Coredem meeting – Barcelona, November 19th 2021

Is your gaze your aim?

Eye position in reward gambling and the role of orbito-frontal cortex in encoding the value of visually cued offers

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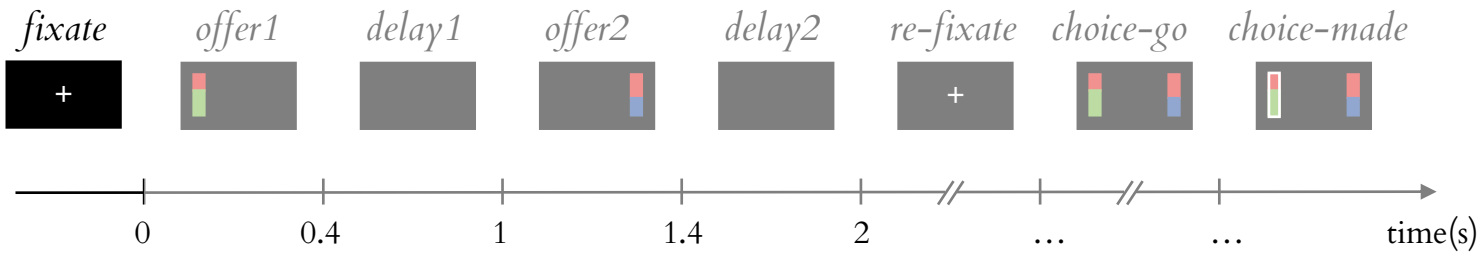
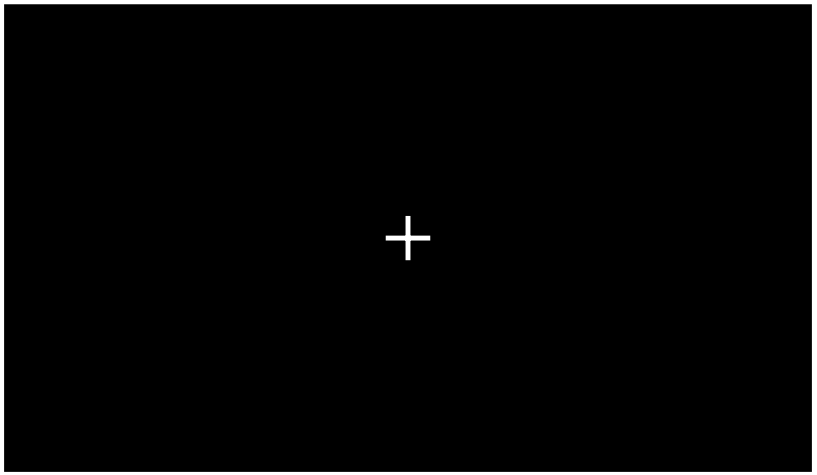
[3]Dept. of Neuroscience, Center for Magnetic Resonance Research, Center for Neuroeng., University of Minnesota, MN55455, Minneapolis – USA;

[*]*demetrio.ferro@upf.edu*

Reward gambling task

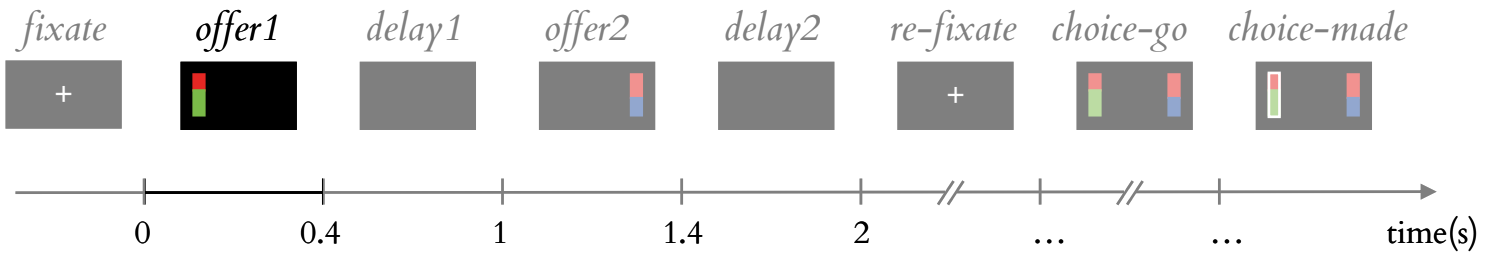


Fixate



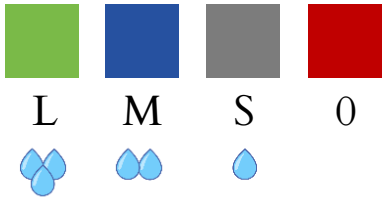
acquire fixation at center of the screen

