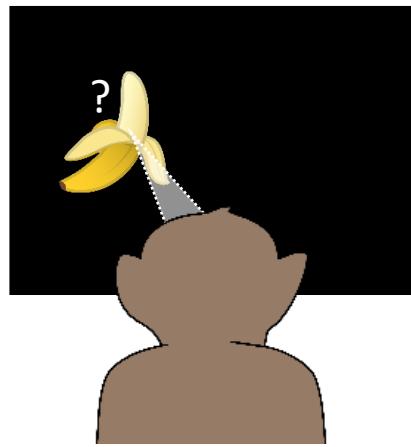
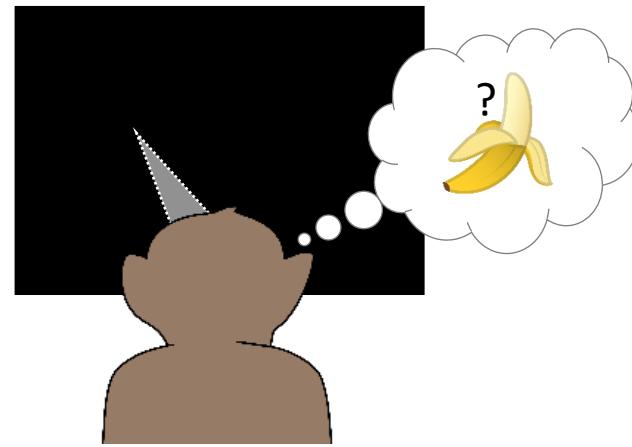


## Economic decision-making in the brain: how does gaze relate to the activity of orbitofrontal cortex neurons?

Presentation time



Delay time



**Demetrio Ferro<sup>1,2,\*</sup>, Tyler Cash-Padgett<sup>3</sup>, Maya Zhe Wang<sup>3</sup>, Benjamin Hayden<sup>3</sup>, Rubén Moreno Bote<sup>1,2,4</sup>**

<sup>1</sup>Center for Brain and Cognition (CBC), Universitat Pompeu Fabra (UPF), 08002, Barcelona – ES;

<sup>2</sup>Department of Information and Communication Technologies, Universitat Pompeu Fabra (UPF), 08002, Barcelona – ES;

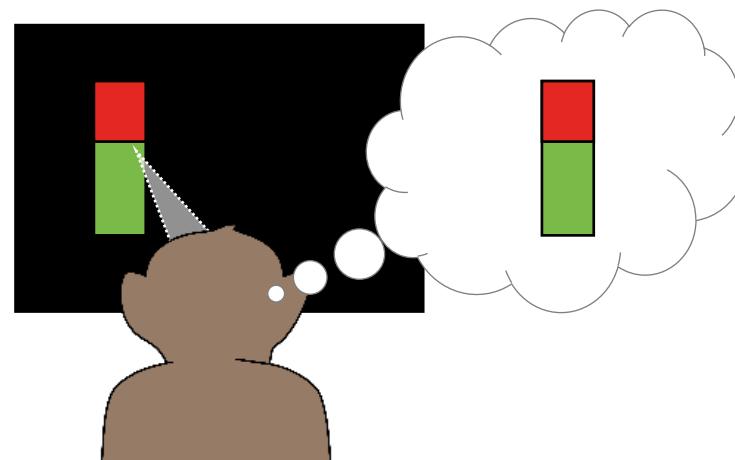
<sup>3</sup>Dept. of Neuroscience, Center for Magnetic Resonance Research, Center for Neuroeng., University of Minnesota, MN55455, Minneapolis – USA;

<sup>4</sup>Serra Húnter Fellow Programme, Universitat Pompeu Fabra, Barcelona, Spain

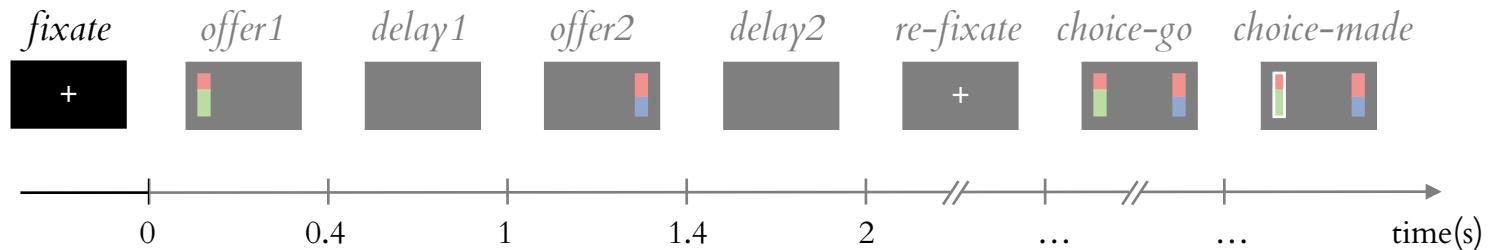
*\*demetrio.ferro@upf.edu*

# Motivations

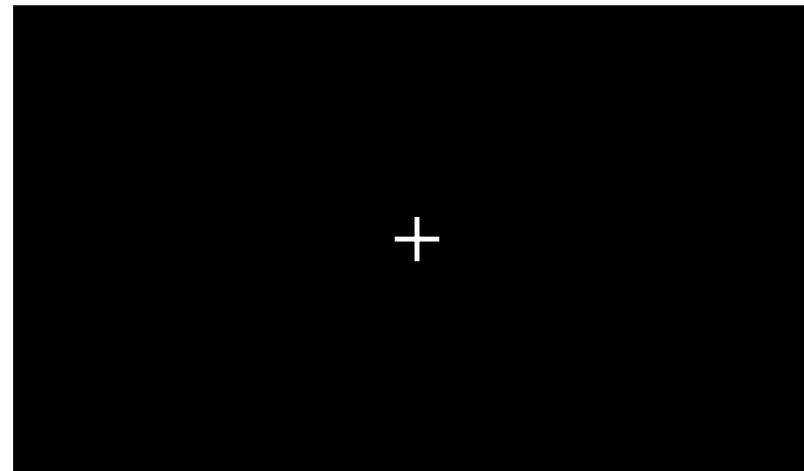
- Is the gaze position relevant for the reward gambling task execution?
- Can we use the gaze position as a marker of what is the animal mentally picturing during task execution? in particular, can we do so during delays?



# Reward gambling task

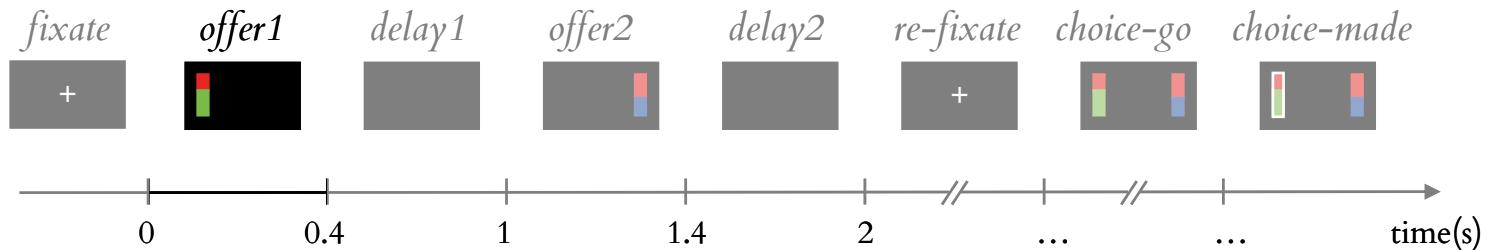


**Fixate**



acquire fixation at center of the screen

# Reward gambling task

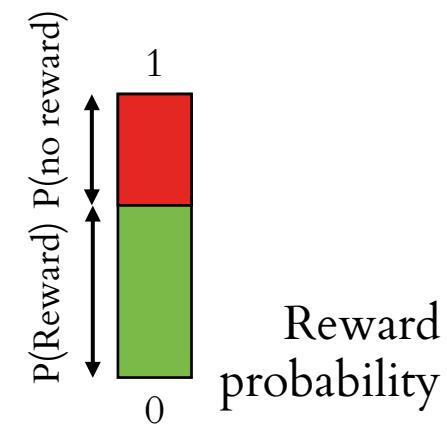


Offer 1



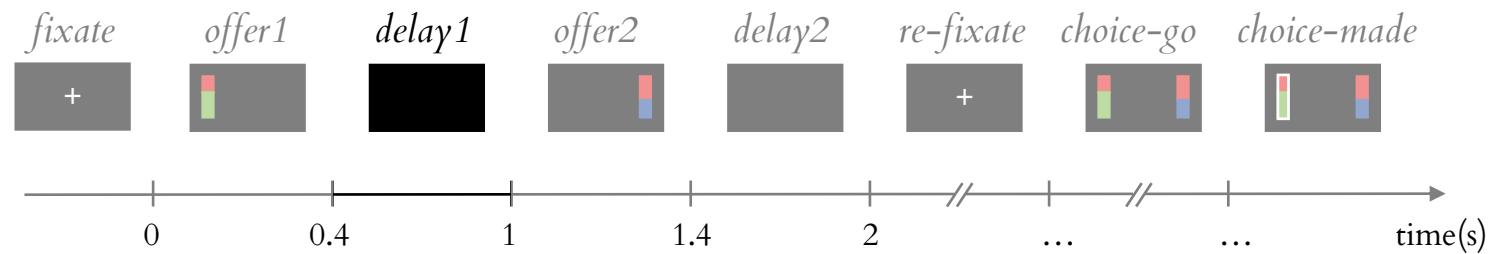
Reward magnitude      L      M      S      0  
first offer is presented

Below the bars are three blue water droplet icons corresponding to L, M, and S.

