

Behavioral/Cognitive

# Selective Increase of Intention-Based Economic Decisions by Noninvasive Brain Stimulation to the Dorsolateral Prefrontal Cortex

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# Backgrounds



Source : <https://www.livescience.com/13917-hated-baby-names.html>

*What does motivate our social behavior?*

# Backgrounds

## Motivations in social decision-making

### Inequity aversion

Outcome-based  
Distributional preferences

: avoid unfair and inequitable outcome  
for the self and the other

### Guilt aversion

Intention-based  
Belief dependant

: avoid disappointing others relative to  
what others believe they should receive



# Backgrounds

## Inequity aversion vs. Guilt aversion

- **Fail to dissociate two distinct motivations**
  - : did not measure nor manipulate individuals' expectations
- **Separate imaging studies of guilt aversion and inequity aversion**
  - : overlapping brain structures were reported, but it remains unclear whether the two systems share a core neural computation

# Goal of the study

- To investigate whether the two systems are causally dissociable in the brain

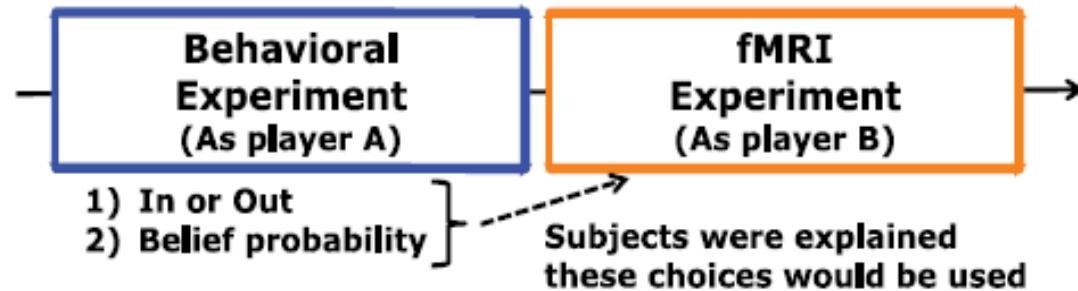


Inequity  
aversion

Guilt  
aversion

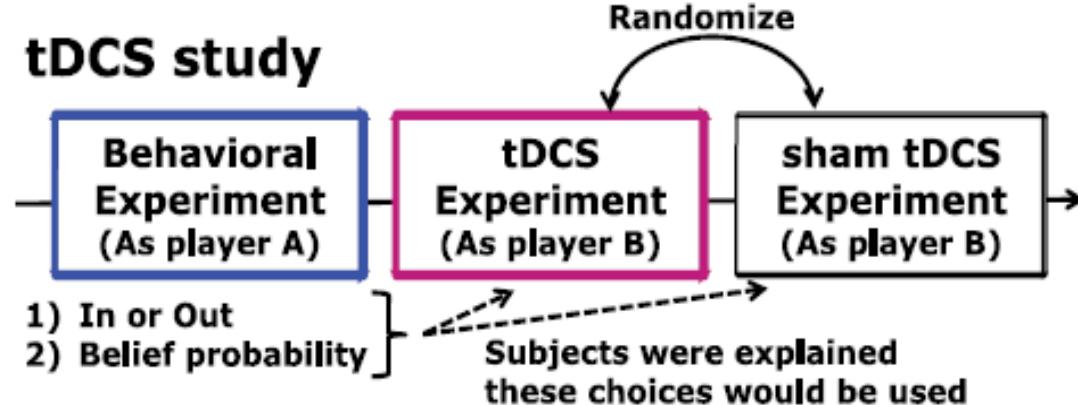
# Methods

## fMRI study



- **fMRI study :** behavioral experiment (69)  
fMRI experiment (49 -> 41)