Reward gambling task

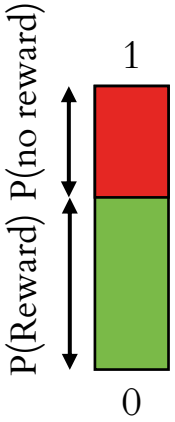


Offer 1

Reward magnitude

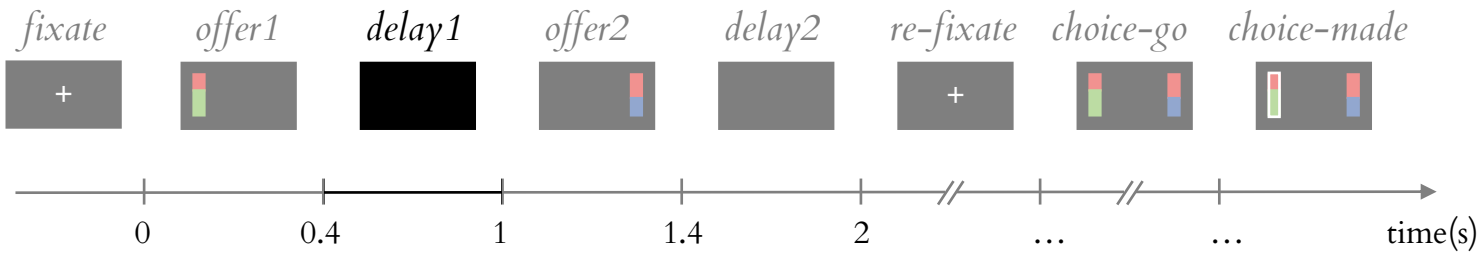


first offer is presented



Reward probability

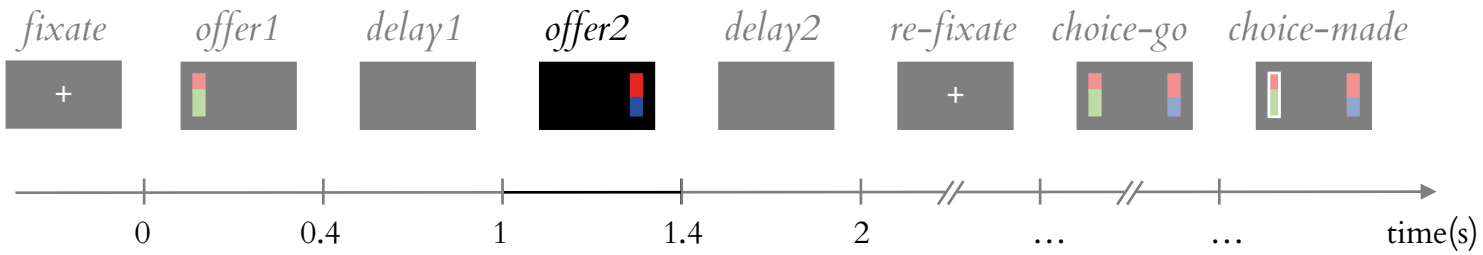
Reward gambling task



Delay 1

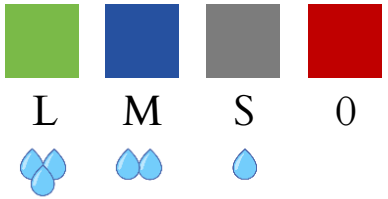
blank screen

Reward gambling task

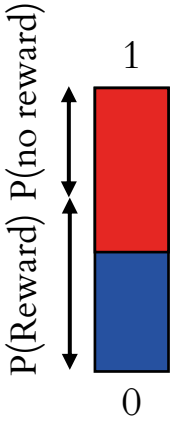


Offer 2

Reward magnitude

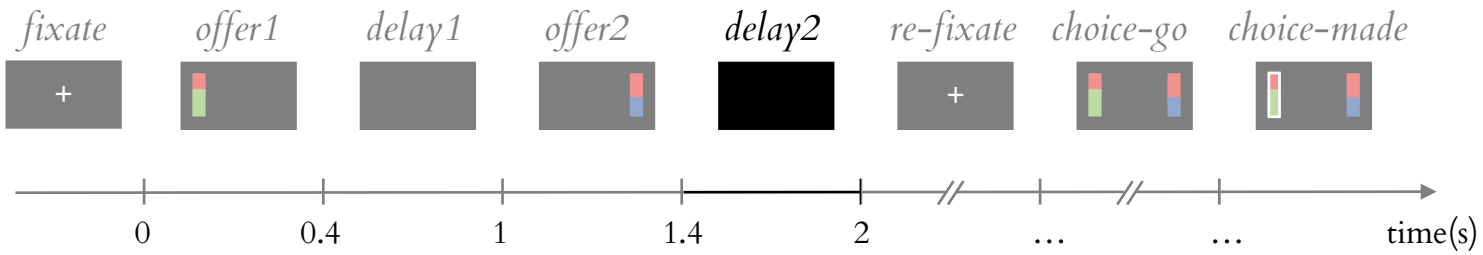


second offer is presented



Reward probability

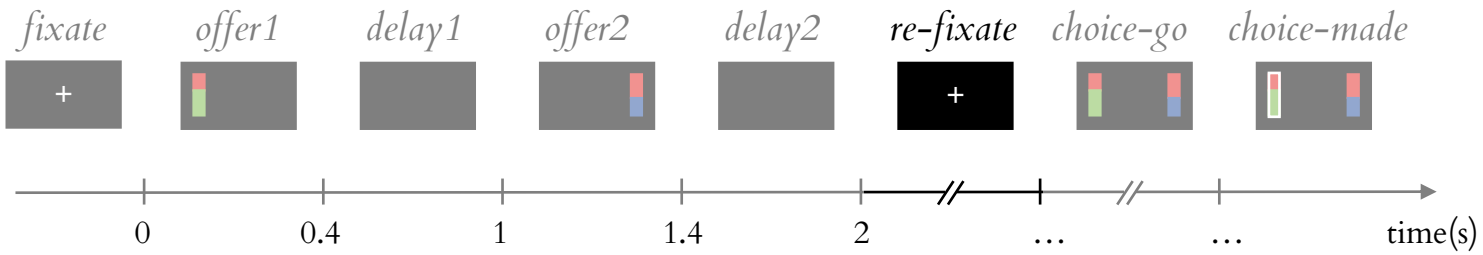
Reward gambling task



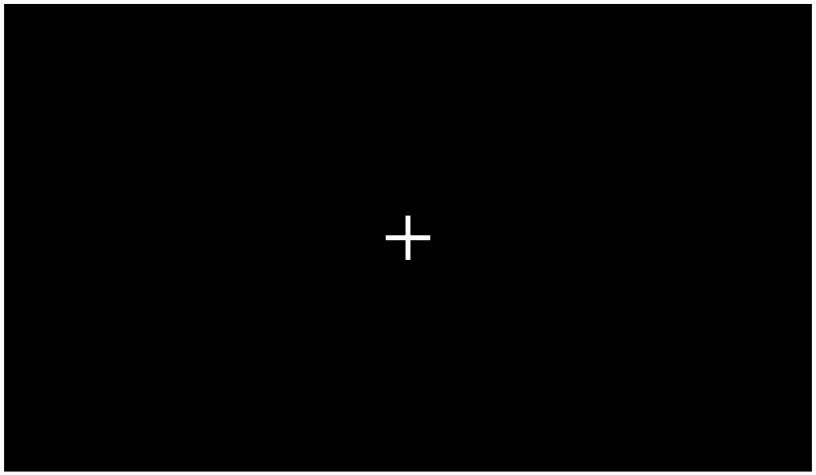
Delay 2

blank screen

Reward gambling task

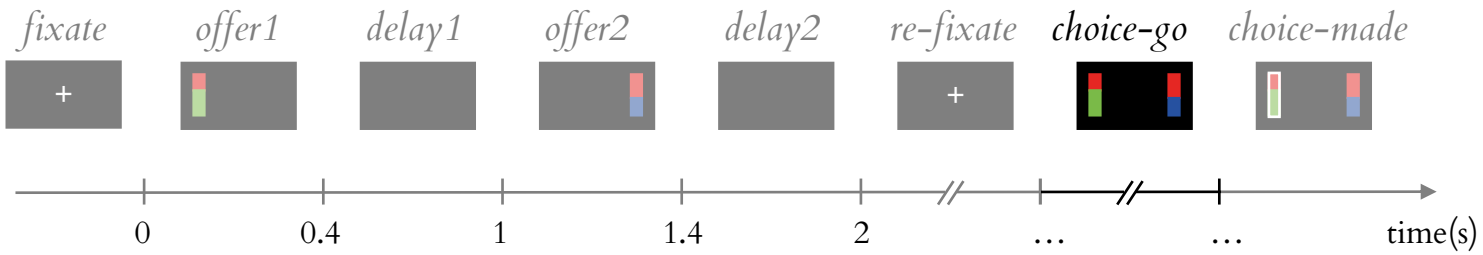


Re-fixate



re-acquire fixation at center of the screen

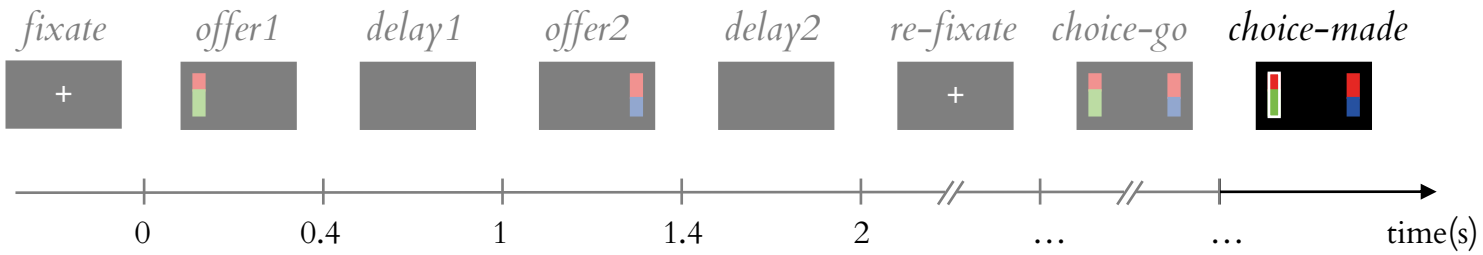
Reward gambling task



Choice-go

saccade to chosen offer side

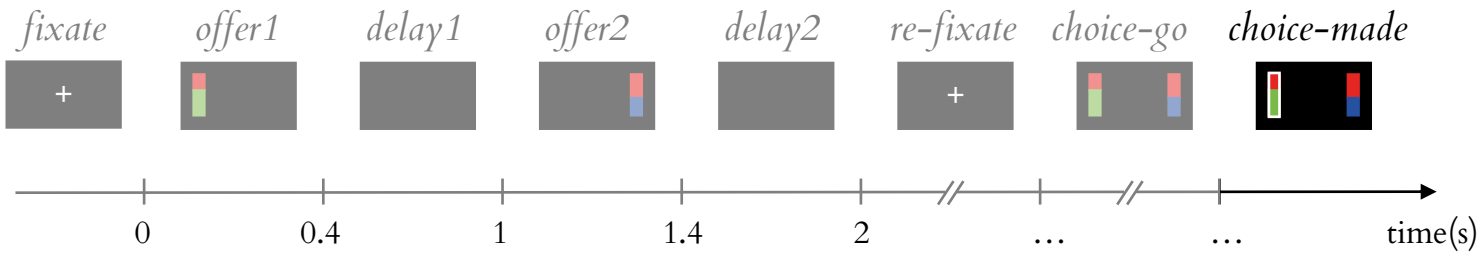
Reward gambling task



Choice-made

hold chosen offer side for at least +200ms

Reward gambling task



Reward

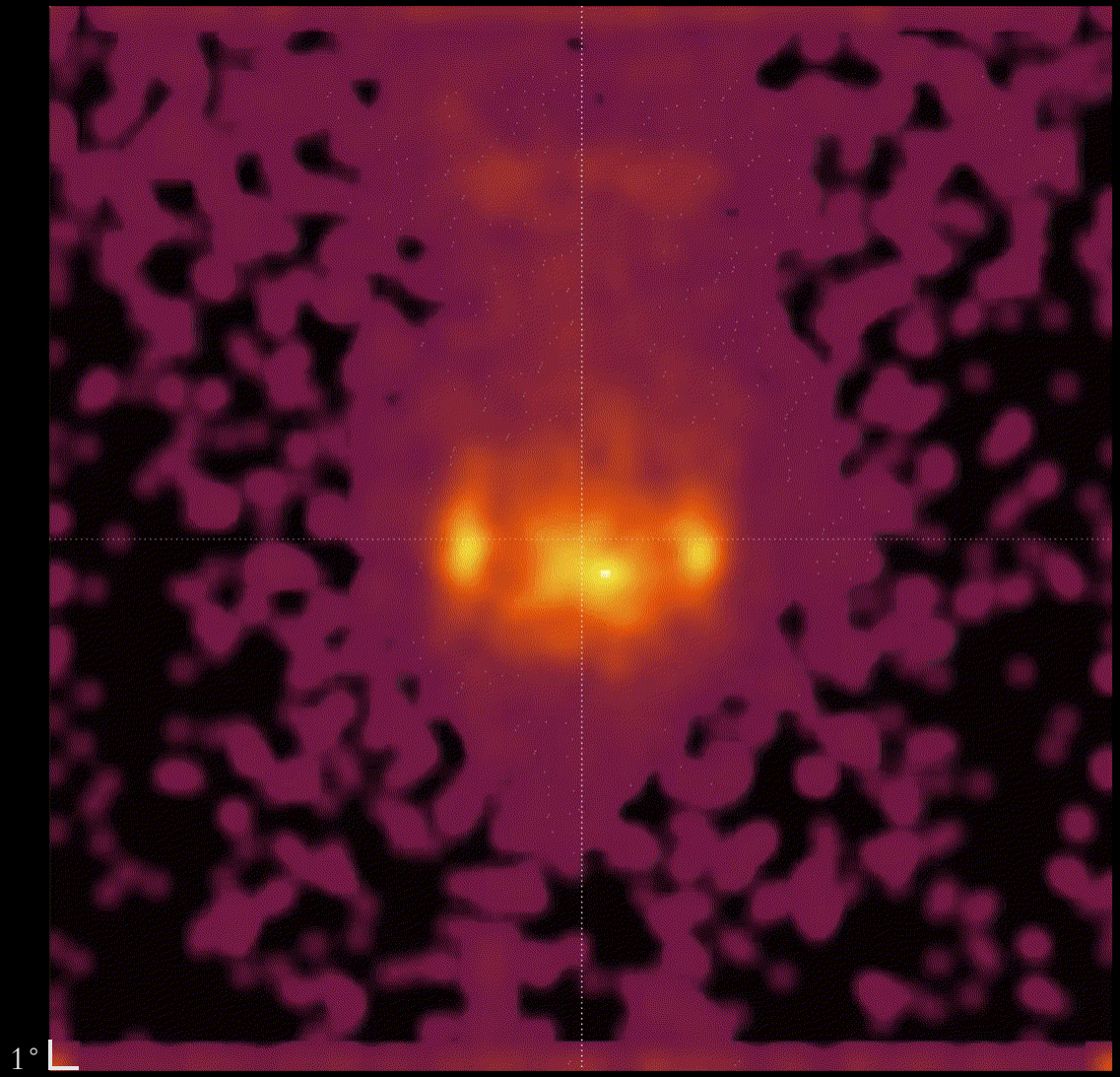
reward is provided

Motivations

- Is the gaze position relevant for the reward gambling task execution?

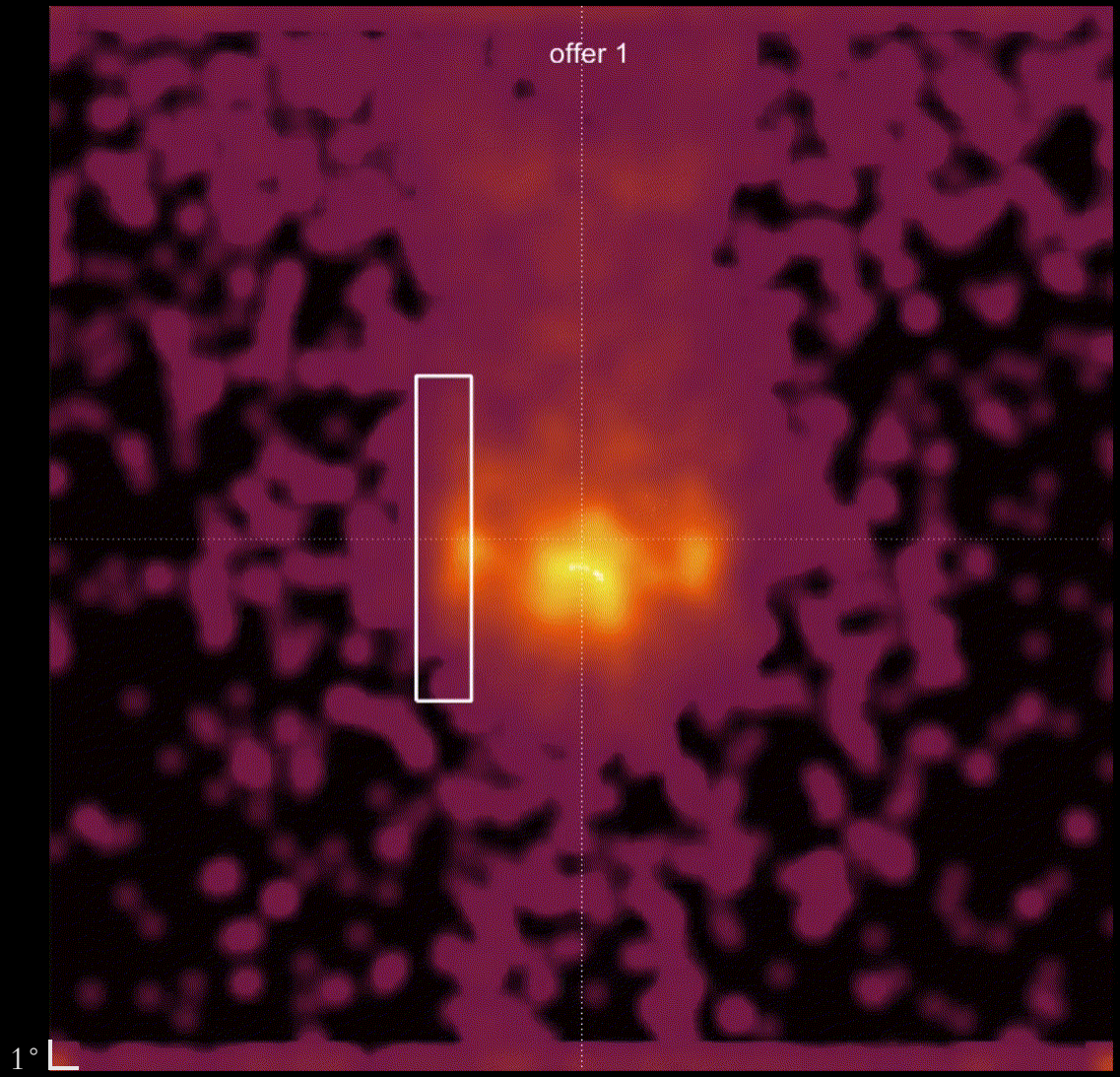
- Can we use the gaze position as a marker of what is the animal mentally picturing during task execution in, particular during delay times?

Eye movements during task execution



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

Eye movements during task execution



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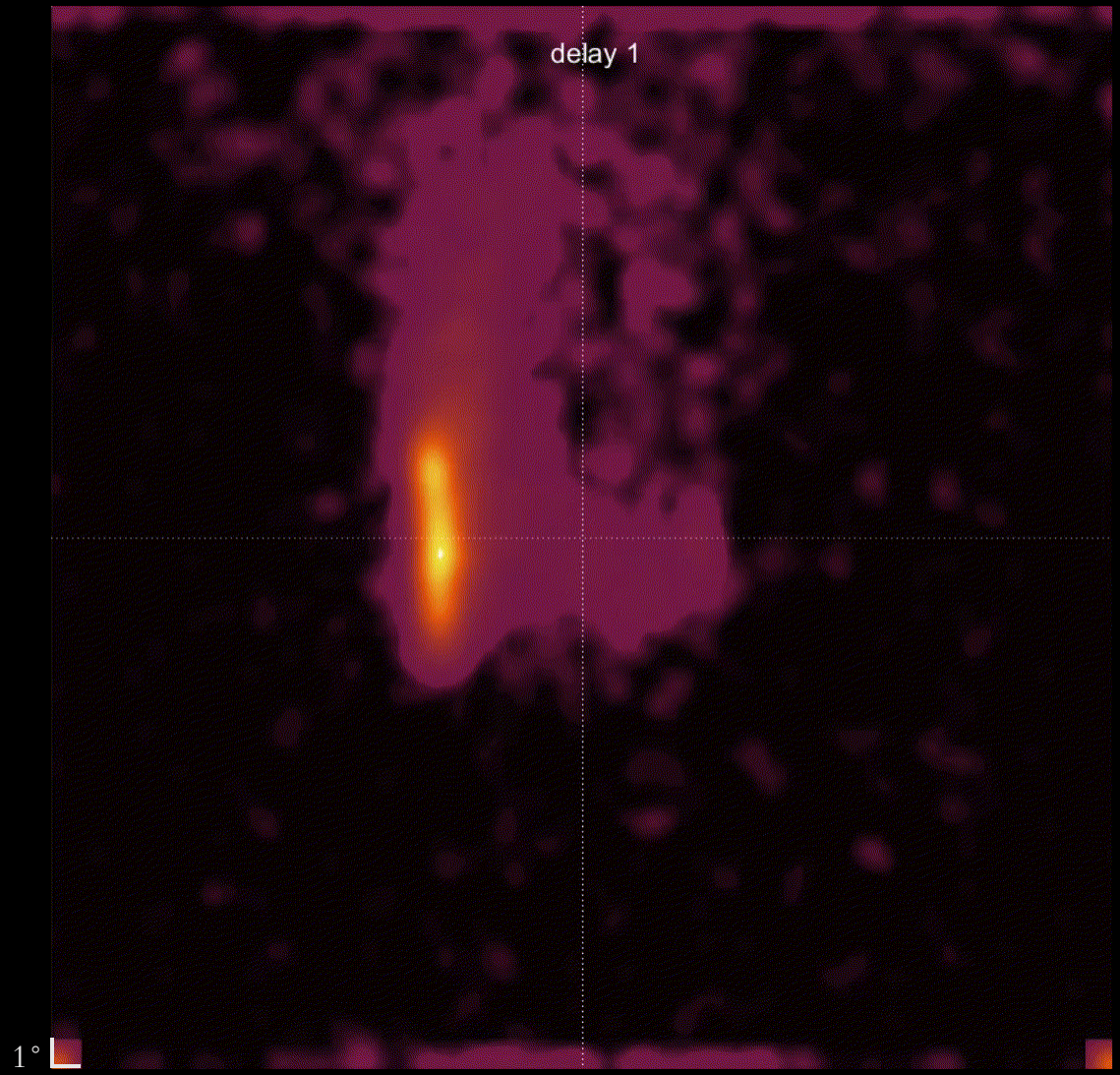
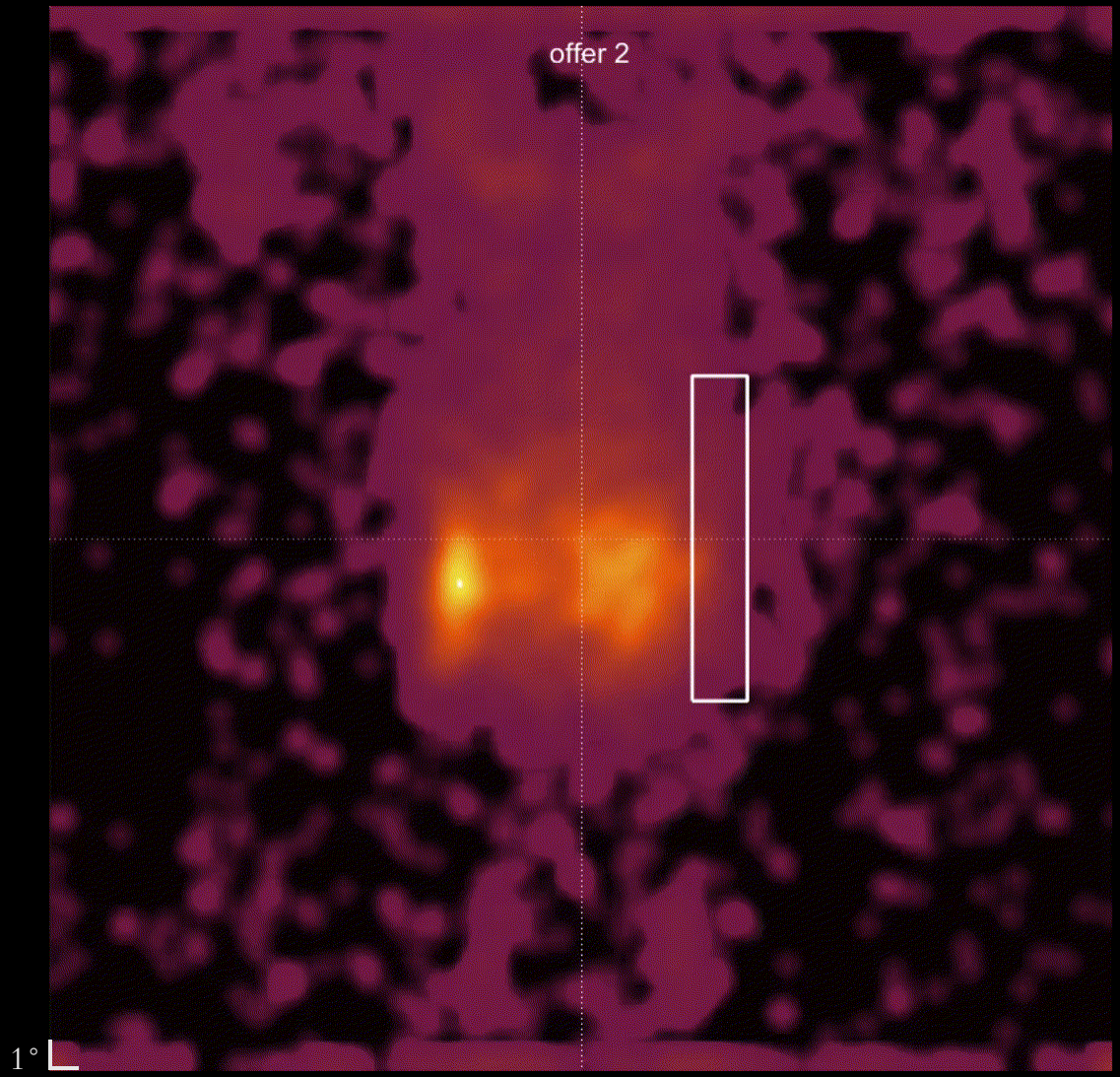
Eye movements during task execution