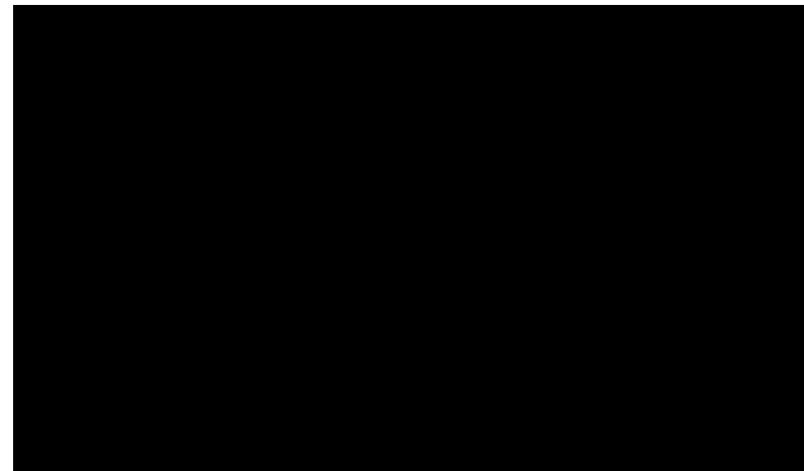


Reward probability

# Reward gambling task

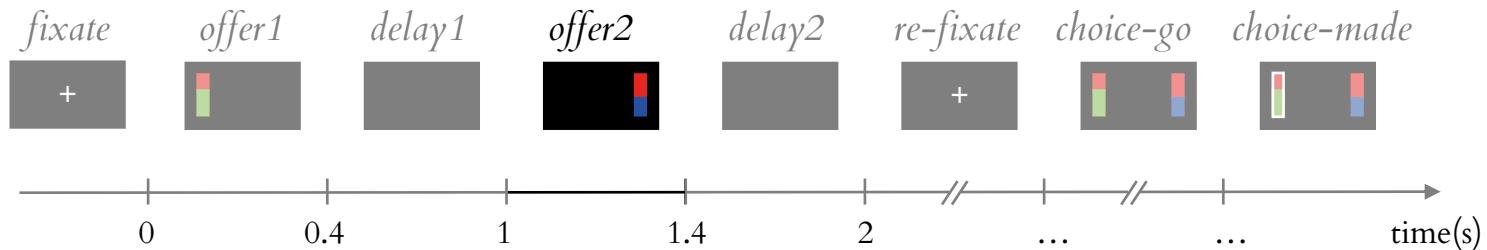


Delay 1

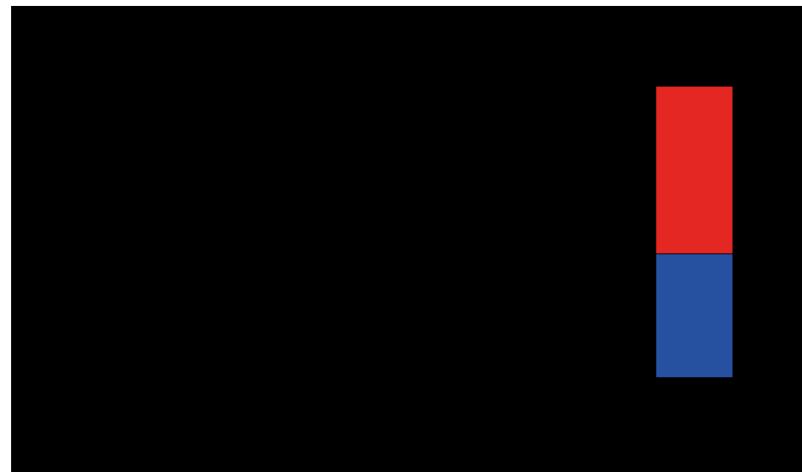


blank screen

# Reward gambling task

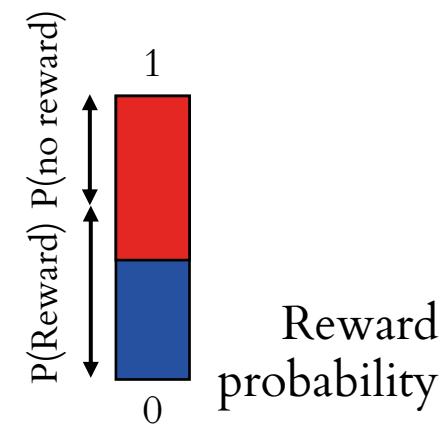


Offer 2

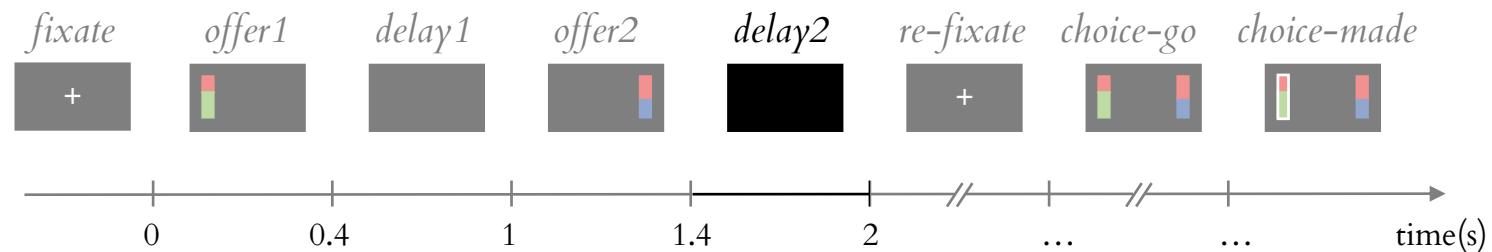


Reward magnitude      L      M      S      0  
second offer is presented

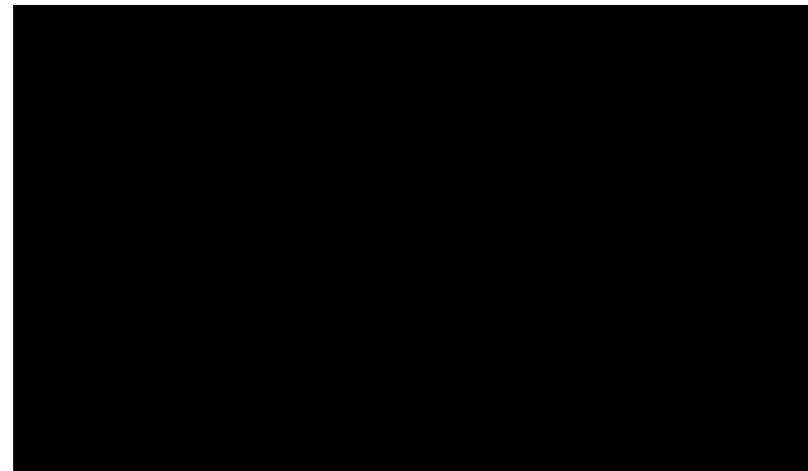
Below each color-coded square is a small blue water droplet icon.



