Investigating Prosociality: Vicarious Reward Circuits in the Brain

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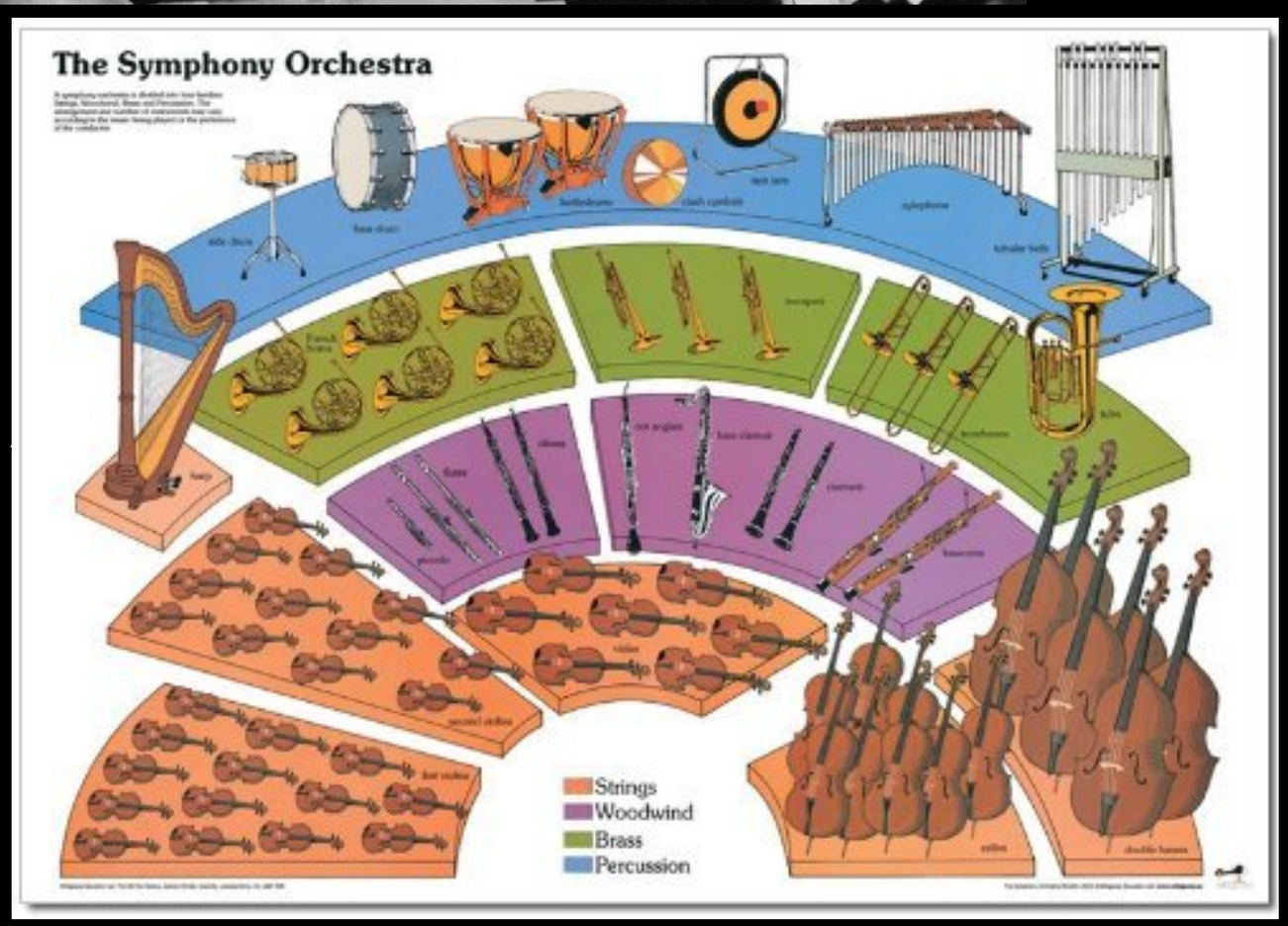
Unraveling the Neurobiology of Empathy and Compassion

The National Academies' Forum on Neuroscience and Nervous System Disorders.
5/19/2025

Importance of <u>neural coordination</u> in prosociality *as examined through the lens of vicarious reward*

Leonard Bernstein conducting a New York Philharmonic Young People's Concert, October 23, 1965. (Credit: CBS/Getty Image)

https://www.gramophone.co.uk/features/article/an-interview-with-karajan-at-80



Importance of <u>neural coordination</u> in prosociality *as examined through the lens of vicarious reward*

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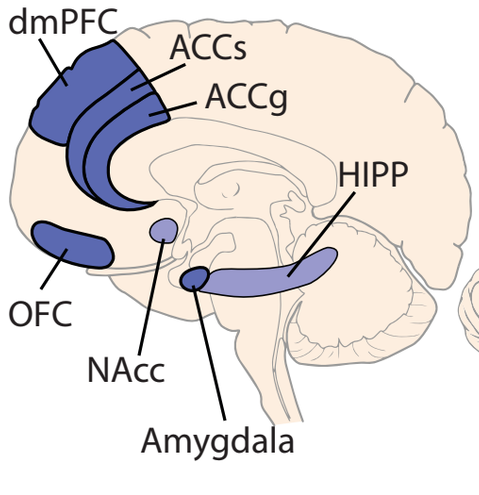
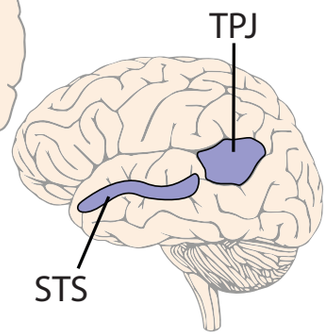
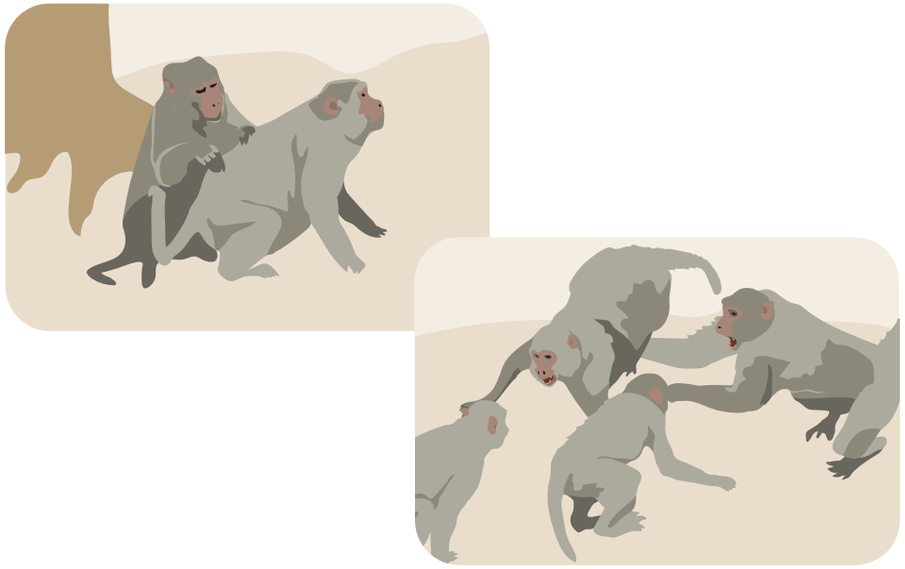
<u>Question asked</u>

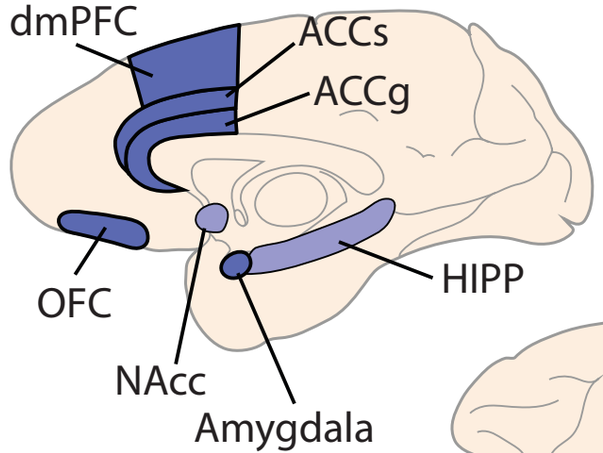
Does the coordination between Anterior Cingulate Cortex & Amygdala guide prosocial decisions based on vicarious reward?

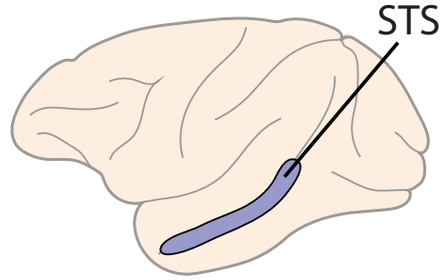
Social brain networks across species

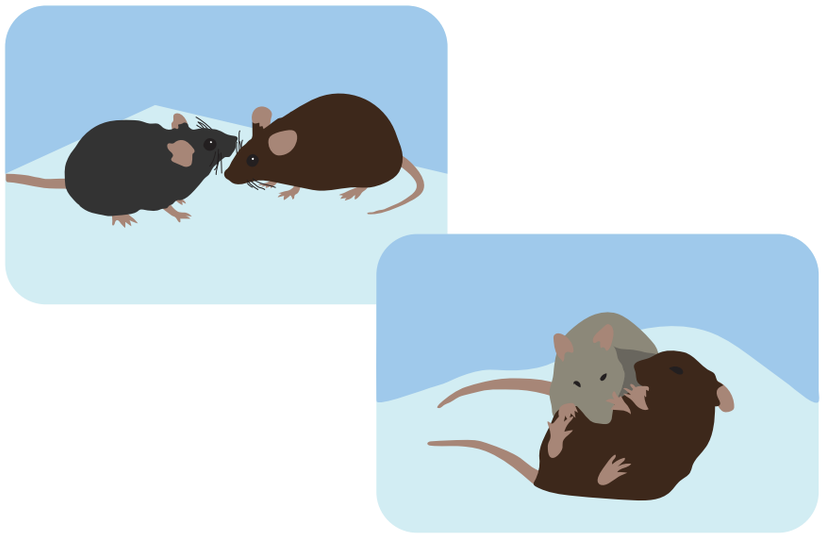


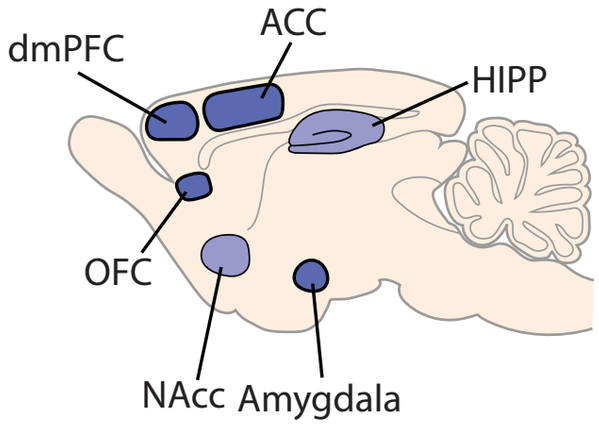








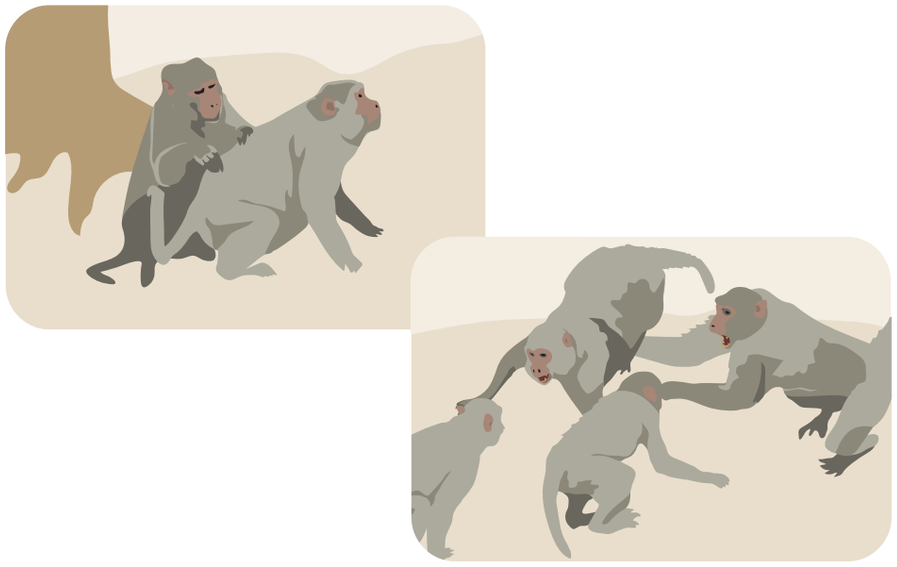


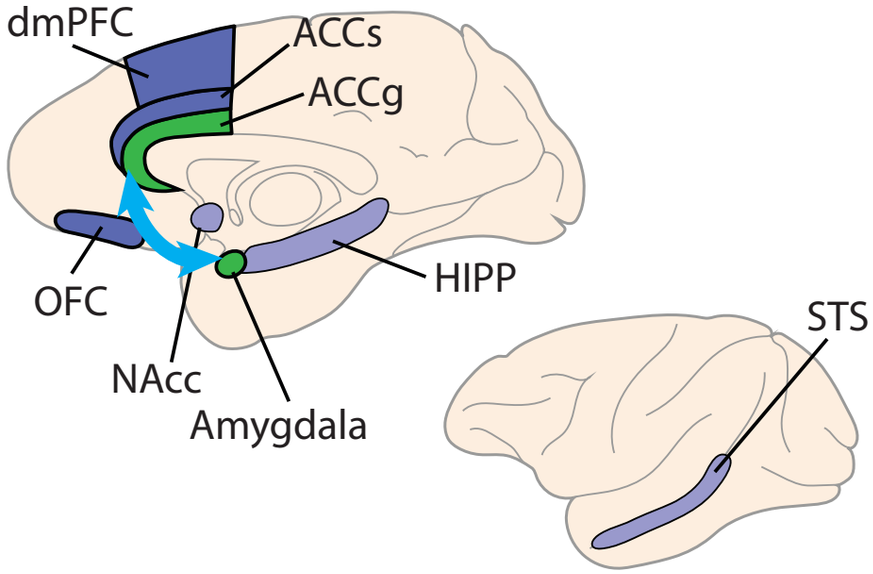


Gangopadhyay, Chawla, Chang (2021) Nat. Neurosci.