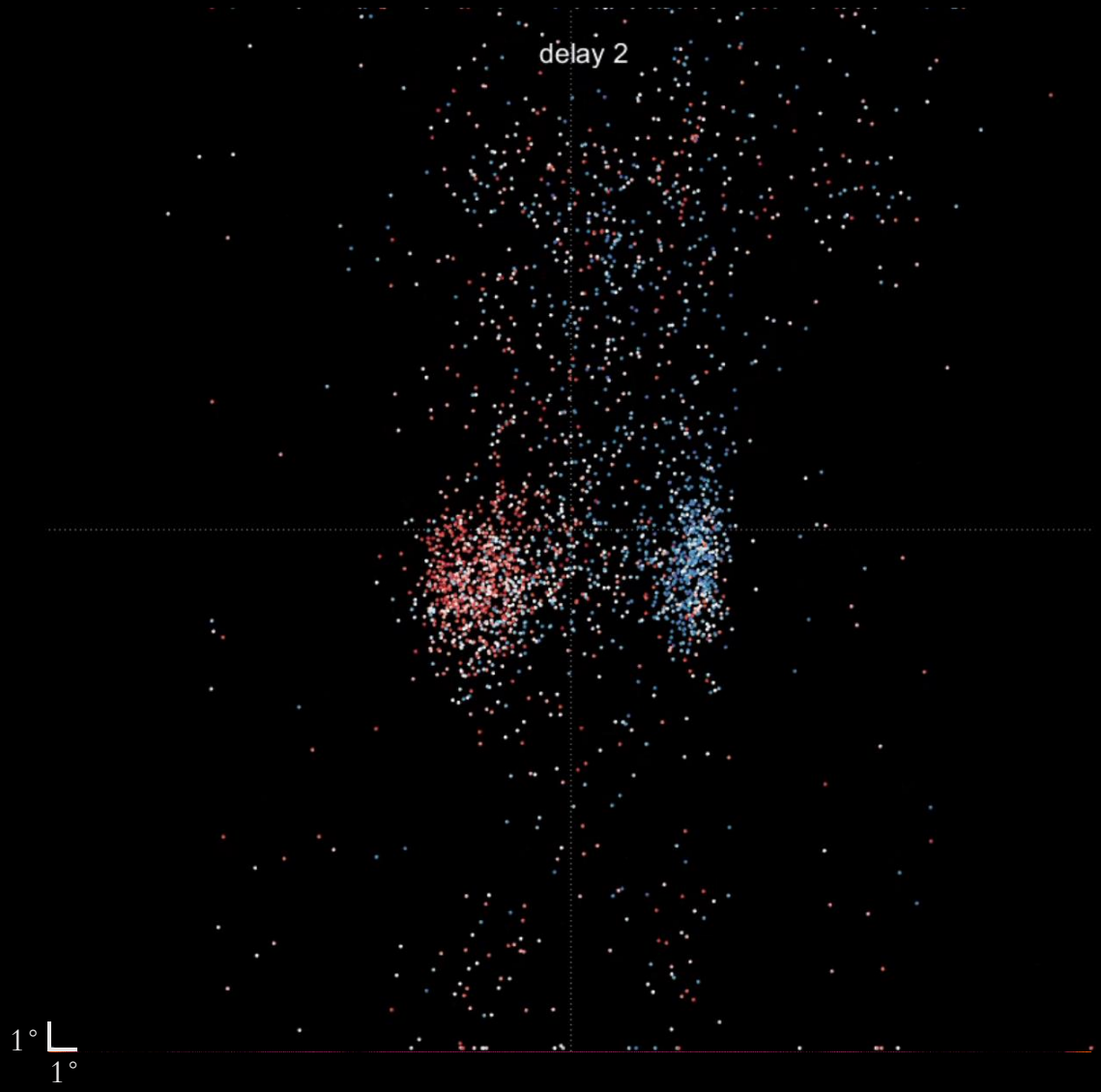
Trials pooled with first offer re-referenced to Left side.

Eye movements during task execution



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

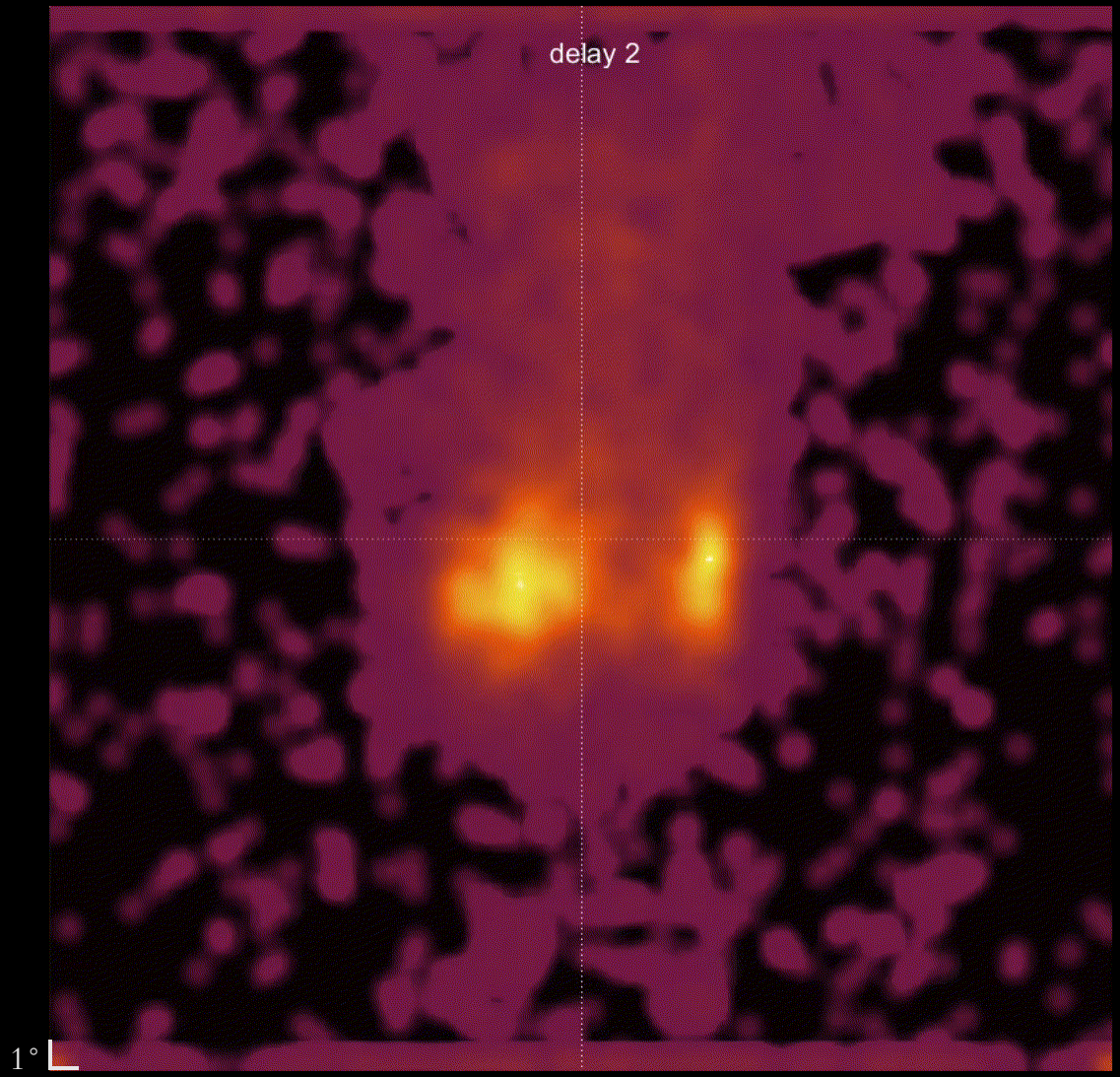
Eye movements during task execution



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

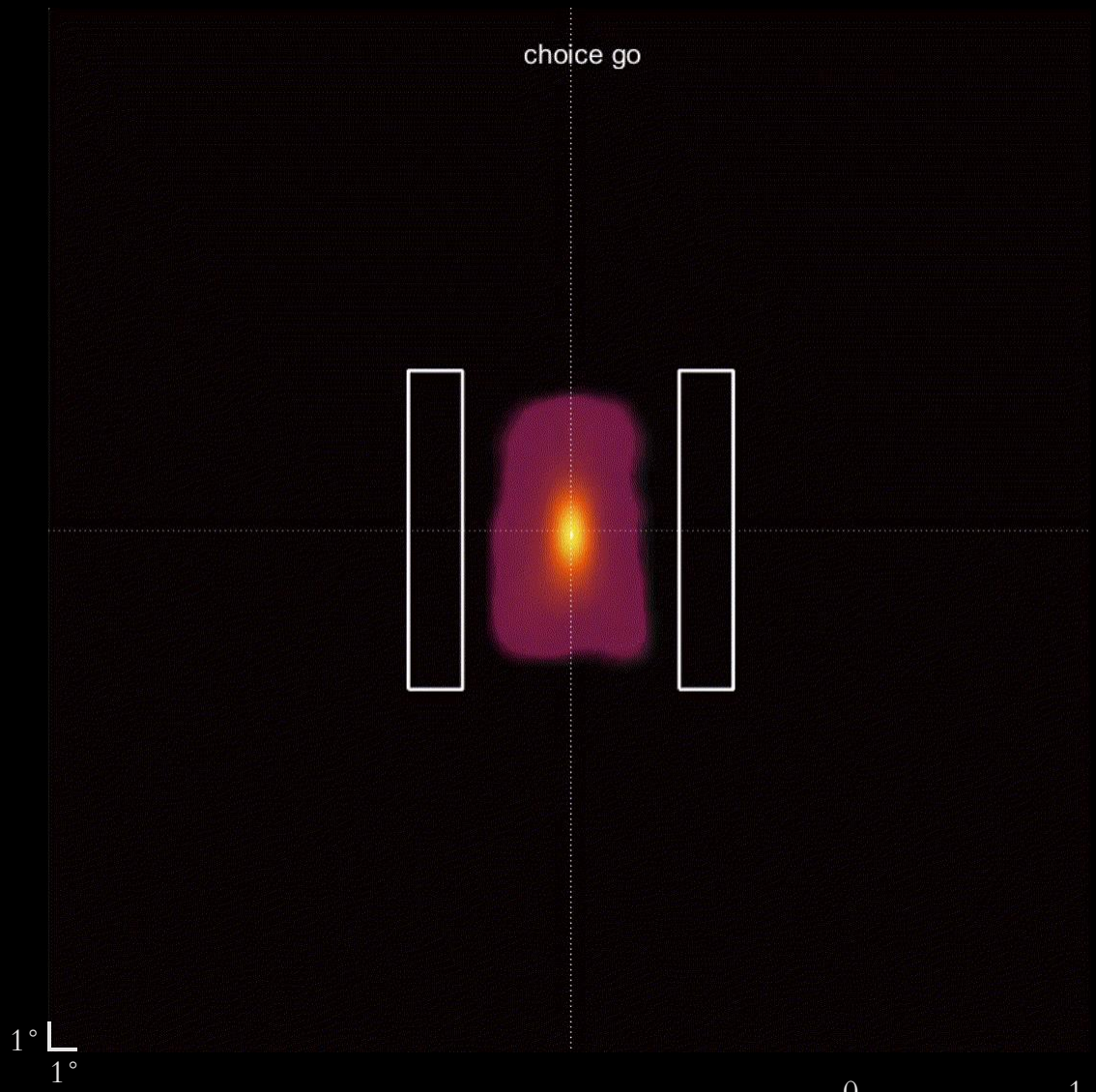
Left is best, E(Left)>E(Right)
Right is best, E(Right)>E(Left)

