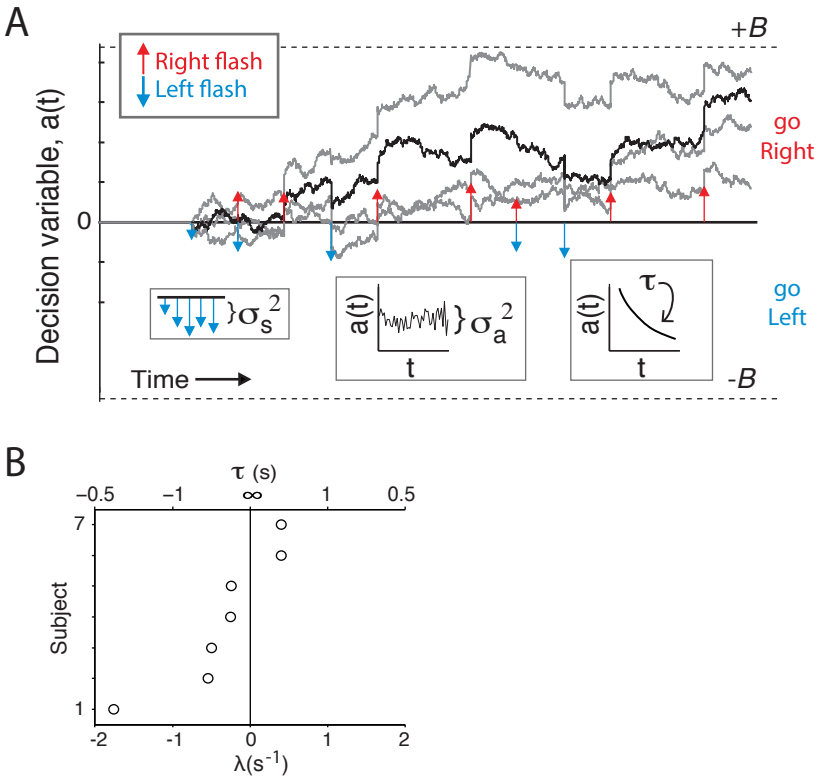

Figure S 1. Related to Figure 2. Behavioral model reveals integration time constants of individual rats.

(A) Schematic of accumulator model of Brunton et al. (2013) used to capture the integration time constants of rats during the accumulation of evidence task. Colored arrows indicate the timing of left (blue) and right (red) flashes. At each time point, the model represents the decision variable, a(t), based on the flashes, noise associated with the flashes and time, and the integration time constant. For a detailed description, see Brunton et al. (2013), and for model-free confirmation of the model's conclusions, see Scott, Constantinople et al. (2015). The memory time constant is parameterized by τ (or $1/\lambda$). If $\lambda<0$, the integrator is leaky and the memory of a pulse decays with time, and if $\lambda>0$, the integrator is unstable and a(t) increases with time. Lines indicate alternative runs of the model on the same trial. (B) The best fit λ values for each rat. For many, but not all, of the rats, the time constant is close to or greater than 2 s ($|\lambda| <= 0.5$).

