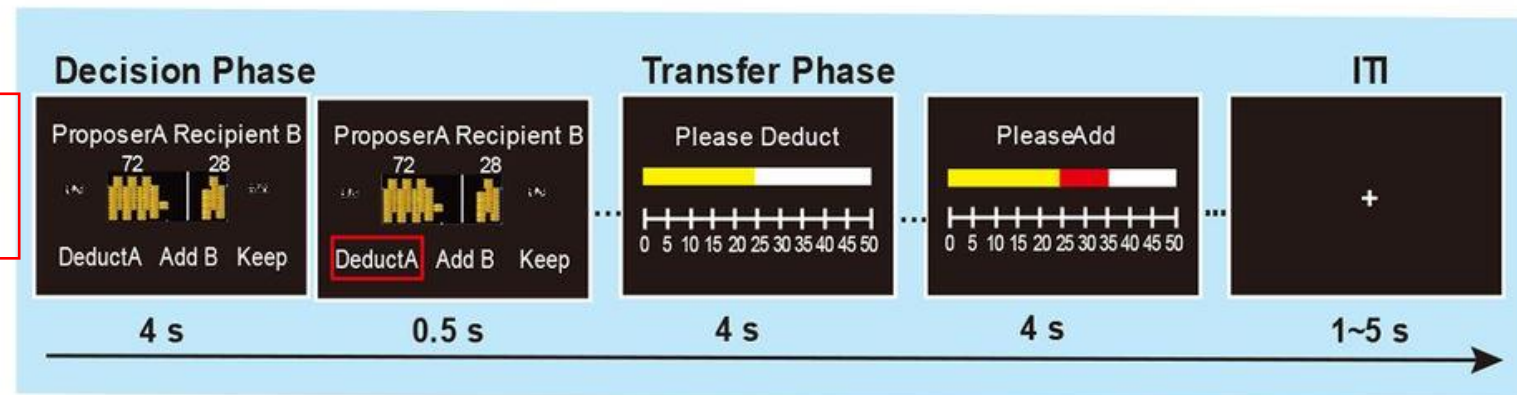
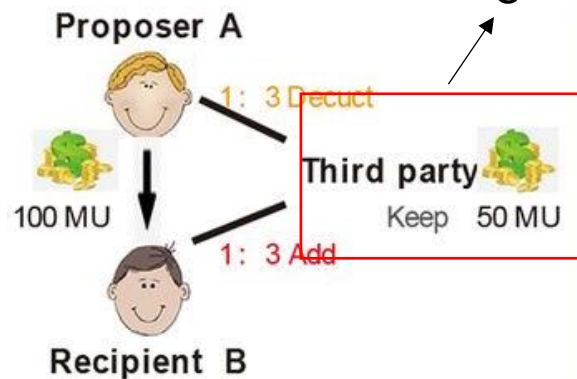
A



A novel third-party intervention game (TPIG)

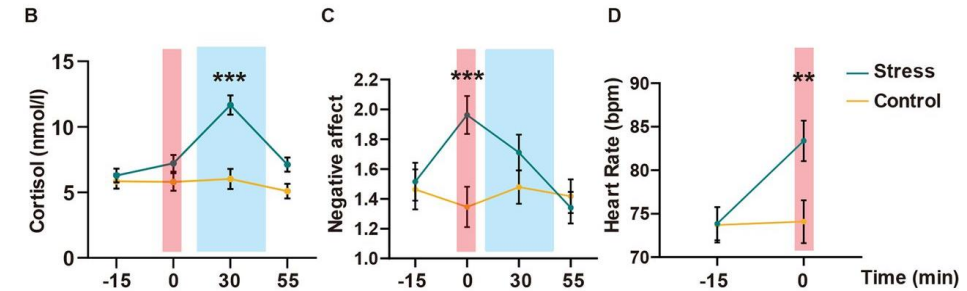
The average offer ratio was 90/10, 80/20, 70/30, 60/40, and 50/50, but the actual offers shown to the participants fluctuated between 1% and 2%, eg, 91/9 and 88/12

