Trends in Neurosciences

Journal Impact Factor™

15.9
2022

16.4
Five Year

Neural basis of prosocial behavior

Ye Emily Wu [1], Weizhe Hong [1]

*interested in understanding how individuals display **different forms of prosocial behavior** and how these behaviors are regulated by **neural circuits** in the brain*

Yang Ziyang

2023.10.19

Intro

Are humans predisposed to help and care for others or are we inherently selfish?

most animal behaviors

feeding mating fighting

driven by

Survival and Reproductive needs

for

serve the purpose of benefitting oneself

survival of one's own genes in subsequent generations

examples of altruistic behaviors

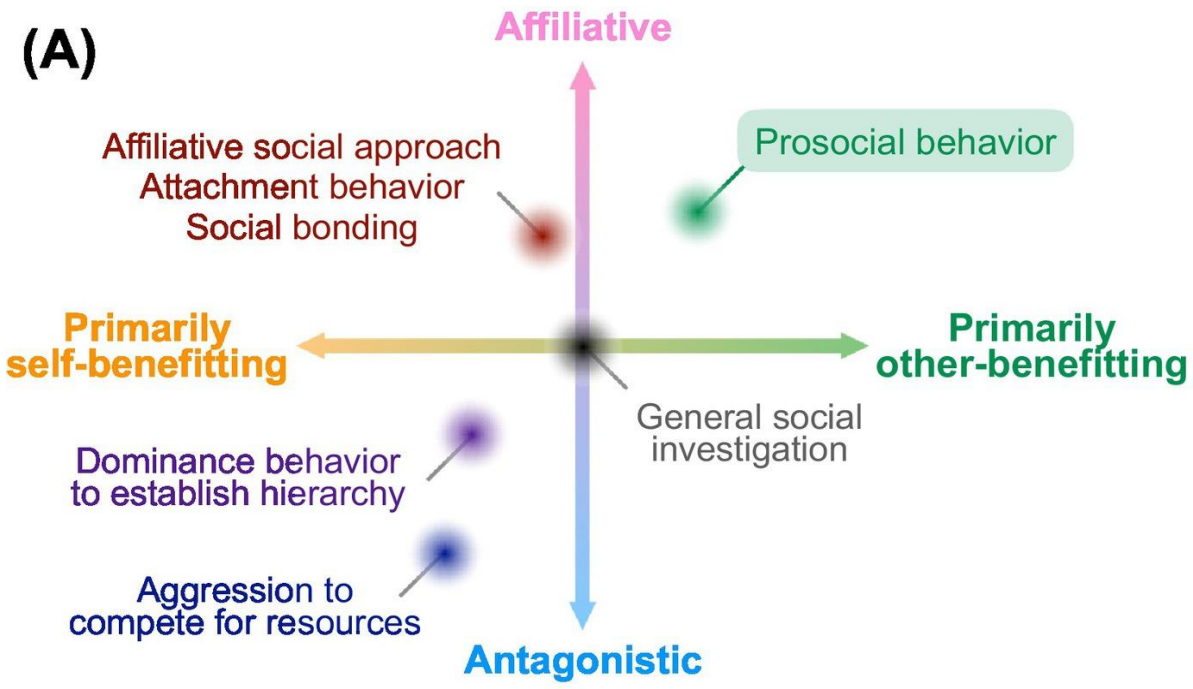
The existence of behaviors that benefit other individuals has long puzzled evolutionary biologists since Darwin

Research through the lens of modern neuroscience can help provide insights into the biological basis and evolutionary roots of our 'good nature'

The concept of prosocial behavior

grouped by characteristics along two wide spectrums :

from affiliative to antagonistic and from self to other-benefitting



Affiliative

behaviors generally **positive and friendly interactions**, including those that foster the development and maintenance of social relationships

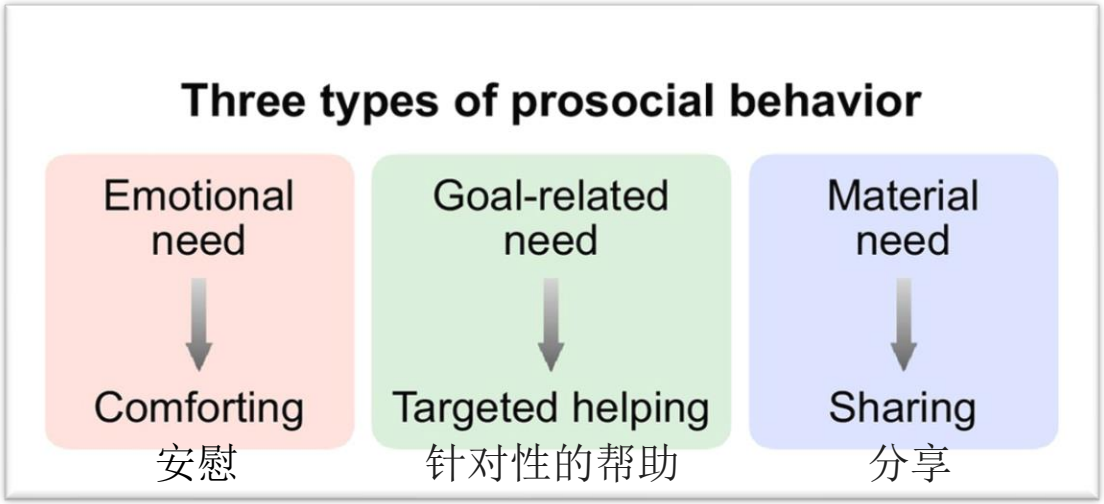
Primarily other-benefitting

prosocial behaviors also associated with the **motivation** and/or **consequence** of benefitting others