# Reward gambling task

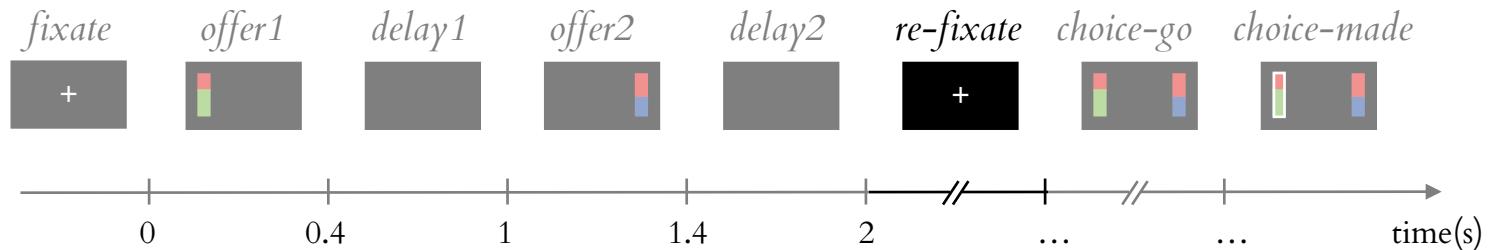


Delay 2

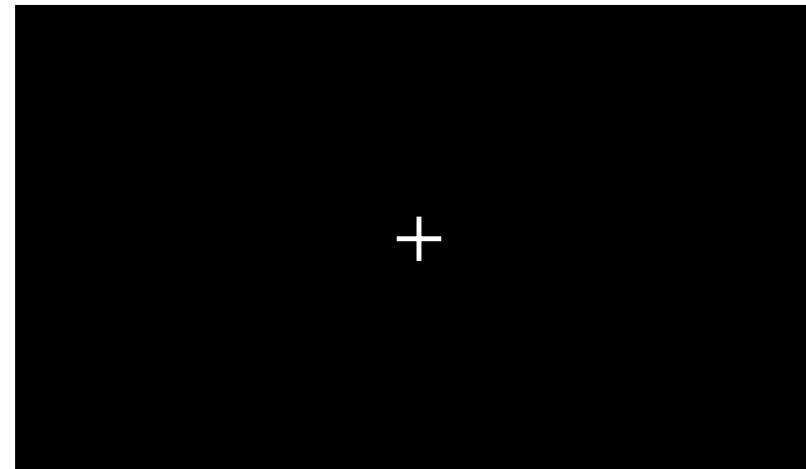


blank screen

# Reward gambling task

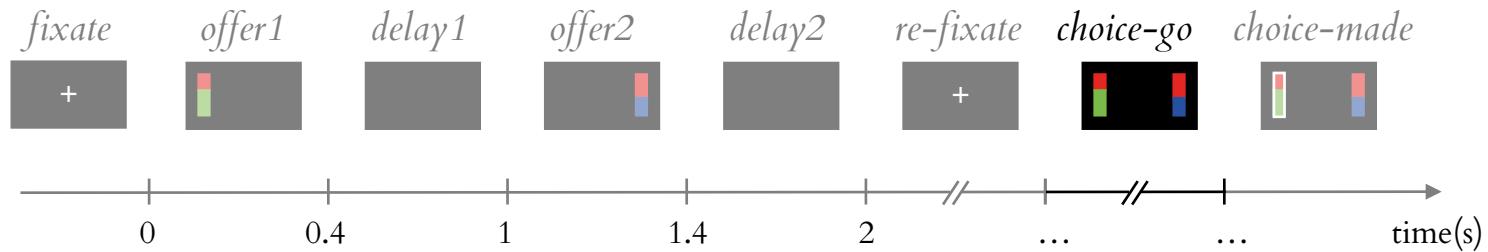


Re-fixate



re-acquire fixation at center of the screen

# Reward gambling task

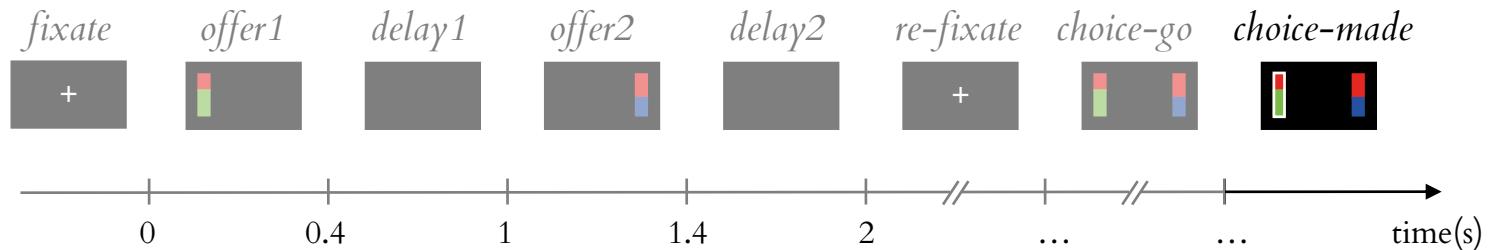


## Choice-go



saccade to chosen offer side

# Reward gambling task

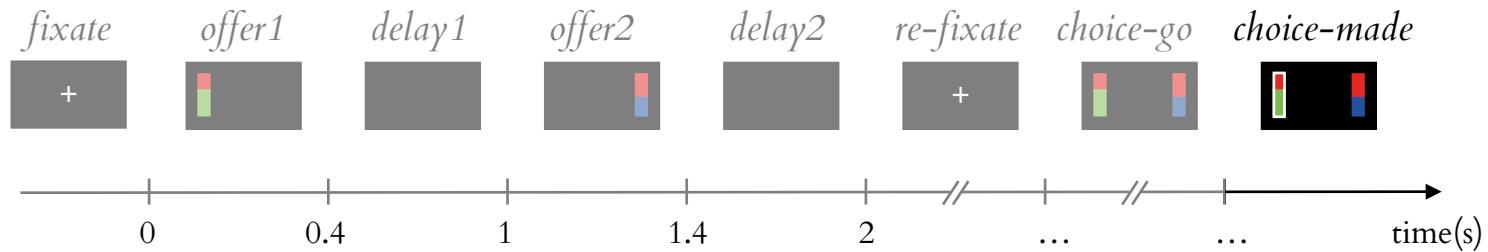


**Choice-made**



hold chosen offer side for at least +200ms

