Looking at previous cue sites reactivates value coding for serial evaluation in orbitofrontal cortex

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Introduction

For decision making tasks with reward gambling and sequential reward offer cues presentation, cells in the orbito-frontal cortex (OFC) have been associated with the coding and maintenance of expected value (*EV*) of a firstly presented offer, so that it is compared with the *EV* of a later, second offer[1-4] for choice selection. Importantly, it is yet to be assessed what is the role of gaze fixation in the encoding and processing of *EV*s during cues presentation and at subsequent delay times when stimuli are no longer present. Accessing delay time activity allows to isolate the neural signature of *EV*s in absence of sensory stimulation, gating the way to investigating the role of fixation for offer *EV* encoding and its re-activation for comparison of alternatives.

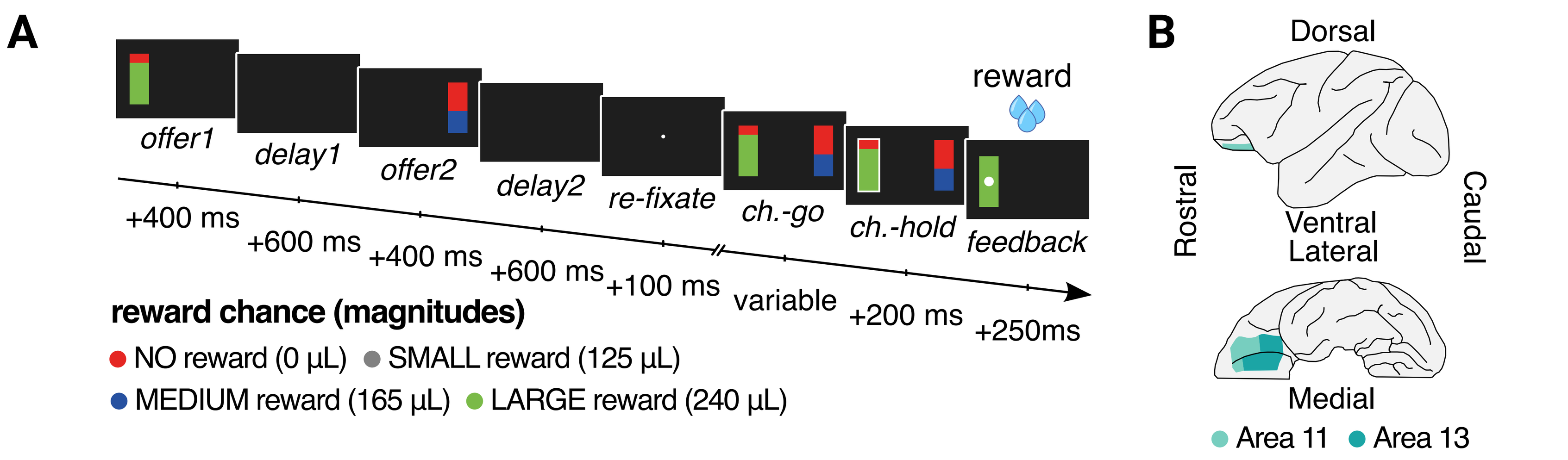

Figure 1. Behavioral Task, recorded brain areas. A) Gambling task, sample trial configuration. Reward offers are cued by visual presentation of stimuli on the two sides of the screen. Stimuli colors cue to safe, small fluid reward (gray) or to risky rewards with size medium (blue) or large (green). Magnitudes were pseudo-randomized across trials. Reward probabilities were random variables drawn from uniform distributions. The height of risky color cues indicates the hit probability, complemeed by red bars indicating miss probability. **B)** Recorded Area 11 and 13, 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