## tDCS study

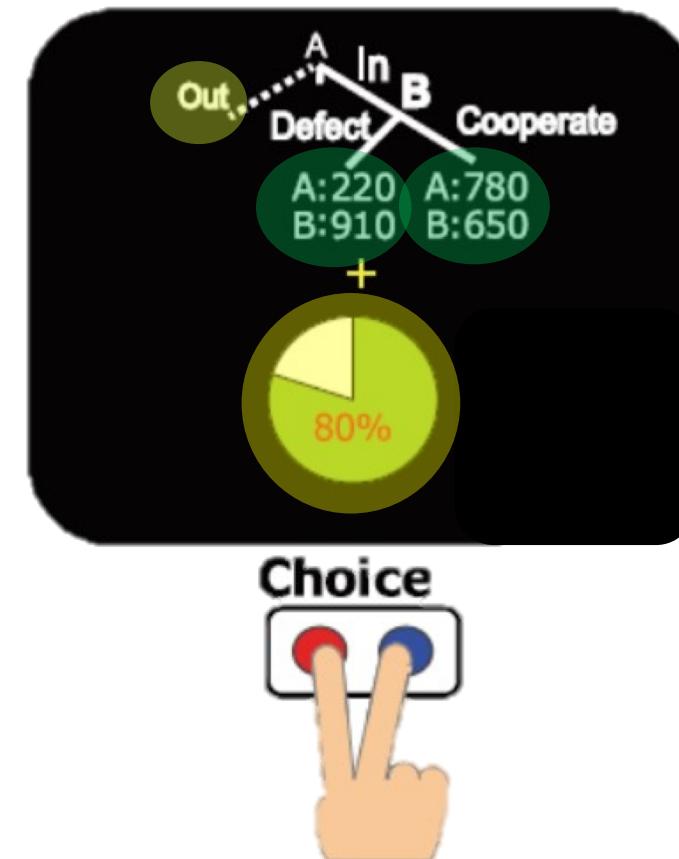
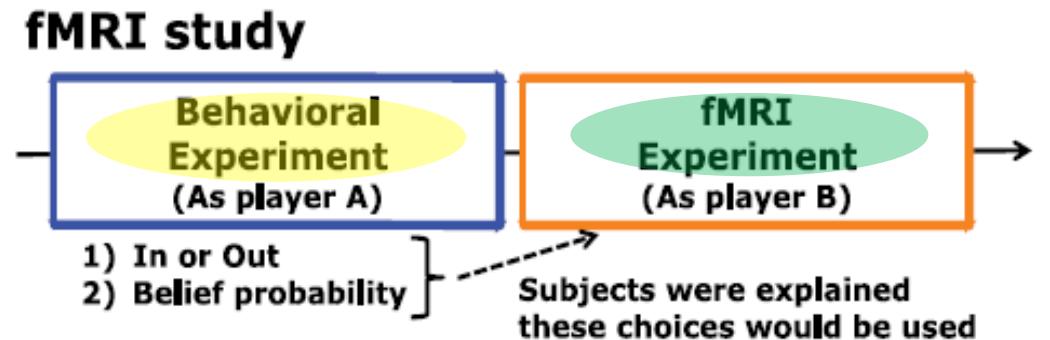


- **tDCS study (22) :** behavioral experiment  
tDCS experiment  
sham tDCS experiment

# Methods

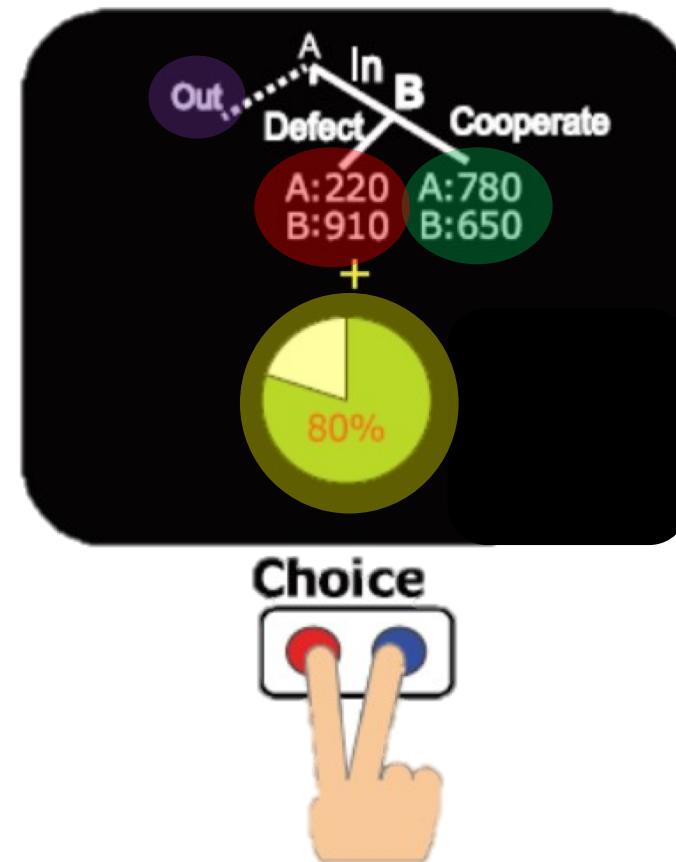
## Modified Trust game

- **Player A** (investor)  
: Out or In ?  
How likely do you believe Player B would choose to Cooperate?
- **Player B** (trustee)  
: Cooperate or Defect?
  - investor's expectation
  - payoffs each player would receive based on his or her decision



# Methods

- $\tau_A$ : player A's belief about the probability that Player B will Cooperate
- $Z_A, Z_B$ : money that players receive when player A choose Out
- $x_A, x_B$ : money that players receive when player B chooses Cooperate
- $y_A, y_B$ : money that players receive when B chooses Defect



# Methods

## Experiment Design

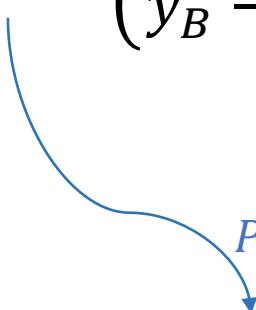
- $y_A < z_A < x_A$  : signal player A's trust message to player B when player A chooses in  
 $\underline{y_A}$  and  $\overline{z_A}$
  - $z_B < x_B < y_B$  : make player B feel guilt upon disappointing the other player relative  
to the other's belief of what he or she receive
- \*x, y, z were assigned so that they do not reveal correlations  
among Reward, Guilt, and Inequity