Social brain networks across species

Anterior cingulate cortex (ACC)-amygdala (BLA) coordination for vicarious reward





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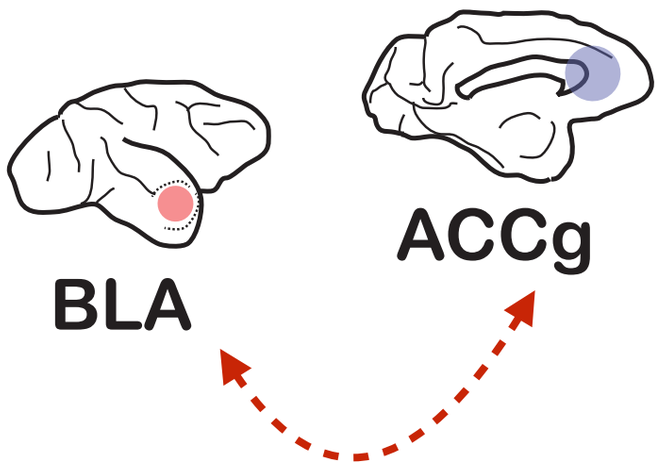
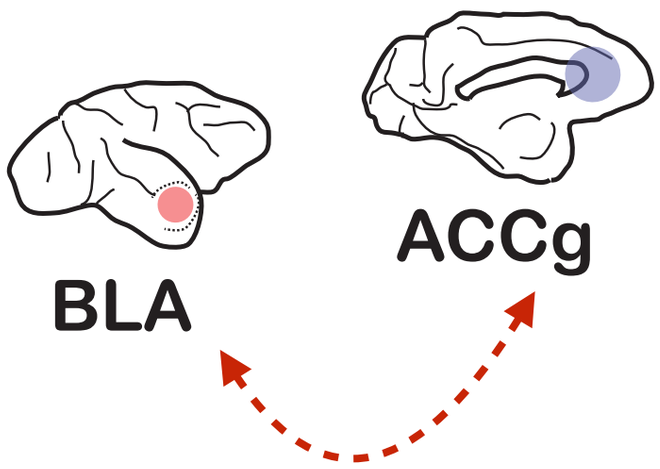
Coordination between ACCg and BLA for making prosocial decisions and evaluating vicarious reward



Anterior cingulate gyrus (ACCg)
Basolateral amygdala (BLA)

Coordination between ACCg and BLA for making prosocial decisions and evaluating vicarious reward



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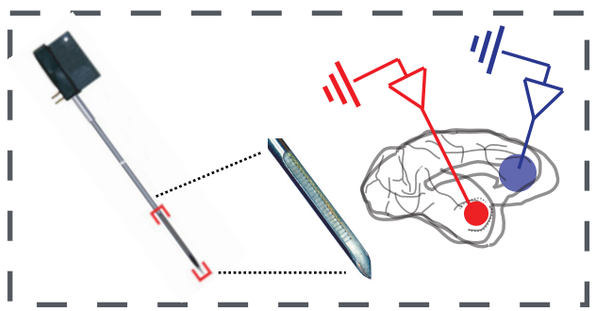
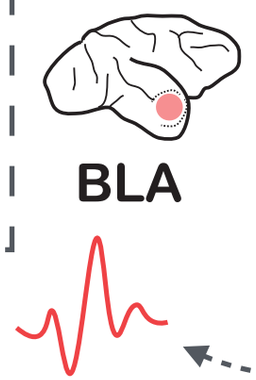
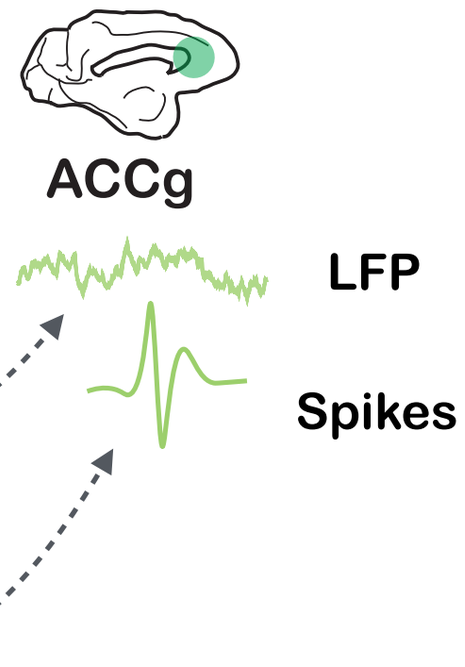
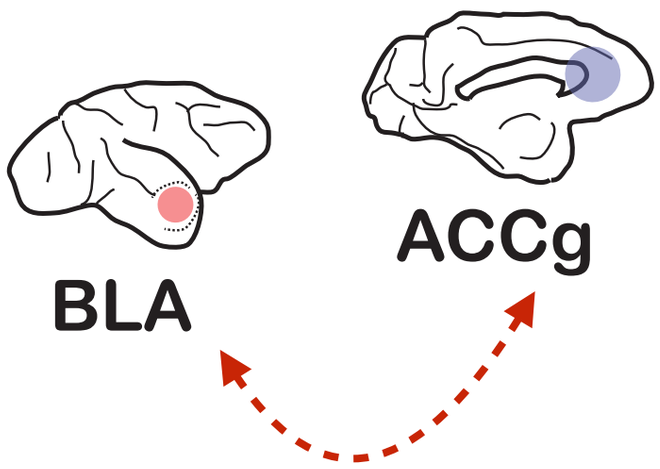


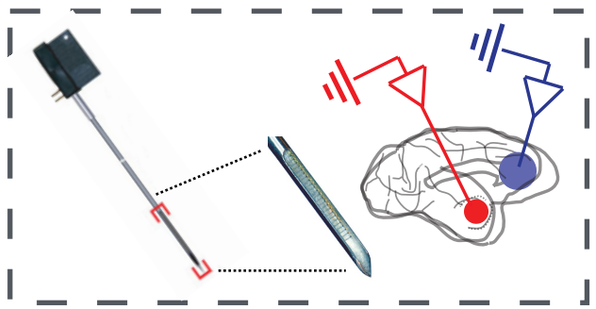


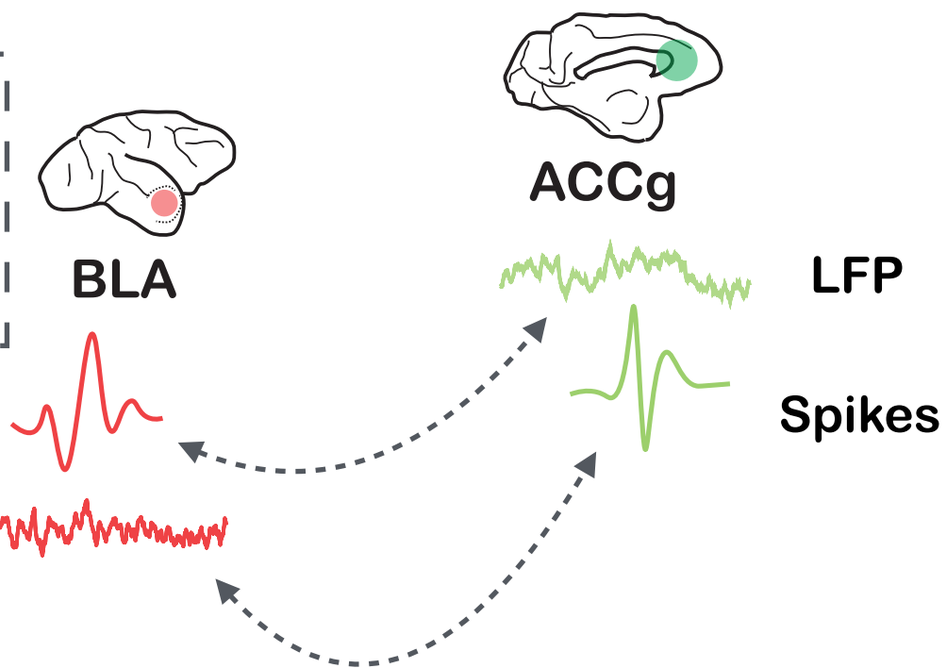


“Spike-field coherence”

Coordination between ACCg and BLA for making prosocial decisions and evaluating vicarious reward



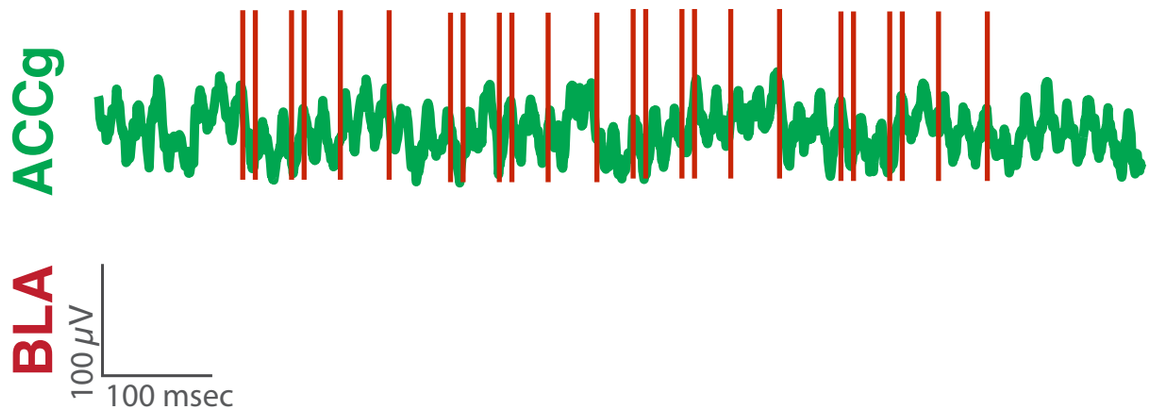




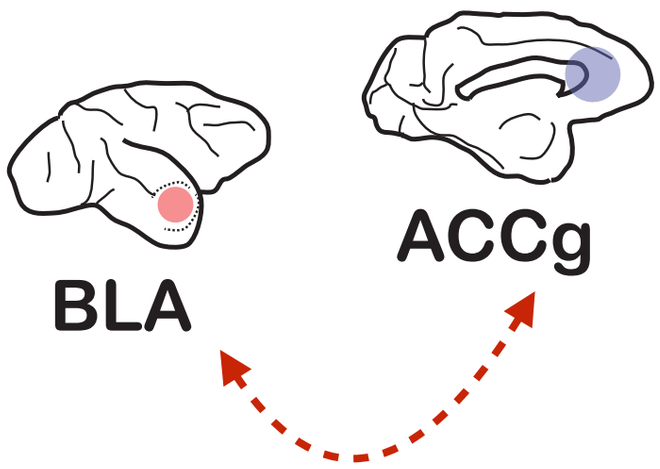
Anterior cingulate gyrus (ACCg)
Basolateral amygdala (BLA)

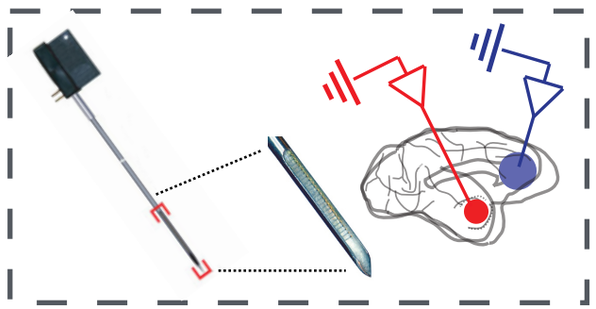
"Spike-field coherence"

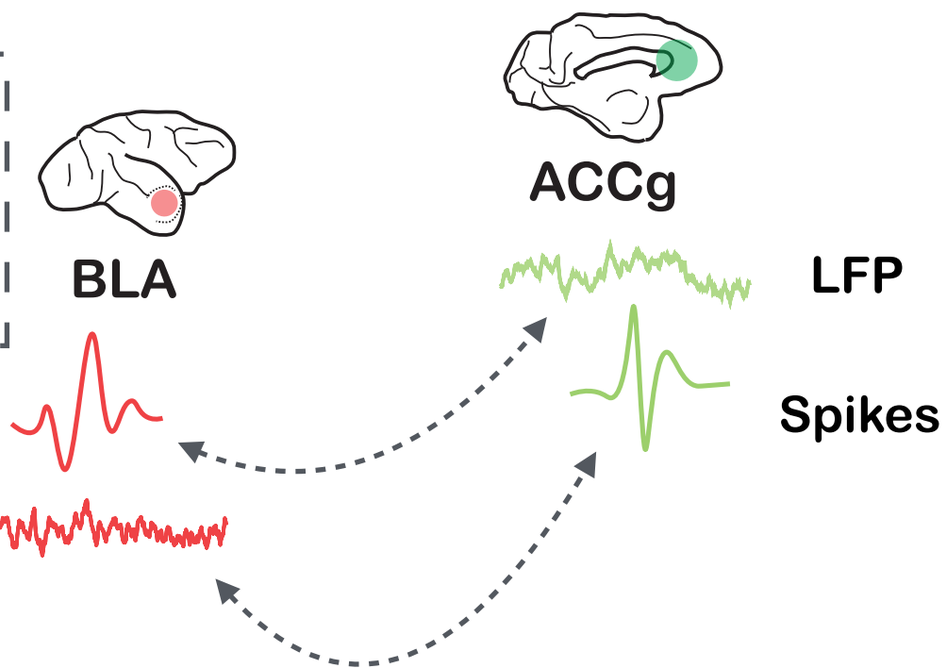
BLA-spike-ACCg-field



Coordination between ACCg and BLA for making prosocial decisions and evaluating vicarious reward