# Reward gambling task



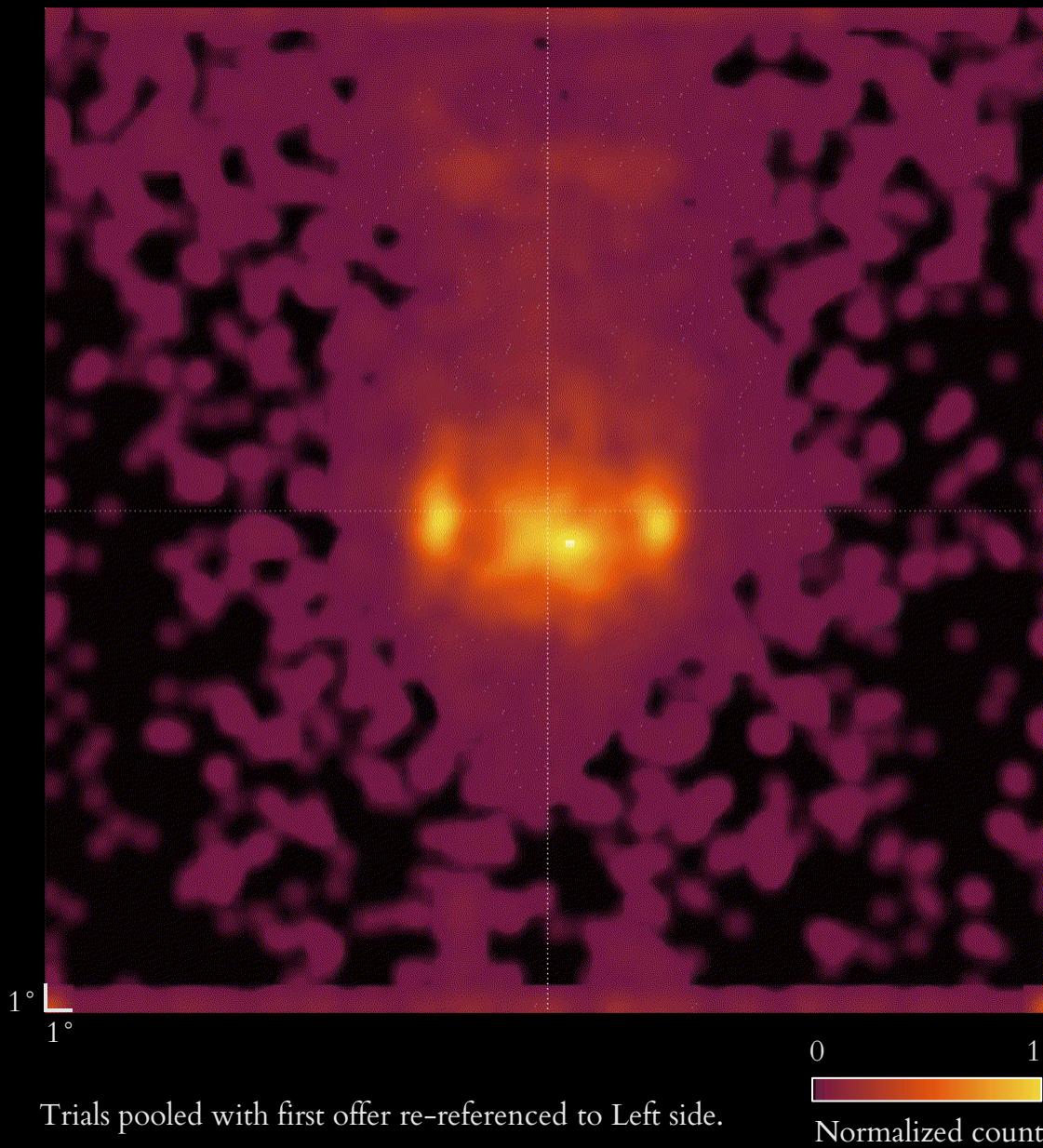
Reward



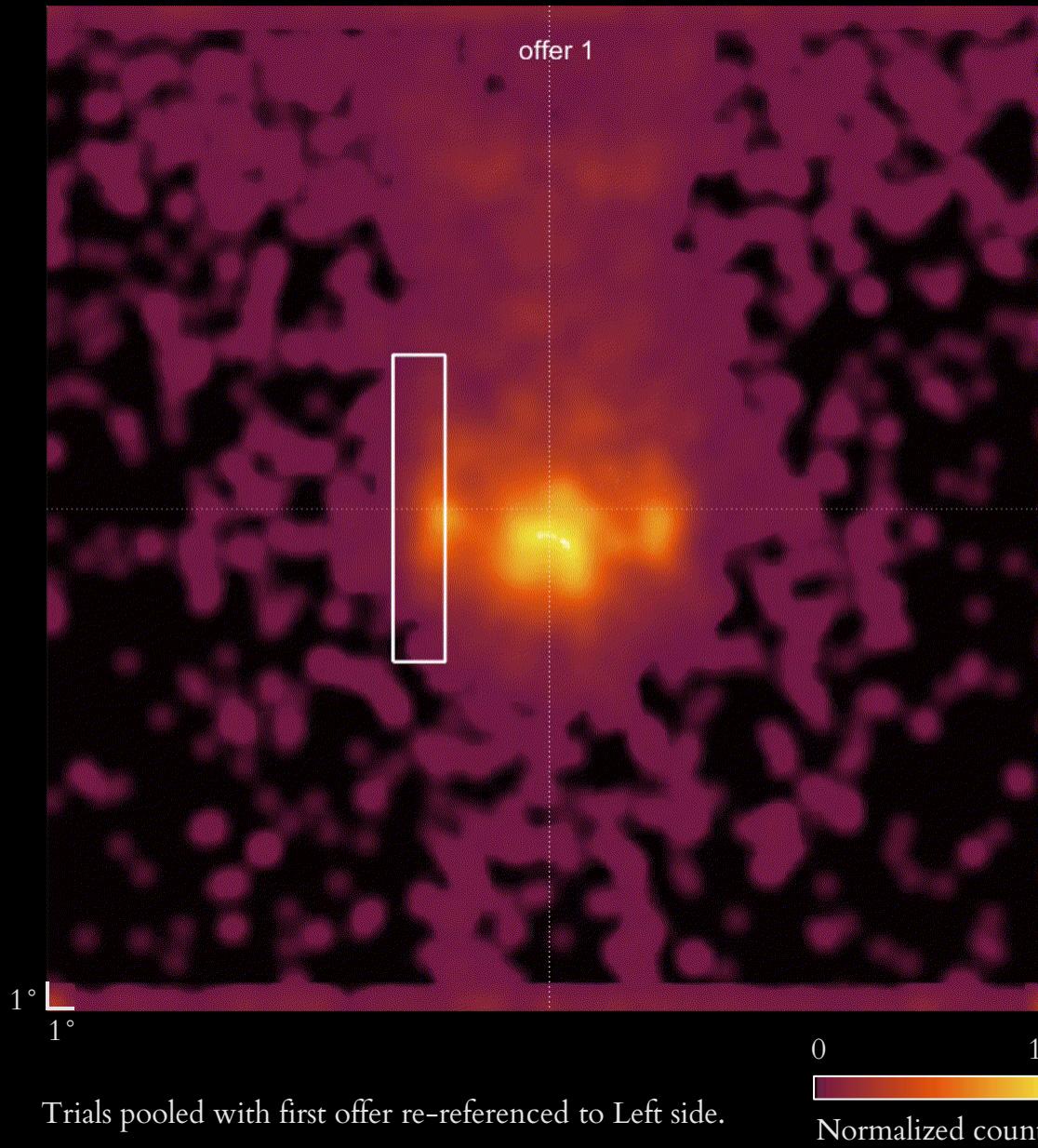
reward is provided



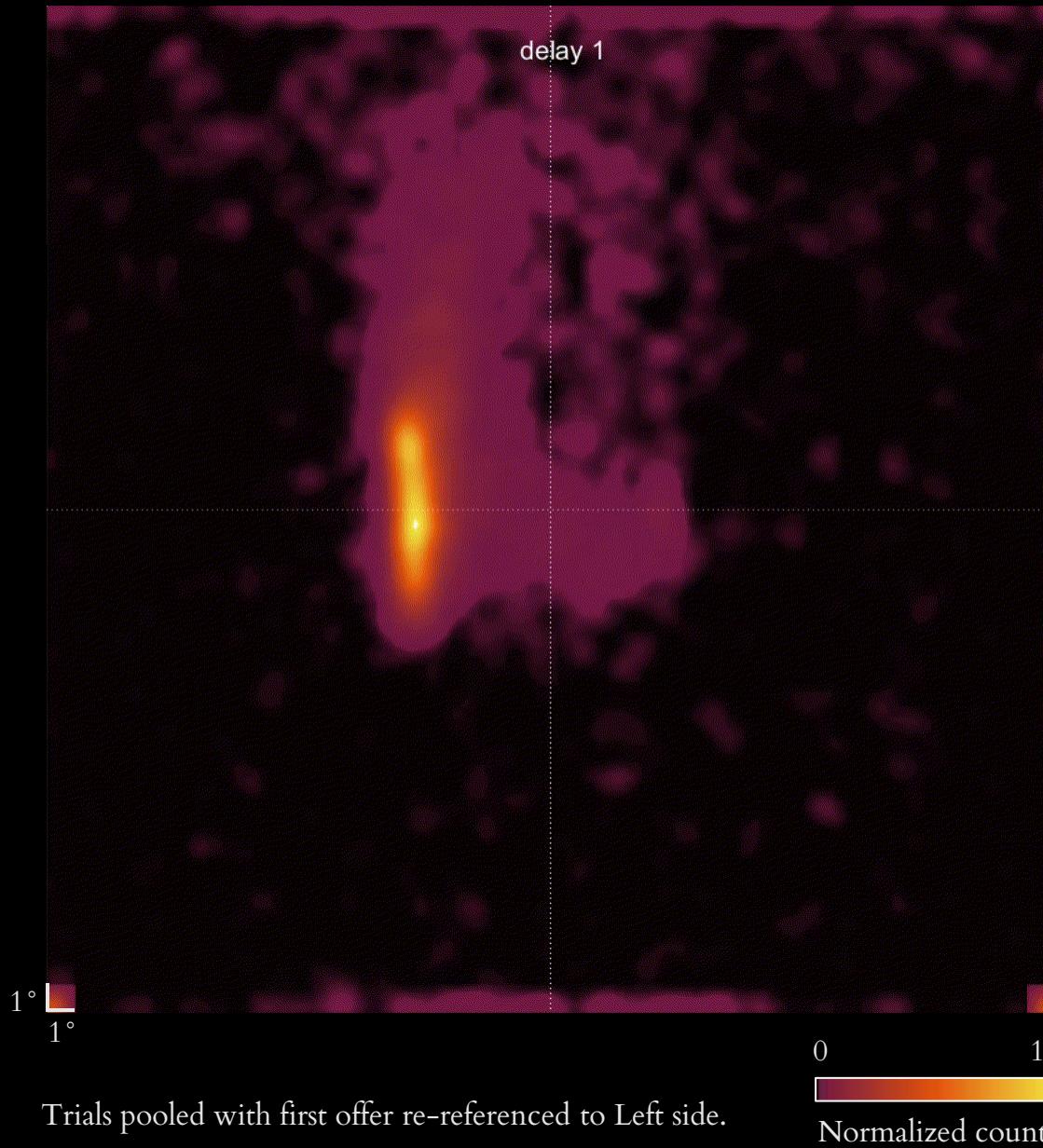
# Eye movements during task execution



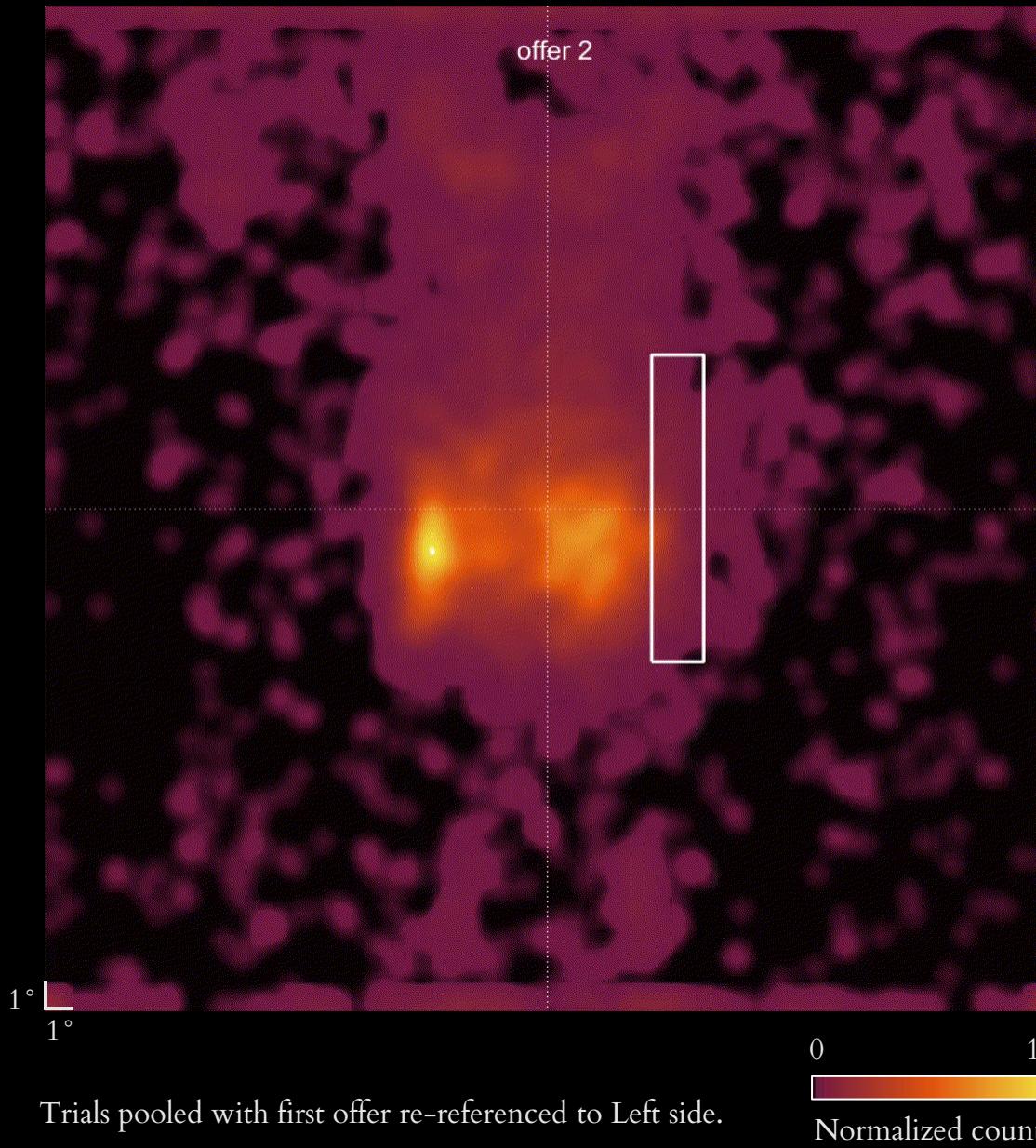
# Eye movements during task execution



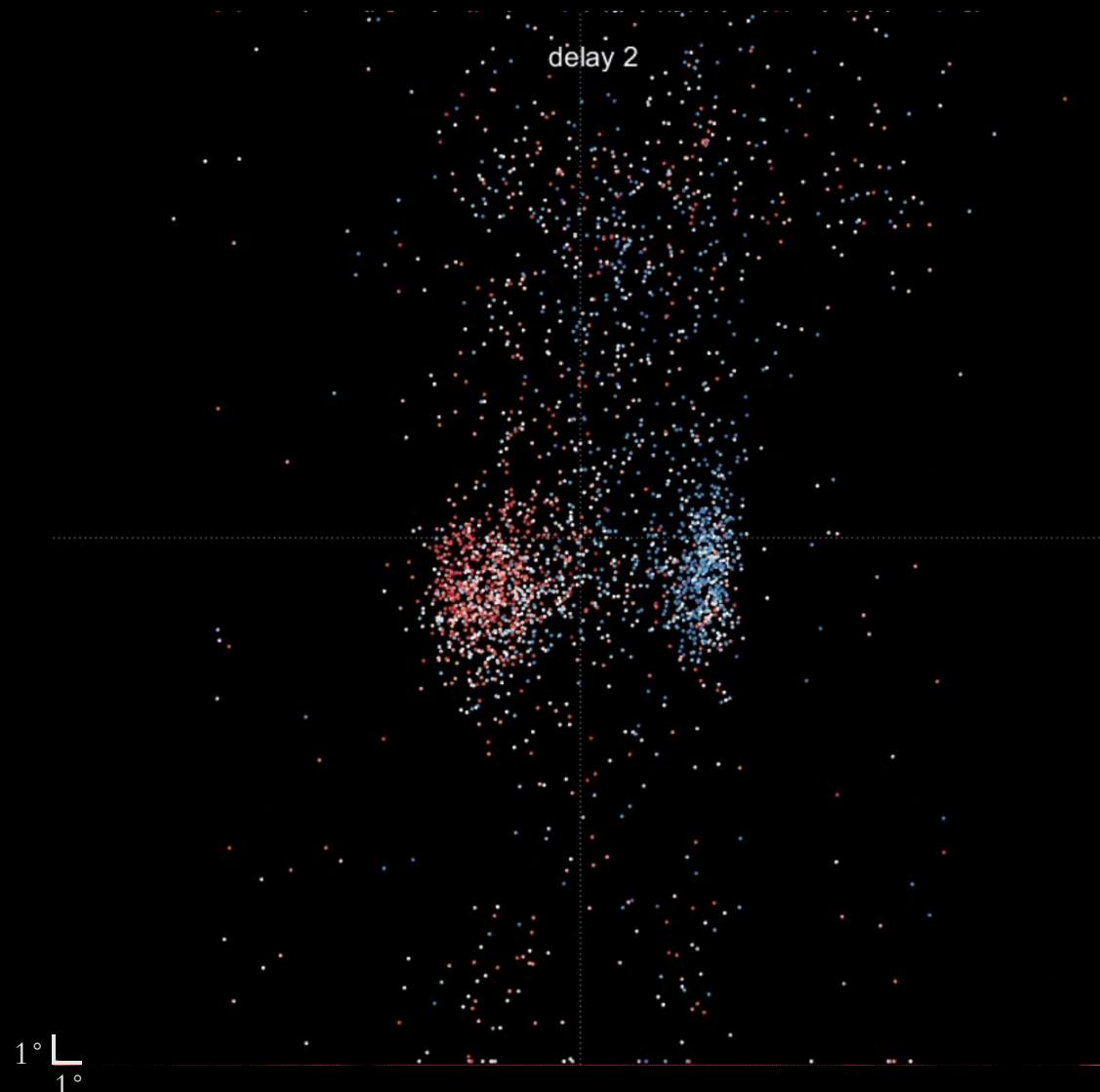
# Eye movements during task execution



# Eye movements during task execution



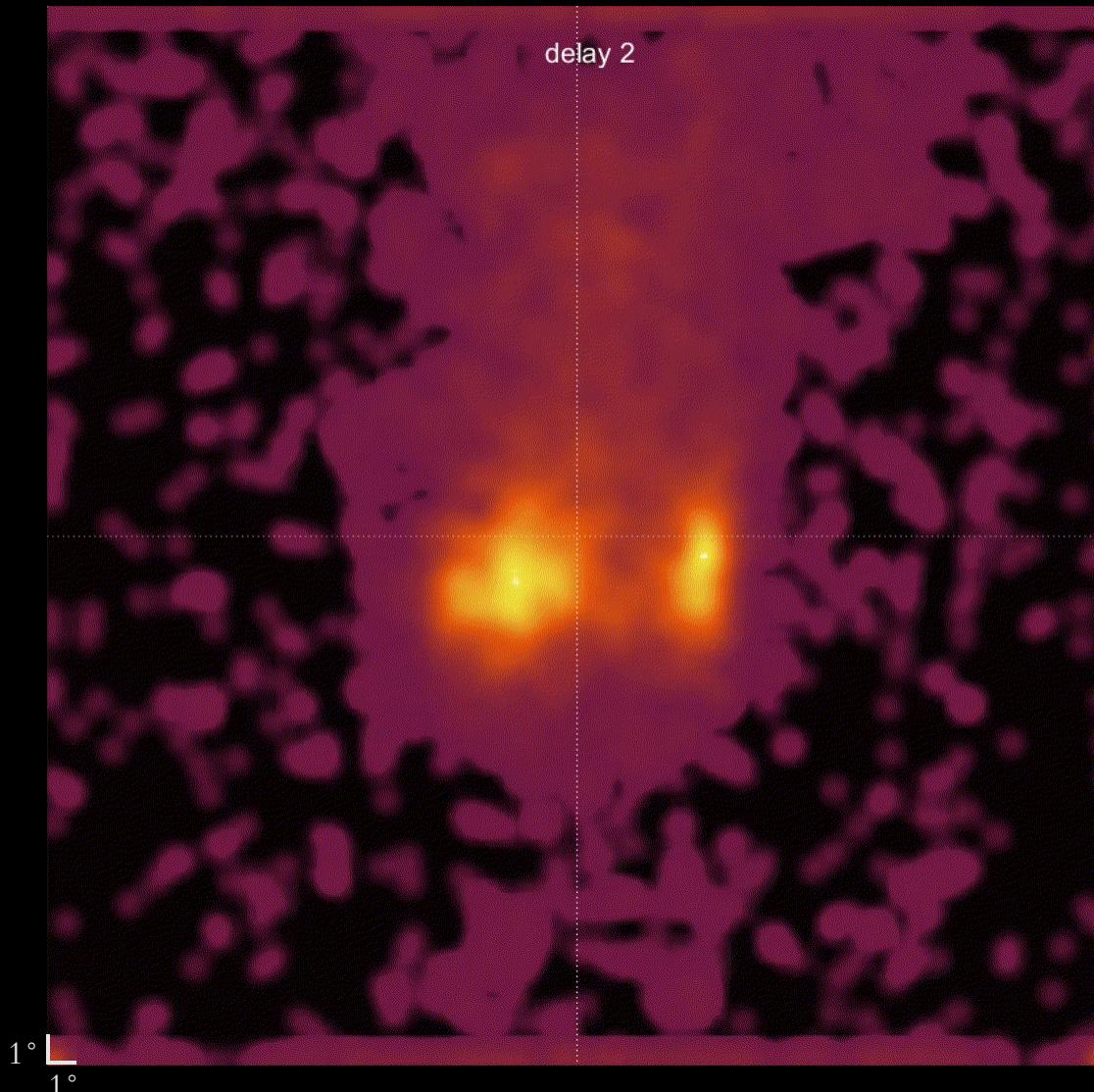