Prosocial behavior

- ✓ *enhances social cohesiveness*
- ✓ *promotes the physical and emotional well-being of social species*

The concept of prosocial behavior



(i) comforting – induced by others' **emotional** distress

(ii) targeted helping – induced by others' difficulty to complete a **goal-related** action

(iii) sharing – induced by others' **material needs** or desires

---

'prosocial behavior'

occurs in response to a negative state and/or unmet need in another individual

and helps to alleviate negative state and/or fulfill the need of the recipient

STATE/NEED { *'emotions, goals, or material'*; *Other's need* } → **KEY** to distinguishing from general sociability

- associated with **immediate social reward and long-term reproductive benefit** to the recipient
- not induced by a specific negative state or need in the recipient and are mainly **driven by and serve the actor's own survival or reproductive needs**.

Behavioral manifestations

Non-primate species
(with wide-ranging levels of cognitive capacities and distinct social structures)

→ Non-human primates → Human

Rodents

Prosocial Behavior

- Emotional need → Comforting
- Goal-related need → Targeted helping
- Material need → Sharing

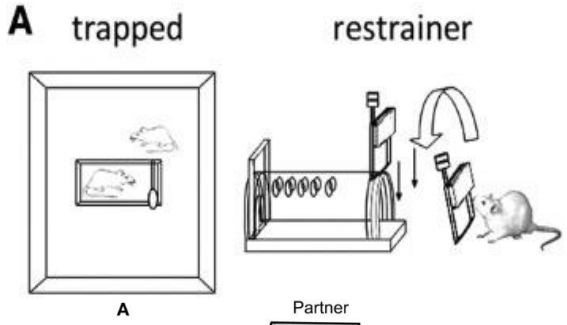
Comforting behavior is defined as an increase in affiliative social contact toward distressed conspecifics

"social buffering"

- ✓ bystanders display **increased allogrooming towards <u>distressed</u> partners** compared with unstressed ones
- ✓ <u>socially defeated</u>, <u>sick</u>, or <u>pain-experiencing</u>

rats are able to learn to open the door to a restrainer to help free a trapped cagemate

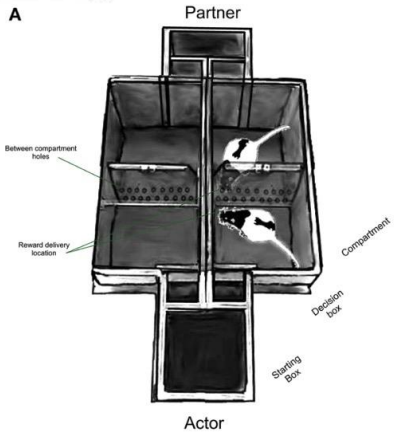
an **anxiolytic impaired door opening when the restrainer contained a cagemate, but not when it contained food*



rats are prefer to deliver mutual food rewards over self-reward only

pairing the preferred lever with observation of foot-shocks to another rat

**harm to others is a negative reinforcer*



Behavioral manifestations

Non-primate species

(with wide-ranging levels of cognitive capacities and distinct social structures)

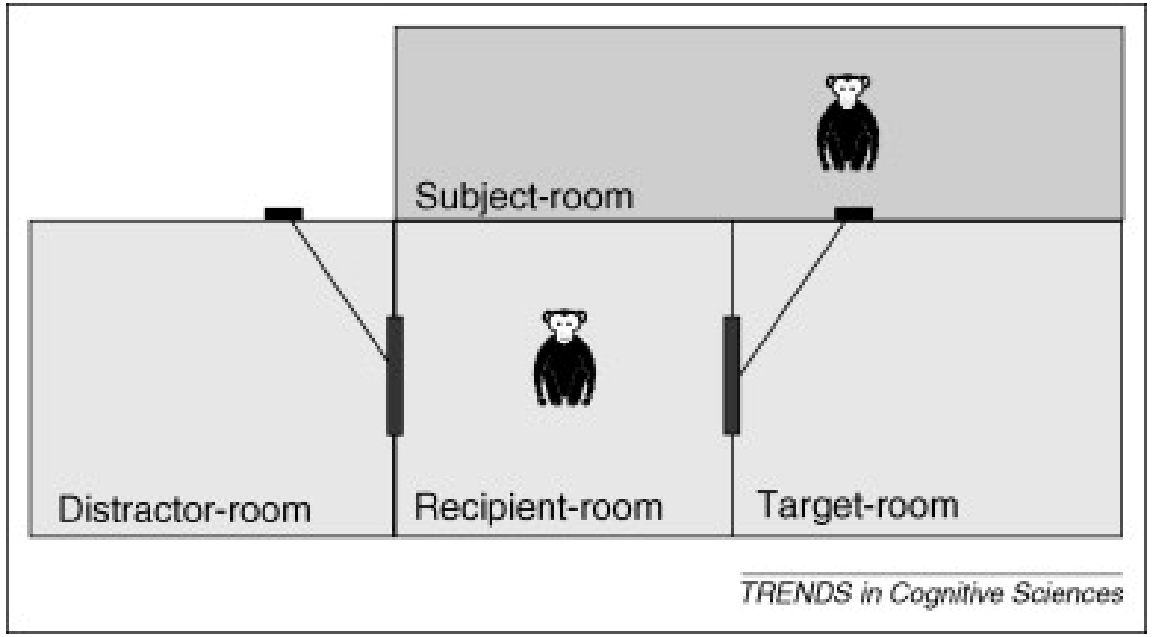
→ **Non-human primates** →

Human

- chimpanzees and bonobos can help others to achieve their goals

such as transferring appropriate tools to conspecifics and helping others to obtain food, even in the absence of immediate reward to the helpers