E



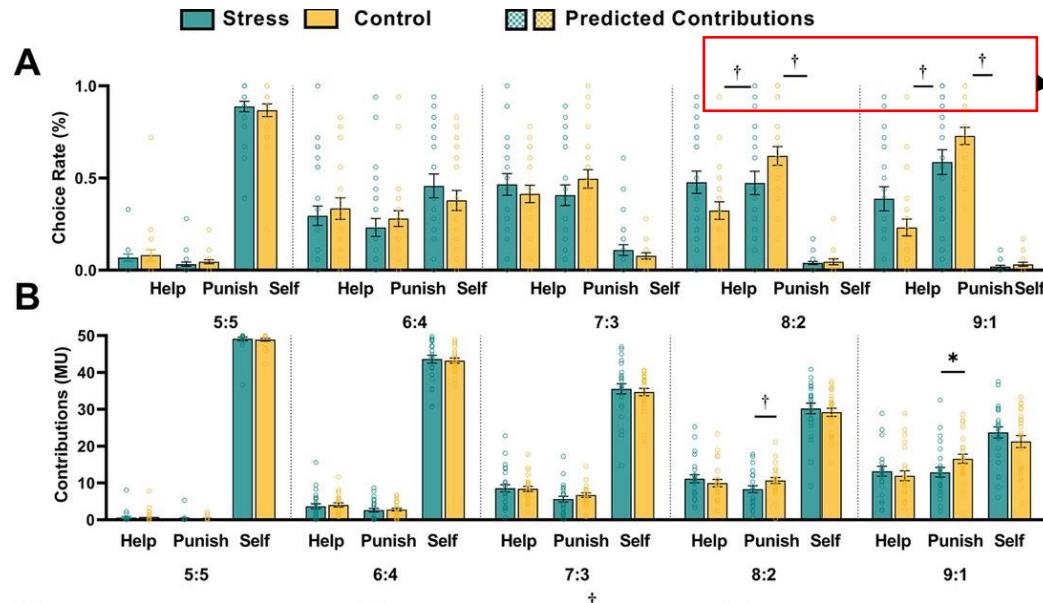
Result

Acute stress induction with psychological, physiological, and endocrinal measures



Acute stress affects third-party decisions between punishment and help in response to inequality events

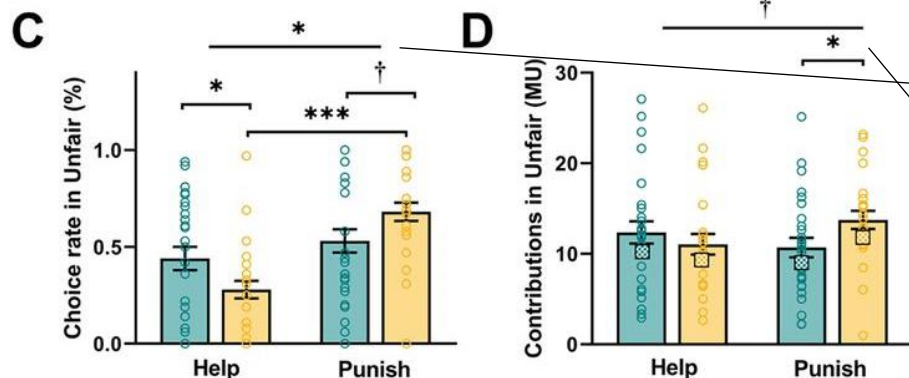
Group (between-subject factor: stress vs. control) \times Fairness (within-subject factor: 50:50 vs. 60:40 vs. 70:30 vs. 80:20 vs. 90:10) \times Intervention type (within-subject factor: punish vs. help)



This analysis revealed a trend of Group \times Fairness \times Intervention interaction.

A further exploratory analysis revealed that **acute stress affects decision-making only in extremely unfair conditions** (i.e., 80:20 and 90:10 trials), **with an increase in third-party decisions to help** ($P < 0.05$ in 80:20 and 90:10 conditions) but a decrease in third-party decisions to punish in the stress group compared with the control group.