# Methods

## Utility function

- Participants make decisions that maximize their expected payoff
- Payoffs could be material or psychological

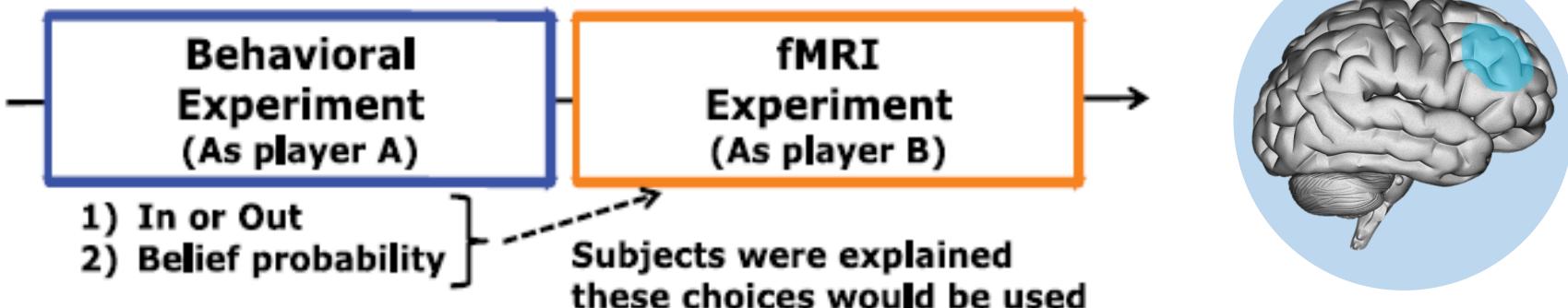
$$\bullet u_B = \begin{cases} x_B - \alpha_B |x_A - x_B| & \text{if the profile (In, Cooperate);} \\ y_B - \gamma_B \cdot (\tau_A \cdot x_A - y_A) - \alpha_B |y_A - y_B| & \text{if the profile (In, Defect)} \end{cases}$$


$$P_{B,Cooperate} = 1/(1 + e^{-(u_B(X) - u_B(Y))})$$

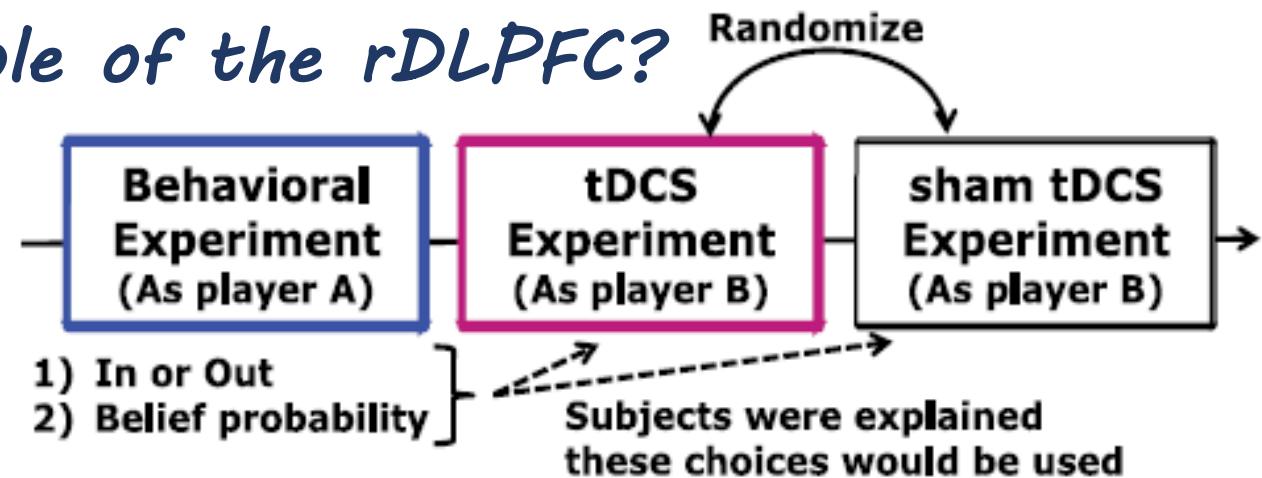
$$\textbf{Utility}_t = \beta_0 + \beta_1 \underset{x_B - y_B}{\textit{Reward}_t} + \beta_2 \underset{\tau_A \cdot x_A - y_A}{\textit{Guilt}_t} + \beta_3 \underset{x_A - x_B + y_B - y_A}{\textit{Inequity}_t}$$