Nor did either species help more frequently when the potential recipient was holding a reward in his hand



18-month-old children and mother-raised chimpanzees

Behavioral manifestations

Non-primate species

(with wide-ranging levels of cognitive capacities and distinct social structures)

→ Non-human primates → **Human**

Three types of prosocial behavior

"prosocial behaviors"

manifest in diverse forms in human prosocial

- Helping
- emotional support
- Sharing
- Donating
- Volunteering
- *Cooperation*
- Acts of bravery or heroism

- complex prosocial behaviors that involve more advanced cognitive

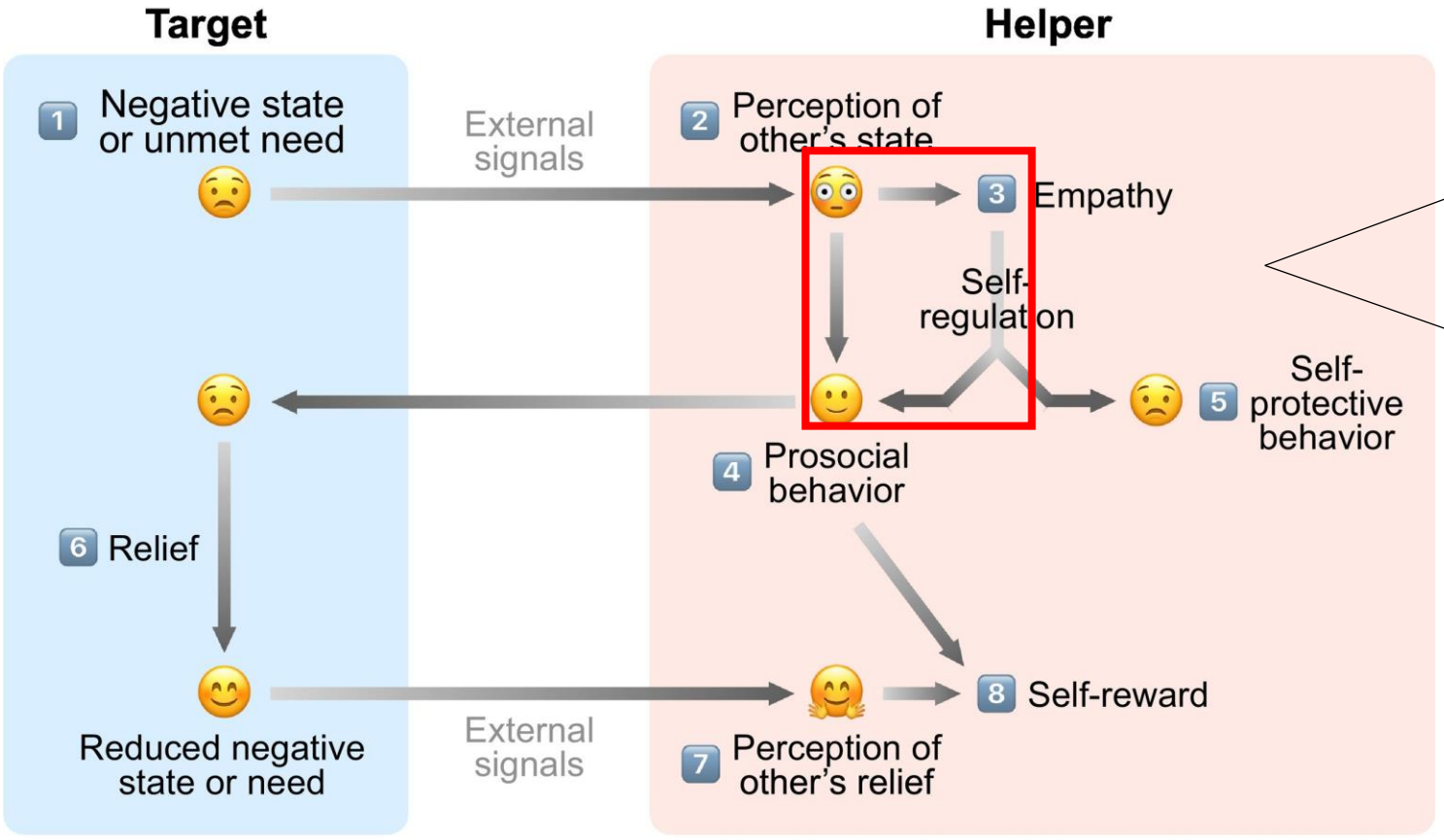
real-world scenarios often involve simultaneous presentation of multiple types of negative states

↓

lead to co-occurrence of different types of prosocial responses

Motivational drives

Different processes involved in prosocial interactions



Trends in Neurosciences

- An important proximate mechanism thought to motivate prosocial behaviors is **empathy**

  - ***"affective empathy,"*** resonating with the affect of others
  - ***"cognitive empathy,"*** understanding the thoughts and affective states of others

- Affective empathy is conserved **across many species**, from rodents to humans

  show social **transfer of emotions and physiological** states, such as pain, fear, and stress

