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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Introduction

For decision making tasks with reward gambling and sequential reward offer cues presentation, neurons in the orbito-frontal cortex (OFC) have been associated with the coding and maintenance of the estimated value of a firstly presented offer expected value (EV) so that it could be compared with the estimated value of a later presented one [1–4]. Importantly, it is yet to be assessed what is the role of sensory offer cues and their features, such as the spatial location and temporal order of offer cues presentation in neural firing. Our research aim is to combine the analyses of the role of task variables such as gambling probability and reward sizes with eye movement behavior and neural spiking activity simultaneously recorded in OFC during the execution of a two-alternative gambling task with sequential visual offer cues presentation.

Behavioral task

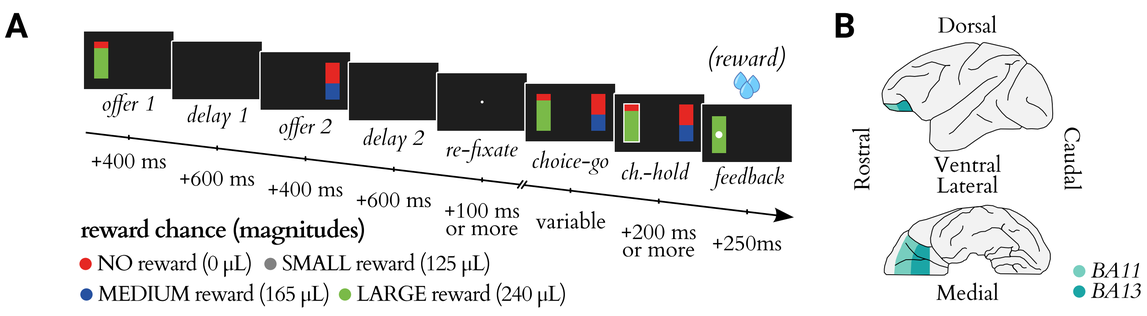

Figure 1. Behavioral Task, recorded brain areas. A) Two-alternative gambling task, sample configuration. Reward offers are sequentially cued by visual presentation of vertical bar stimuli on the two opposite sides of the screen. Stimuli colors either cue to a safe, small fluid reward (gray) or to risky rewards with size medium (blue) or large (green). Reward magnitudes were pseudo-randomized across trials. Risky reward probabilities were continuous random variables drawn from uniform distributions. The height of risky offers cues indicates the probability of achieving reward. No reward probability is indicated by complementing offer bars with red color. **B)** Recorded areas: Brodmann Areas 11 (BA11) and 13 (BA13), shown in the anatomical sketch redrawn from Mansouri et al., 2014[5]. Two adult male rhesus macaques (*Macaca mulatta*) served as subjects. All procedures were approved by the University Committee on Animal Resources at the University of Rochester or at the University of Minnesota, designed and conducted by T.C.-P., M.Z.W. and B.H. in compliance with the Public Health Service's Guide for the Care and Use of the Animals.