Result

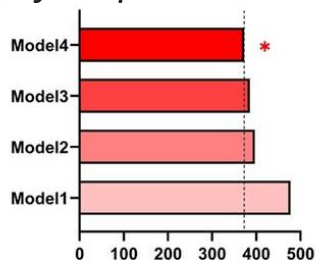


stress increased the likelihood of choosing helping but slightly decreased the likelihood of choosing punishment compared with the control group

stress decreased the contribution made to punish the norm violator but had no effect on the contribution made to help the receiver

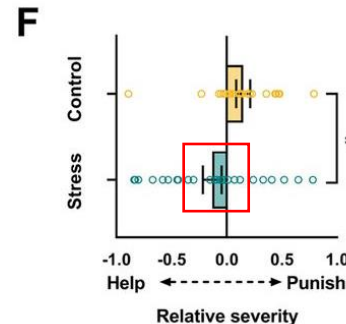
Acute stress alters the latent computations of third-party intervention behaviors

E four plausible computational models



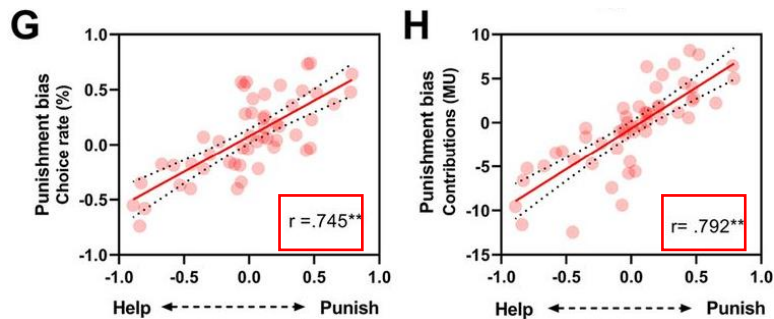
To further investigate the latent cognitive computations underlying how acute stress modulates third-party intervention behaviors,

$$\text{MODEL4 } U_{i(t)} = \pi_{i(t)} - 3S_{i(t)}^p - 3S_{i(t)}^h$$



the extent of help(β) and the severity of punishment (α), which are quantified by parameters β and α

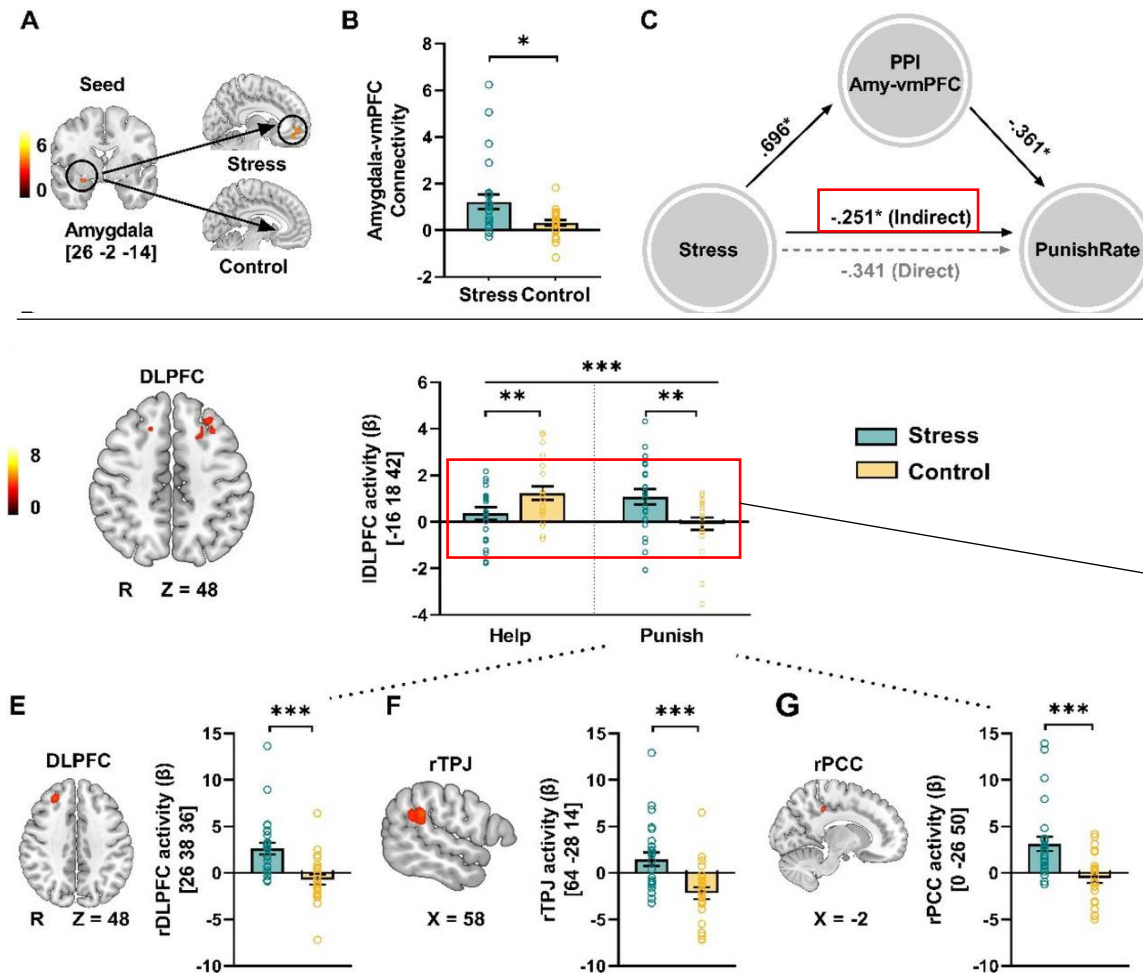
Computed the value of parameter α minus parameter β as an **index of punishment bias($\alpha-\beta$)**.