- The association between empathy and prosocial behavior can be modulated by **other factors**

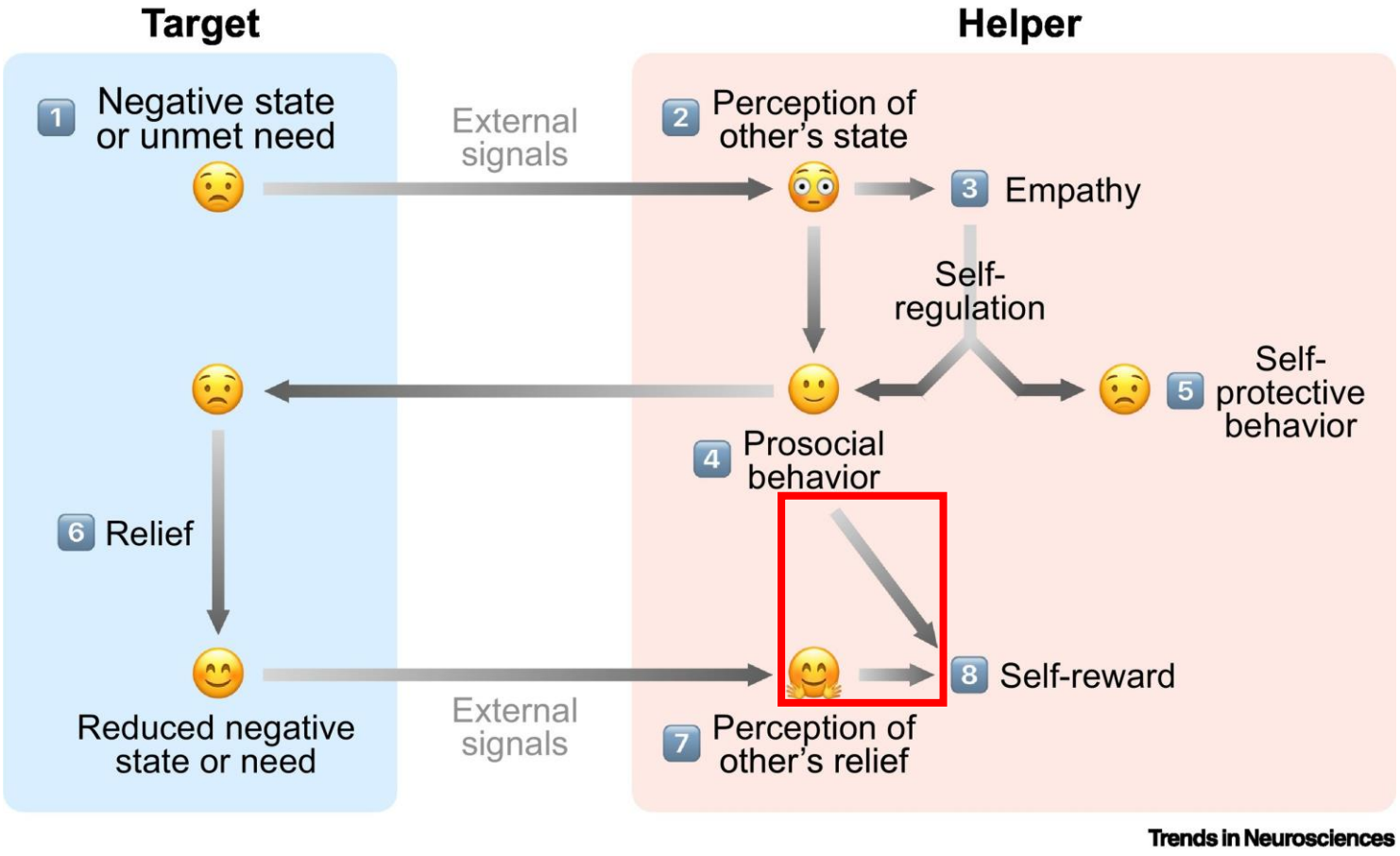
  ✓ cost–benefit relationship ✓ perceived ability to help

It is worth noting that:

- the **experience of empathy** and the **ensuing active prosocial responses** are distinct processes that should not be conflated

Motivational drives

Different processes involved in prosocial interactions



4 → 8

acting to improve another's state could in turn lead to personal relief or joy in the helper

⬇

'warm glow'

people report **higher positive affect** after acting kindly towards others

7 → 8

The positive experience resulting from the intrinsic reward associated with prosocial behavior or the perception of improvements in others' states