# Eye movements during task execution



Trials pooled with first offer re-referenced to Left side.

Left is best,  $EV(Left) > EV(Right)$   
Right is best,  $EV(Right) > EV(Left)$

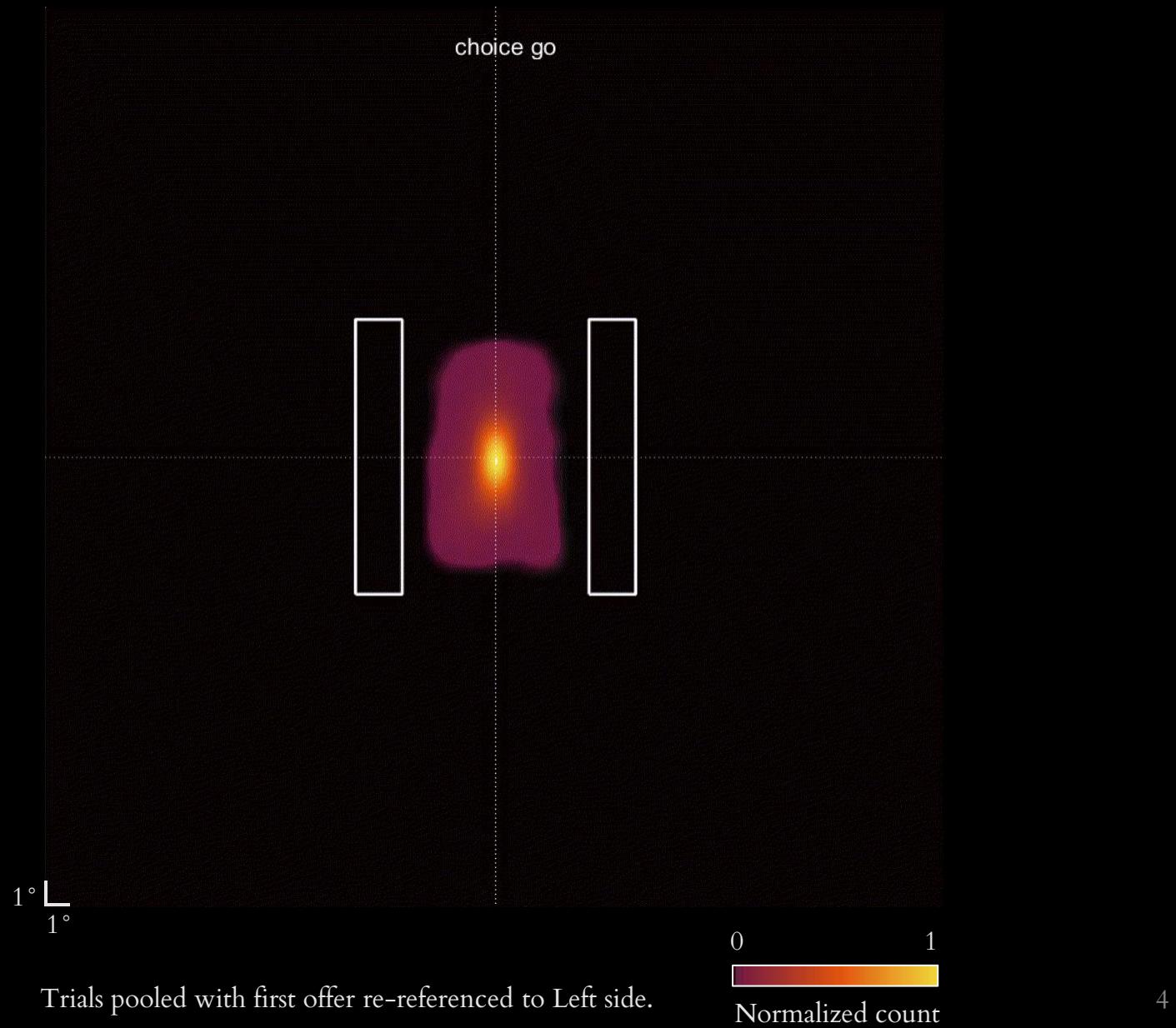
# Eye movements during task execution

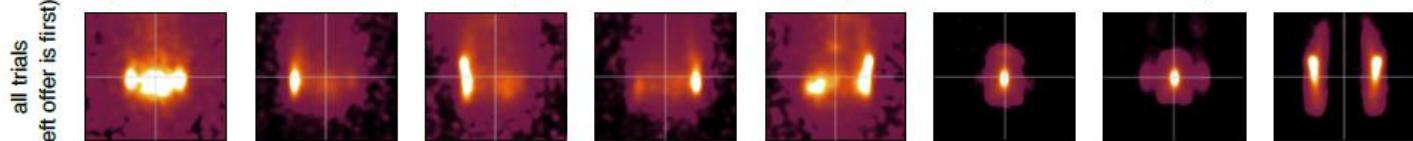
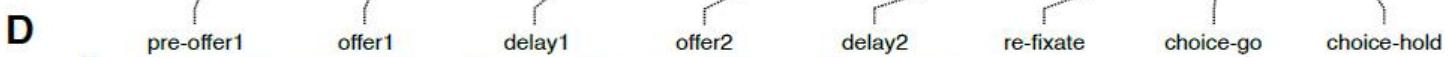
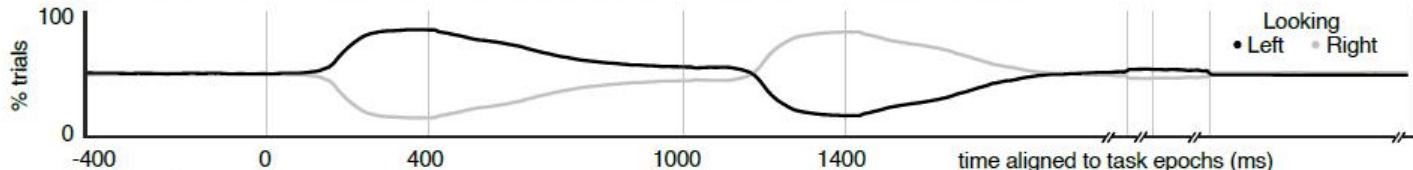
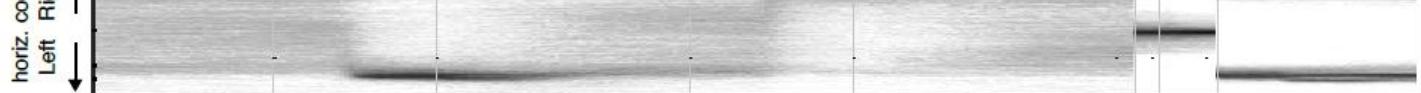
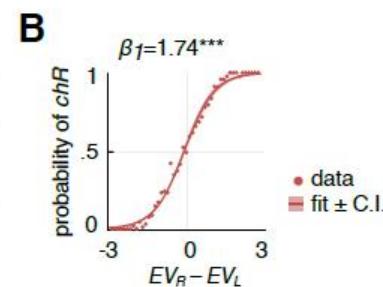


Trials pooled with first offer re-referenced to Left side.