Eye movements during task execution

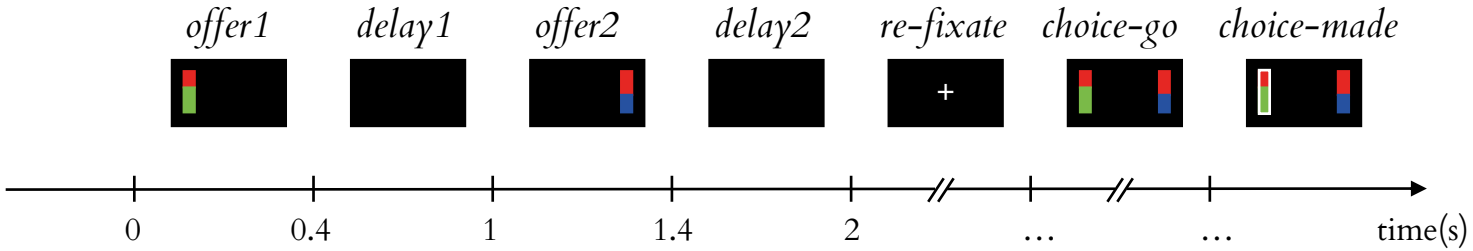


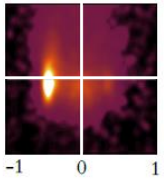
Trials pooled with first offer re-referenced to Left side.

Eye movements during task execution



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





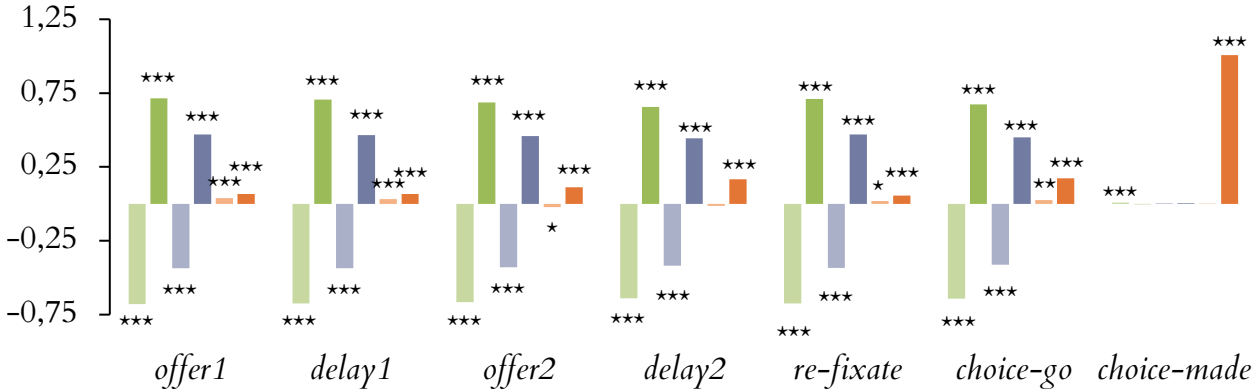
tL time spent looking at the Left screen side

tR time spent looking at the Right screen side

tR/(tR+tL)
Fraction of time spent looking at the Right screen side

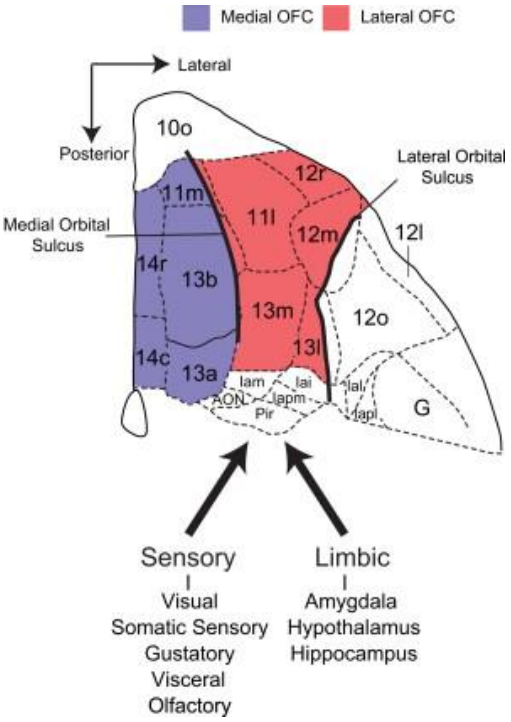
Generalized Linear Model (GLM) for behavioral choice

p_R = P(Choose R) logit $p_R \approx w_0 + \Sigma_i\, w_i\, x_i$



x_1, w_1, *Left offer EV*
x_2, w_2, *Right offer EV*
x_3, w_3, *Left offer VAR*
x_4, w_4, *Right offer VAR*
x_5, w_5, *order 1stL=1*
x_6, w_6, *tR/(tR+tL)*

Neural Data



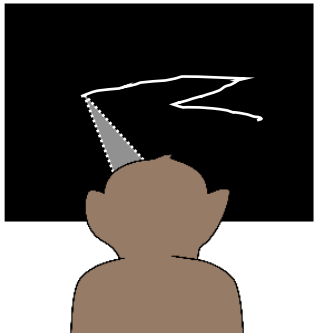
Carmichael, S.T., and Price, J.L. (1994). *Architectonic subdivision of the orbital and medial prefrontal cortex in the macaque monkey.* J. Comp. Neurol.346,366–402.

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

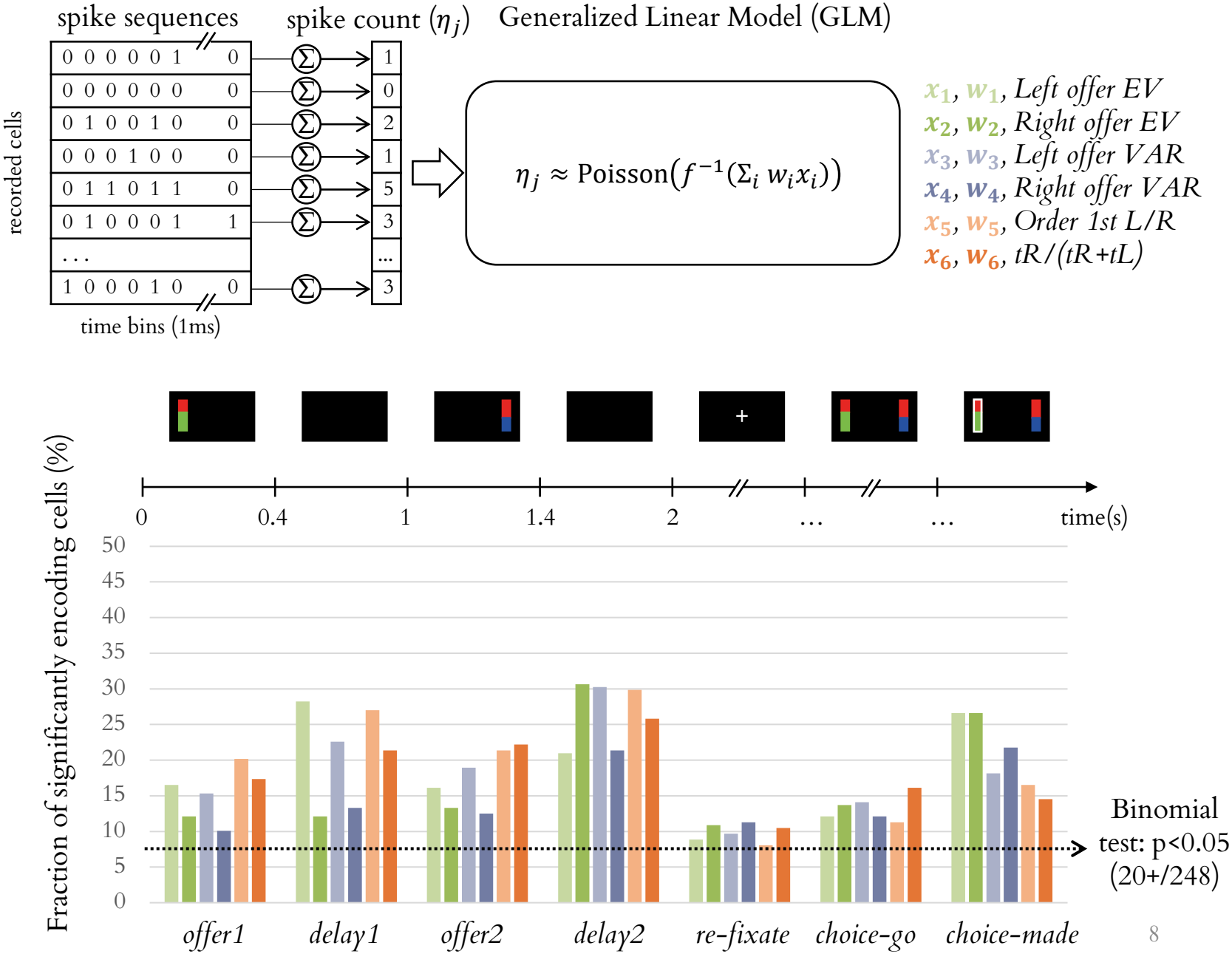
Tyler Cash-Padgett, Maya Zhe Wang, Benjamin Hayden,
Hayden Lab, Dept. of Neuroscience, Center for Magnetic Resonance Research,
Center for Neuroengineering, University of Minnesota, Minneapolis, USA;

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.

Motivations

- Are task-relevant variables encoded by OFC cells?
- Is the gaze position relevant in the neural process of encoding the offer values?

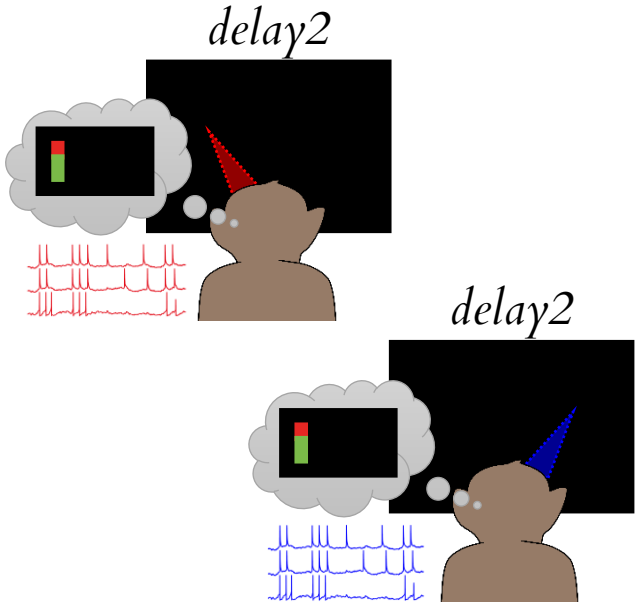
GLM for OFC spiking activity



Hypothesis:

Focusing on the Left offer EV, E(L)

if the monkey looks at Left/Right side, is the **E(L)** coding in OFC affected?



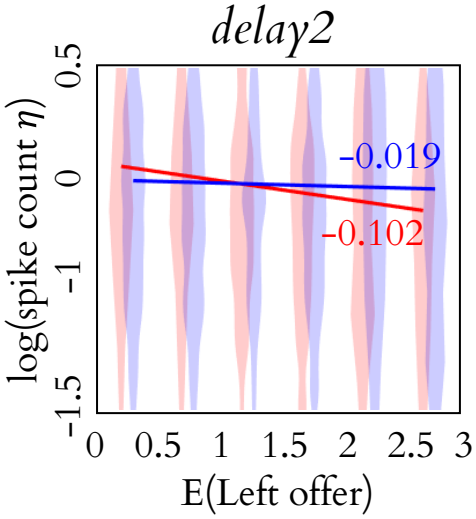
Test:

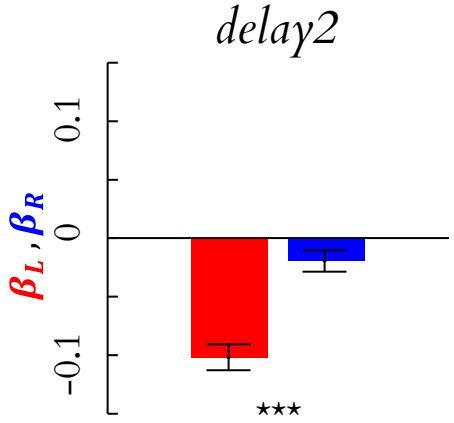
Consider trials where monkey mostly
- *LookL*: tR/(tR+tL)<0.5
- *LookR*: tR/(tR+tL)>0.5