Neural mechanisms of prosocial behavior

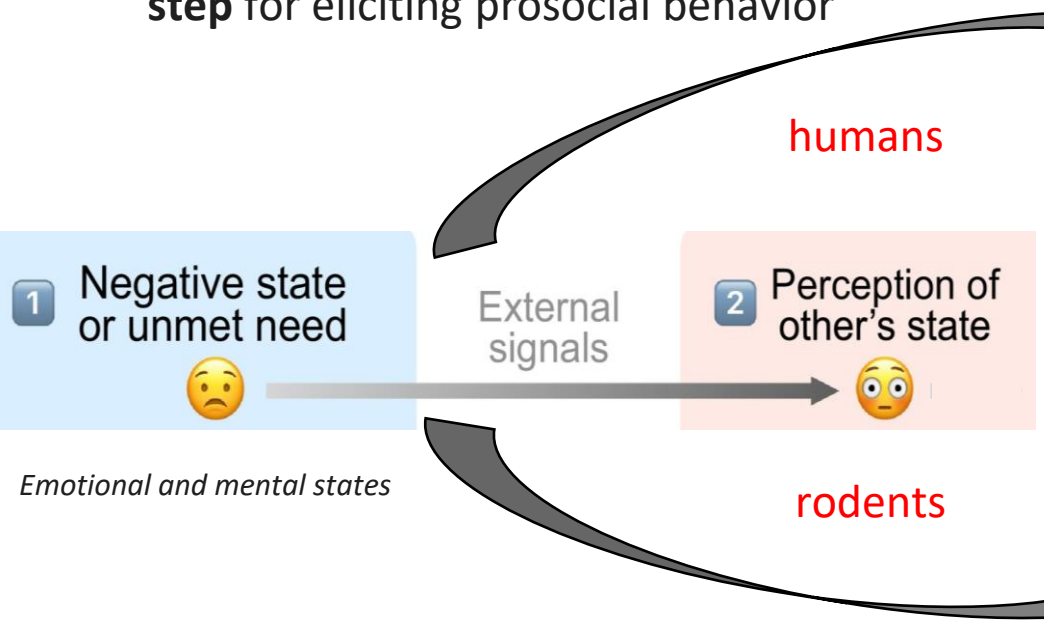
summarize studies → humans / rodents

which represent two major branches of research that have provided complementary insights

**limited spatial resolution of noninvasive techniques*

Mechanisms mediating perception of others' affective states

- Perception of other's mental state is a **prerequisite step** for eliciting prosocial behavior



Emotional and mental states

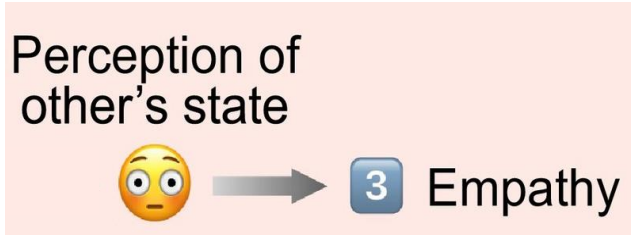
humans: visual, vocal, and tactile cues

- Processing dynamic **facial features** (**emotional facial expressions**) → inferior occipital gyrus; superior temporal sulcus; amygdala
- 'voice areas' that respond more strongly to emotional vocalizations → 'mid-temporal regions'
- affective experience induced by gentle tactile stimulations → posterior insula; posterior STS

rodents: olfactory cues ***"volatile chemicals"*** lead to **fear, stress, and anxiety-related** responses in receiving animals

Neural mechanisms of prosocial behavior

Mechanisms of shared experience (empathy)



The perception of others' states may **further elicit an empathic** experience in the self

- ✓ In humans, the **neural correlates of empathy** have been mainly investigated using **functional neuroimaging**

Affective empathy tasks

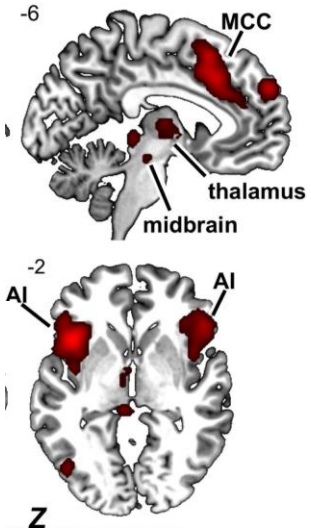
Cognitive empathy tasks

*empathic experience is usually self-reported

Neural mechanisms of prosocial behavior

Affective empathy tasks (Human)

Many studies have focused on empathic pain, due to the robustness of pain in inducing empathy



- The AI and dACC/aMCC are activated during both direct and vicarious pain experiences

  encode the **negative affect** associated with self and empathic pain

- These regions are also recruited during (other)vicarious experience associated with other aversive stimuli and positive stimuli

such as disgust and anxiety *such as reward*

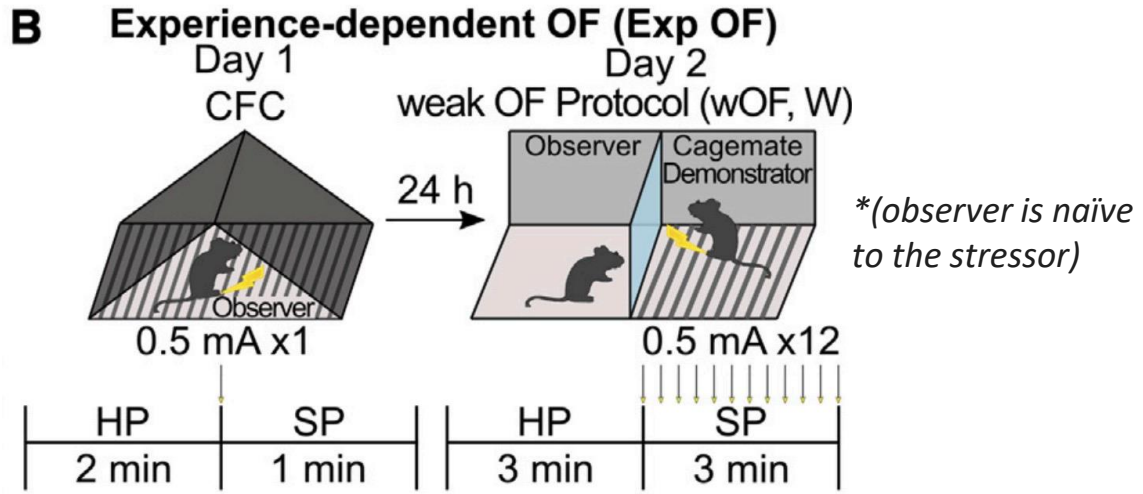
- self and other experience of emotions and sensations appear to recruit some overlapping brain regions

self and empathic experience may involve shared neural substrates

* directly from a shared representation of self and others' states is still debated