0 1  
Normalized count

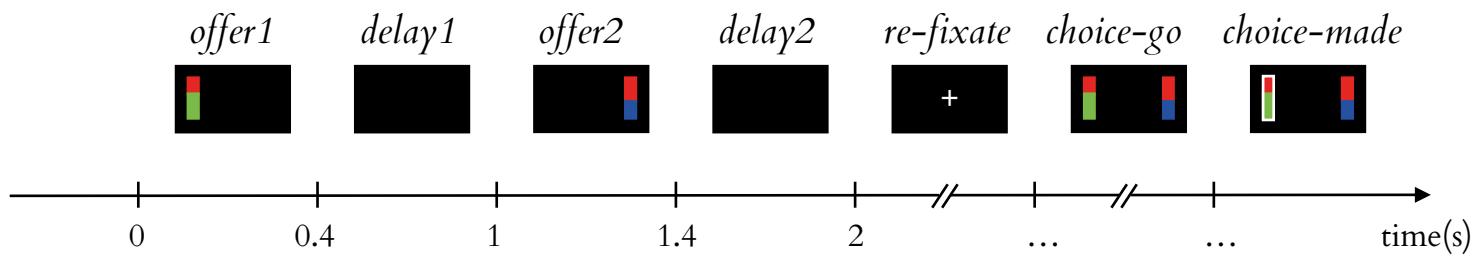
# Eye movements during task execution





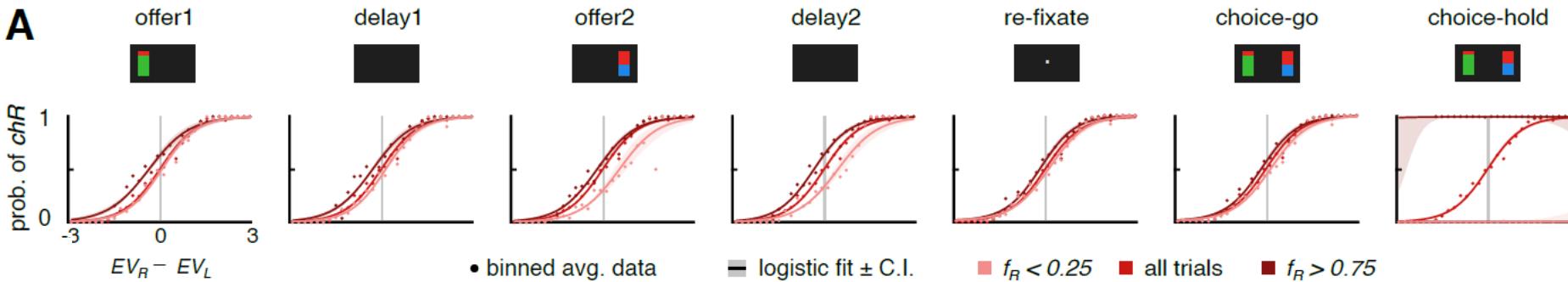
# Motivations

- Is the gaze position relevant for the reward gambling task execution?
  - Let us look how the time spent looking to either screen side affects the choice



$$f_R = \frac{t_R}{t_R + t_L}$$

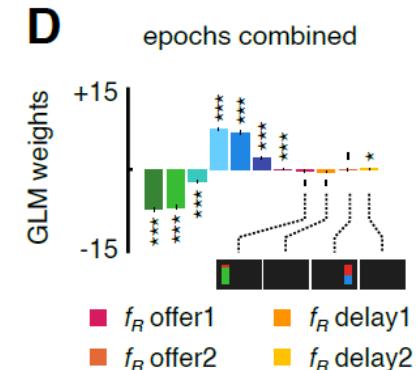
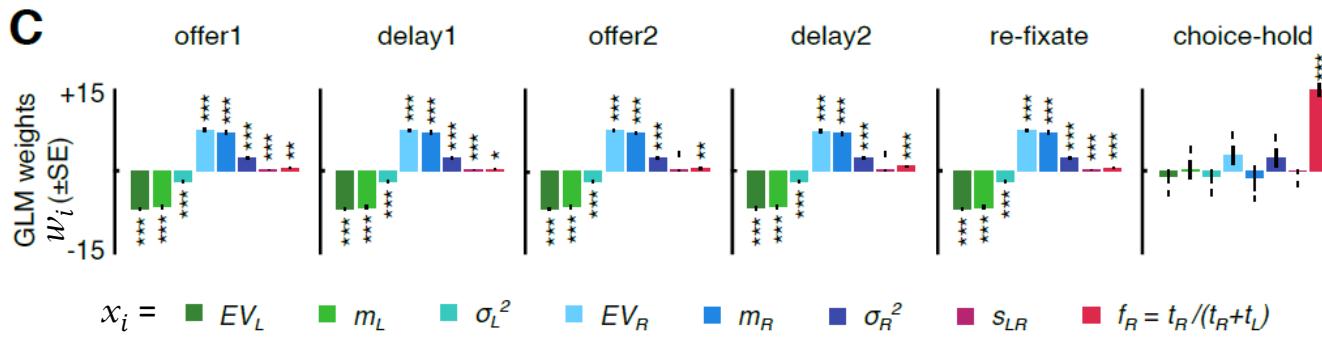
Fraction of time spent looking at the Right screen side



## Generalized Linear Model (GLM) for behavioral choice

$p_{chR}$  = probability of  $chR$

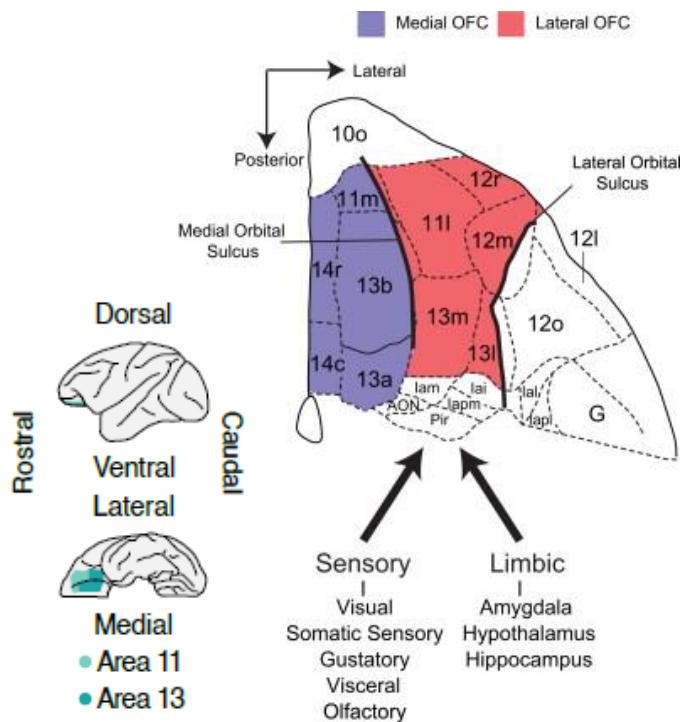
$$\text{logit}(p_{chR}) \approx w_0 + \sum_i w_i x_i$$



# Motivations

- Is the gaze position relevant for the reward gambling task execution?
- Can we use the gaze position as a marker of what is the subjects mentally picture during task execution? in particular, can we do so during delays?
  - Are task-relevant variables encoded by OFC cells?

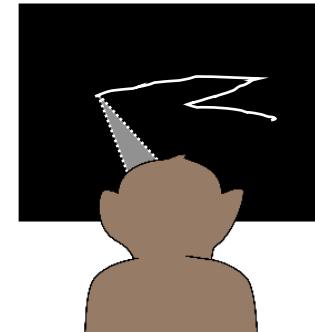
# Neural Data



Carmichael, S.T., and Price, J.L. (1994).  
*Architectonic subdivision of the orbital and medial prefrontal cortex  
in the macaque monkey*. J. Comp. Neurol. 346, 366–402.

## Subject 1

| area  | session  | #cells | # trials |
|-------|----------|--------|----------|
| BA13  | 12/07/17 | 51     | 643      |
| BA13  | 12/08/17 | 59     | 700      |
| BA11  | 12/09/17 | 24     | 697      |
| BA11  | 12/10/17 | 29     | 603      |
| Total |          | 163    | 2643     |



## Subject 2

| area  | session | #cells | # trials |
|-------|---------|--------|----------|
| BA11  | 3/06/19 | 18     | 1015     |
| BA11  | 3/07/19 | 32     | 323      |
| BA11  | 3/08/19 | 9      | 1084     |
| BA11  | 3/11/19 | 26     | 906      |
| total |         | 85     | 3328     |

- 2 Subjects
- 8 Sessions
- 248 Cells

## Data acquisition



Tyler Cash-Padgett, Maya Zhe Wang, Benjamin Hayden,  
Hayden Lab, Dept. of Neuroscience, Center for Magnetic Resonance Research,  
Center for Neuroengineering, University of Minnesota, Minneapolis, USA;



Two adult male rhesus macaques (*macaca mulatta*) served as experimental subjects. All procedures were approved by the University Committee on Animal Resources at the University of Rochester and at the University of Minnesota, conducted in compliance with the Public Health Service's Guide for the Care and Use of the Animals.

$$EV = \begin{array}{cccc} L & M & S & 0 \\ \text{blue} & \text{blue} & \text{blue} & \end{array} \quad \text{Reward magnitude} * \text{Reward probability}$$