# Methods

## *Q· Different Neuronal Circuitry?*



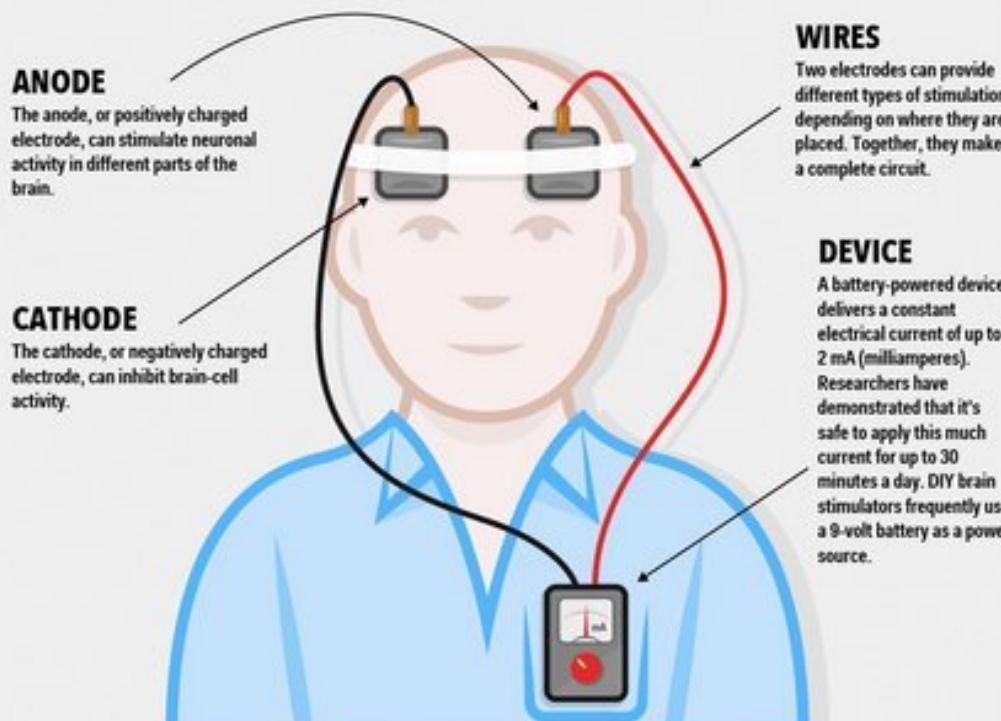
## *Q· Casual role of the rDLPFC?*



# Methods

## TRANSCRANIAL DIRECT CURRENT STIMULATION

Some studies show that stimulating the brain with electricity can immediately boost memory, focus, energy, and vigilance. Researchers say that it also shows promise as a means of treating drug-resistant mental illness like depression, as well as conditions like epilepsy and chronic pain. Here's how it works:



Source: Wright State Research Institute, Johns Hopkins Medicine

BUSINESS INSIDER

# tDCS

## Anodal stimulation

: temporarily enhance the neuronal excitability of cortex

## Cathodal stimulation

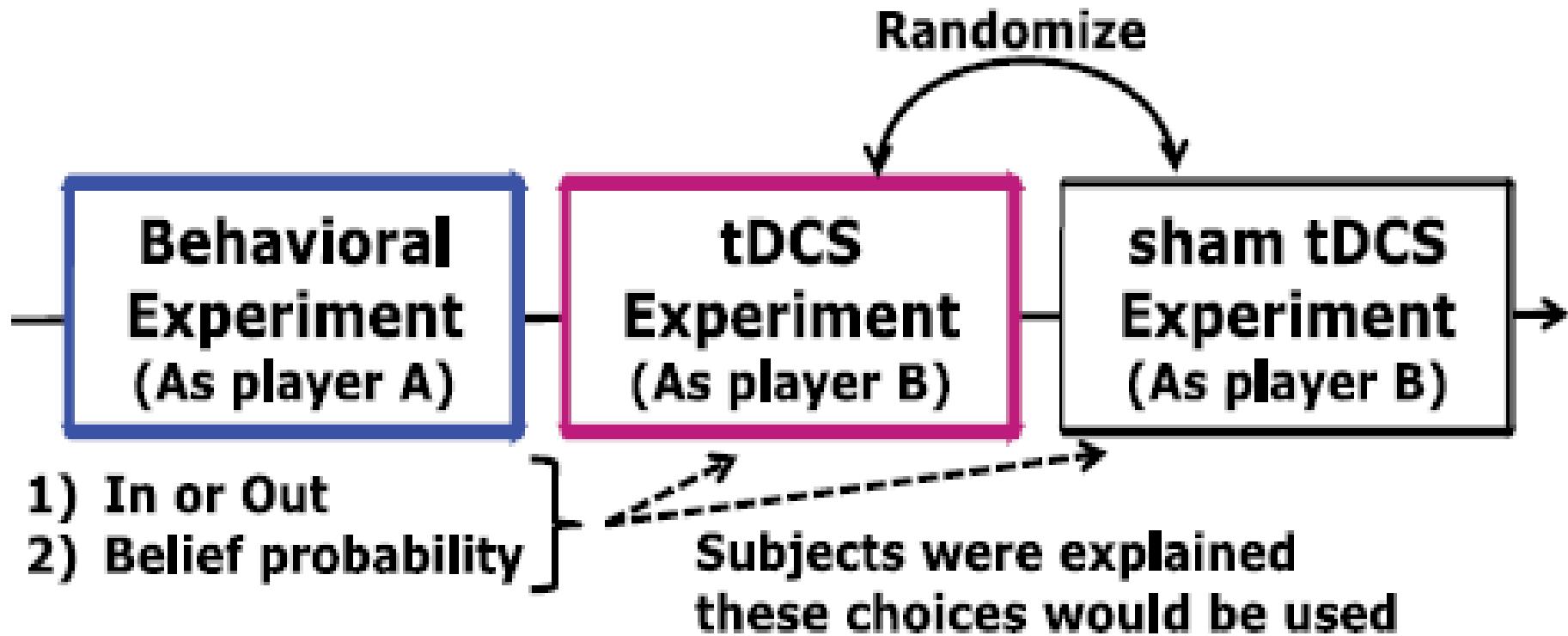
: temporarily decrease the neuronal excitability of cortex