Neural mechanisms of prosocial behavior

Affective empathy tasks (Non-human primates)



(observer is naïve to the stressor)

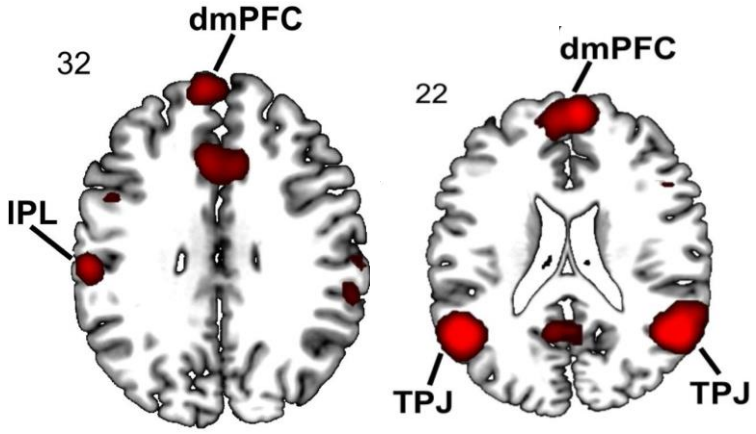
observational fear paradigm

As self-report of empathy is **not feasible** in animals

ACC is required for experience-independent observational fear and its function relies on somatostatin-positive interneurons and the Ca v 1.2 Ca^{2+} channel subunit

Cognitive empathy tasks

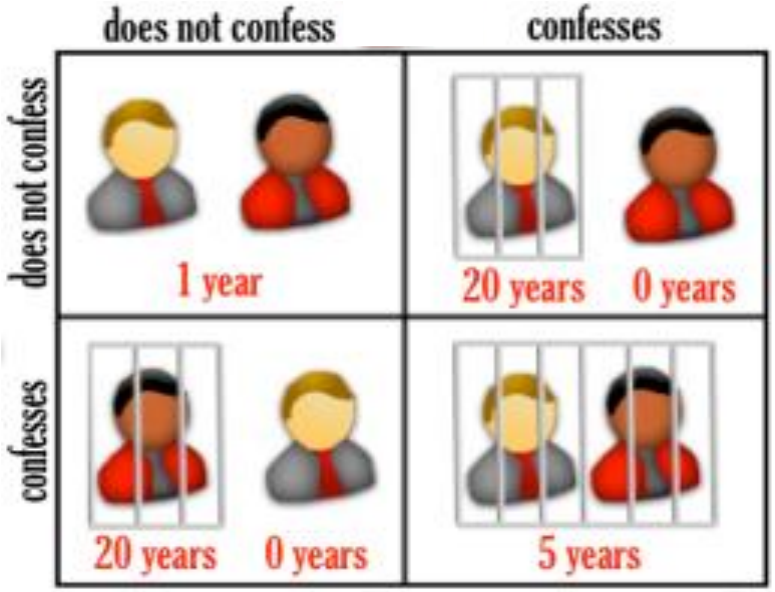
Cognitive empathy in humans has been studied using paradigms such as **false beliefs**, **trait judgements**, **social animations**, and **inference of intentions**



Mechanisms of prosocial decisions and actions

attribution and/or sharing of others' emotional and mental states

produce a motivation to act prosocially according to others' needs and intentions