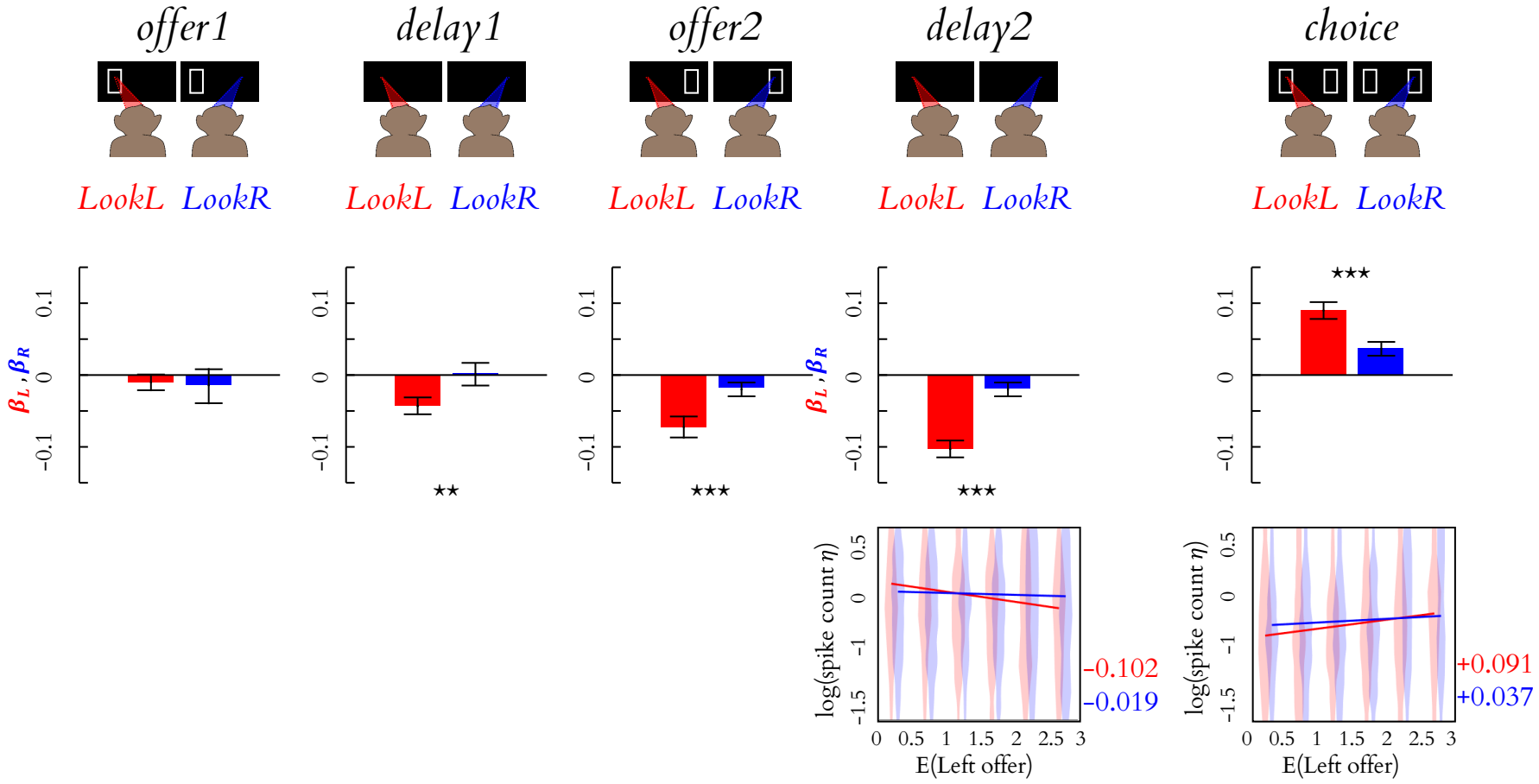
- *GLM for* E(L): *Look Left*
  $\eta \approx \mathrm{Poiss}(f^{-1}(\beta_{0,L} + \boldsymbol{\beta_L} \cdot \mathbf{E(L)}))$

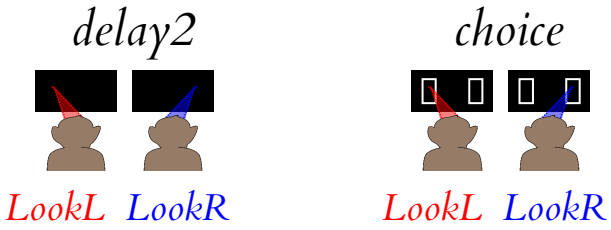
- *GLM for* E(L): *Look Right*
  $\eta \approx \mathrm{Poiss}(f^{-1}(\beta_{0,R} + \boldsymbol{\beta_R} \cdot \mathbf{E(L)}))$

$\boldsymbol{\beta_L}$ vs $\boldsymbol{\beta_R}$??

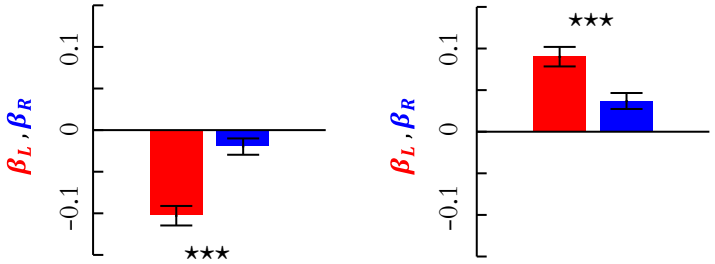




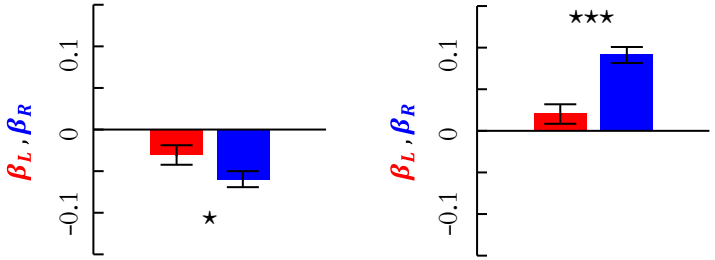

offer1
delay1
offer2
delay2
choice
LookL LookR
LookL LookR
LookL LookR
LookL LookR
LookL LookR
β_L, β_R
0.1
0
-0.1
**
***
***
***
log(spike count η)
-1.5
-1
0
0.5
0 0.5 1 1.5 2 2.5 3
E(Left offer)
-0.102
-0.019
+0.091
+0.037



GLM for **E(L)**:
LookL vs LookR



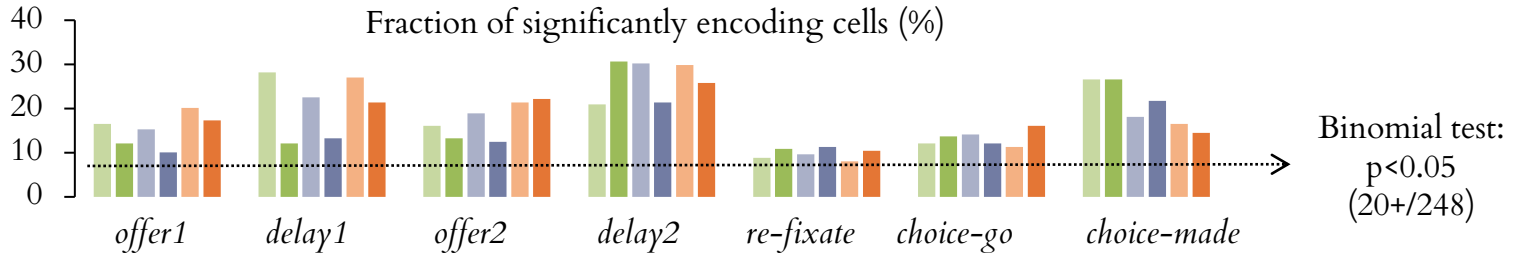
GLM for **E(R)**:
LookL vs LookR



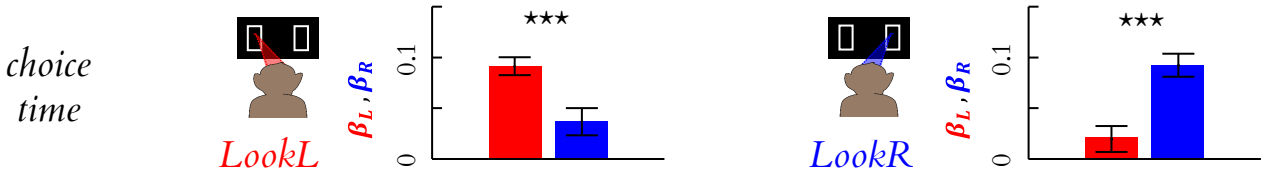
Conclusions

- 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.



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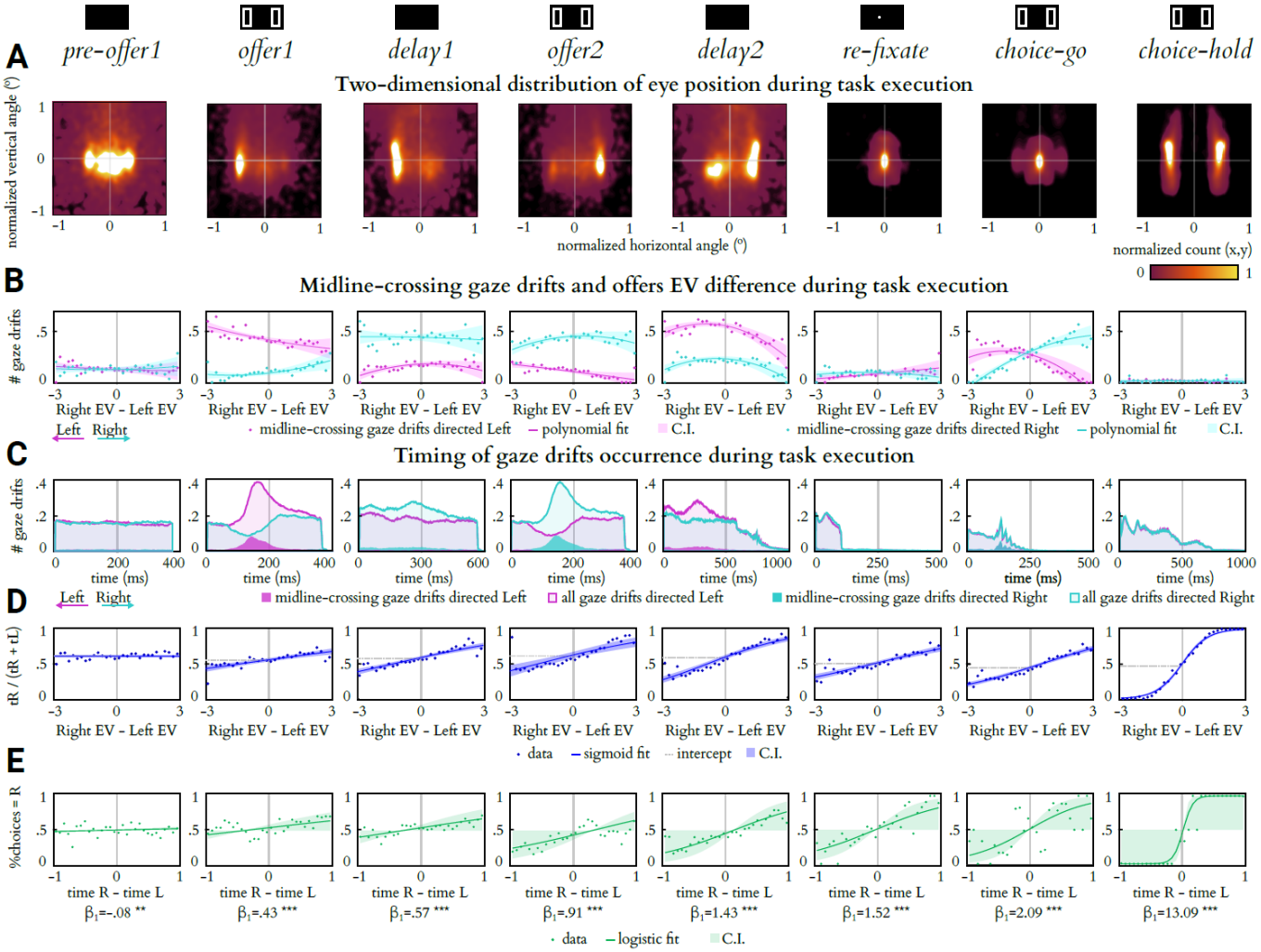
Fundings

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

hhmi
Howard Hughes Medical Institute

Thank you for your attention.

Eye Data

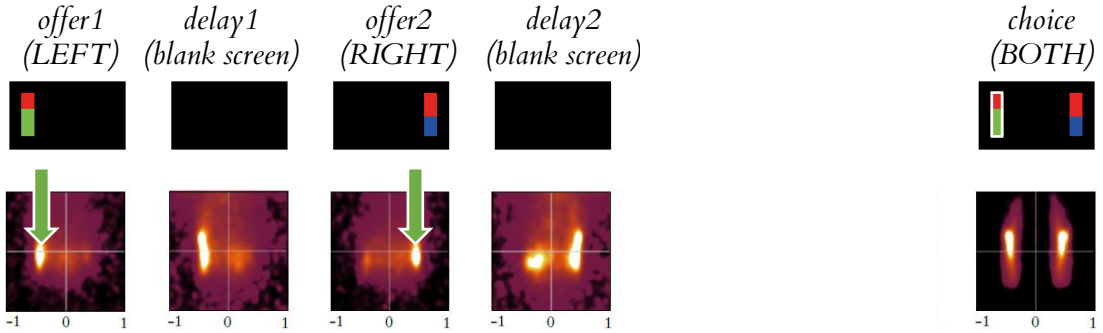


What is the eye position during task execution?

What is the fraction of time spent on either side given EV difference?