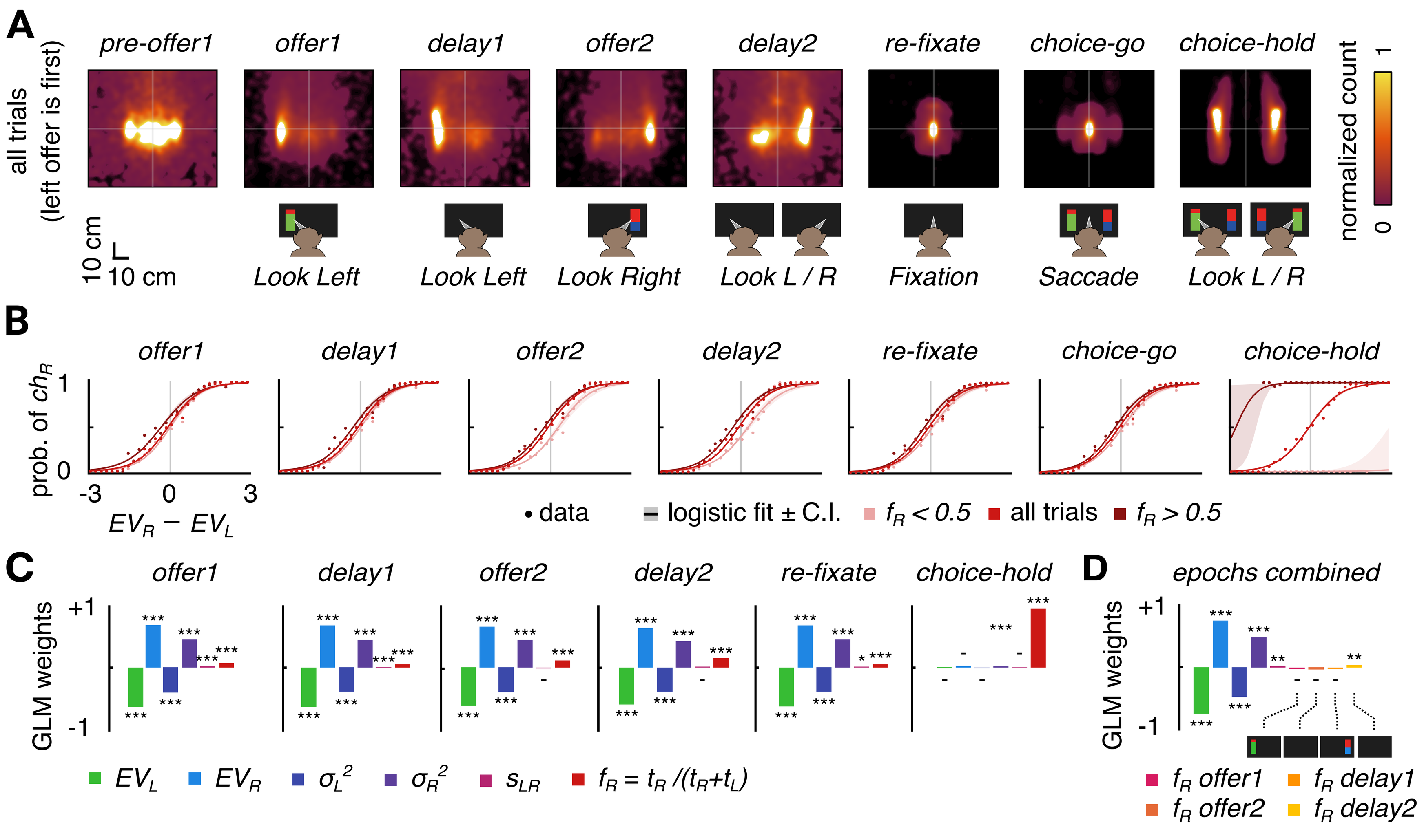

Figure 2. Behavioral data analyses. A) Heatmaps of eye position during task execution, smoothed with 2D Gaussian filter (width: 5 bins). The heatmaps magnitude is normalized in each epoch to its maximum value. **B)** Behavioral performances of task execution, showing choice probability vs *EV* difference (ch_R=1 if right offer is chosen, *0* otherwise). The analysis is repeated considering the time spent fixating either screen side, f_R being the fraction of time spent on right side ($f_R = t_R/(t_R+t_L)$, t_R (t_L) time spent on right (left) side). Trials where subject mainly look left have $f_R < 0.5$, we consider mainly look right for $f_R > 0.5$. Solid lines: logistic fits; shaded areas: 95% C.I. **C)** Generalized Linear Model of the subject's choice ($logit(chR) = w_0 + w_1 EV_L + w_2 EV_R + w_3 \sigma^2_L + w_4 \sigma^2_R + w_5 s_{LR} + w_6 f_R$; with s_{LR}=1 if first offer is left, -1 otherwise). Weights are normalized across epochs to their maximum value to be within unitary disc [-1,1]. **D)** Same as C, but combining offer-related regressors and f_R across epochs. **A-D)** Data include 5971 correctly reported trials (2643 performed by subject 1, 3328 by 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.