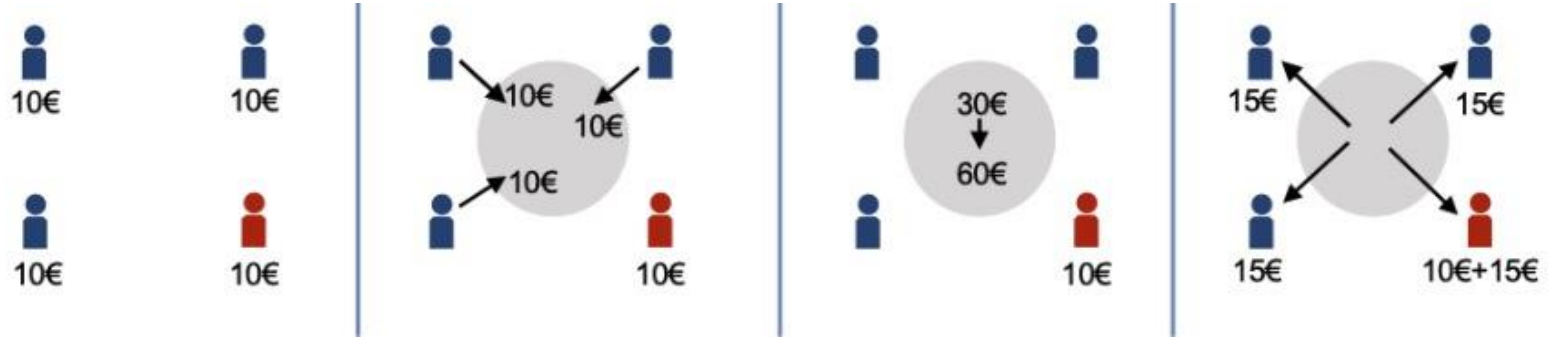
Others' need

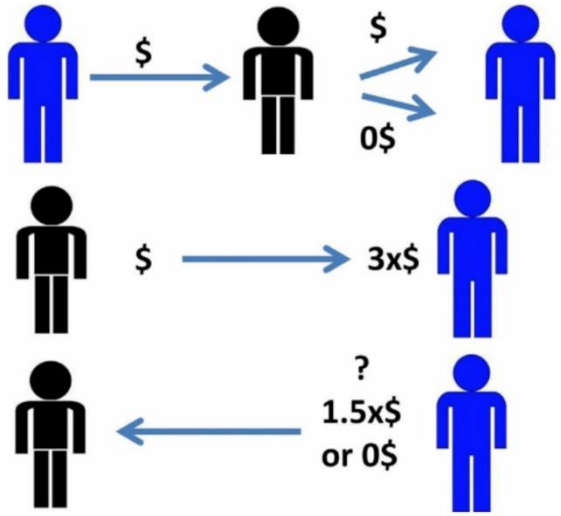
↓

motivation

→ **decide which behavioral option to choose**

can be modulated by contextual and social factors such as **norms** and **group identity**





Mechanisms of prosocial decisions and actions

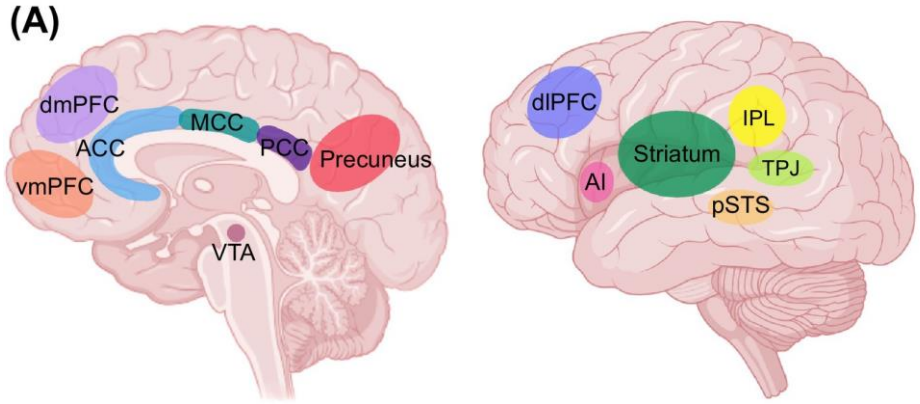
Others' need

↓

motivation

→ can be modulated by contextual and social factors such as **norms** and **group identity**

→ decide which behavioral option to choose



In prosocial decision-making, individuals need to assign subjective values to the expected outcomes of different options to select the option of optimal value

self- and/or other-regarding values ➡ mPFC, ACC, and ventral striatum

attribution of others' values recruits **mentalizing-related** brain areas ➡ TPJ, precuneus, and IPL

*mediate inference of others' intentions or anticipation of others' responses

the vmPFC and dmPFC preferentially encode self- and other-regarding values, **respectively**

responses in the vmPFC and VS correlate with self-regarding values, whereas TPJ activity correlates with other-regarding

in a prosocial learning task

In a prosocial choice task

Mechanisms of prosocial decisions and actions

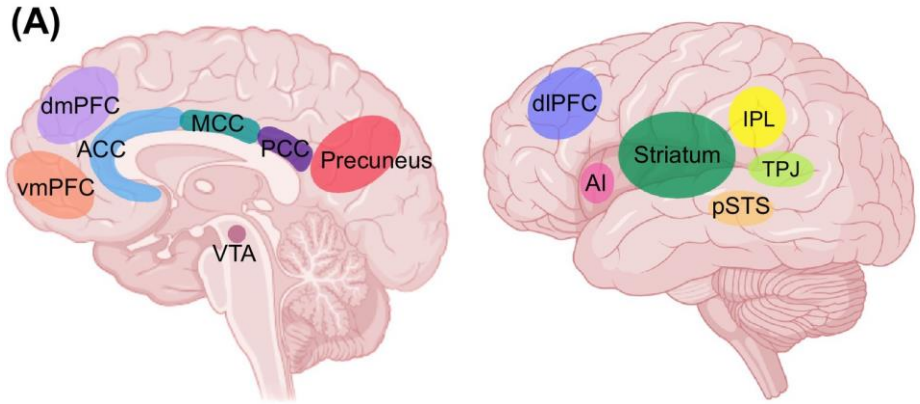
Others' need

↓

motivation

→ can be modulated by contextual and social factors such as **norms** and **group identity**

→ decide which behavioral option to choose



rules and norms (such as fairness) influence prosocial decisions

- Single-neuron recording in monkeys showed that **lPFC neurons** can encode **rules**
  - lPFC activity correlates with rule-complying decisions
- Neuroimaging in humans found that the **lPFC shows higher activity** during decision-making in the presence of **stronger rules**
  - lPFC may exert cognitive control of impulsive decisions that **violate norms**
  - modulate the subjective values of different options by integrating information about rules and norms → *norm/rule-conforming decisions are assigned higher subjective values