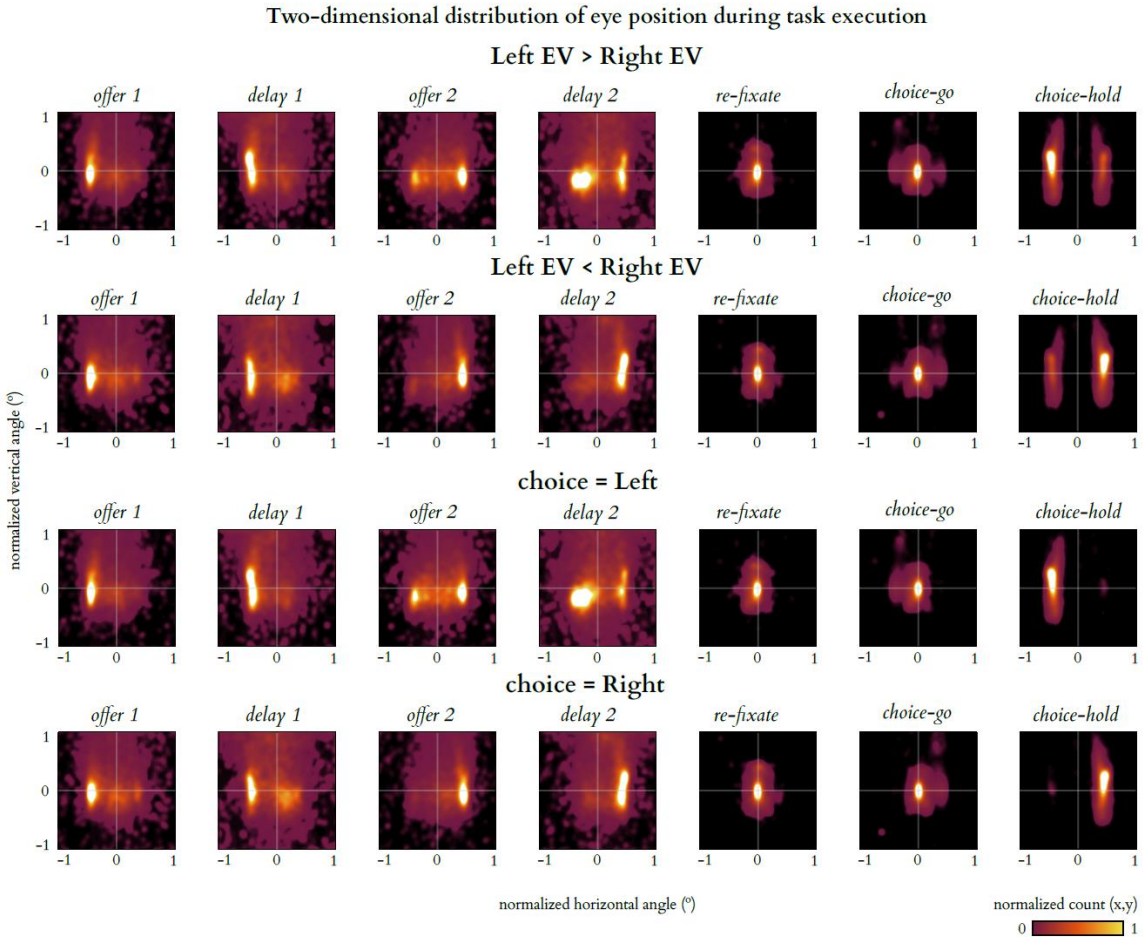
Is the difference in time related to the final choice?

Eye movements during task execution



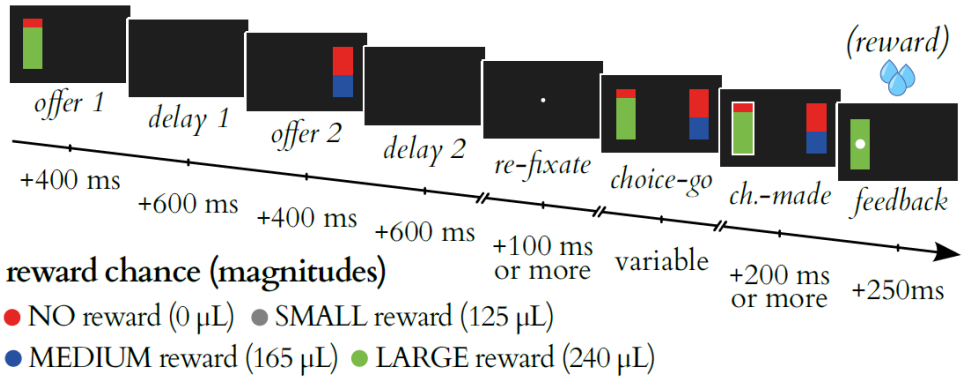
- Subject is inspecting the CURRENT offer (on screen)
- Subject is not interested in CURRENT offer (on screen) since it is not the best
- Subject drifts the gaze to NEXT offer location (blank screen) for a better value
- Subject drifts the gaze back to PREVIOUS location (blank screen) for a better value
- Subject correctly holds the gaze to choose the BEST offer

Eye Data

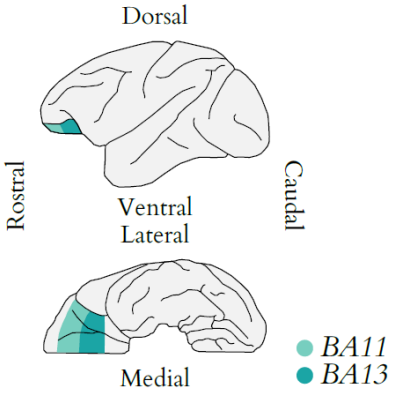

Two-dimensional distribution of eye position during task execution
Left EV > Right EV
Left EV < Right EV
choice = Left
choice = Right
offer 1
delay 1
offer 2
delay 2
re-fixate
choice-go
choice-hold
normalized vertical angle (°)
normalized horizontal angle (°)
normalized count (x,y)
0
1

Experimental paradigm

Reward gambling task



Orbito-Frontal Cortex (OFC)



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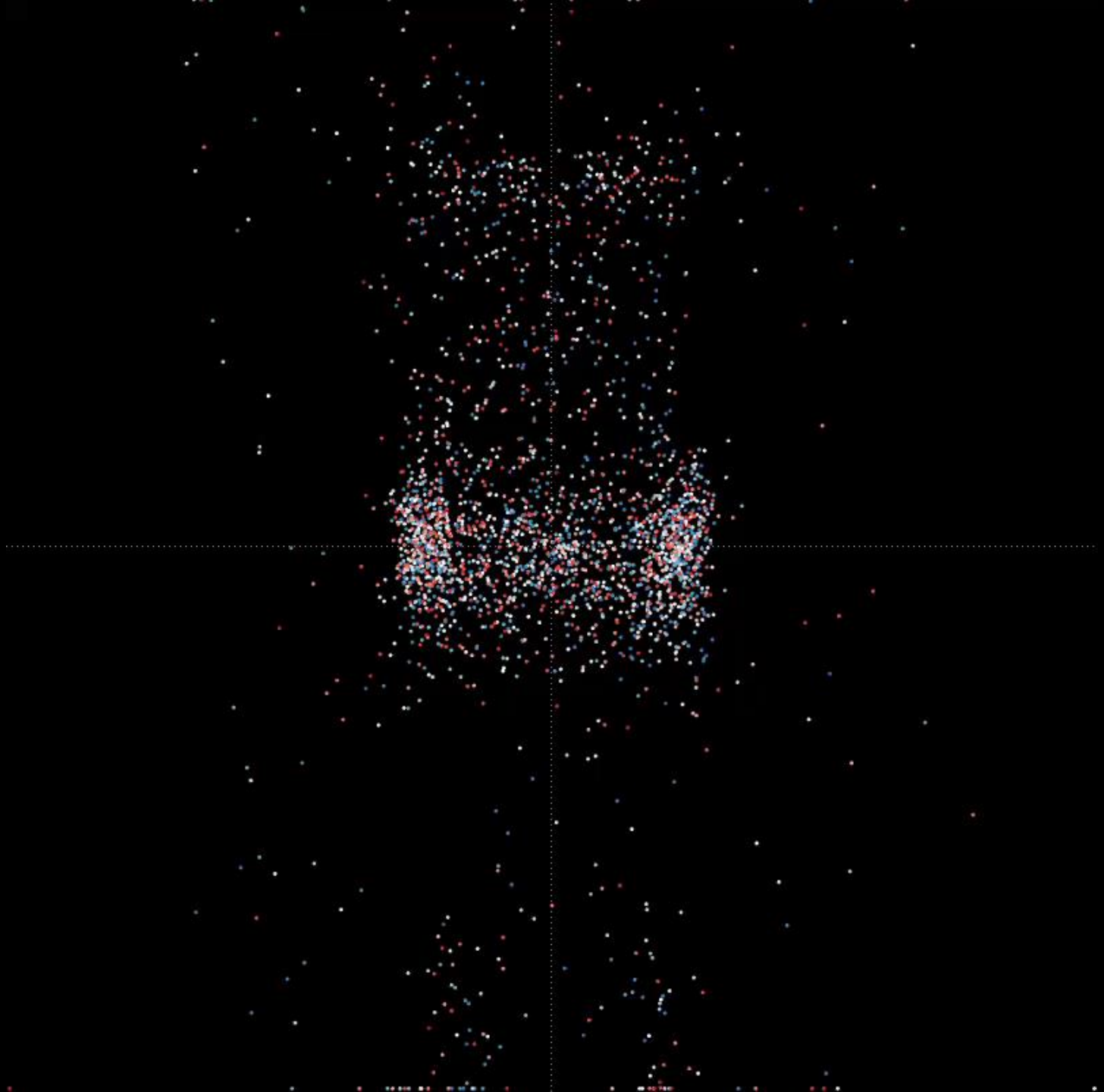
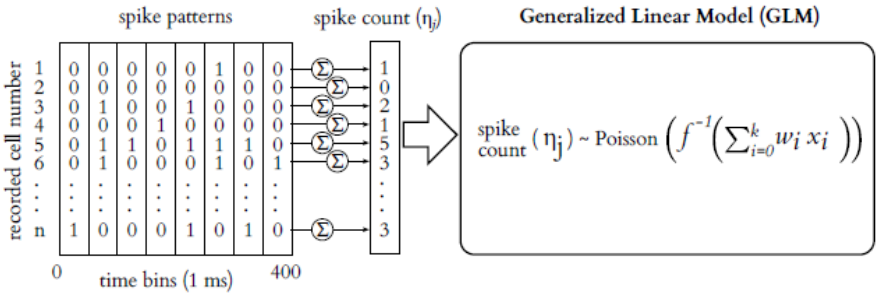
Eye Data

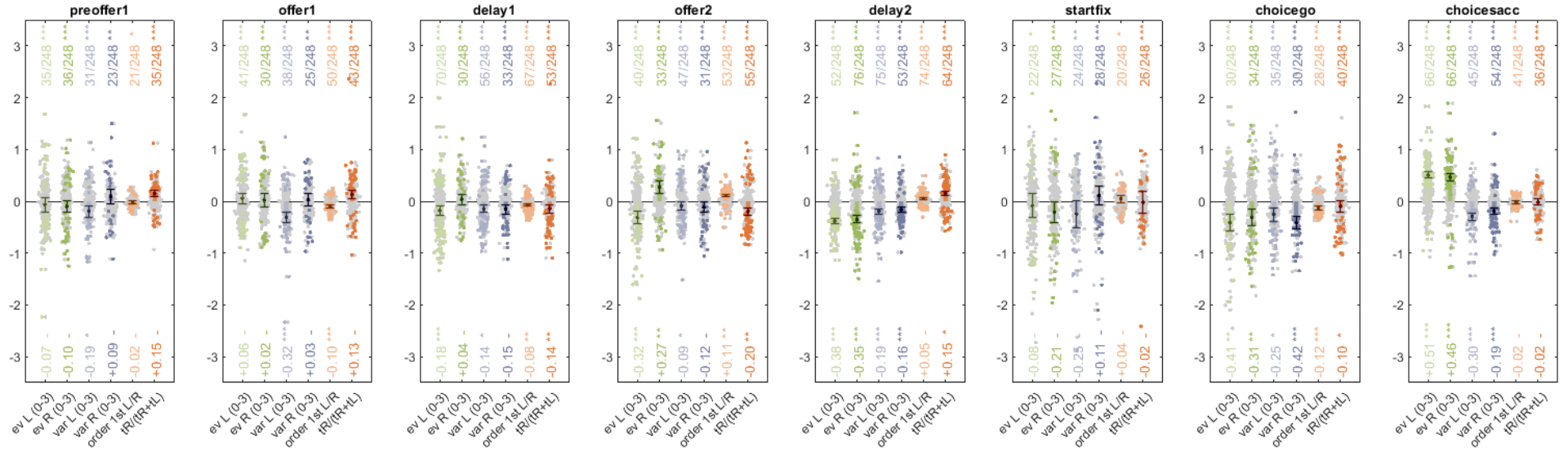


GLM for neural spiking activity

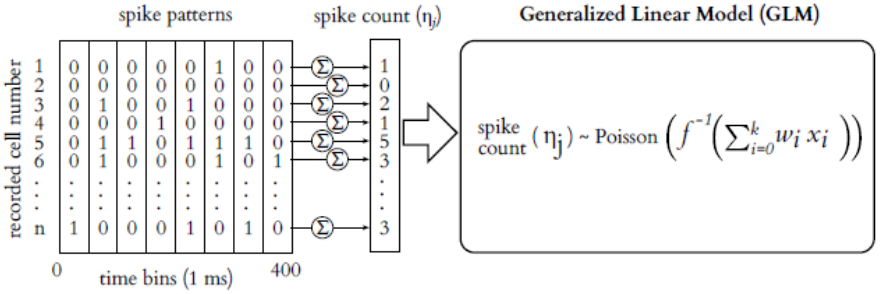


x_1, w_1, *Left offer EV*
x_2, w_2, *Right offer EV*
x_3, w_3, *Left offer VAR*
x_4, w_4, *Right offer VAR*
x_5, w_5, *order 1stL=1*
x_6, w_6, *tR/(tR+tL)*