We found a positive correlation of the punishment bias value with the relative punishment rate in the decision phase as well as with the relative punishment severity in the transfer phase.

Result

Stress increases amygdala and prefrontal network integration in third-party intervention responses to inequality events in the decision phase



the correlation between the **right amygdala** and the degree of distributional inequality was significantly higher in control individuals than in stressed individuals

PPI analysis(B)

revealed higher functional connectivity of the **right amygdala with the vmPFC** in response to trials where **participants chose the punishment option in the stress group** but not in the control group

Brain activation maps(left) for trials in which punishment was selected with trials in which help was selected between the stress and control groups.

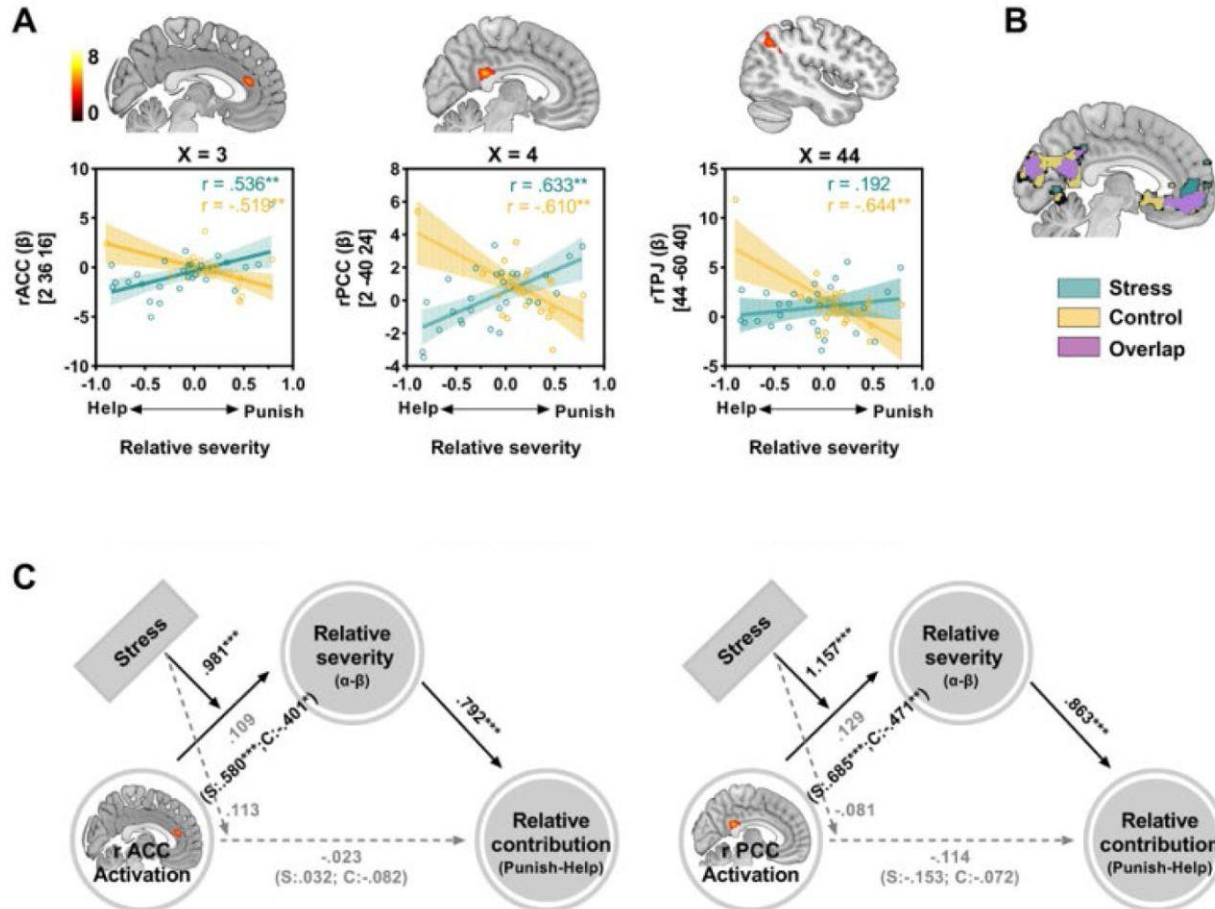
In the control group, we found **higher activity in the DLPFC when selecting the helping option** than when the punishment option was selected. However, the **stress group showed an inverse pattern**