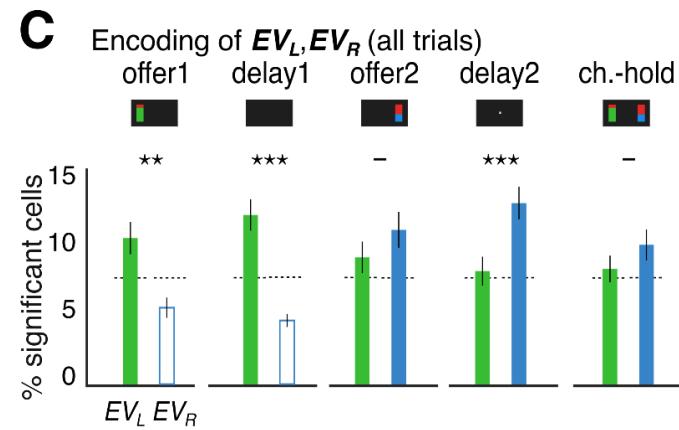
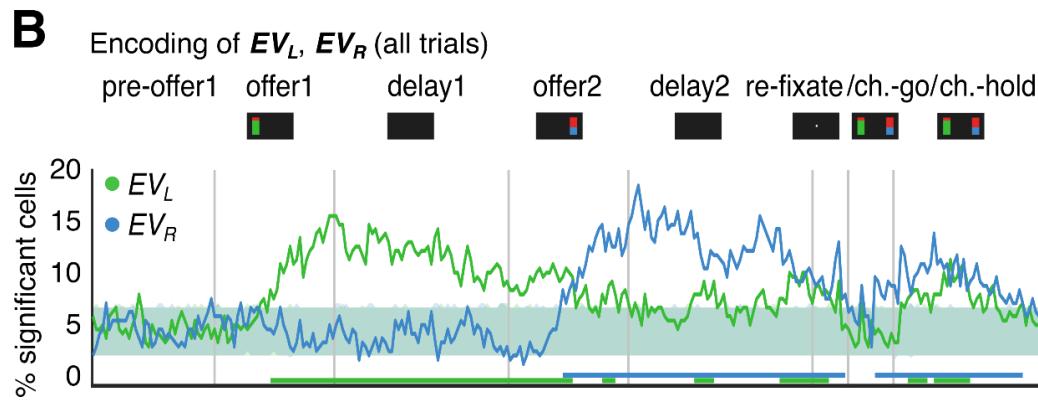
For each cell,

in each 10 ms bin:

$$\text{spike count} \quad \eta = \beta_0 + \beta_1 EV$$

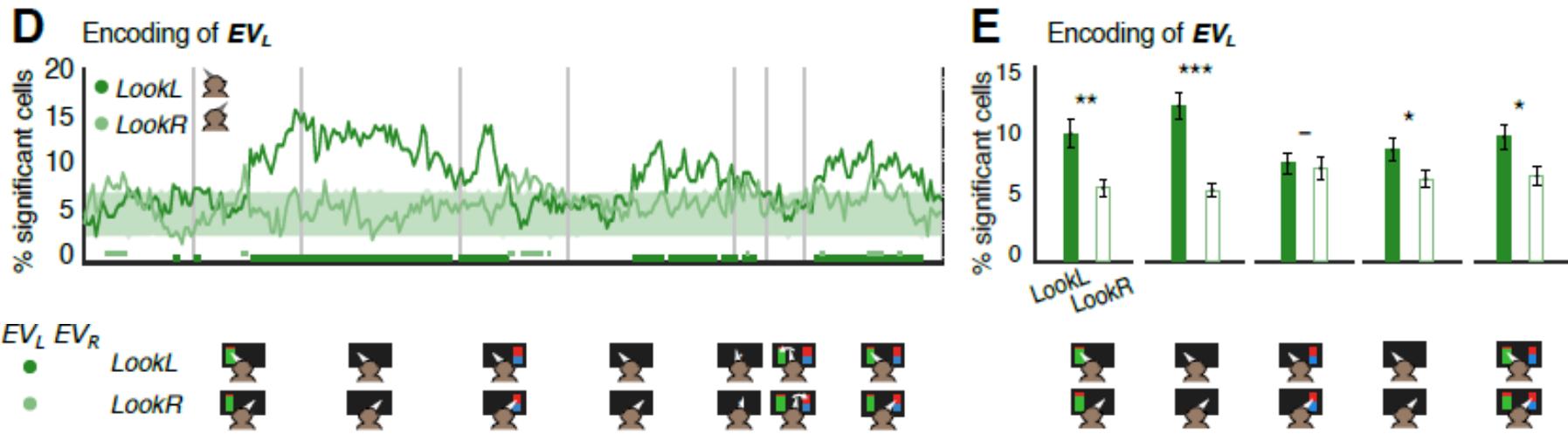
if  $p < 0.05$  for  $\beta_1$ , the cell is significantly encoding offer EV

(spike count starts at the start of current time bin and covers the following 200ms)



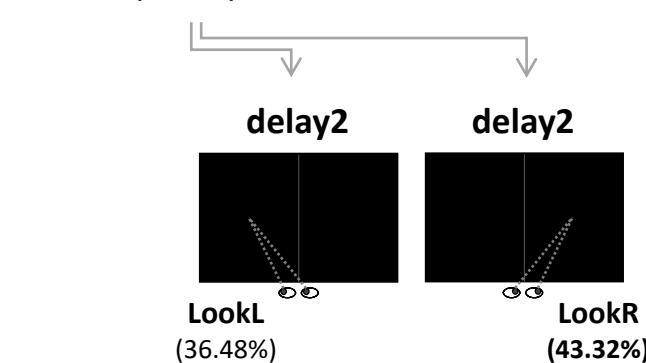
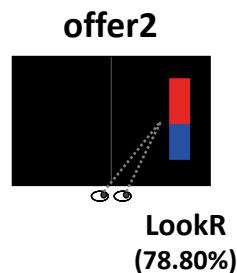
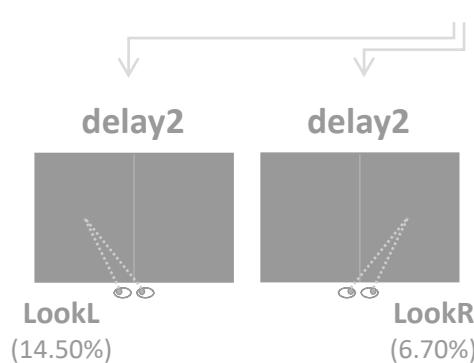
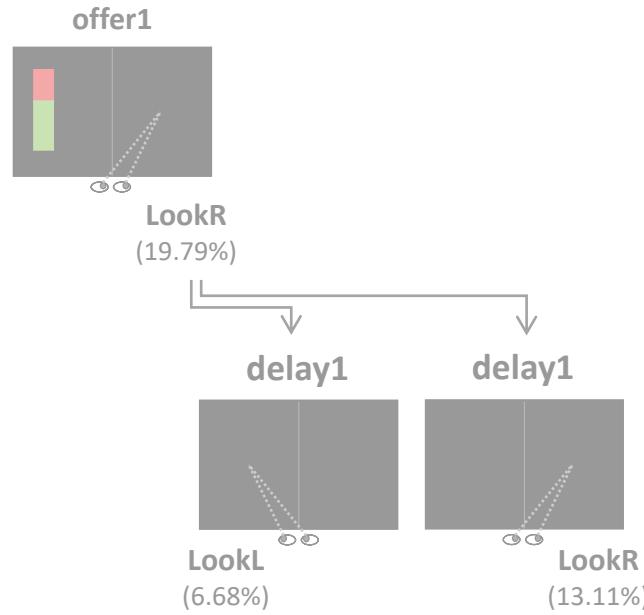
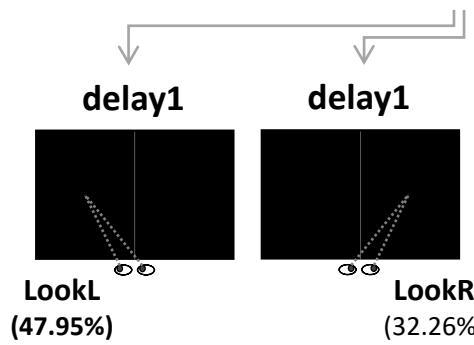
# Motivations

- Is the gaze position relevant for the reward gambling task execution?
- Can we use the gaze position as a marker of what is the animal mentally picturing during task execution? in particular, can we do so during delays?
  - Are task-relevant variables encoded by OFC cells?
  - Is the gaze position relevant in the neural process of encoding the offer values?



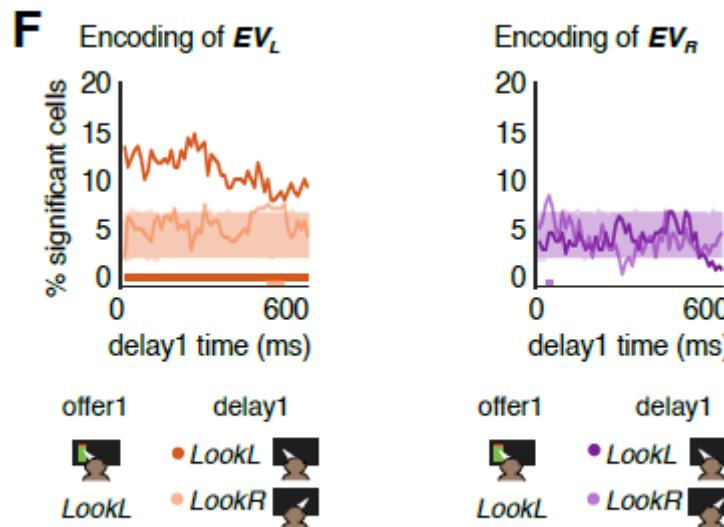
# Motivations

- Is the gaze position relevant for the reward gambling task execution?
- Can we use the gaze position as a marker of what is the animal mentally picturing during task execution? in particular, can we do so during delays?
  - Are task-relevant variables encoded by OFC cells?
  - Is the gaze position relevant in the neural process of encoding the offer values?
  - What about encoding of values at delay time?