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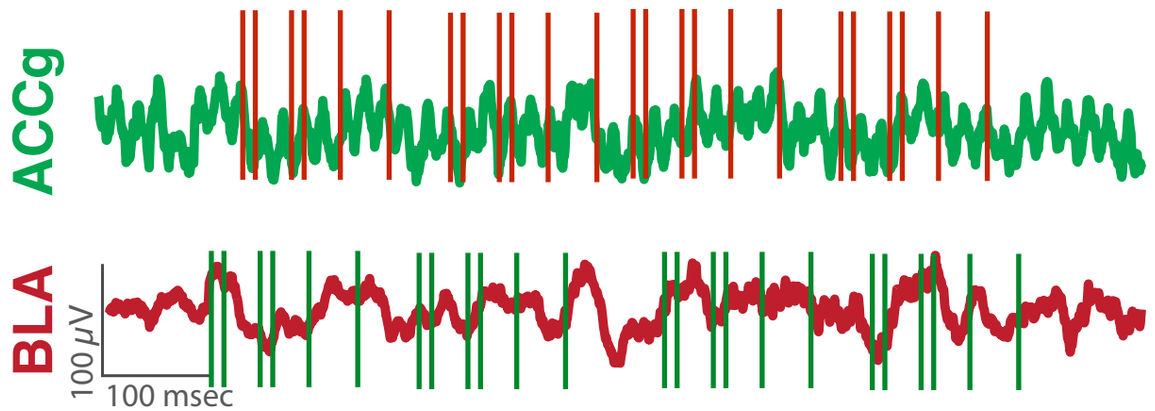
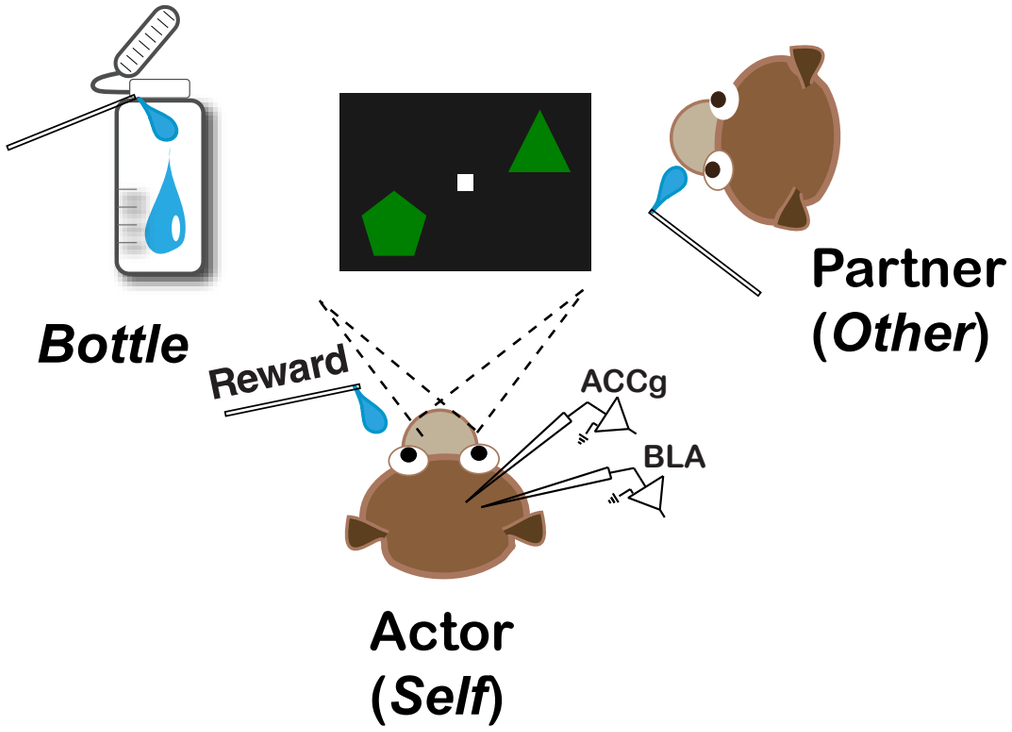
BLA-spike-ACCg-field

ACCg-spike-BLA-field



Measuring prosocial preferences in monkeys



Chang et al (2011) Front. Neurosci.
Chang et al (2012) PNAS
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Putnam, …, Chang (2023) Neuron

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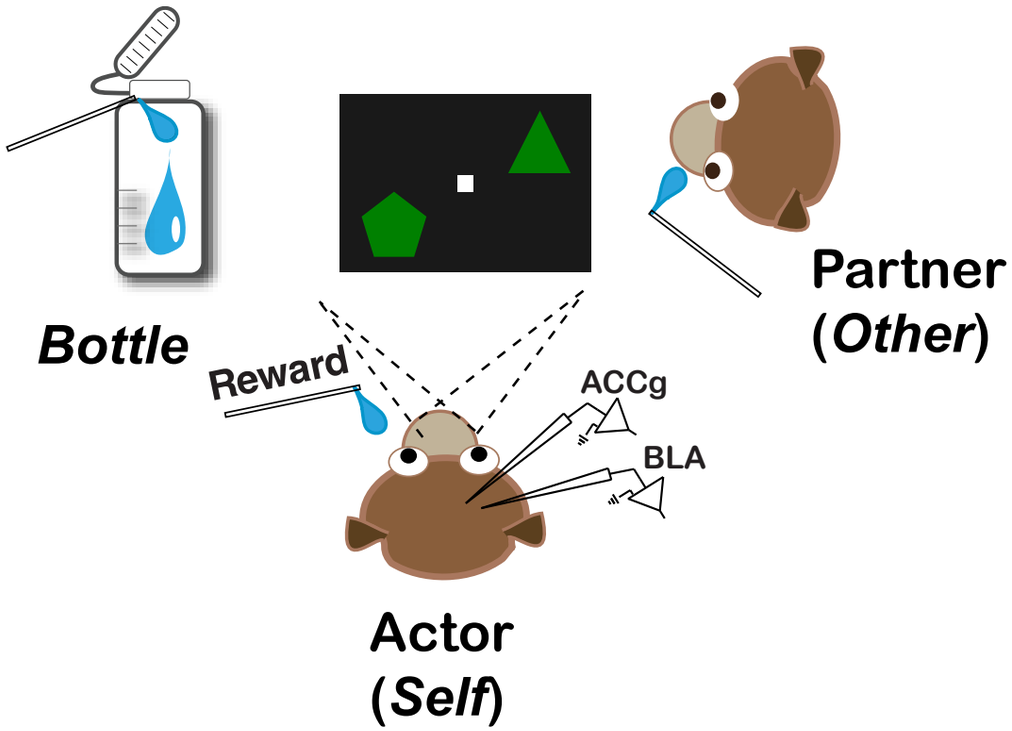
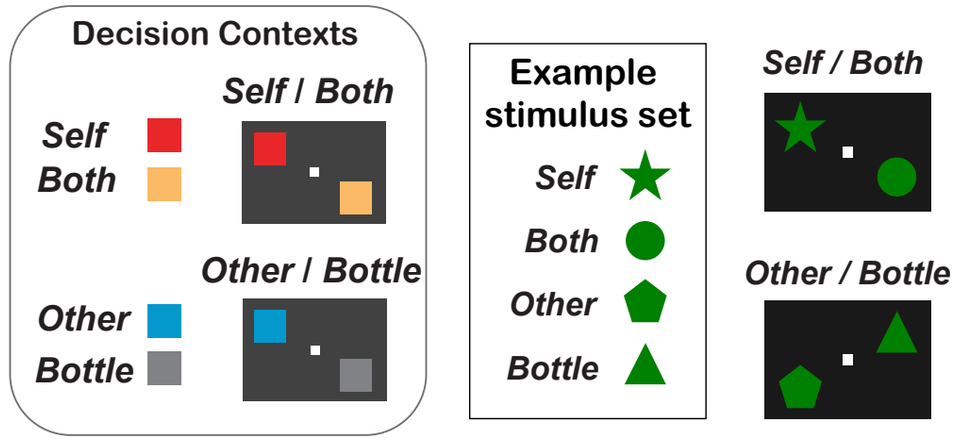


Some example stimuli used



Choosing between:

Self and ***Both***
(actor always rewarded)

Other and ***Neither (Bottle)***
(actor never rewarded)

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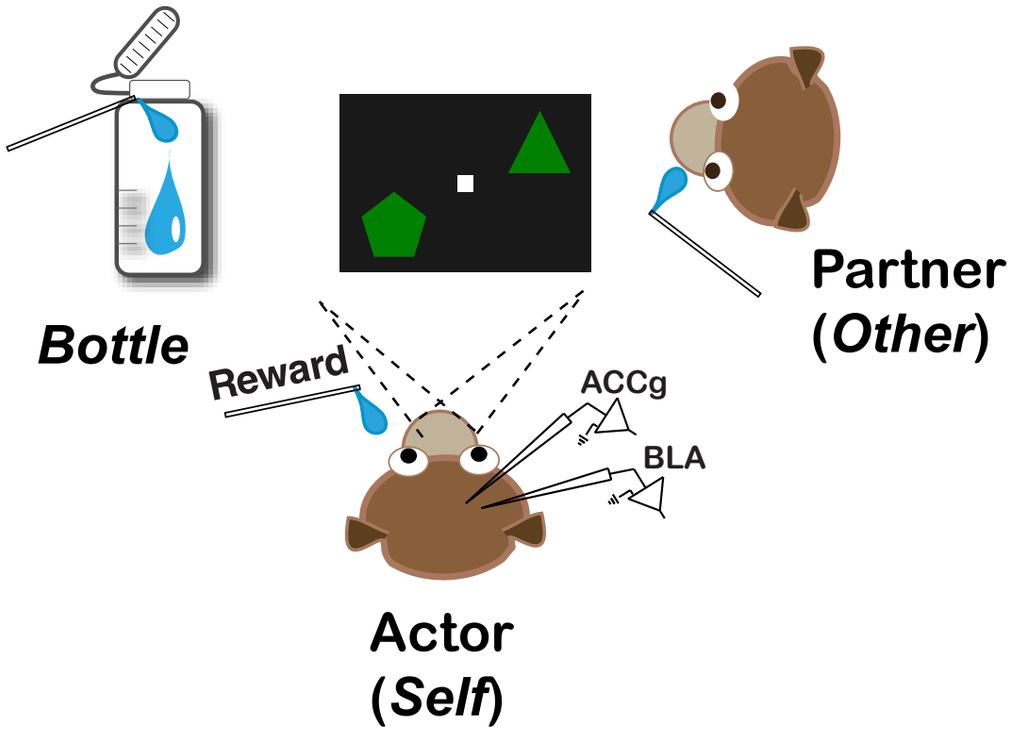

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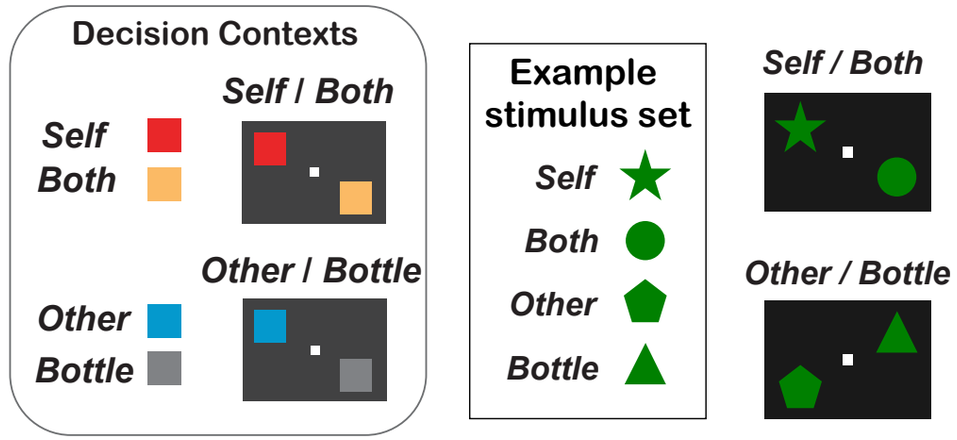

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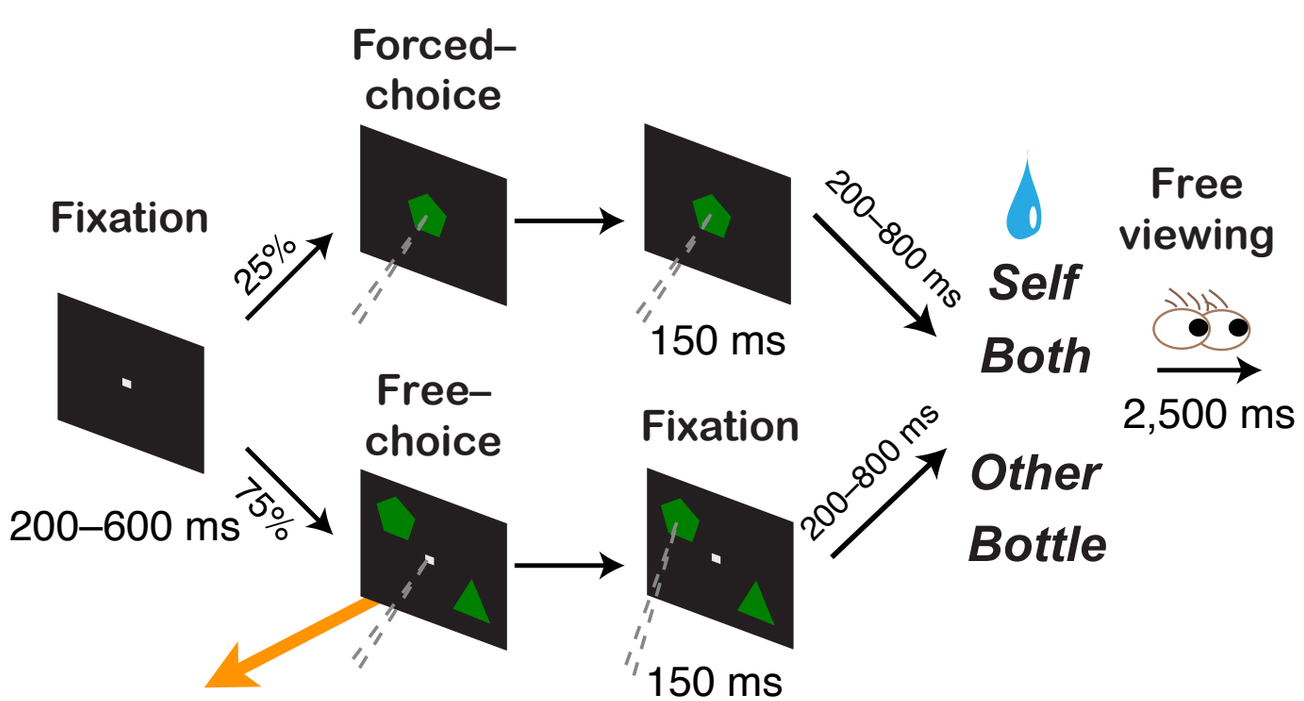

Self* vs. *Both

***Other* vs. Bottle (or Neither)**

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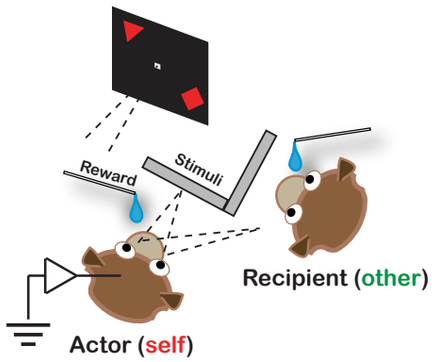
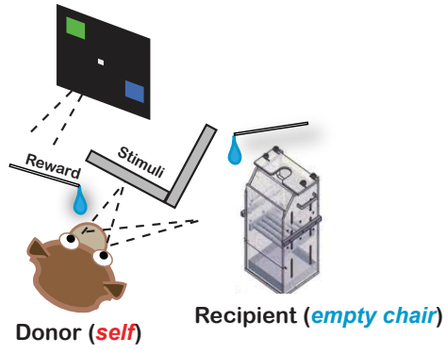
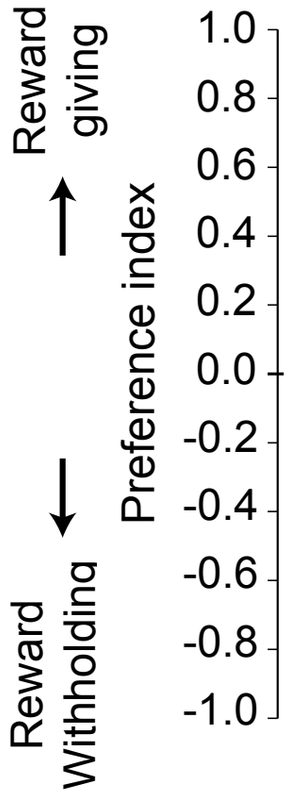
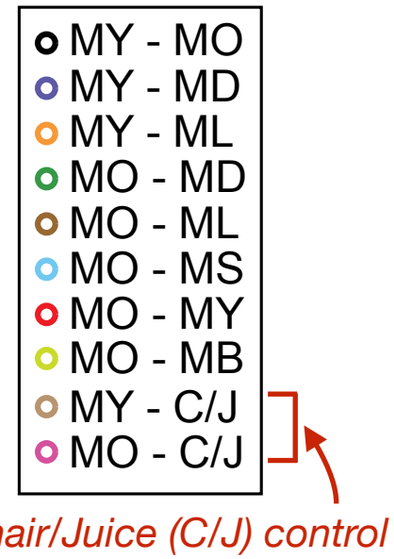
Monkeys show context-specific prosocial preference





$$Preference\ Index = \frac{R_A - R_B}{R_A + R_B}$$





Other:**Neither** Context

Self:**Both** Context

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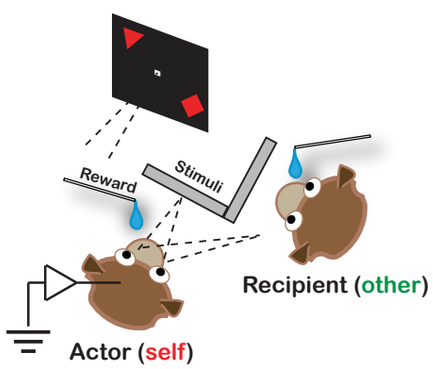