Results

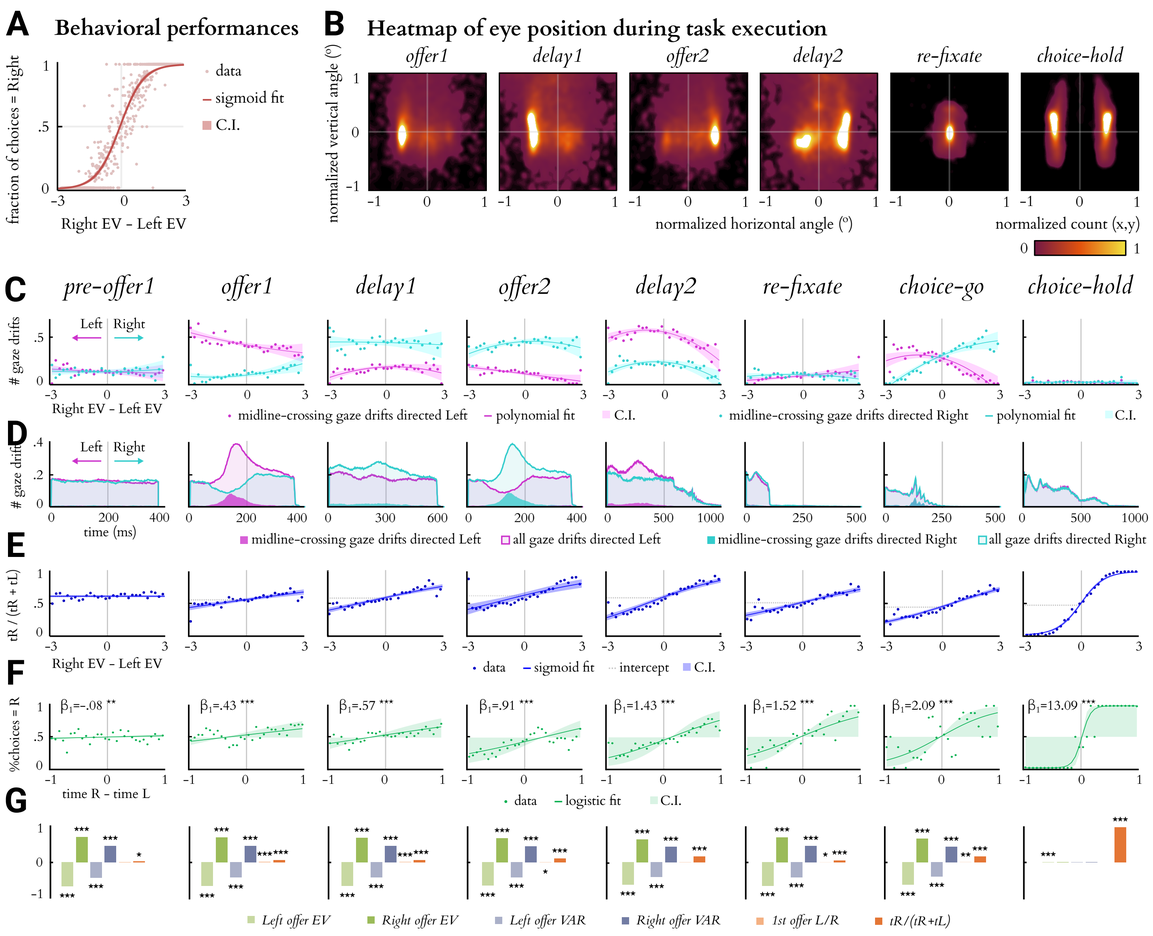

Figure 2. Behavioral data analyses. A) Behavioral task execution performances: chosen offer side vs difference in Expected Value of the two offers (R_{EV} - L_{EV}). **B)** Heatmaps showing the distribution of eye position during task execution, smoothed with Gaussian filter with sigma = 5 bins. **C)** Screen midline crossing saccades labelled by direction. Solid lines: second order polynomial fit; shaded areas 95% Confidence Interval (C.I.). **D)** Time histograms of saccades occurrence labelled by direction (Left/Right). Solid areas: midline-crossing gaze drifts only; shaded areas: all gaze drifts. **E)** Fraction of time spent inspecting the Right screen side (tR) vs EV difference (R_{EV} - L_{EV}, binned at 0.05 nominal units: 1=small, 2=medium, 3=large reward). Solid lines: sigmoid fits; shaded areas: 95% C.I. **F)** Chosen offer vs difference in time spent at either screen side. Solid lines: logistic regression fits (logit(fraction of choices = Right) ≈ β_0 + (*tR - tL*) β_1); **G)** Generalized Linear Model of the subject's choice (logit(fraction of choices = Right) ≈ $w_0 + w_1 L_{EV} + w_2 R_{EV} + w_3 L_{VAR} + w_4 R_{VAR} + w_5$ *order* $+ w_6$ *tR/(tR+tL)*). **A-G)** Data include 5971 trials correctly performed (2643 from subject 1, 3328 from subject 2). Pooling is made with reference to the first offer side: eye data in trials with first offer on the Right side are horizontally mirrored; *p<0.05, **p<0.01,***p<0.001.