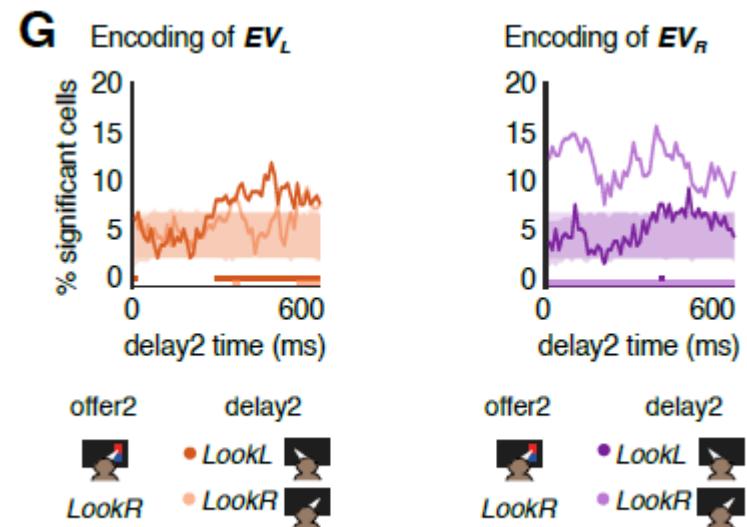
## *Let us consider the most frequent cases*

### Offer 1 Look Left Delay 1



|                                      |        |
|--------------------------------------|--------|
| <i>offer1 LookL and delay1 LookL</i> | 47.95% |
| <i>offer1 LookL and delay1 LookR</i> | 32.26% |
| <i>offer1 LookR and delay1 LookL</i> | 6.68%  |
| <i>offer1 LookR and delay1 LookR</i> | 13.11% |

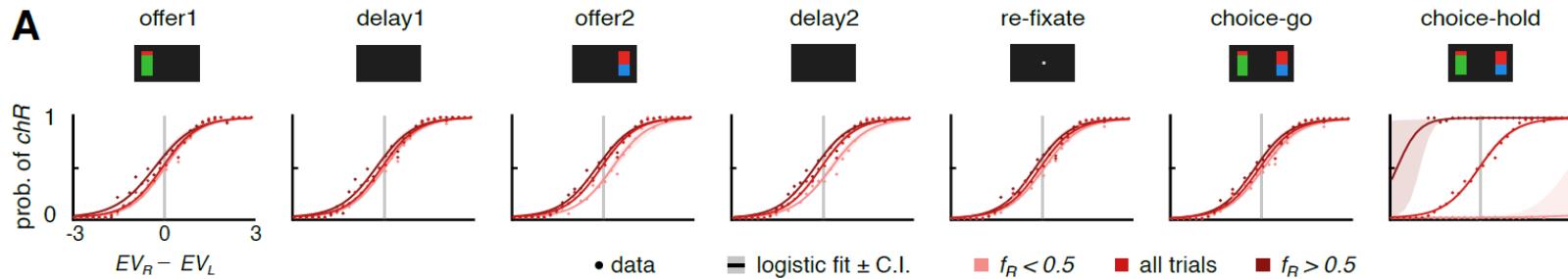
### Offer 2 Look Right Delay 2



|                                      |        |
|--------------------------------------|--------|
| <i>offer2 LookL and delay2 LookL</i> | 14.50% |
| <i>offer2 LookL and delay2 LookR</i> | 6.70%  |
| <i>offer2 LookR and delay2 LookL</i> | 36.48% |
| <i>offer2 LookR and delay2 LookR</i> | 42.32% |

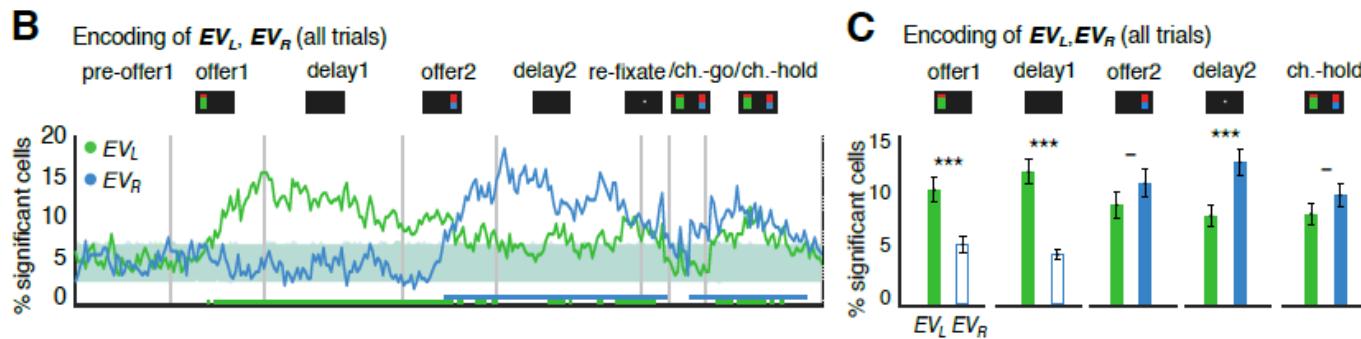
# Conclusions

- The gaze position has a significant role in the reward gambling task execution: the fraction of time spent at either screen side is predictive of the chosen side;



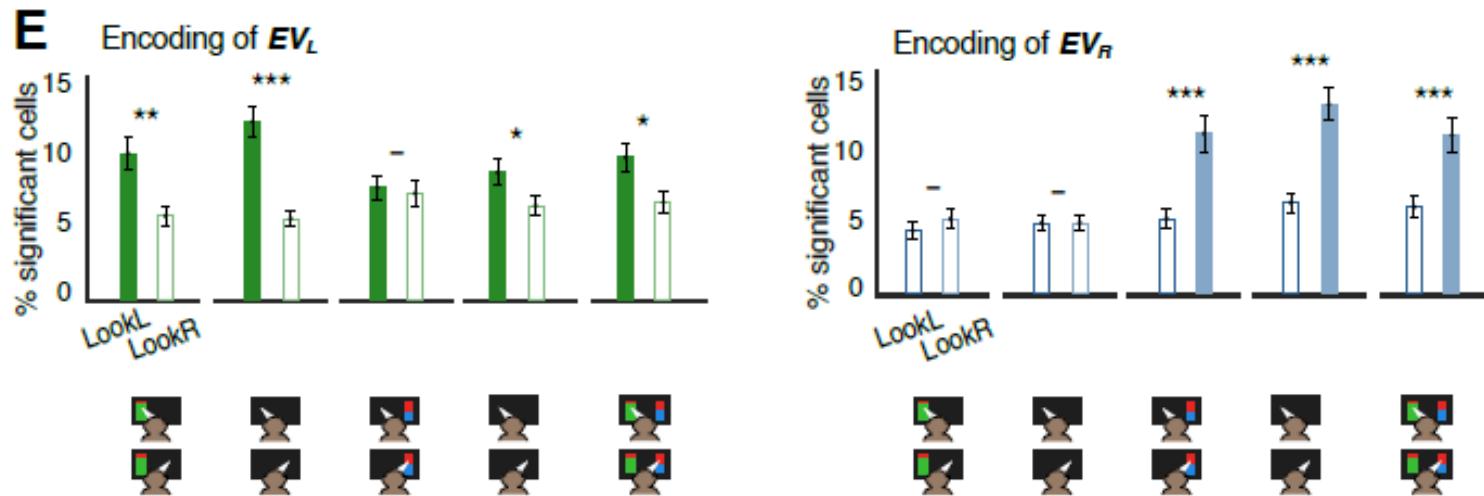
# Conclusions

- The gaze position has a significant role in the reward gambling task execution: the fraction of time spent at either screen side is predictive of the chosen side;
- Task-relevant variables are encoded by a significant fraction of OFC cells, including the fraction of time spent inspecting either screen side;



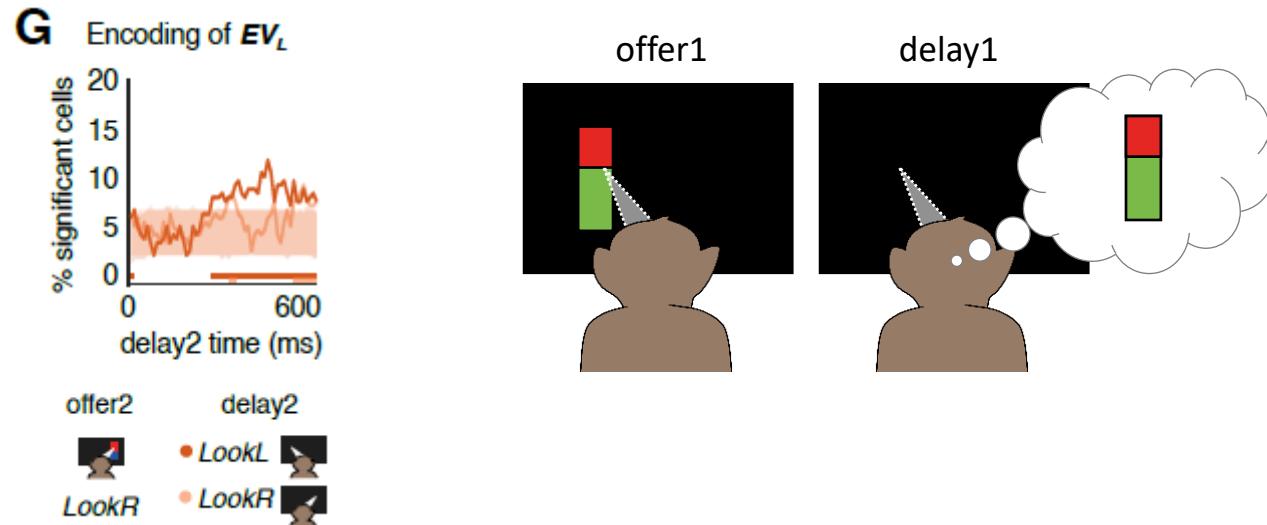
# Conclusions

- The gaze position has a significant role in the reward gambling task execution: the fraction of time spent at either screen side is predictive of the chosen side;
- Task-relevant variables are encoded by a significant fraction of OFC cells, including the fraction of time spent inspecting either screen side;
- The gaze position is relevant in the process of encoding offer values: looking at either side possibly yields stronger coding of the ipsi-later offer EV.



# Conclusions

- The gaze position has a significant role in the reward gambling task execution: the fraction of time spent at either screen side is predictive of the chosen side;
- Task-relevant variables are encoded by a significant fraction of OFC cells, including the fraction of time spent inspecting either screen side;
- The gaze position is relevant in the process of encoding offer values: looking at either side possibly yields stronger coding of the ipsi-later offer EV.
- During delays, looking back to earlier presentation sites exclusively re-activates the neural encoding of ipsilateral EV.



D. Ferro, T. Cash-Padgett, M. Zhe Wang, B. Hayden, R. Moreno Bote,  
Gaze-centered gating and re-activation of value encoding in orbitofrontal cortex  
*bioRxiv*, April 2023.



scan to  
know  
more



## TCN Lab

Rubén Moreno Bote, Demetrio Ferro, Anna Rifé Mata,  
Chiara Mastrogiovanni, Dmytro Grytskyy, Farhad Razi,  
Devin Ozbagci, Francesco Damiani, Fatma Aboalasaad,  
Justo Montoya, Yamen Habib, Michael De Pass,  
Carolina Schneider, Alice Vidal, Jorge Ramirez-Ruiz



**Universitat  
Pompeu Fabra  
Barcelona**

**TCN** [upf.edu/web/tcn](http://upf.edu/web/tcn)  
Research Group on Theoretical  
and Cognitive Neuroscience

## Fundings



Howard Hughes  
Medical Institute



al servicio de su Salud



Thank you for your attention.