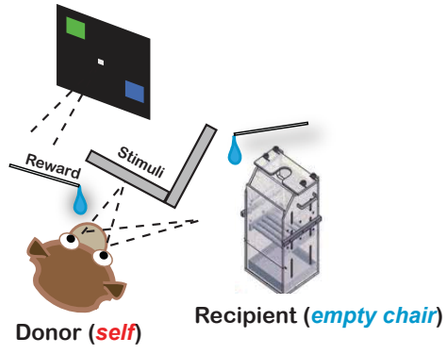

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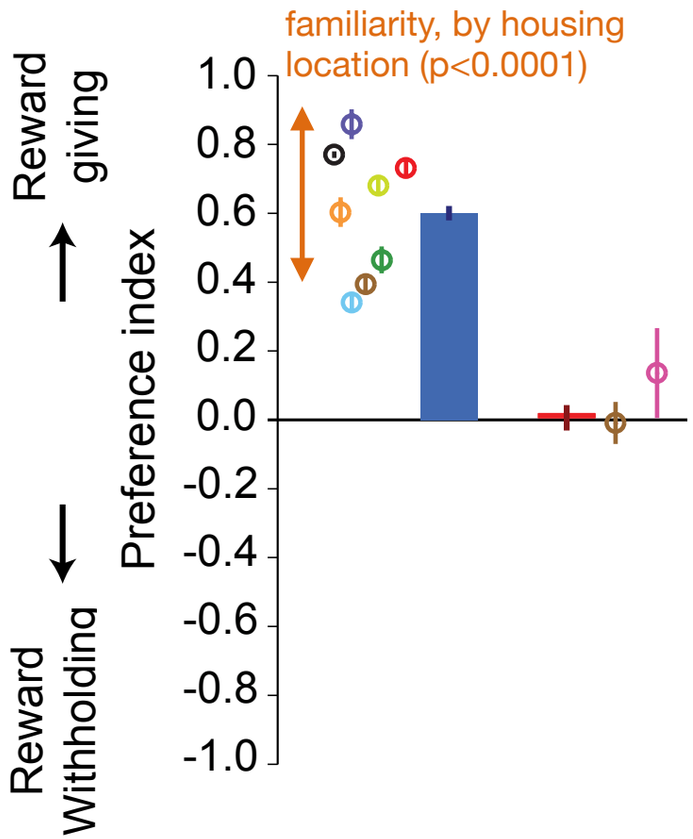

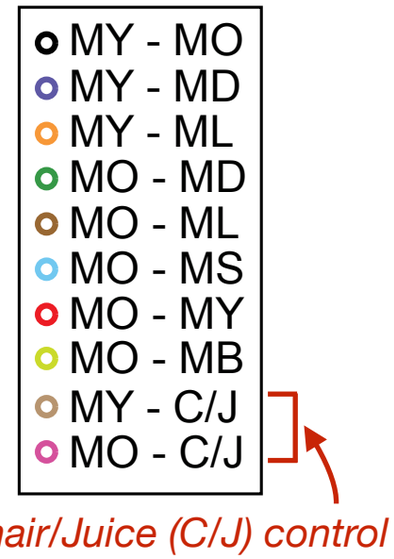

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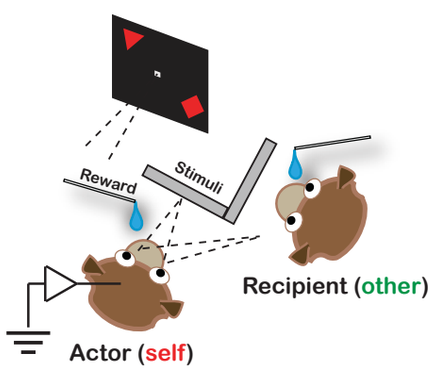

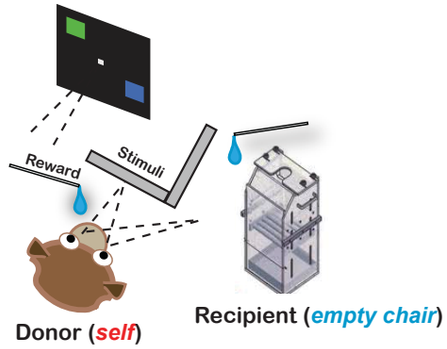

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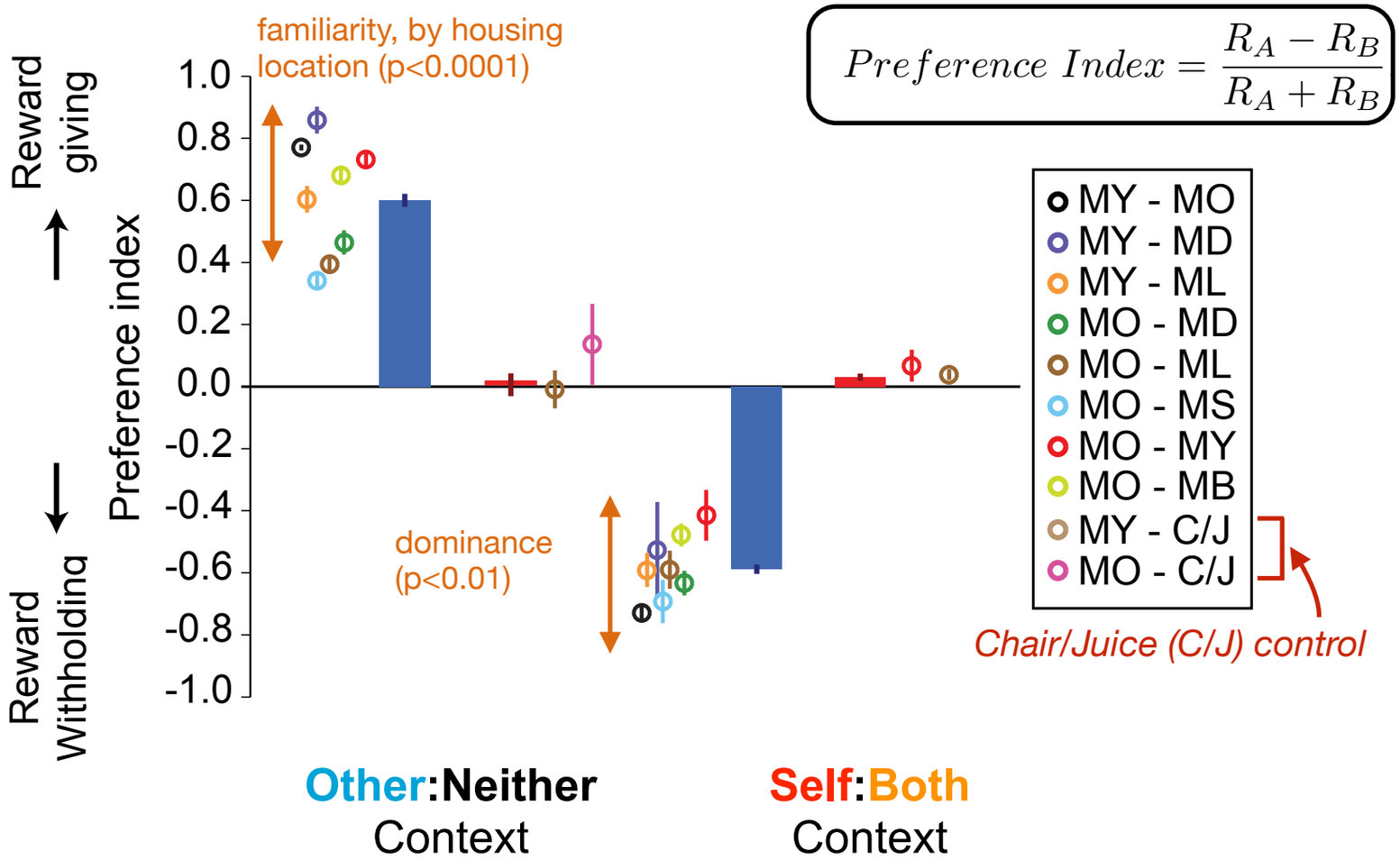
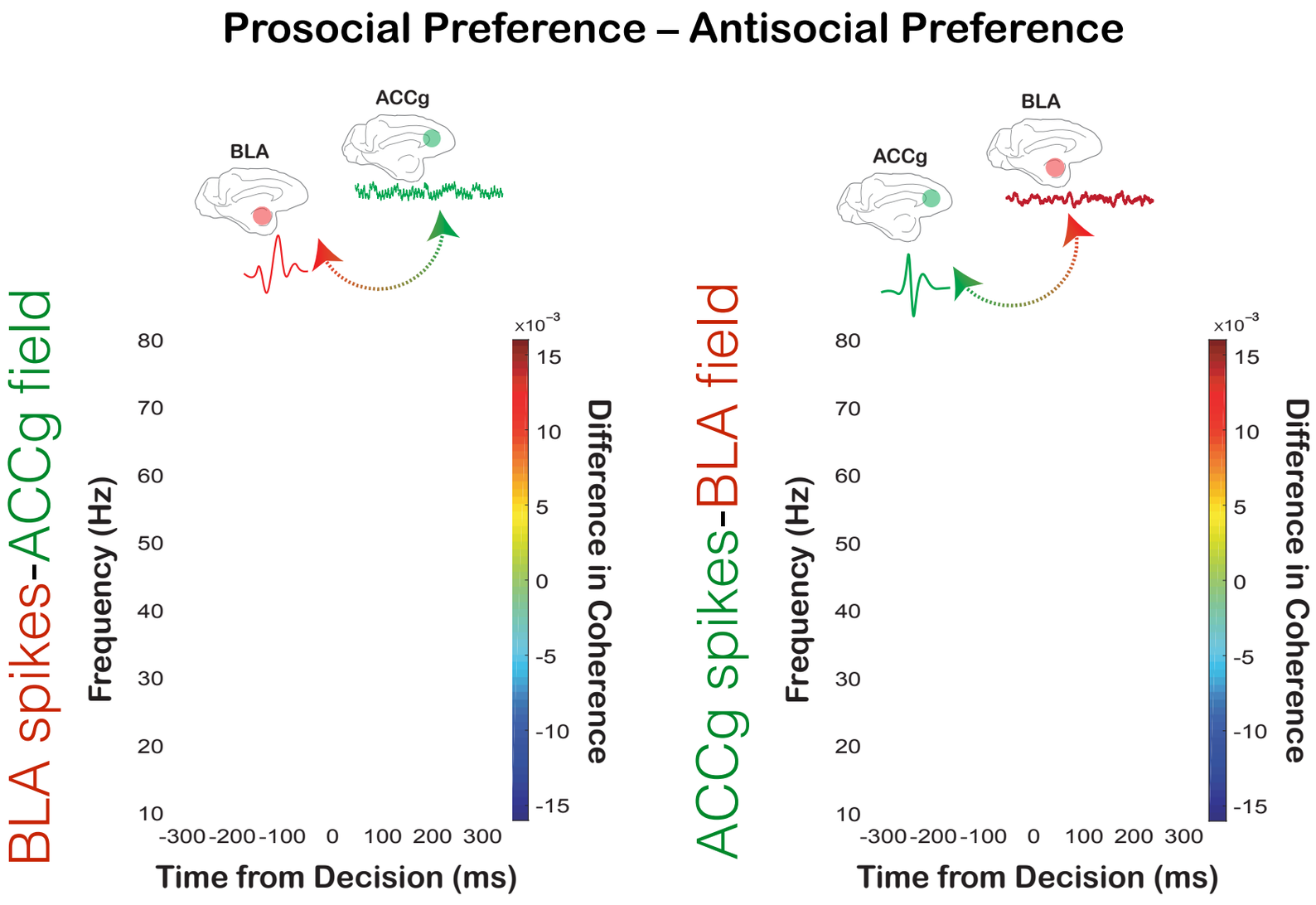


ACCg and BLA show <u>frequency-specific</u> coordination for expressing prosocial preference



Dal Monte, Chu, Fagan, Chang (2020) Nat. Neurosci.