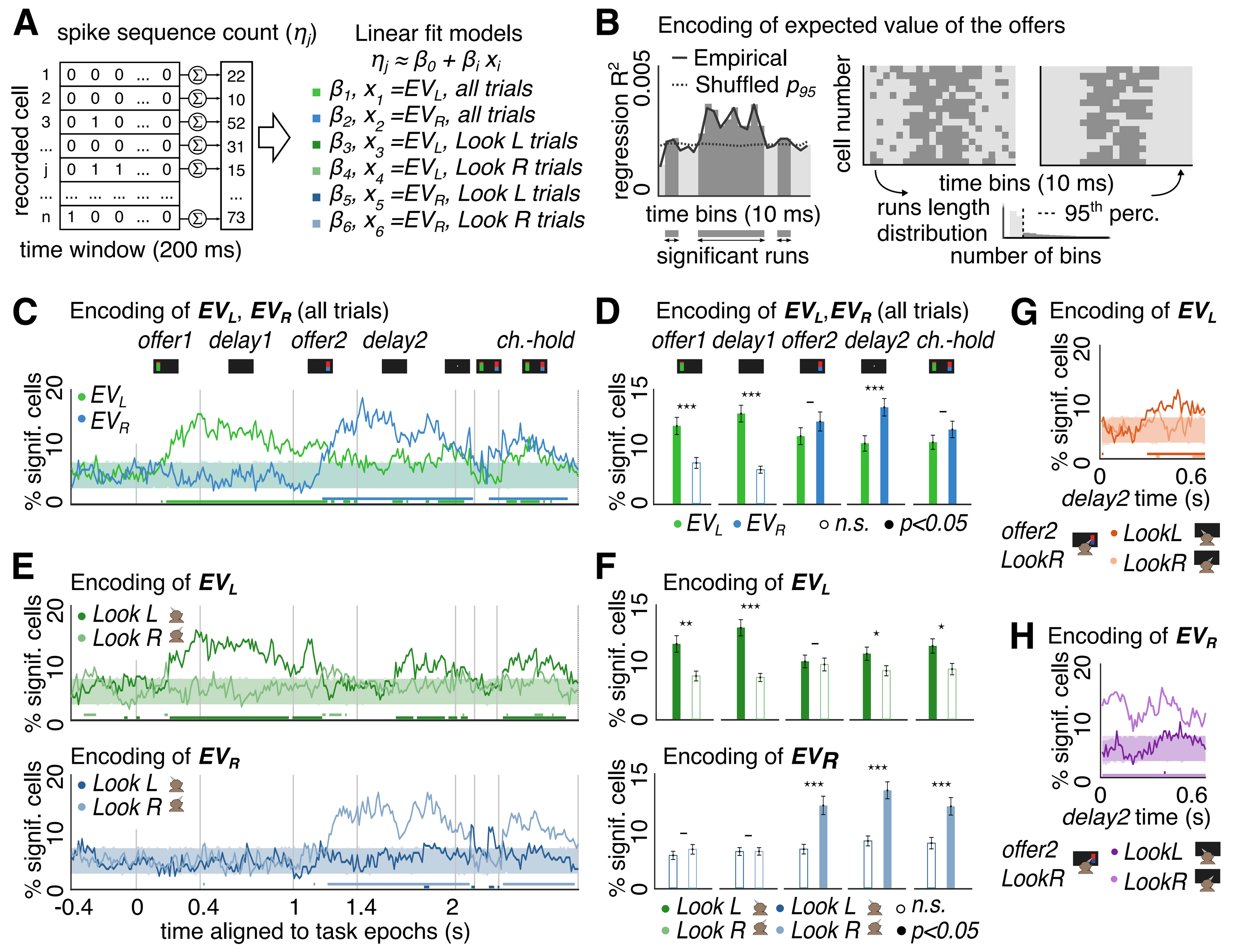

Figure 3. Analysis of OFC neural activity. A) Schematic of the *EV* encoding analyses. Spike count is applied in time windows of 200ms in 10ms bins. EV_L and EV_R are first analysed separately by including all trials, then they are analysed for subsets of trials where subjects mostly *LookL* or *LookR*, based on average eye position in the 10ms at the start of spike count windows. **B)** Significance of the encoding of *EV*s in time bins. The empirical R^2 is compared with a significance threshold set as 95th percentile of R^2 for shuffled trial order. The length of significant (threshold crossing) time bins runs is assessed to the 95th percentile of significant run lengths for time-scrambled sequences[6-8]. **C)** Fraction of significantly encoding cells during task times: for EV_L, EV_R including all trials. **D)** Same as C, but integrated in time for the most relevant task epochs. **E)** Same as C, but for trial pools where subjects mostly *LookL* or *LookR* for EV_L (top) and EV_R (bottom). **F)** Same as D, but for results in E. **G)** Focus on delay 2 time for EV_L including only trials where subjects LookR during offer 2. **H)** Same as G, but for EV_R. **C-H)** Eye data pooled with reference to the first offer on the L screen side (trials with first offer on R side are horizontally flipped). Neural units n=248 (163 from subect 1, 85 from subject 2), recorded in 4 sessions (2 for each subject). **D,F)** Significance assessed through non-parametric Wilcoxon signed rank tests: * is for p<0.05, ** is for p<0.01,*** is for p<0.001, - is for n.s.

Conclusions

- The fraction of time spent on either screen side is predictive of the choice (Fig. 2 B-C);
- The eye position is relevant in encoding offer values and the activation of value signals in OFC: looking at either screen side yields stronger coding of the ipsi-later *EV* both during offer presentation and at delay times, despite the screen is blank (Fig. 3 C-F);
- Looking back at first offer presentation side during delay 2 allows to re-activate the encoding of the value of previously shown offer, improving the strength of its encoding above the strength of encoding for most recent, contro-lateral offer (Fig. 3 G-H).

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External findings

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