## Sham stimulation

: control for the placebo effect of sensation associated with tDCS

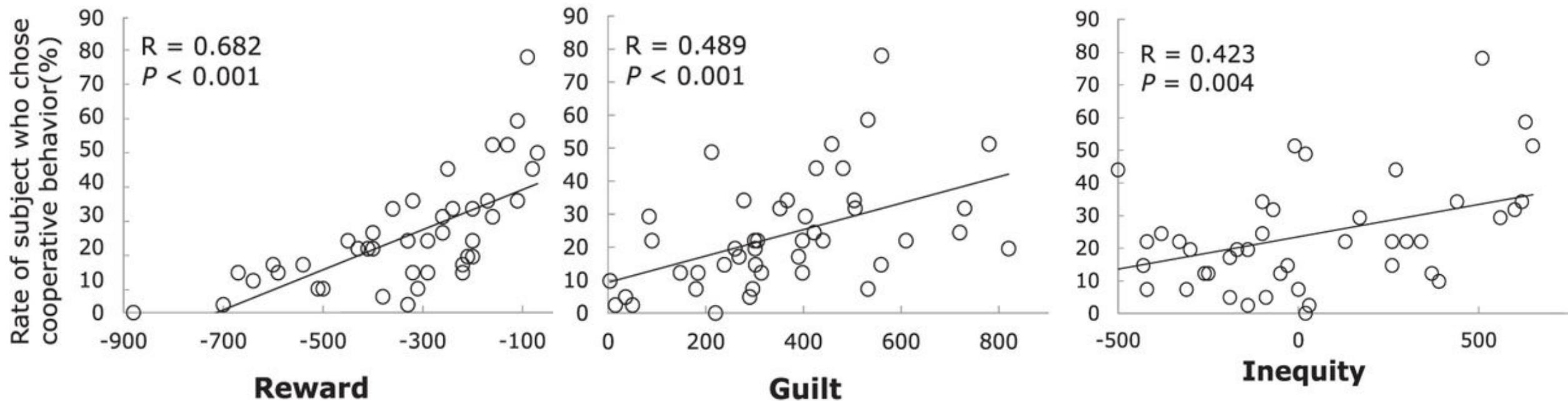
# Methods

*Q. Casual role of the rDLPFC?*



# Results

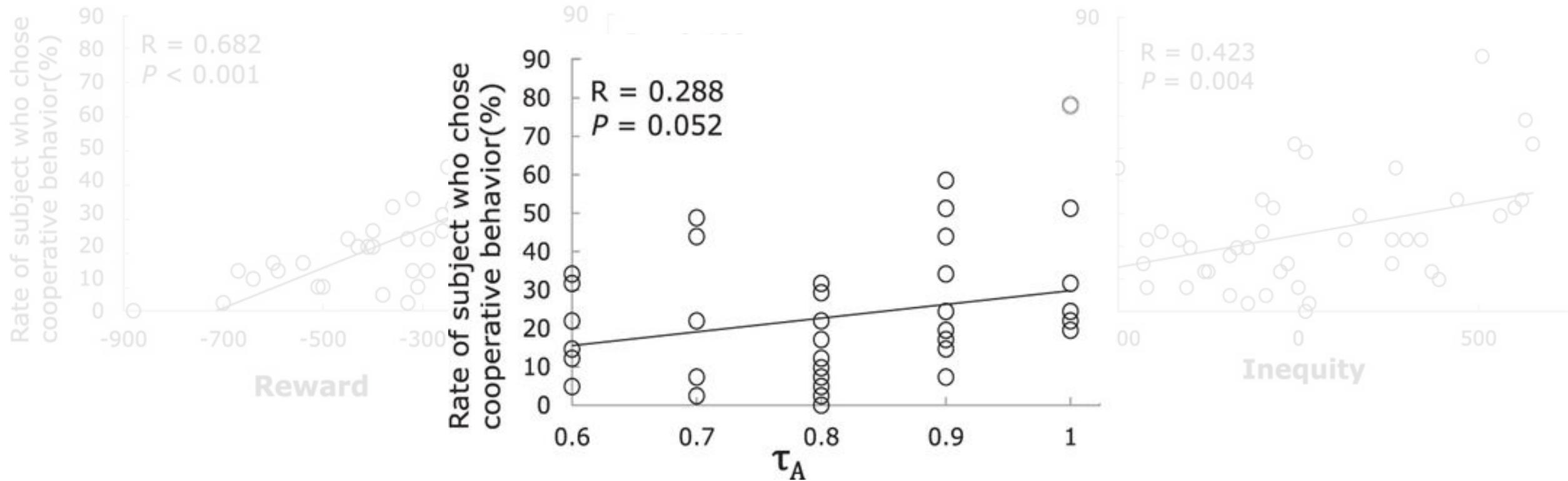
Participants chose cooperation against **reward, guilt, inequity**