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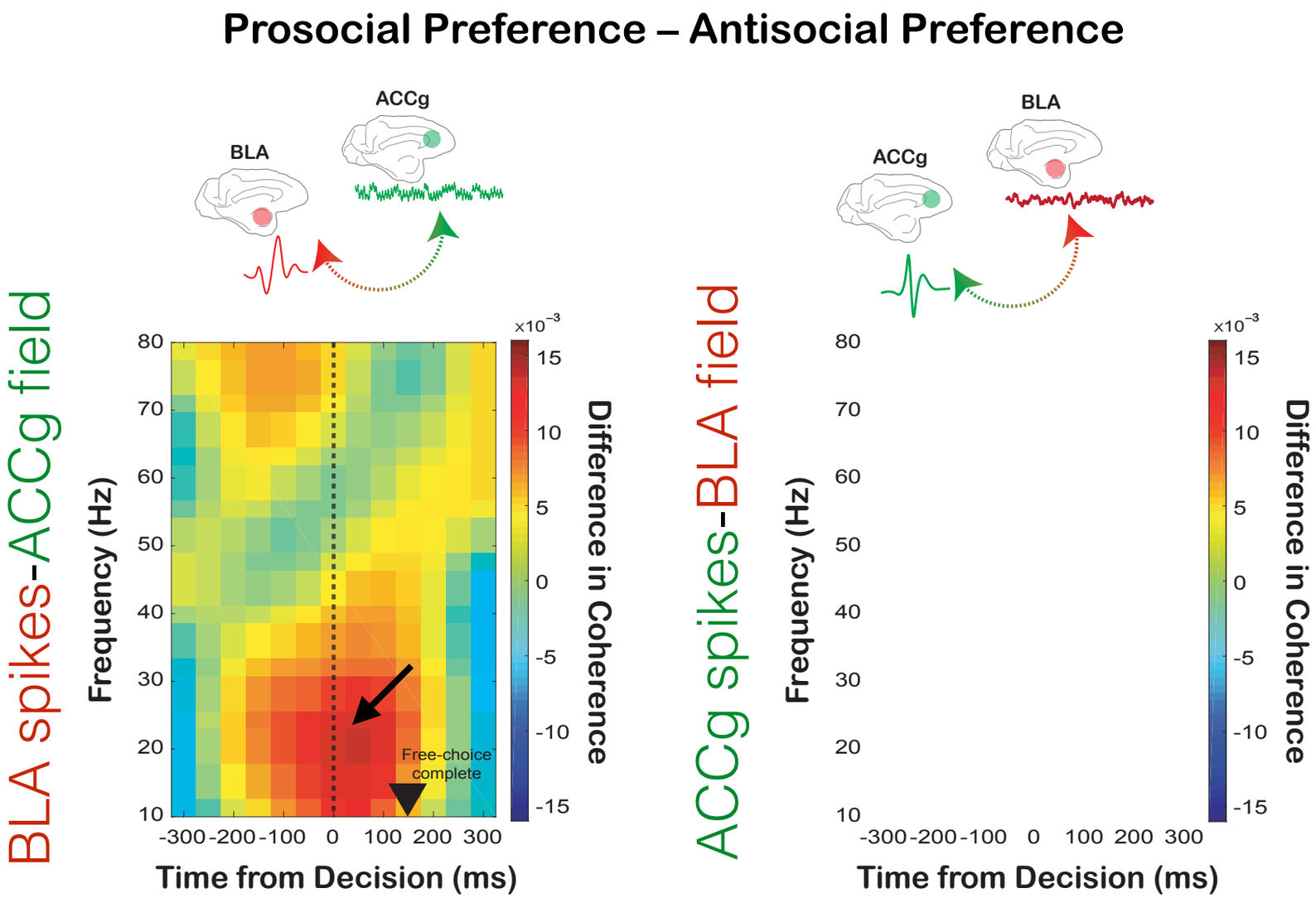

- BLA-spikes & ACCg-fields: Enhanced for prosocial preference at the beta frequency

Dal Monte, Chu, Fagan, Chang (2020) Nat. Neurosci.

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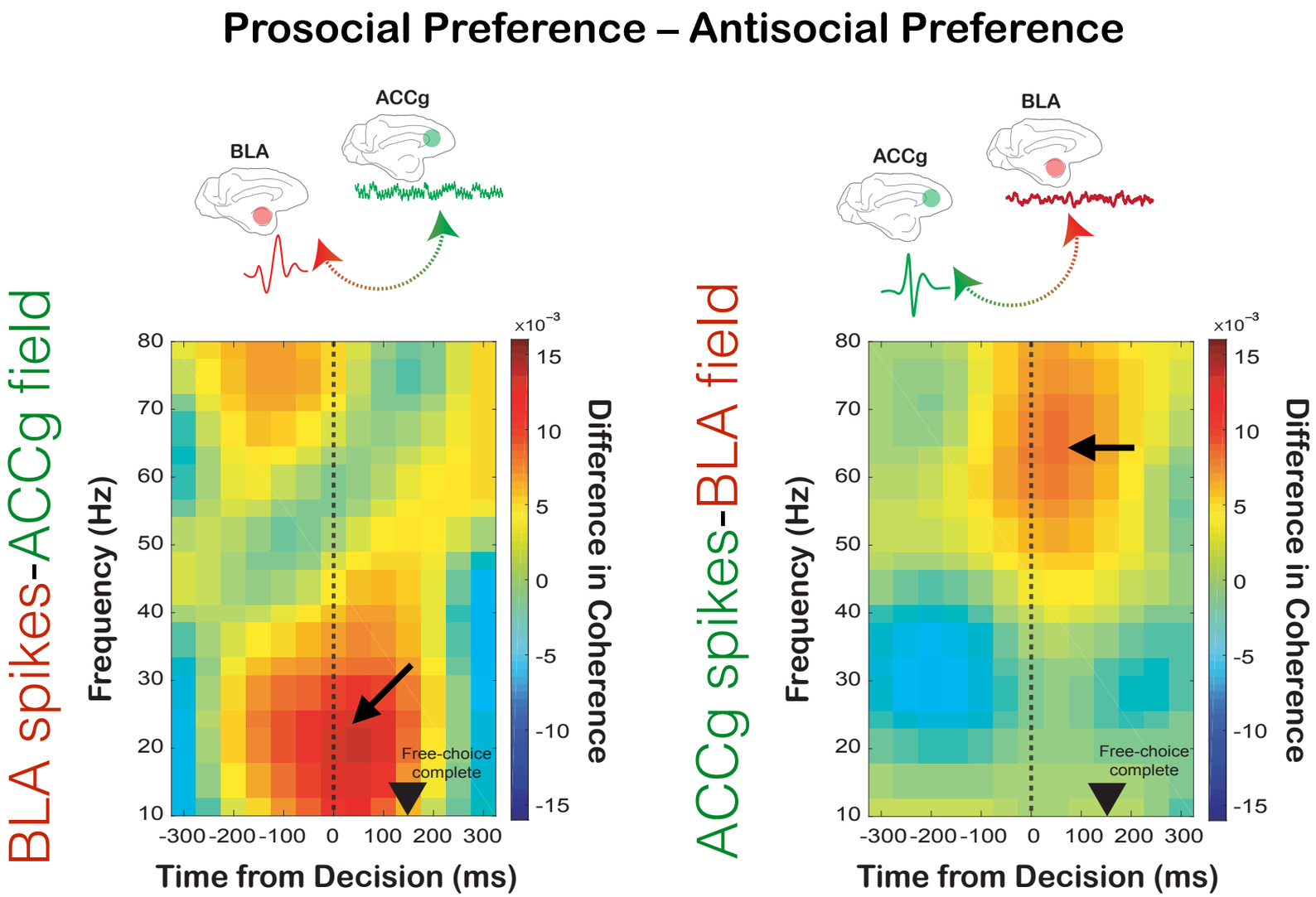

- BLA-spikes & ACCg-fields: Enhanced for prosocial preference at the beta frequency
- ACCg-spikes & BLA-field: Enhanced for prosocial decision preference at the gamma frequency

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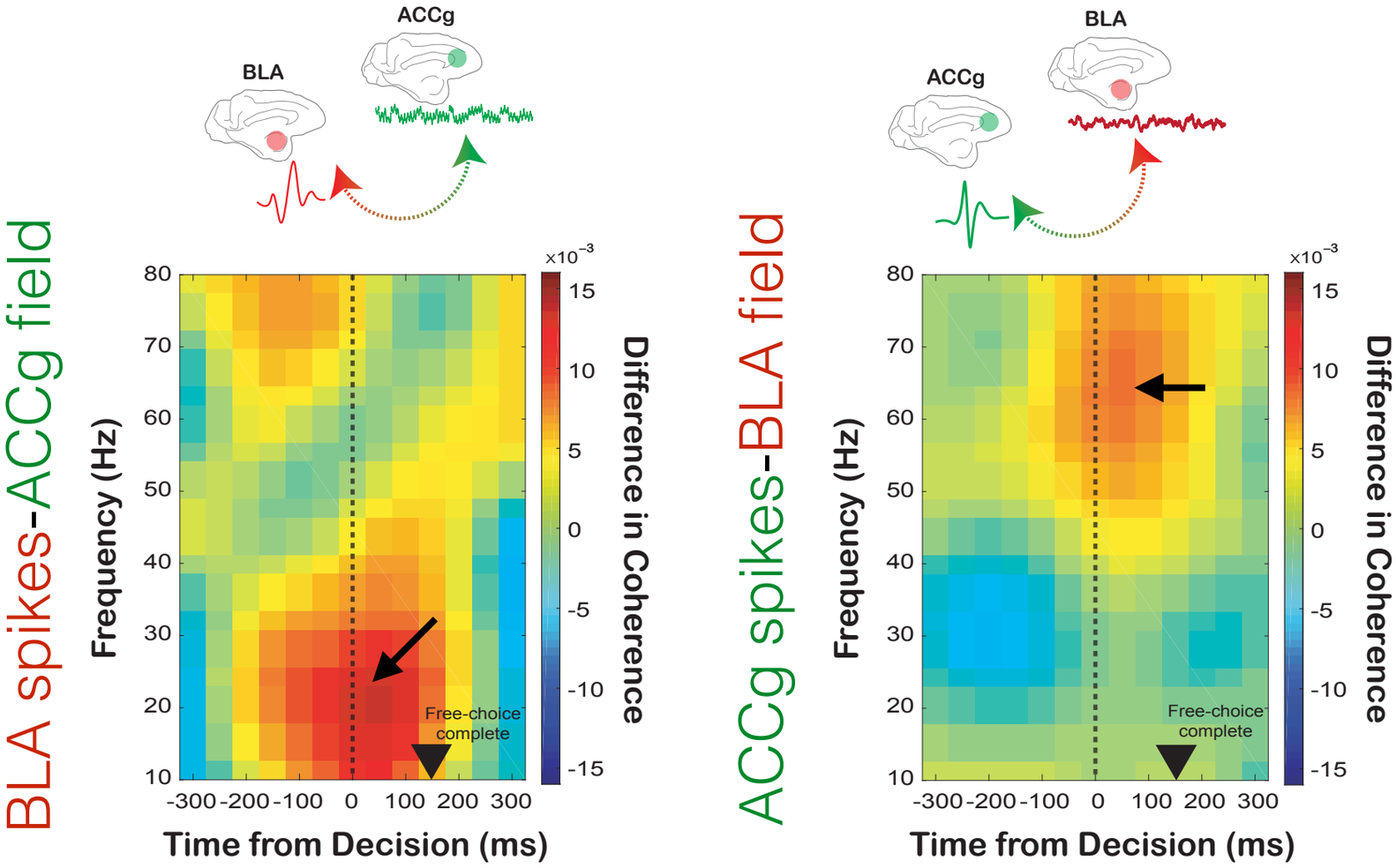
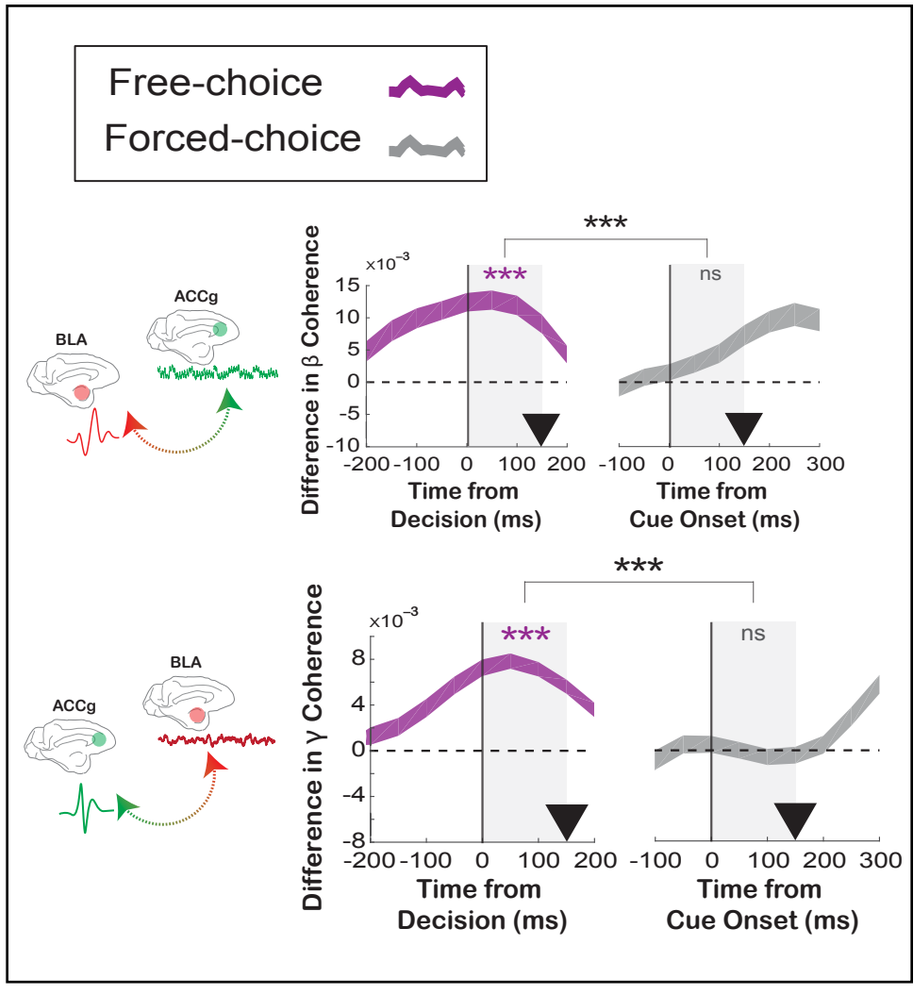
ACCg and BLA show <u>frequency-specific</u> coordination for expressing prosocial preference

Prosocial Preference – Antisocial Preference



- Both of these enhancements were specific to when <u>actively making</u> prosocial choices



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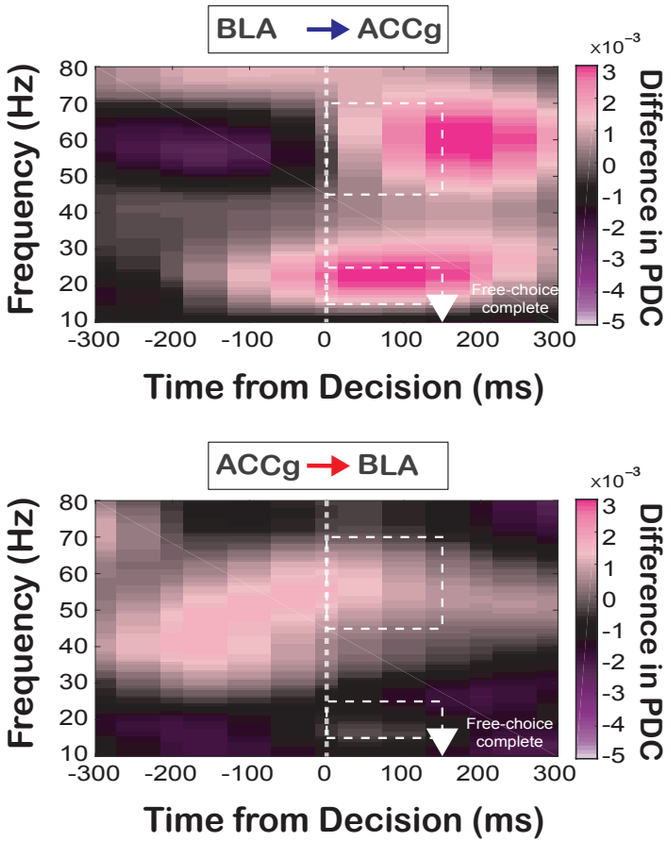
Dal Monte, Chu, Fagan, Chang (2020) Nat. Neurosci.