only during the punishment choices did acute stress induce higher activity in the right DLPFC, right TPJ (rTPJ), and right PCC (rPCC)

Punishment might be a more intuitive and automated process

Result

Acute stress alters brain functional connectivity and latent computations in the transfer phase



In the stress group, we observed a positive correlation between punishment bias and activity in the ACC, PCC, and rTPJ, while the control group showed negative correlations

The stressed participants must recruit more ACC and PCC cognitive resources for a larger punishment severity bias and impose a higher punishment contribution.

*These results indicate that **acute stress moderates the mediatory role of latent computations on the association between neural activity and behavior outputs.***

Discussion

Behaviorally → support the “**tend-and-befriend**” theory

Acute stress led to a decrease in the third-party's willingness to punish the violator and the severity of the punishment but an increase in their willingness to help the victim.

Computational modeling

when subjective value utility calculations are made in stressful situations, people devote more of their psychological preferences to deciding how to help the victim than how to punish the offender.

- ✓ *Evolutionally, a “tend-and-befriend” strategy can lead to a good reputation and promote self and offspring safety*
- ✓ *punishment entails a cost for both the punisher and the punished, and it is expensive and inefficient. especially in uncontrollable stress situations*
- ✓ *These results from the computational model further suggest that helping, rather than punishment, is the more intuitive and efficient response pattern*

Discussion

Neuroimaging level

*Stressed individuals demonstrated increased **DLPFC**, **PCC**, and **rTPJ** activity when selecting punishment options instead of help options*

- ✓ ***DLPFC** commonly associated with top-down executive function in controlling selfishness-related impulses, social norm compliance in adjusting inequity aversion, and integrating distinct information streams for appropriate decisions*
- ✓ ***PCC** plays an important role in value-based decision-making, especially in terms of behavioral control and the evaluation of affordances*
- ✓ *linked neural activity in the **rTPJ** and **PCC** with mentalizing-related computations and strategic choice*

stress increased amygdala-vmPFC functional connectivity, and this connectivity, in turn, inhibited the punishment option

- ✓ *psychological stress and early life stress increased vmPFC functional connectivity with the amygdala*
- ✓ *top-down regulation of the vmPFC to the amygdala is implicated in emotion regulation and extinction learning*