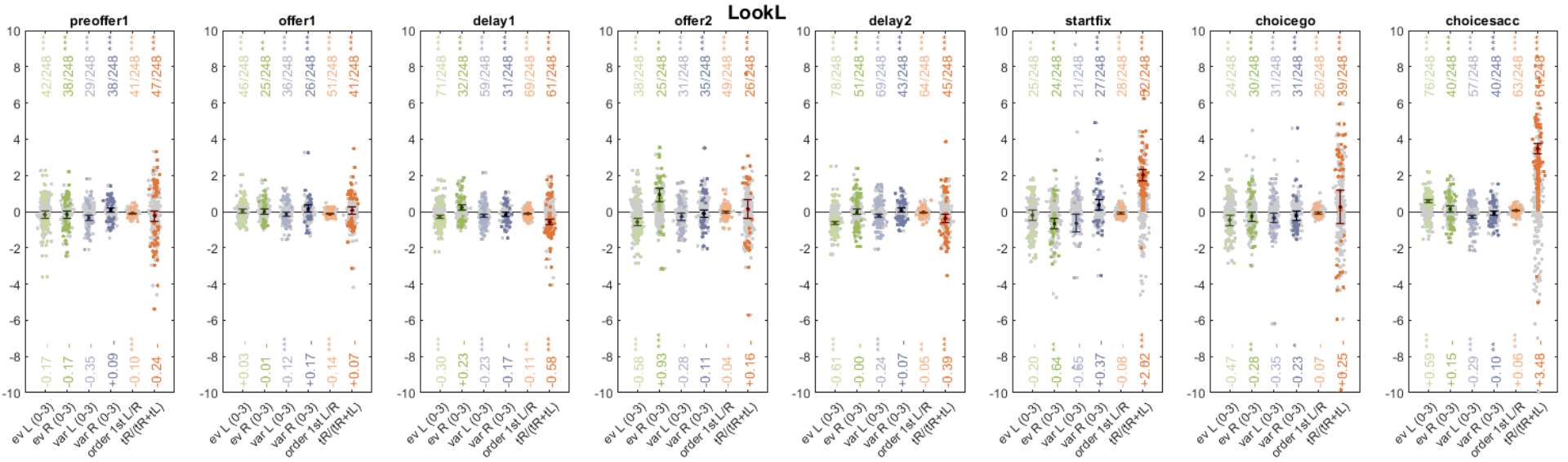
n.s. *P<0.05*



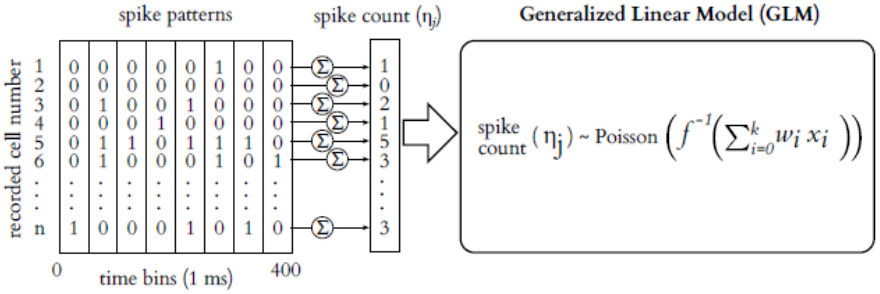
GLM for neural spiking activity



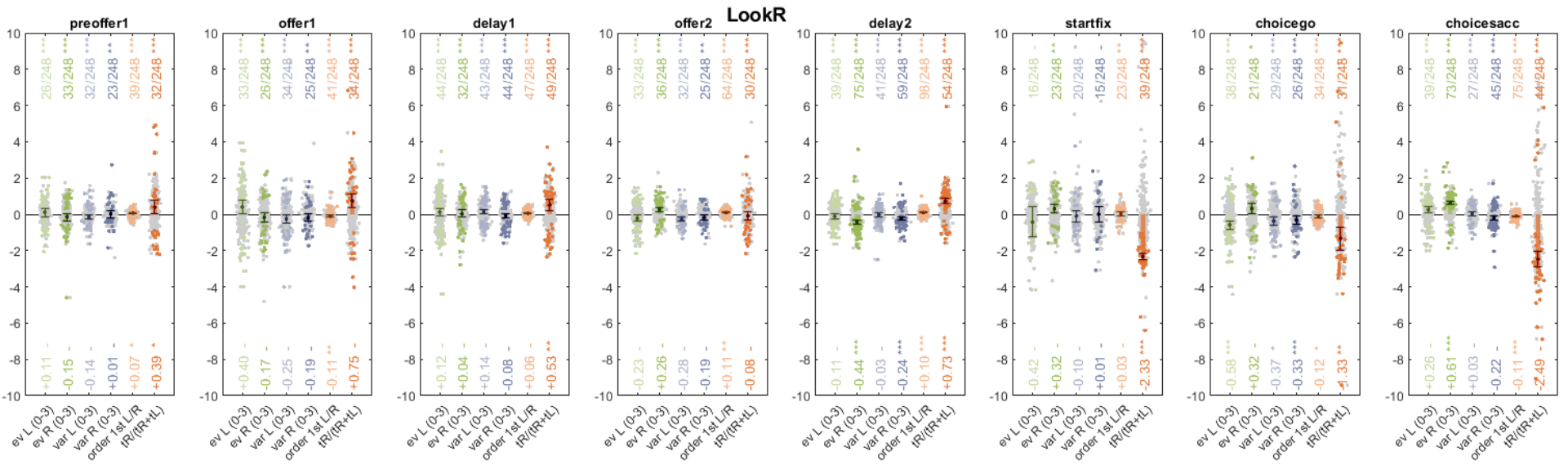
x_1, w_1, *Left offer EV*
x_2, w_2, *Right offer EV*
x_3, w_3, *Left offer VAR*
x_4, w_4, *Right offer VAR*
x_5, w_5, *order 1stL=1*
x_6, w_6, *tR/(tR+tL)*
n.s. *P<0.05*

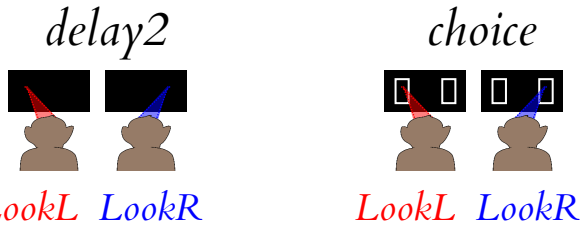


GLM for neural spiking activity

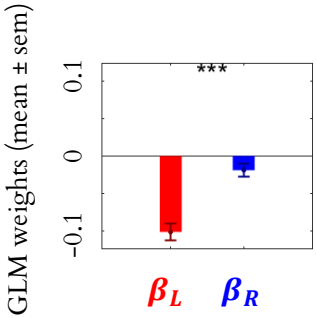


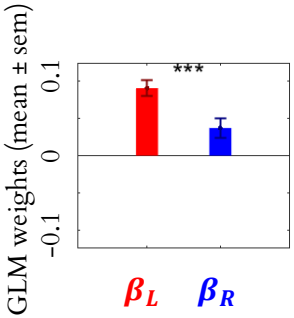
x_1, w_1, *Left offer EV*
x_2, w_2, *Right offer EV*
x_3, w_3, *Left offer VAR*
x_4, w_4, *Right offer VAR*
x_5, w_5, *order 1stL=1*
x_6, w_6, *tR/(tR+tL)*
n.s. *P<0.05*