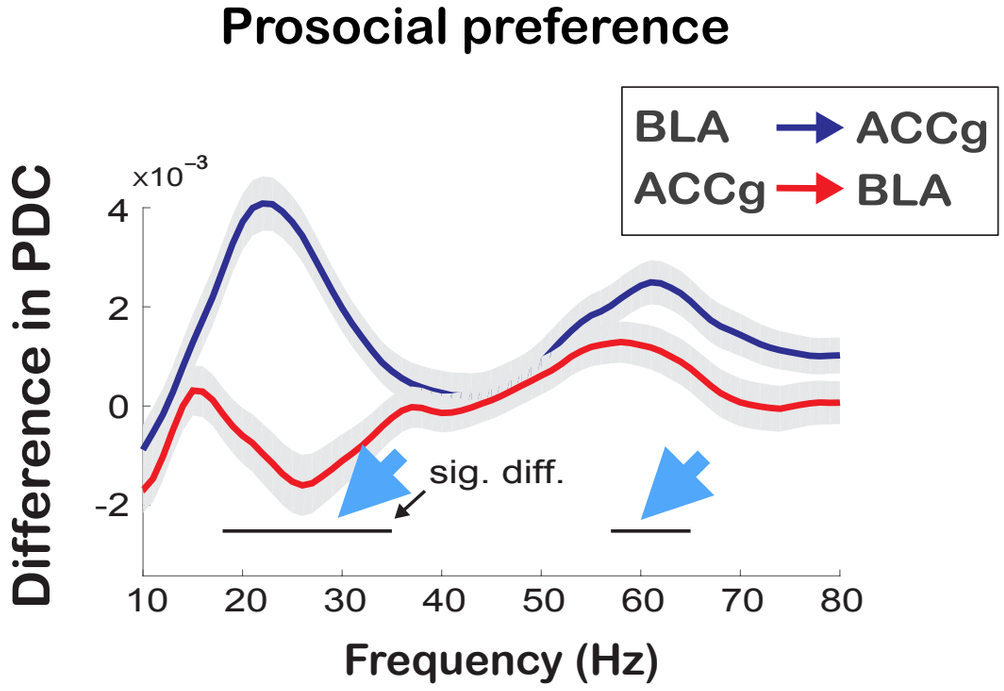
Selective directional influence from BLA to ACCg for expressing prosocial decision

- Partial Directed Coherence (PDC) to examine <u>directionality</u> of information routing

Prosocial preference



Prosocial preference

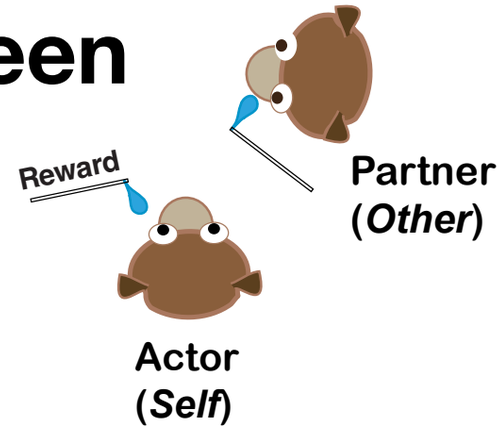


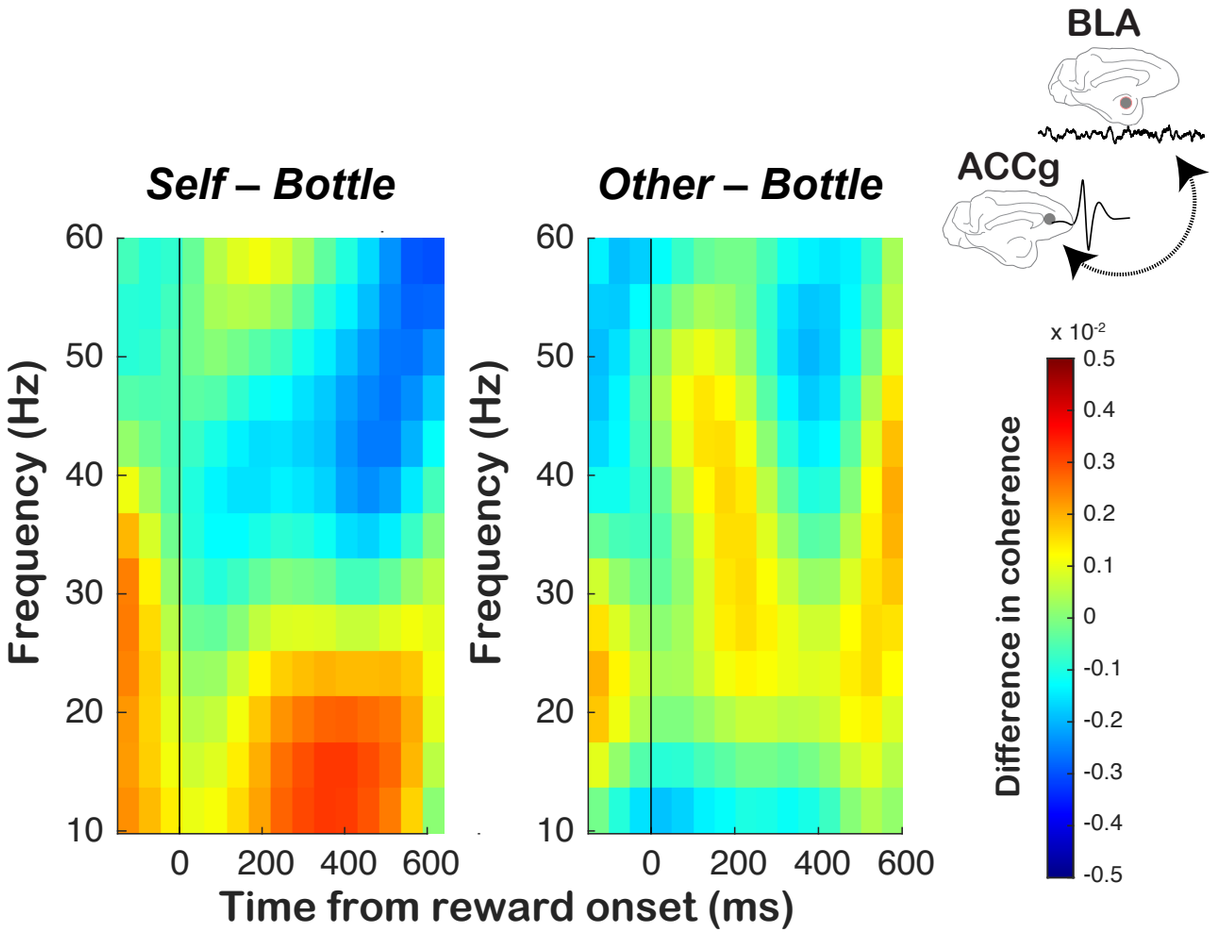
- **Prosocial preference** is associated with **BLA → ACCg information flow directionality**, in both the beta & gamma bands

Dal Monte, Chu, Fagan, Chang (2020) Nat. Neurosci.

Vicarious reward (versus experienced reward)

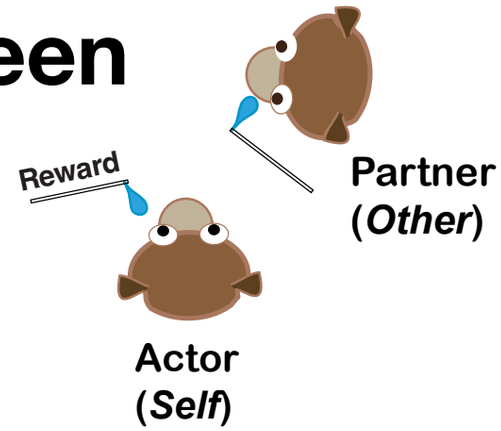
Distinct ACCg-BLA coordination channels between vicarious and experienced rewards

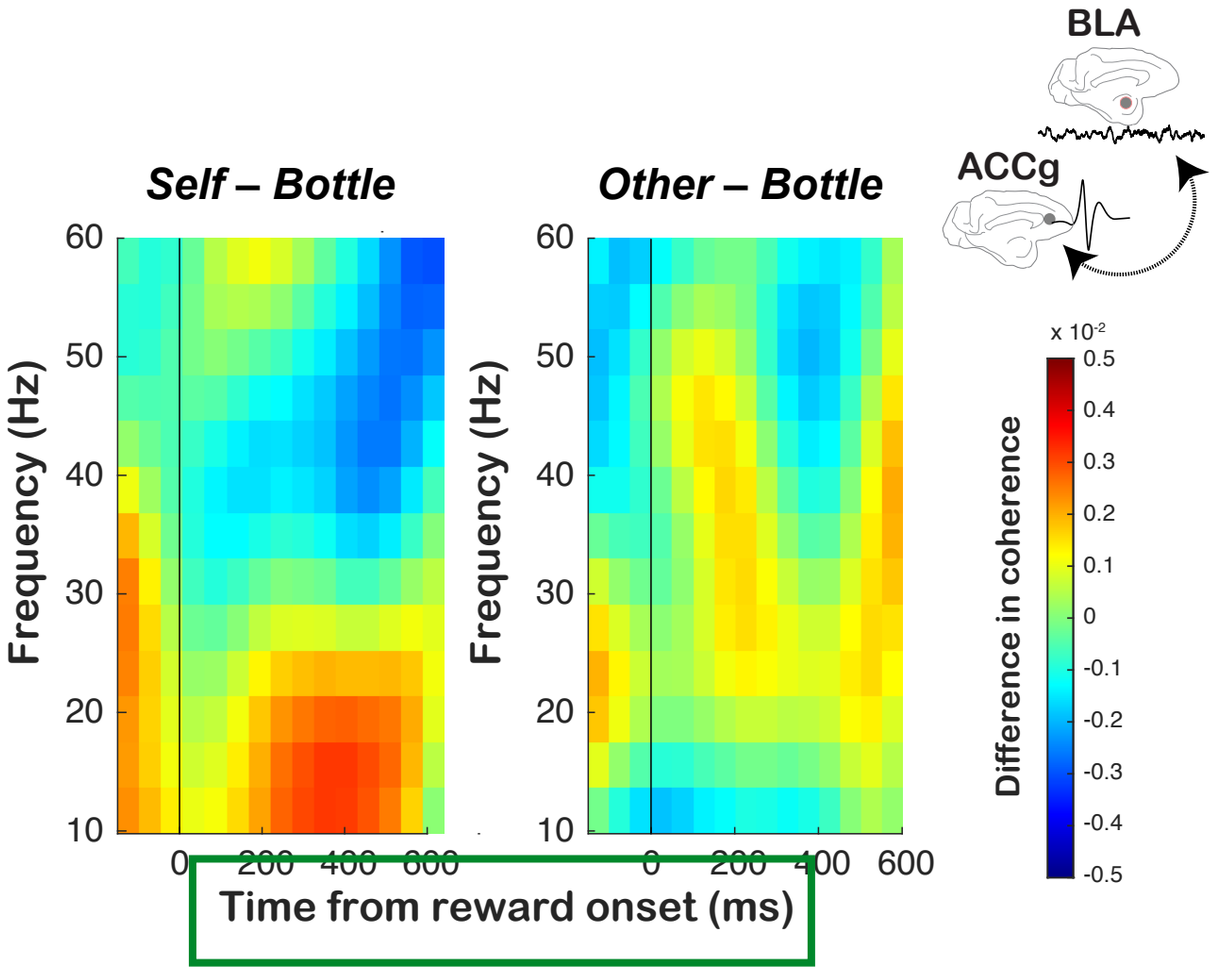




Putnam, Chu, Fagan, Dal Monte, Chang (2023) Neuron

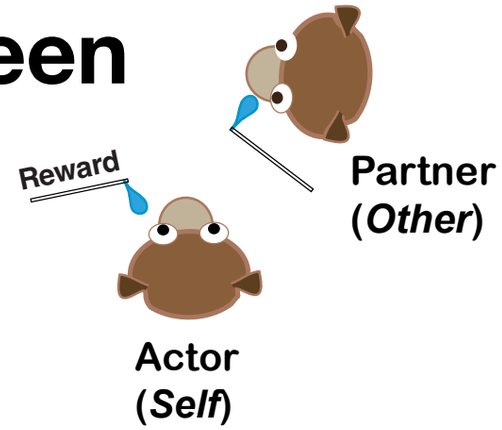
Distinct ACCg-BLA coordination channels between vicarious and experienced rewards