$$\text{Utility}_t = \beta_0 + \beta_1 \frac{x_B - y_B}{\tau_A \cdot x_A - y_A} + \beta_2 \frac{\text{Guilt}_t}{\tau_A \cdot x_A - y_A} + \beta_3 \frac{\text{Inequity}_t}{x_A - x_B + y_B - y_A}$$

# Results

Participants chose cooperation against **reward, guilt, inequity**

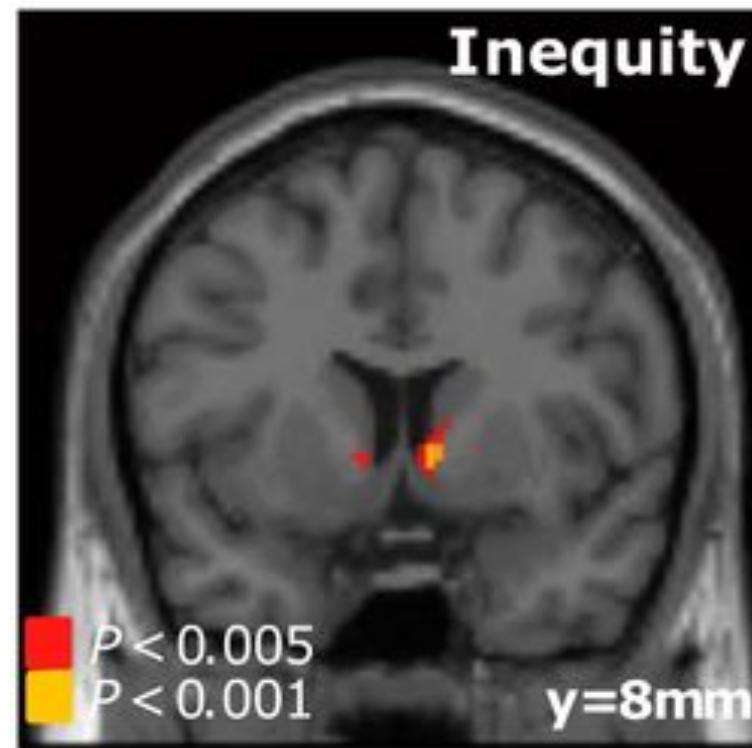


# Results

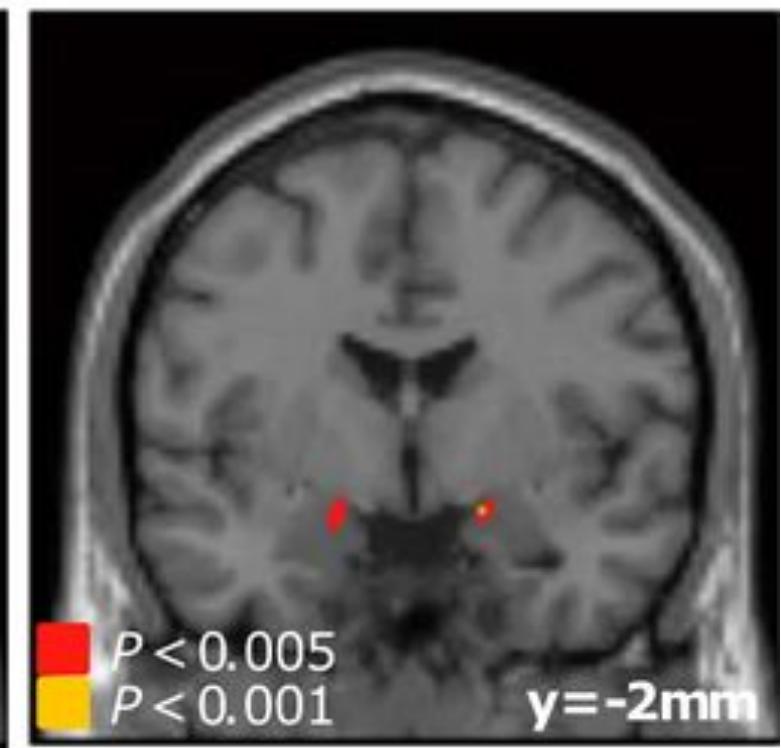
Two motivations associated with **different neural circuitry**