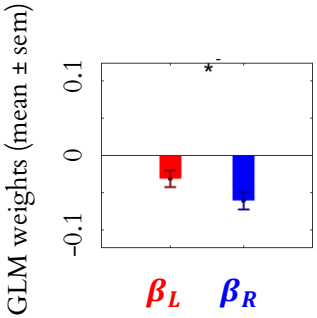


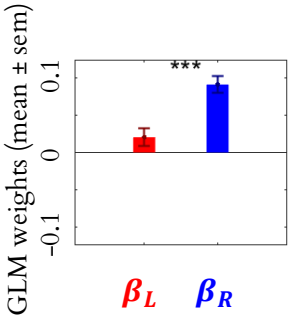
GLM for **E(L)**:
LookL vs LookR



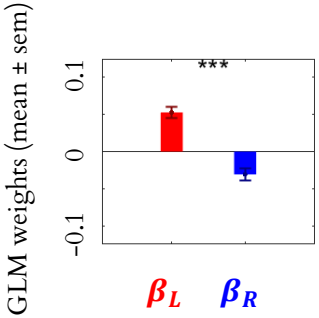


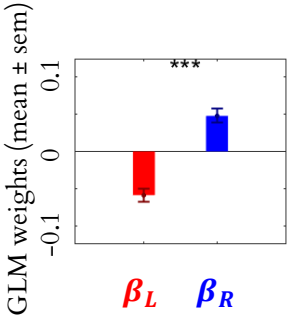
GLM for **E(R)**:
LookL vs LookR

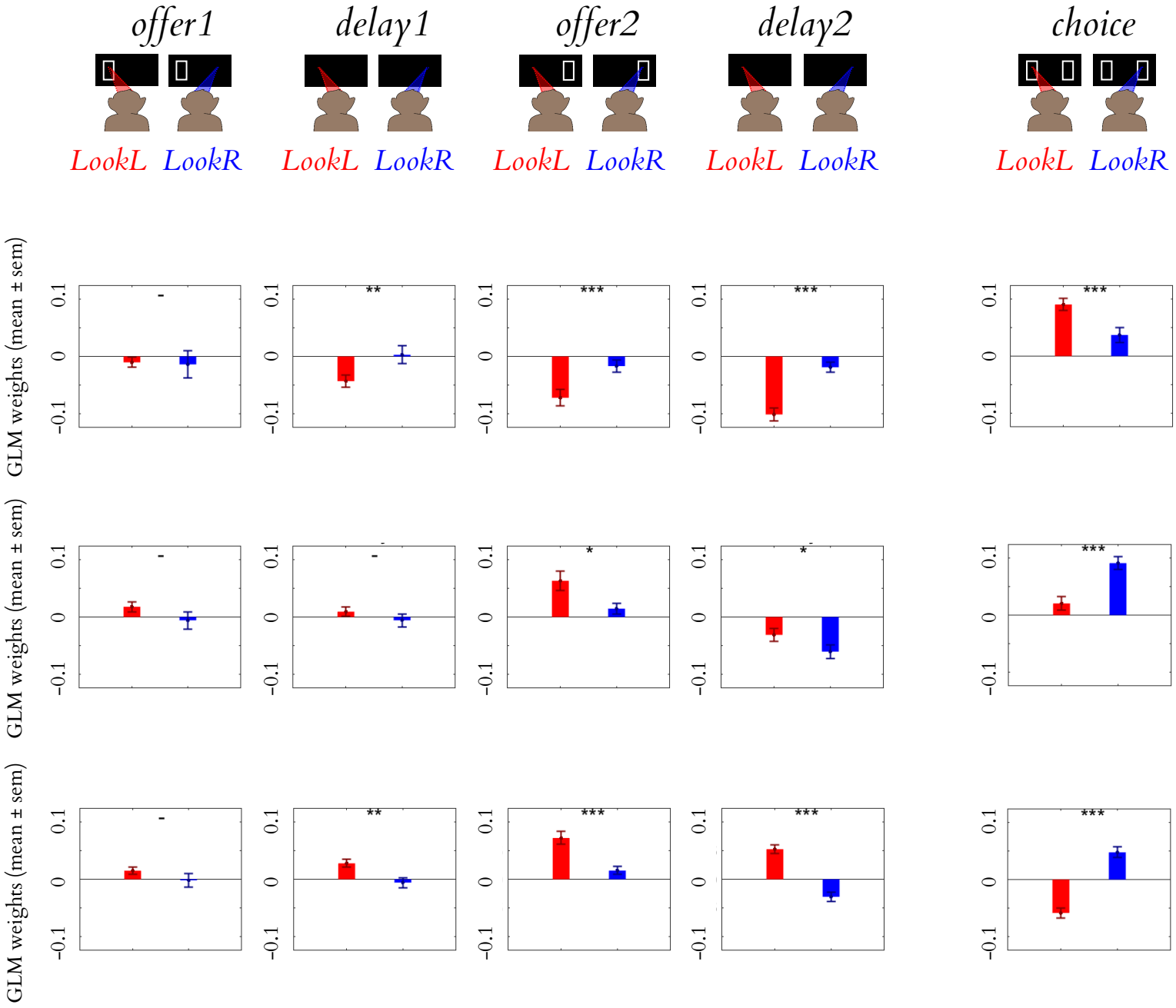


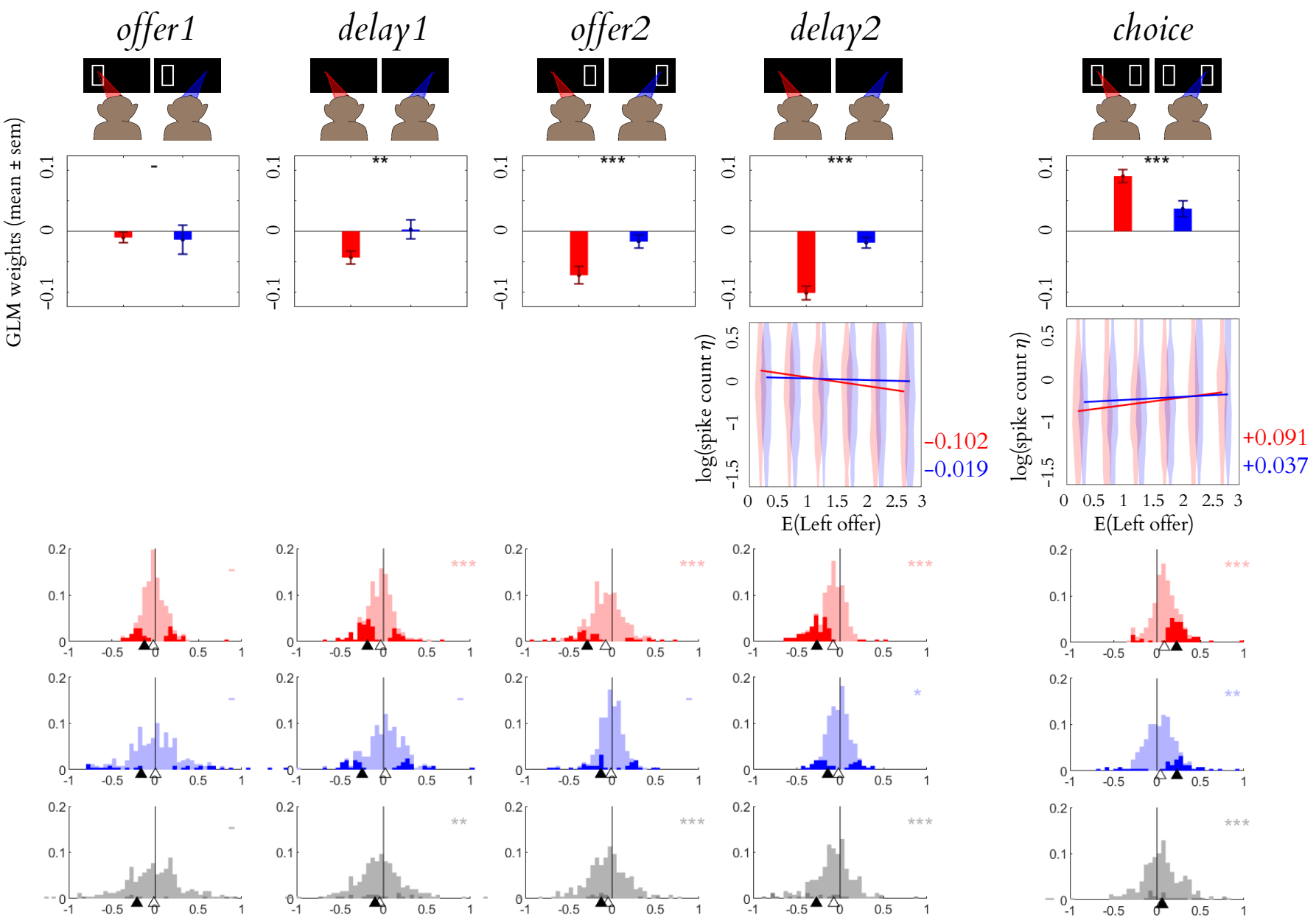


GLM for
E(R)−E(L):
LookL vs LookR



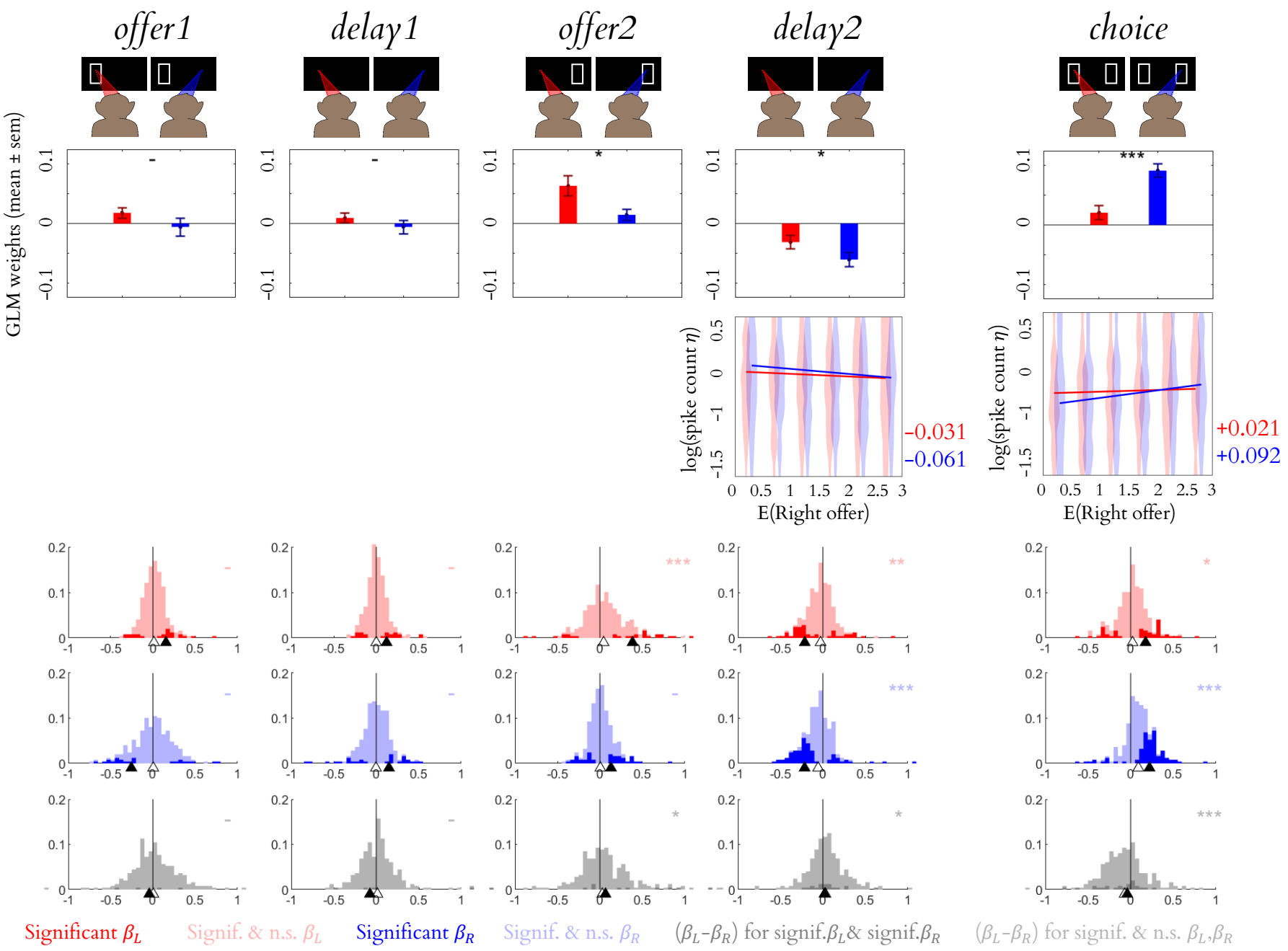



offer1
delay1
offer2
delay2
choice
LookL LookR
LookL LookR
LookL LookR
LookL LookR
LookL LookR
GLM for E(L): LookL vs LookR
GLM for E(R): LookL vs LookR
GLM for E(R)-E(L): LookL vs LookR
GLM weights (mean ± sem)
0.1
0
-0.1
-
**
***
***
***
GLM weights (mean ± sem)
0.1
0
-0.1
-
-
*
*
***
GLM weights (mean ± sem)
0.1
0
-0.1
-
**
***
***
***

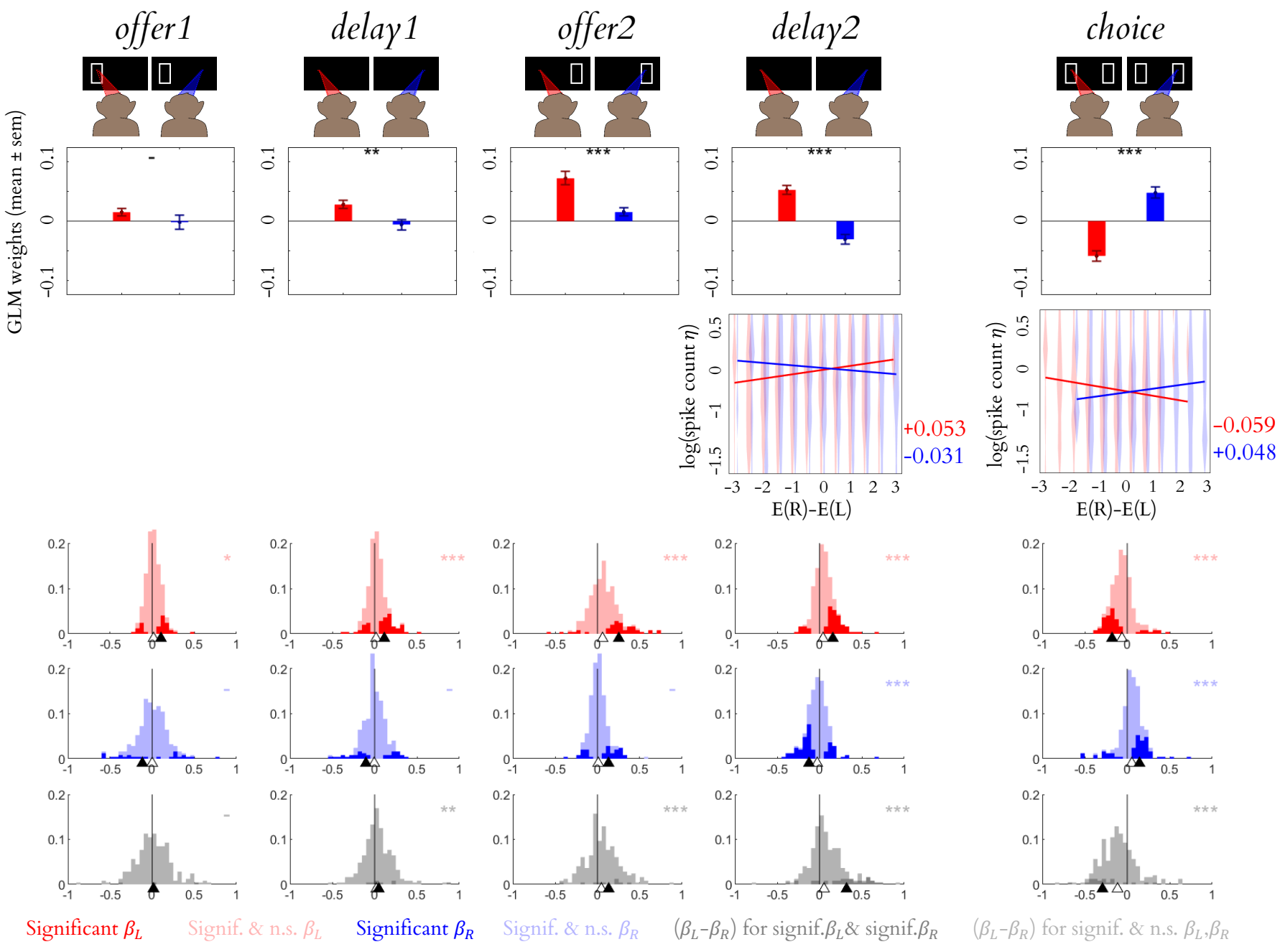


Significant β_L Signif. & n.s. β_L Significant β_R Signif. & n.s. β_R $(\beta_L-\beta_R)$ for signif.β_L& signif.β_R $(\beta_L-\beta_R)$ for signif. & n.s. β_L,β_R

	Preoffer1	Offer1	Delay1	Offer2	Delay2	Re-fixate	Choice-Go	Choice-saccade
OfferLev lookL	44/248***	47/248***	73/248 (%)***	42/248 ***	71/248 (%)***	25/248**	26/248***	69/248 (%)***
OfferLev lookR	27/248***	33/248***	45/248 (%)***	38/248 ***	43/248 (%)***	16/248	37/248***	49/248 (%)***



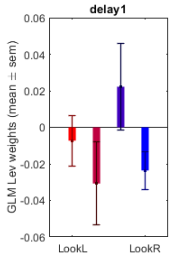
	Preoffer1	Offer1	Delay1	Offer2	Delay2	Re-fixate	Choice-Go	Choice-saccade
OfferLev lookL	43/248***	25/248**	22/248 (%)*	28/248 ***	47/248 (%)***	27/248***	30/248***	48/248 (%)***
OfferLev lookR	38/248***	24/248**	29/248 (%)***	43/248 ***	78/248 (%)***	23/248**	27/248***	89/248 (%)***

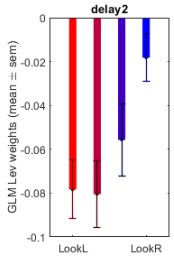


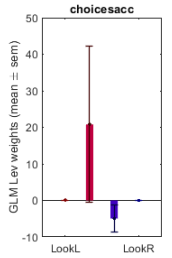
	Preoffer1	Offer1	Delay1	Offer2	Delay2	Re-fixate	Choice-Go	Choice-saccade
OfferLev lookL	49/248***	35/248***	58/248 (%)***	45/248 ***	67/248 (%)***	28/248**	31/248***	61/248 (%)***
OfferLev lookR	39/248***	26/248***	34/248 (%)***	40/248 ***	78/248 (%)***	21/248*	22/248*	66/248 (%)***

What if we used more bins for Look L vs Look R? i.e. tR/(tR+tL) binned as [0, 0.25, 0.5, 1]

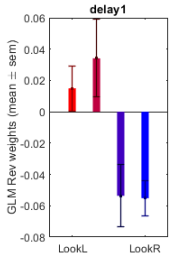
GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{L_{EV}}))$

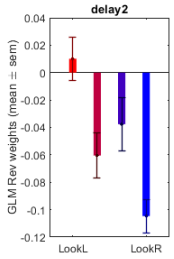


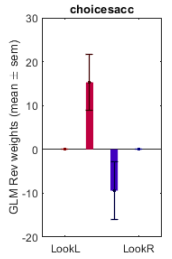




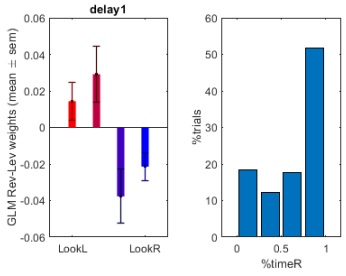
GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{R_{EV}}))$

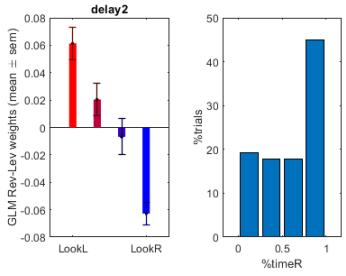


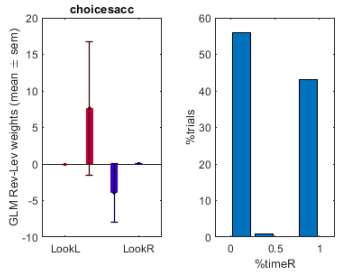




GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{R_{EV}} - \boldsymbol{L_{EV}}))$

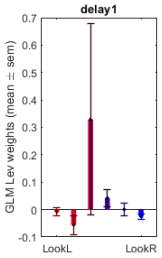


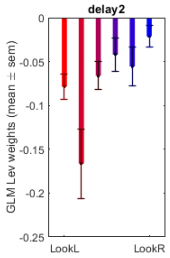


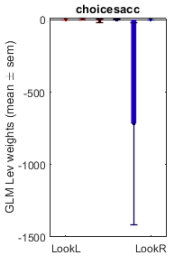


What if we used more bins for Look L vs Look R? i.e. tR/(tR+tL) binned as [0, 1/6, 2/6, 3/6, 4/6, 5/6, 1]

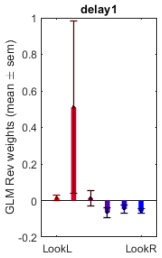
GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{L_{EV}}))$

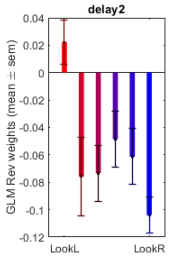


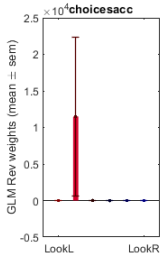




GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{R_{EV}}))$







GLM for spike count η:
$\eta \approx \exp(\beta_0 + \beta_1 \cdot (\boldsymbol{R_{EV}} - \boldsymbol{L_{EV}}))$