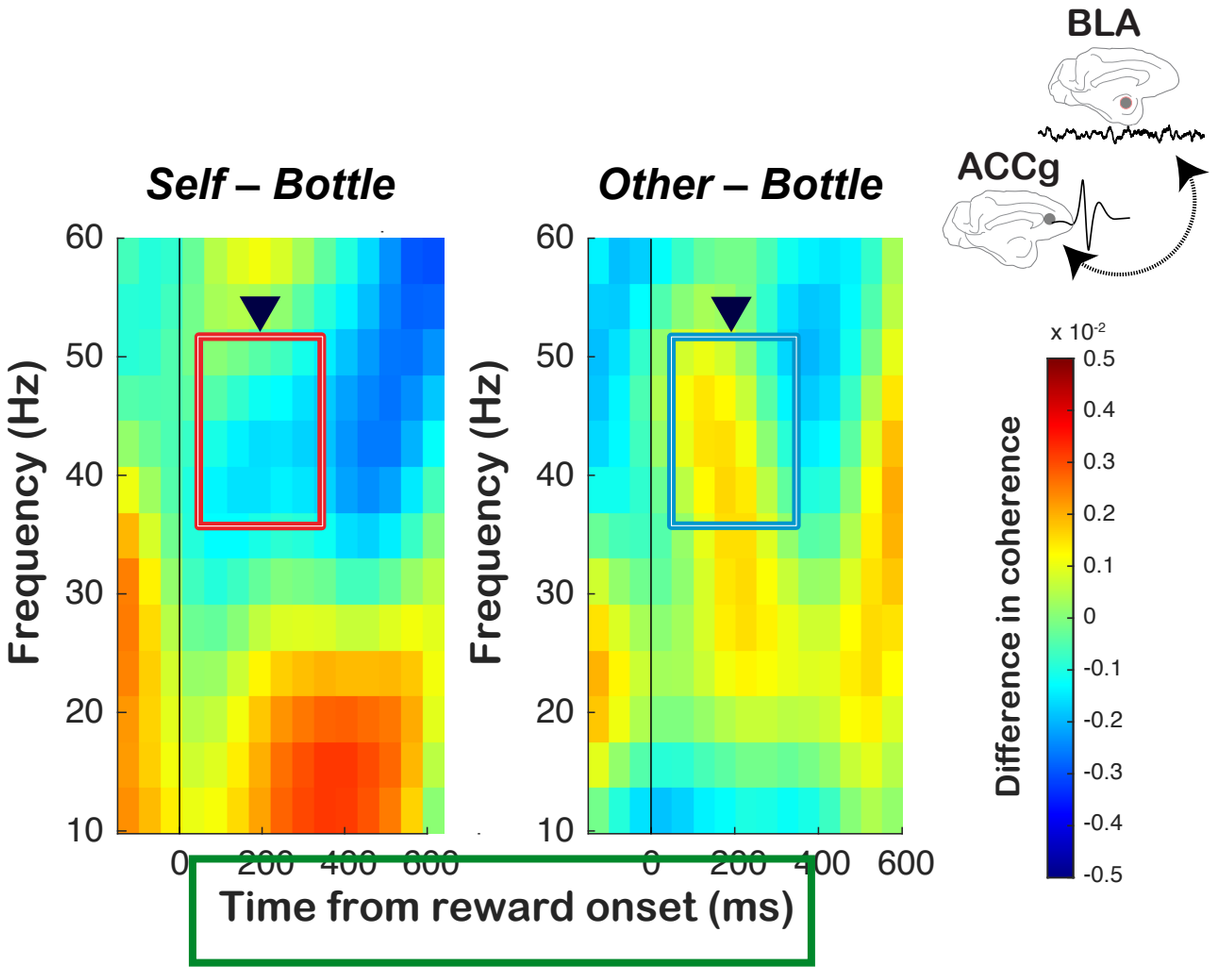


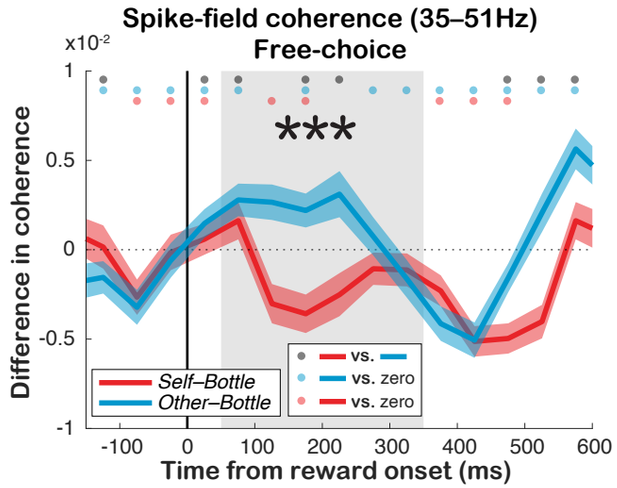


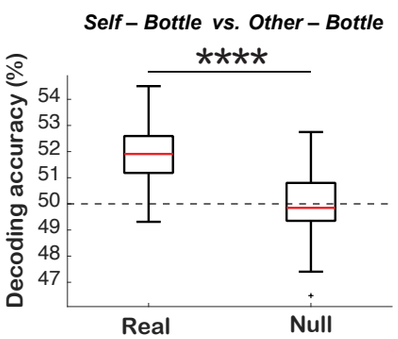
Putnam, Chu, Fagan, Dal Monte, Chang (2023) Neuron

Distinct ACCg-BLA coordination channels between vicarious and experienced rewards









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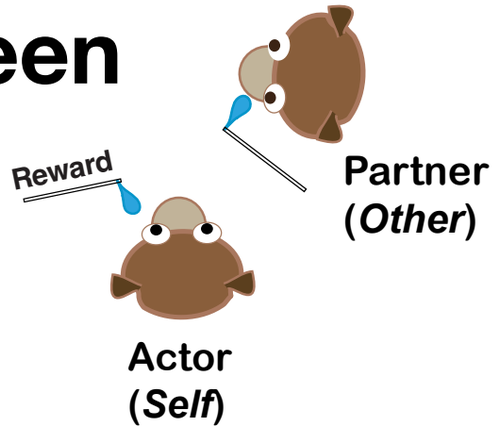
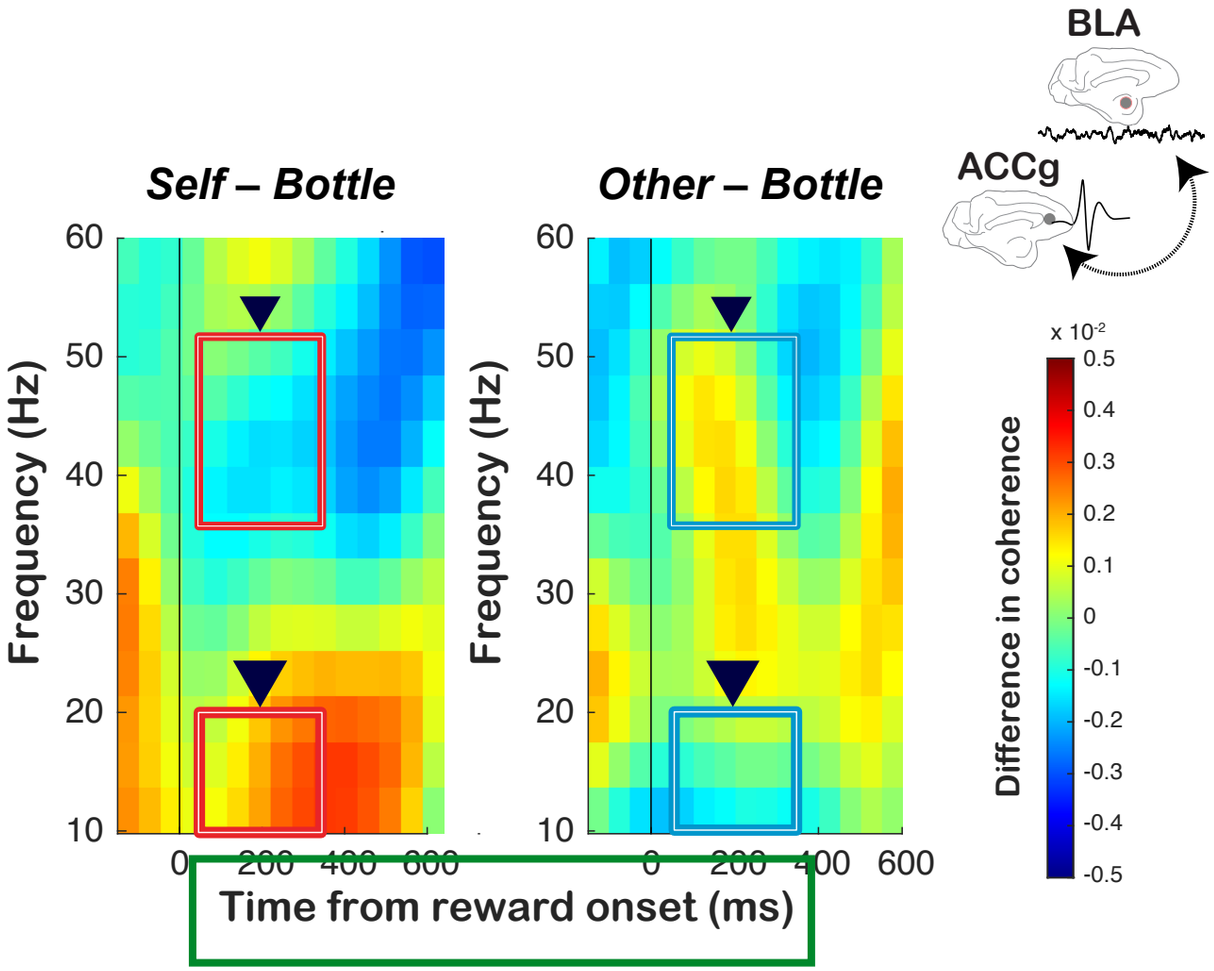
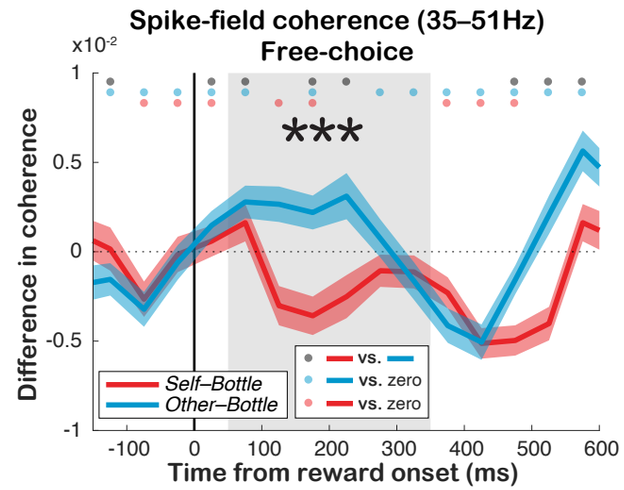
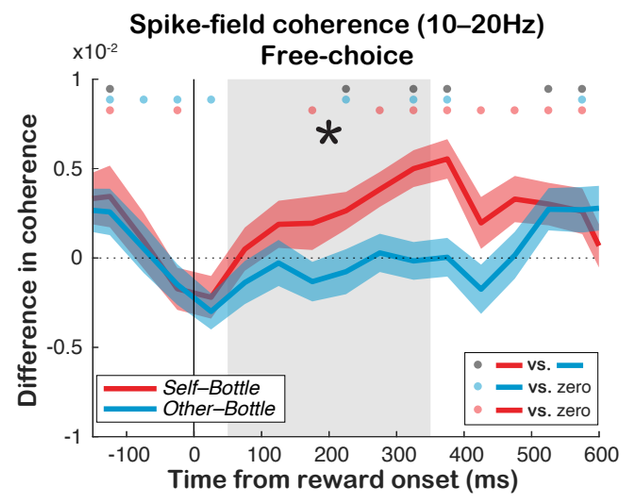
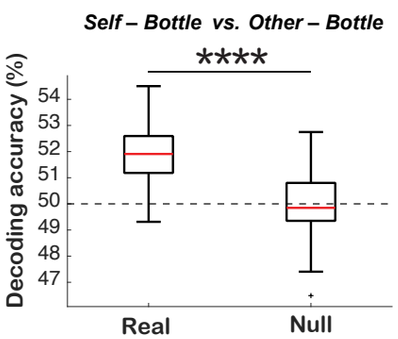
Distinct ACCg-BLA coordination channels between vicarious and experienced rewards

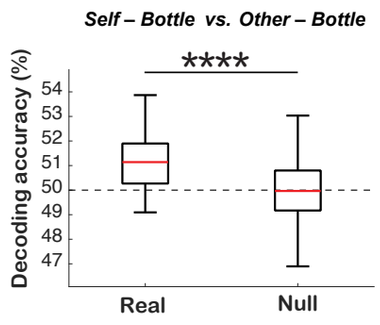












- Vicarious and experienced rewards are communicated by distinct frequency channels during ACCg-spikes & BLA-field coordination

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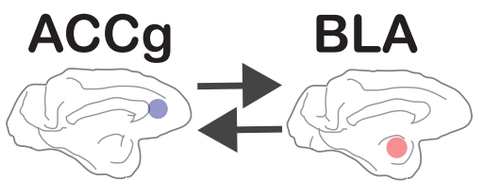
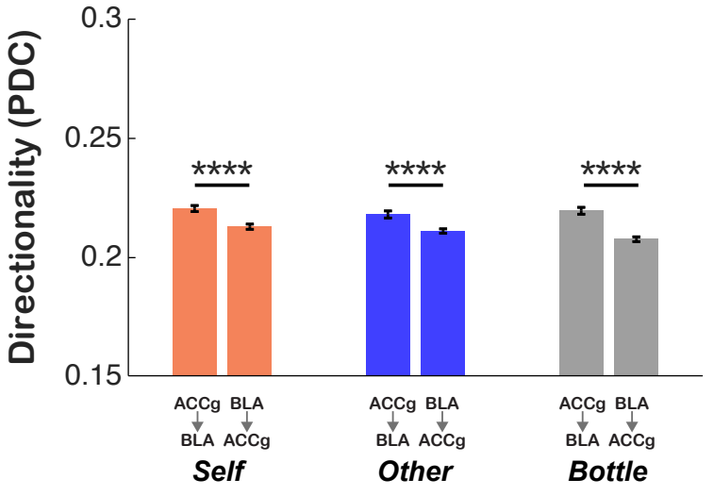
Reward information flow: ACCg—>BLA for both vicarious and experienced rewards

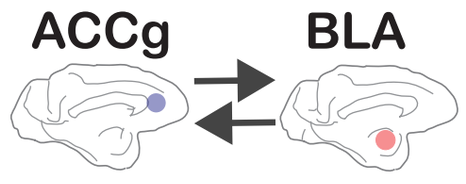
Vicarious reward channel



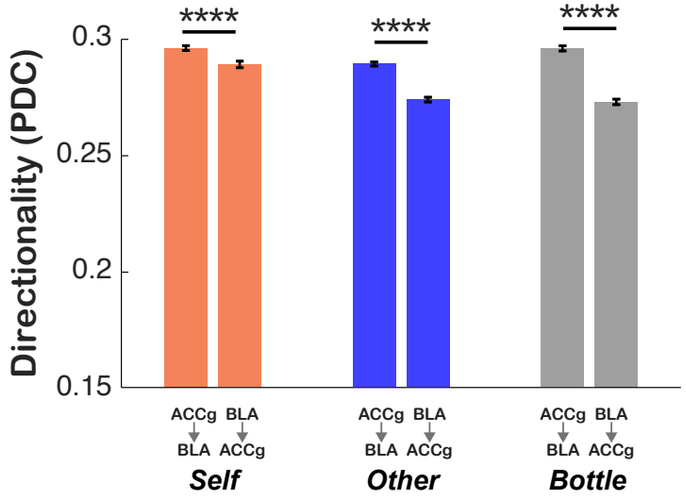
35–51Hz; reward epoch



Experienced reward channel



10–20Hz, reward epoch



- Robust ACCg—>BLA directionality for all both vicarious and experienced reward outcomes in both frequency ranges