rDLPFC

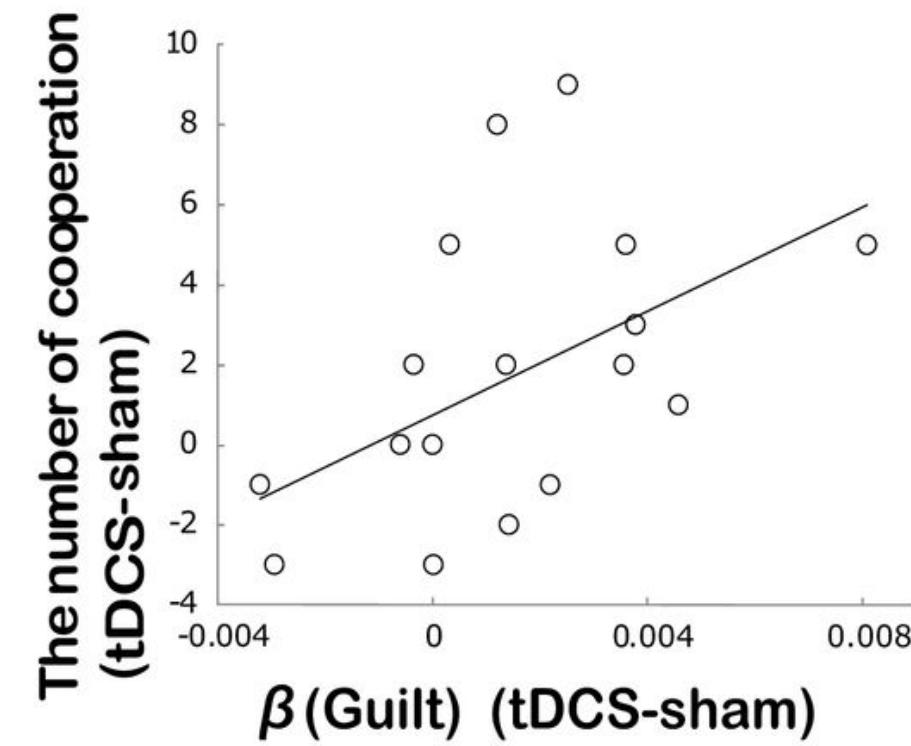
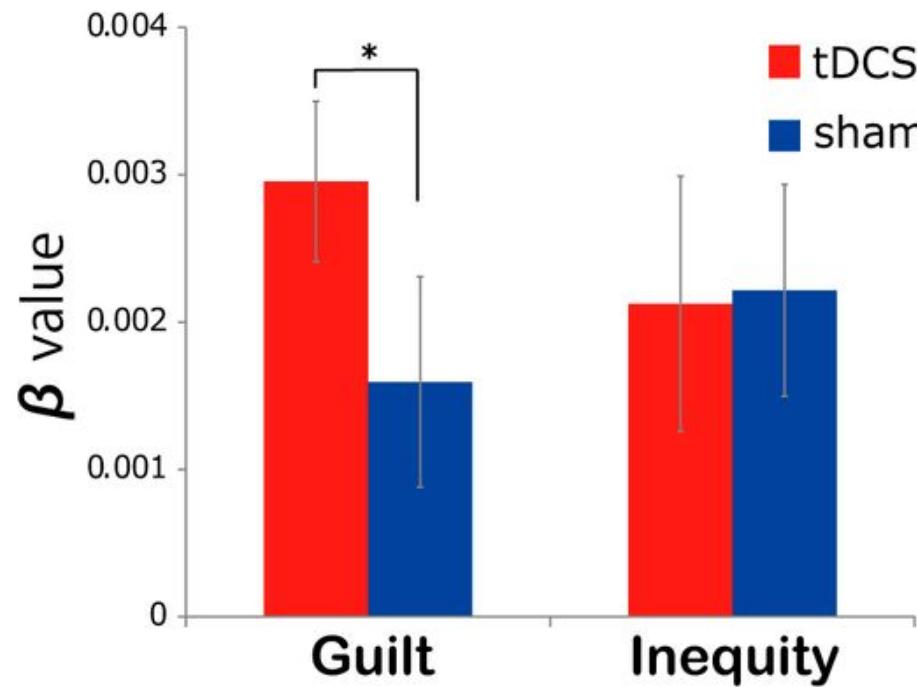