Mechanisms of prosocial decisions and actions

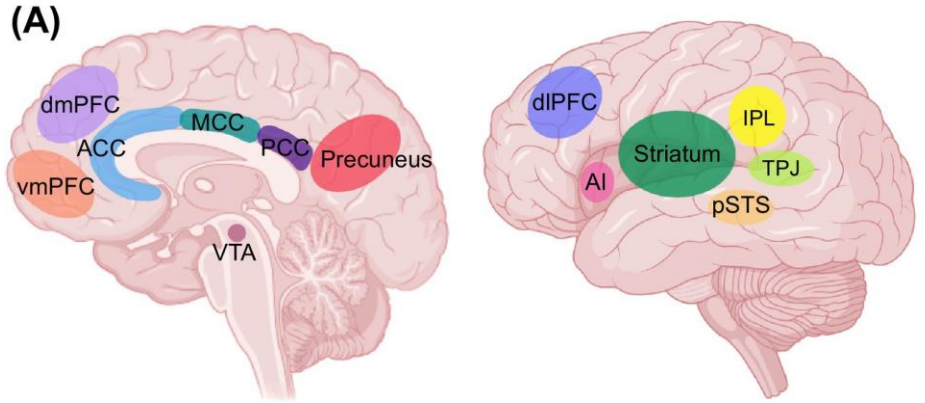
Others' need

↓

motivation

→ can be modulated by contextual and social factors such as **norms** and **group identity**

→ decide which behavioral option to choose



Group membership based on different social identities also impacts prosocial behaviors

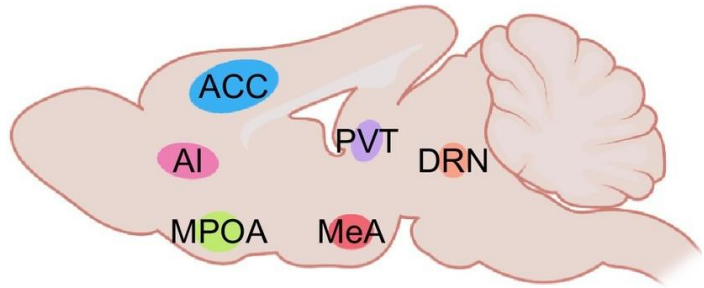
humans **tend to** share with, help, and cooperate **with in-group targets** more than out-group targets.

These effects may be due to:

- a **weakened ability to empathize** with **out-group** individuals compared with in-group members
- benefitting **in-group** members may be **assigned higher values** and is subjectively more satisfying

Mechanisms of prosocial decisions and actions

- recent studies in rodents began to uncover specific neuronal populations and neural circuits that control the expression of prosocial actions

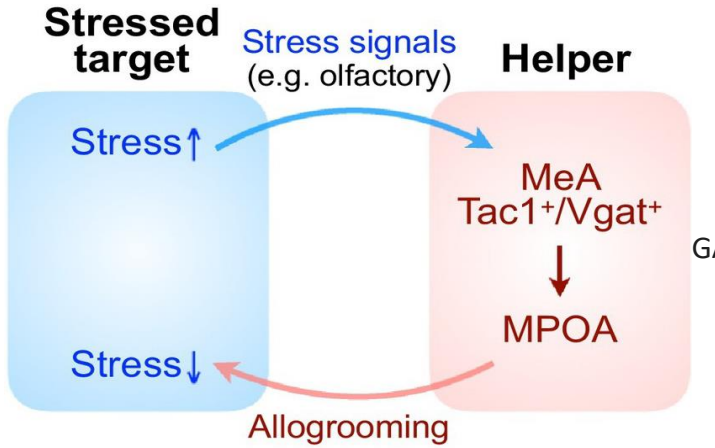


Brain areas shown to regulate prosocial behaviors in rodents

perception of others' emotional distress induces increased affiliative social contact

MeA

- MeA is an important hub that receives social sensory inputs
- link the **perception of others' distress** with the expression of **comforting behavior**



GABAergic neurons

These bidirectional, time-locked effects support a direct role of these neurons in promoting this behavior

In vivo calcium imaging showed that MeA neurons respond differentially to stressed versus unstressed animals both at single-cell and population levels

a potential direct link between the perception of other's stress state and the control of allogrooming

Summary

Recent studies of prosocial behavior using modern neuroscience tools have advanced our understanding of the brain mechanisms of this evolutionarily conserved phenomenon

Human

cognitive processes during complex prosocial decision-making
- attribution of others' emotional and mental states
- evaluation of self- and other-regarding outcomes
- compliance to rules and norms

Rodent

enabled interrogation of the neural representations and causal circuit mechanisms of these behaviors using techniques for high-resolution monitoring and manipulation of neural activity

Complement

- These studies have also shed light on neural mechanisms that may be shared between rodents and humans

ACC, insula, amygdala, and the reward system

Future research should investigate the neural representation of **social information and behavioral decisions** during prosocial interactions at both single-cell

Summary

Conceptual questions in understanding the neural mechanisms of prosocial behaviors

- Disambiguating mechanisms for different stages of prosocial interaction
  - ACC
    - mediates the initial empathic sharing
    - different role in regulating the subsequent
- Unique and converging mechanisms across prosocial contexts
  - highly dependent on the context of interaction
- Multi-brain framework for prosocial interactions
  - apply a multi-brain framework and monitor neural activity

- ✓ How is prosocial interaction represented in different brain areas at single-cell and population levels?
- ✓ How is information communicated and integrated across different brain regions to coordinate prosocial decisions and actions?
- ✓ How do inter-brain neural dynamics and emergent neural properties across interacting individuals relate to different behavioral features during prosocial interaction?
- ✓ How do inter-brain neural dynamics and emergent neural properties across interacting individuals relate to different behavioral features during prosocial interaction?