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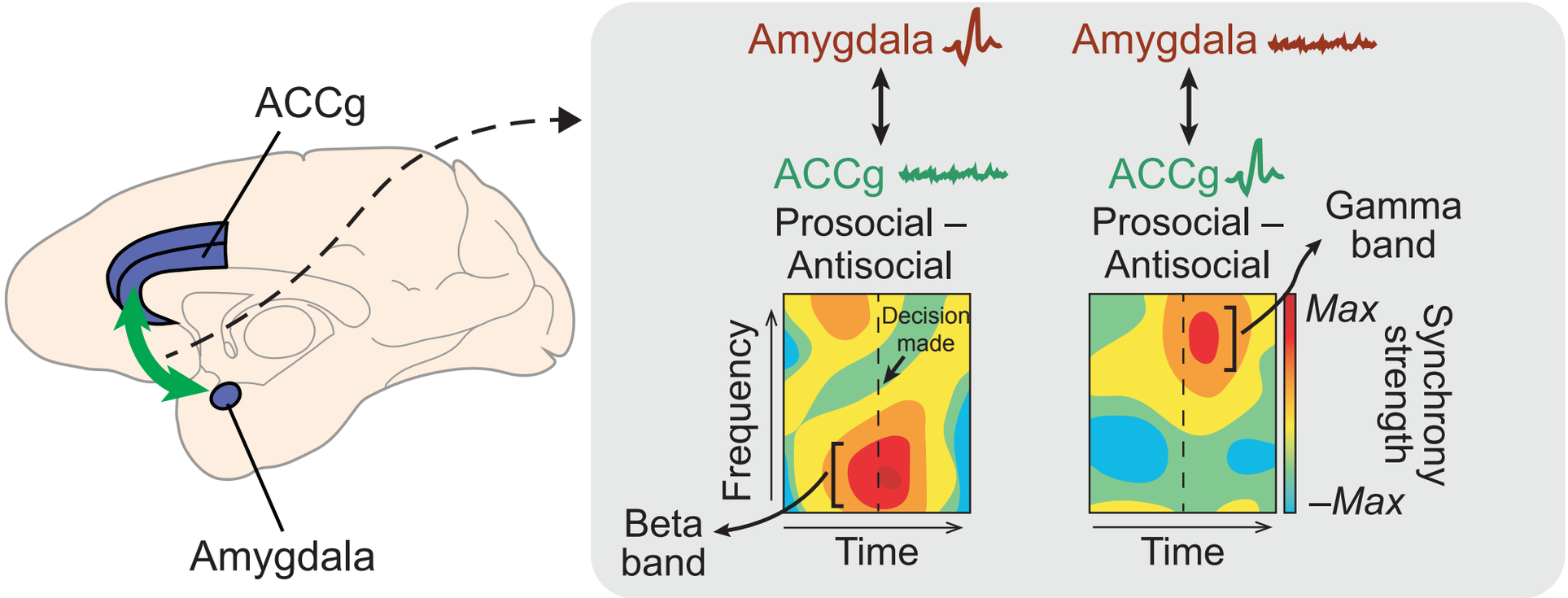
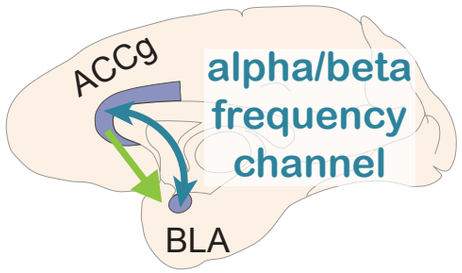
Summary I: Expressing prosocial preference

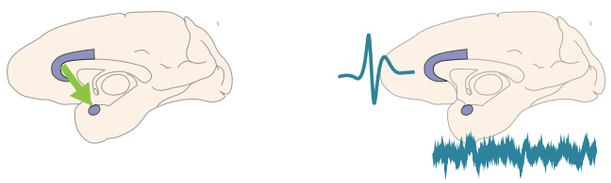


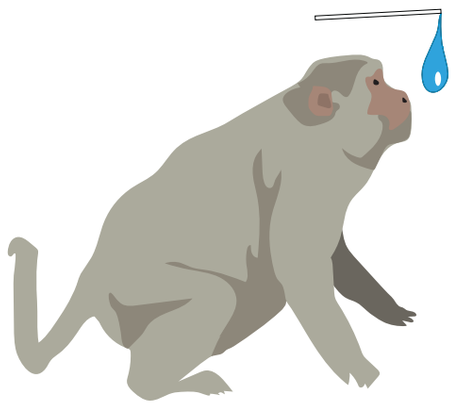
Summary II: Vicarious and experienced reward signaling differ in ACCg-BLA communication patterns

Experienced reward outcome information

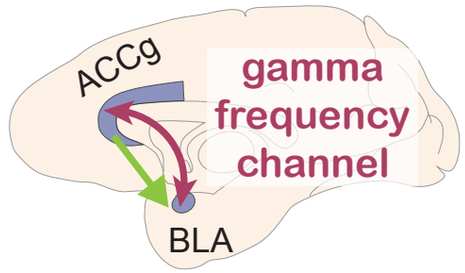


directionality coordinated

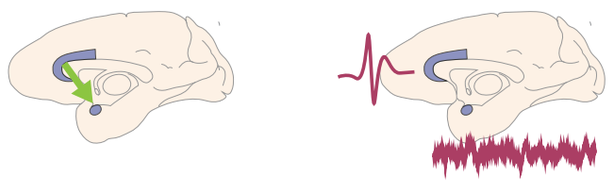


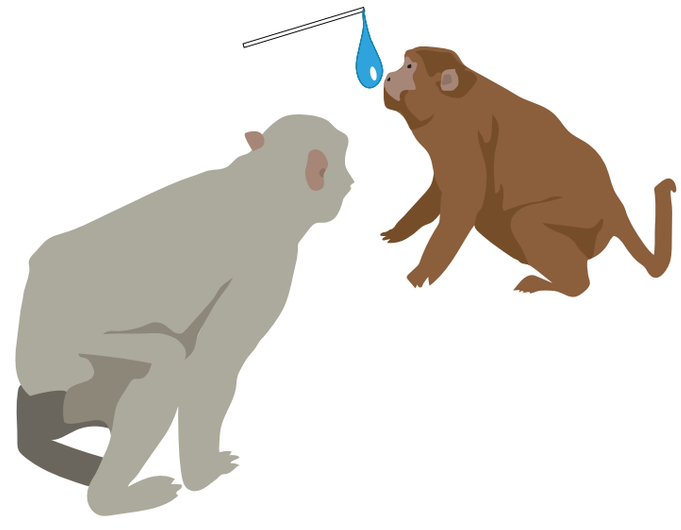


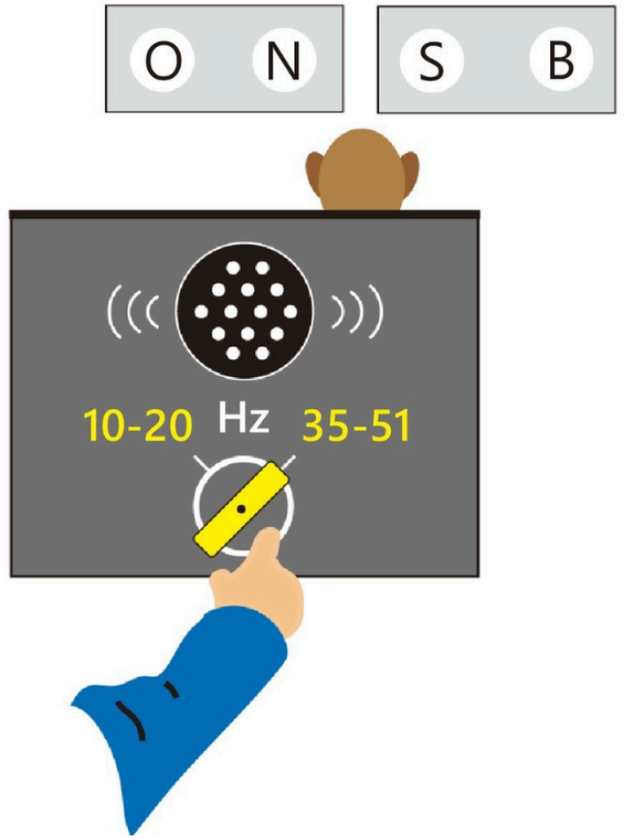
Vicarious reward outcome information

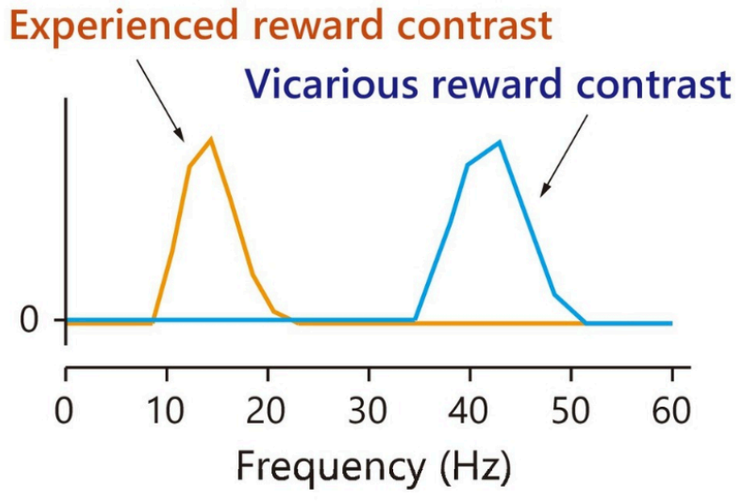


directionality coordinated









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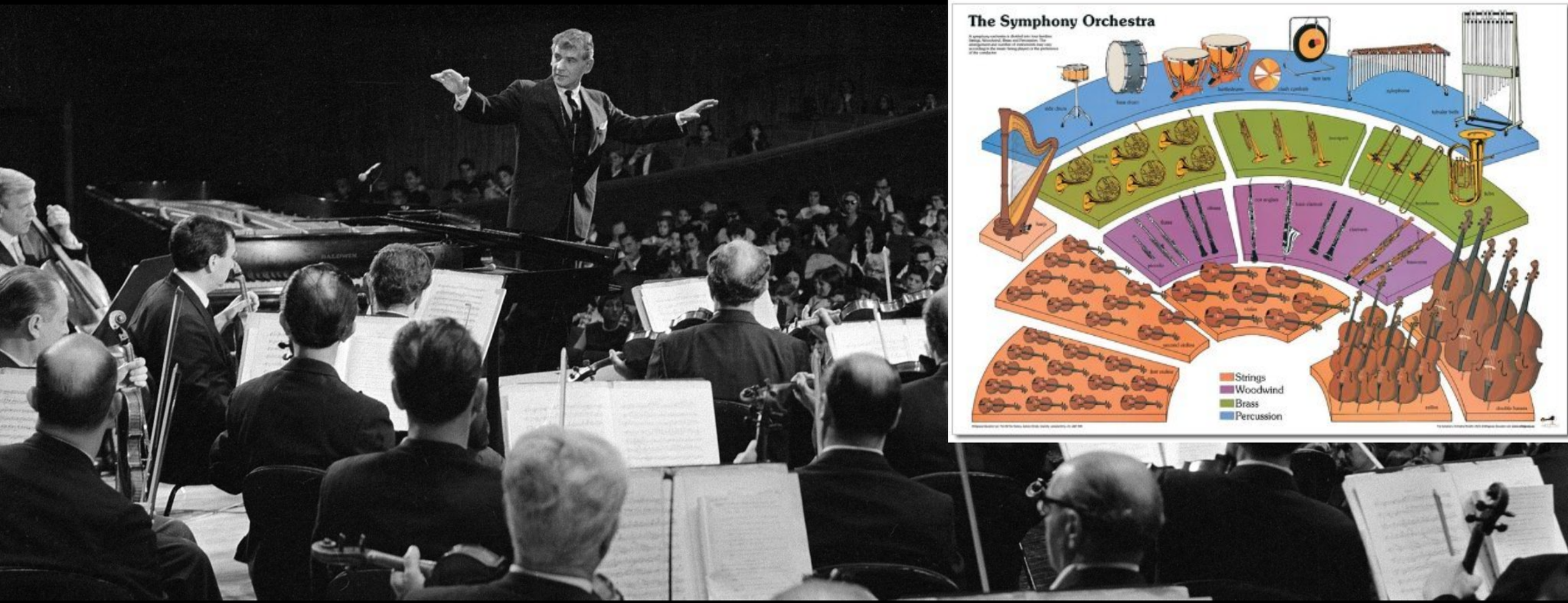
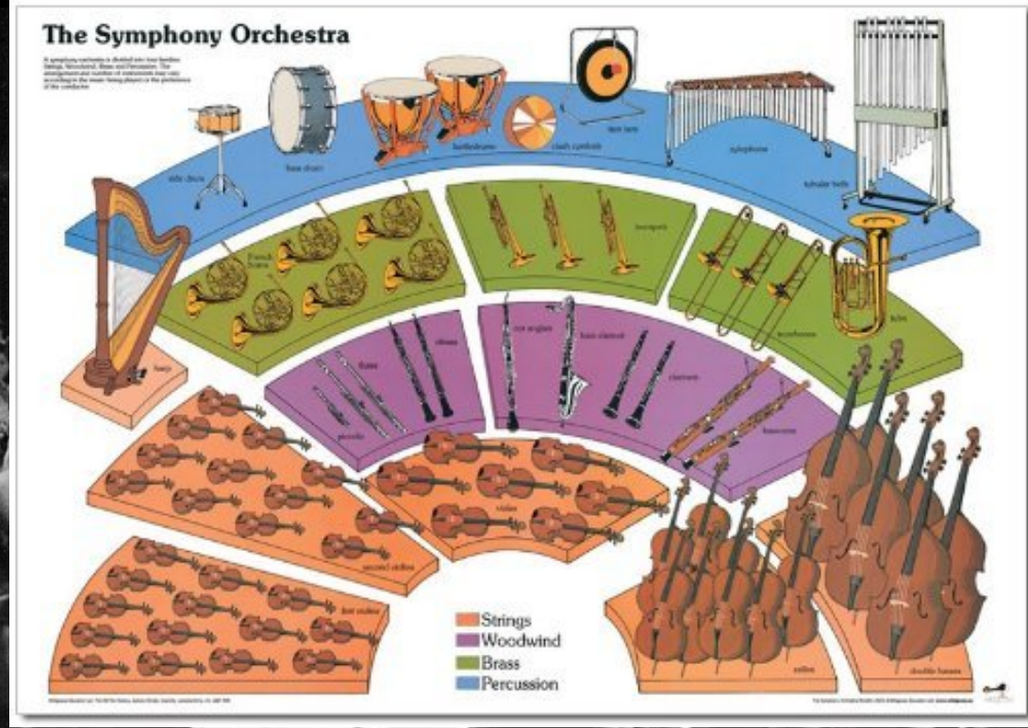


Leonard Bernstein conducting a New York Philharmonic Young People's Concert, October 23, 1965. (Credit: CBS/Getty Image)

https://www.gramophone.co.uk/features/article/an-interview-with-karajan-at-80



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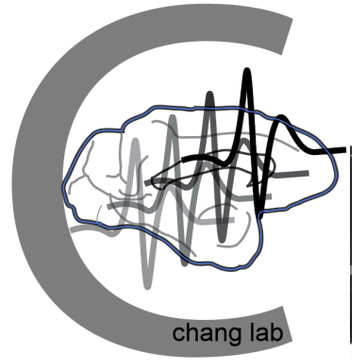
Coordination between ACCg and BLA may serve as 'functional modules' for prosocial behaviors interfacing empathy

Chang lab
at Yale University
Dept. of Psychology
Dept. of Neuroscience



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Guangyao Qi, PhD (postdoc)
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Machine Shop
Tony DeSimone

Kavli Neurotechnology Core
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