Ventral striatum and Amygdala



# Results

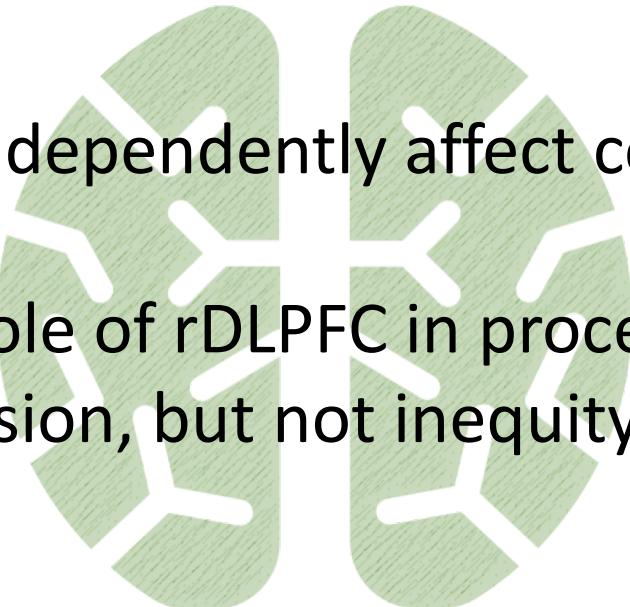
## The causal role of rDLPFC in processing anticipated guilt



# Conclusion

## Demonstrated dual neural processes involved in social decision making

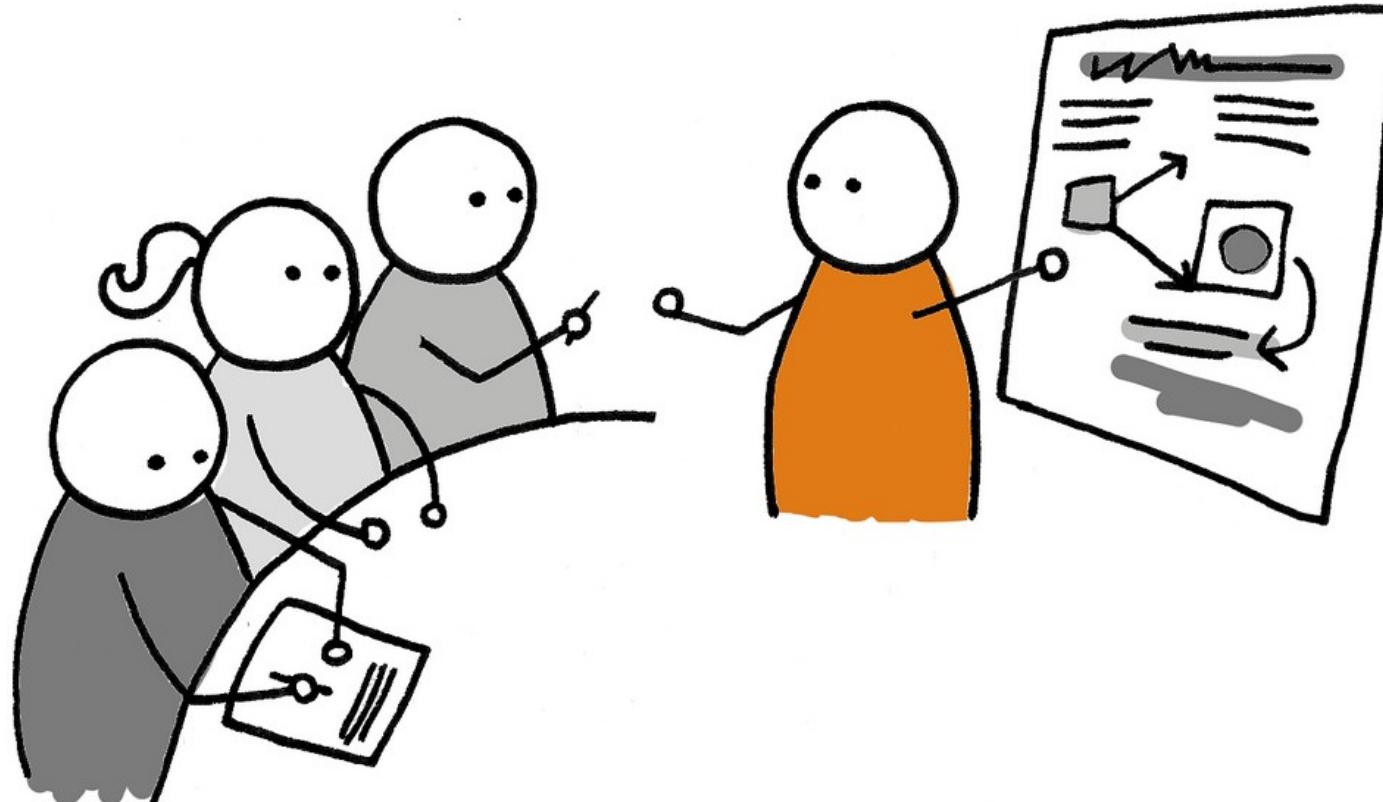
- Both motivations independently affect cooperative decision
  - The role of rDLPFC in processing guilt-aversion, but not inequity-version



# Limitations and Strengths



Let's discuss!



A blurred background photograph shows two young girls in a kitchen. One girl, on the left, is wearing a yellow t-shirt with a floral emblem on the chest and is holding a bowl of cereal. The other girl, on the right, is wearing a pink t-shirt and is also holding a bowl of cereal. A carton of orange juice sits on the counter between them.

Thank you 😊

## Trust game