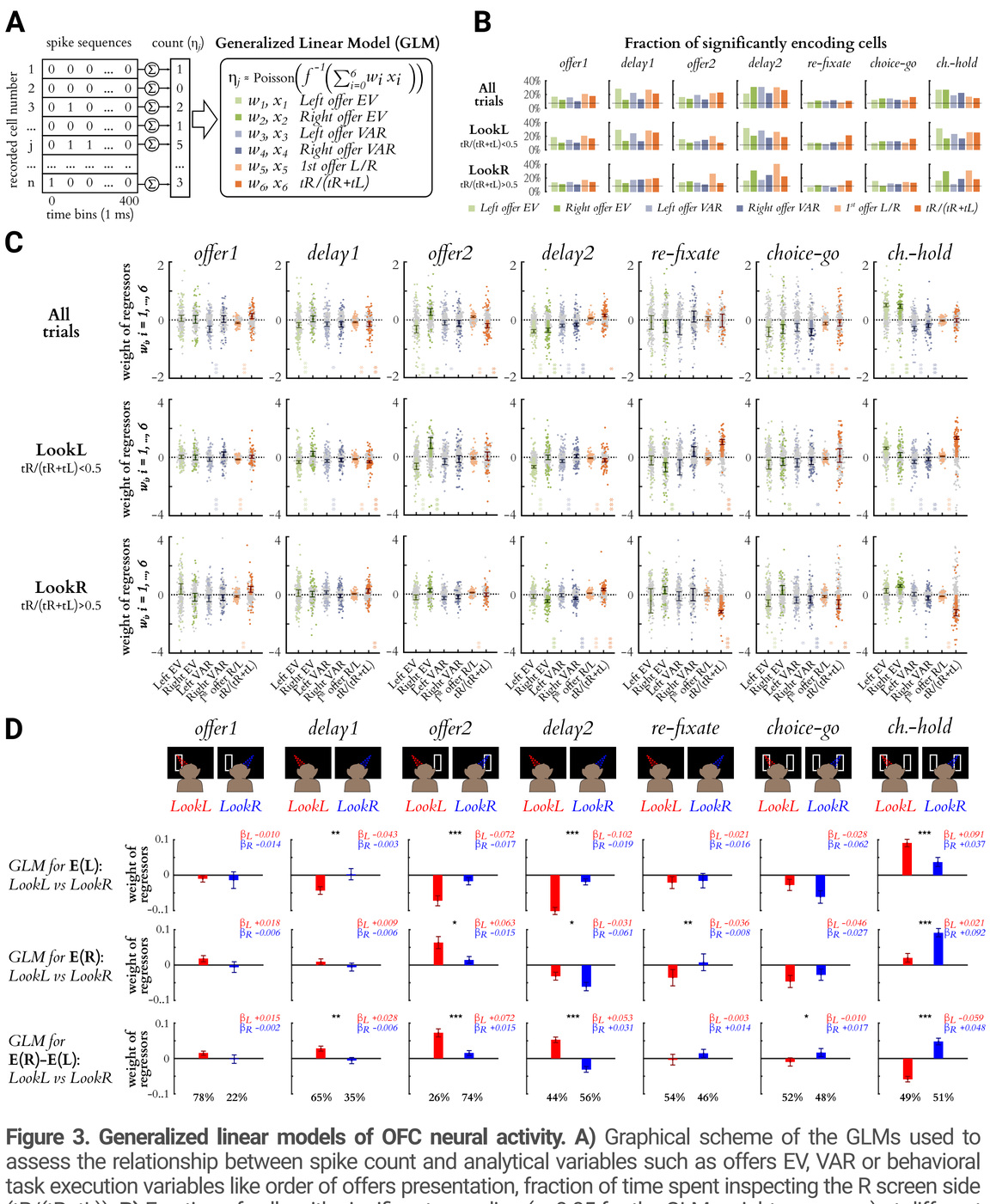

Figure 3. Generalized linear models of OFC neural activity. A) Graphical scheme of the GLMs used to assess the relationship between spike count and analytical variables such as offers EV, VAR or behavioral task execution variables like order of offers presentation, fraction of time spent inspecting the R screen side (tR/(tR+tL)). **B)** Fraction of cells with significant encoding (p<0.05 for the GLM weights w_1, ..., w_6) at different task exectution times. Dotted lines report significant fraction of cells for binomial tests with n=248 cells. Panels include either all trials, or trials where subjects mostly looks L (fraction of time looking R tR/(tR+tL) is <0.5) or mostly looks R (tR/(tR+tL)>0.5). **C)** GLM weights (w_1, ..., w_6) at different task execution times. Data include all cells (colored dots: p<0.05; gray dots: n.s.), mean ± s.e.m of significantly encoding cells is overlayed. The significance of each weight is assessed via Wilcoxon signrank tests by including all cells (*p<0.05, **p<0.01, ***p<0.001). **D)** Top row: comparison of the encoding of Left offer EV (*E(L)*) in lookL and lookR conditions. Separate GLMs are fitted with lookL and lookR trial pools: log(η) ≈ $\beta_0 + \beta_L$ *E(L)* and log(η) ≈ $\beta_0' + \beta_R$ *E(L)*. Bars report mean ± s.e.m of β_L and β_R values including all cells, with significance between the two conditions tested via Wilcoxon signrank tests (*p<0.05, **p<0.01, ***p<0.001). Middle row: same as above but for Right offer EV. Bottom row: same as above, but for difference between R and L offers EV. Percentages at the bottom report the percentage of trials where monkeys most looks L or R, respectively.

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 possilby yields stronger coding of the ipsi-later offer EV.

References

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