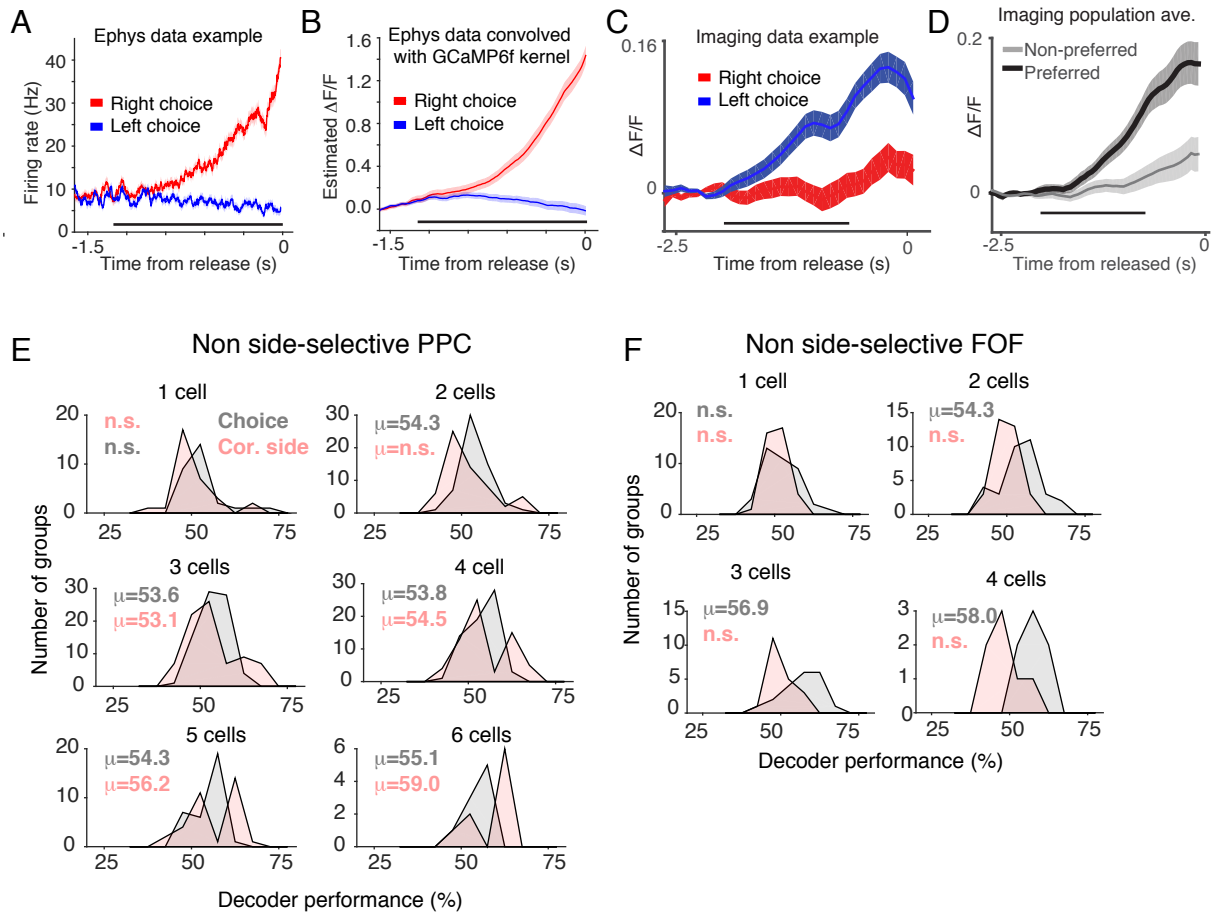

Figure S2 related to Figure 4. (A) Example response of a side selective neuron recoded less than 250 microns below the cortical surface during the auditory accumulation of evidence task. Red line indicates the average firing rate on trials in which the animal chose right, blue line indicates the average firing rate on trials in which the animal chose left. Horizontal black line indicates the duration of the cue period. B) Predicted GCaMP6f response for the neuron in panel A based on a simulation in which the spike times were convolved with a kernel matched to the rise and decay times of GCaMP6f. Red line indicates the average predicted GCaMP6f response on right trials, blue line indicates the average predicted GCaMP6f response on left trials. C) Example GCaMP6f response of a side selective neuron imaged in FOF layer 2/3 during the visual accumulation of evidence task. Red line indicates the response (ΔF/F) on trials in which the animal chose right, blue line indicates the average response on trials in which the animal chose left. Horizontal black line indicates the duration of the cue period. D) Average response of all side selective neurons imaged in PPC and FOF during the visual accumulation of evidence task. Black line indicates the average response across all neurons in which the animal chose the neuron's preferred side, gray line indicates the average response on trials in which the animal chose right. Horizontal black line indicates the duration of the cue period. Shaded area indicates s.e.m. (E-F) Performance of the decoder based on different numbers of simultaneously recoded non-side selective neurons in PPC (E) and FOF (F). Each panel plots the distribution of decoder performances across all groups of cells for a given group size (1-6 cells for PPC; 1-4 cells for FOF). The distribution of decoder performances for predicting the choice of the animal is plotted in gray. The distribution of the performances for the correct side on each trial is plotted in red. Note that for both classifiers based on 2 or more neurons, non-side selective cells in PPC and FOF enable decoding of the animal's choice significantly better than chance ($p<0.01$, t-test). However, classifiers based on the activity of 3 or more PPC neurons were capable of decoding of the correct side significantly better than chance ($p<0.01$, t-test), whereas classifiers based on groups of FOF neurons were not ($p>0.01$, t-test).

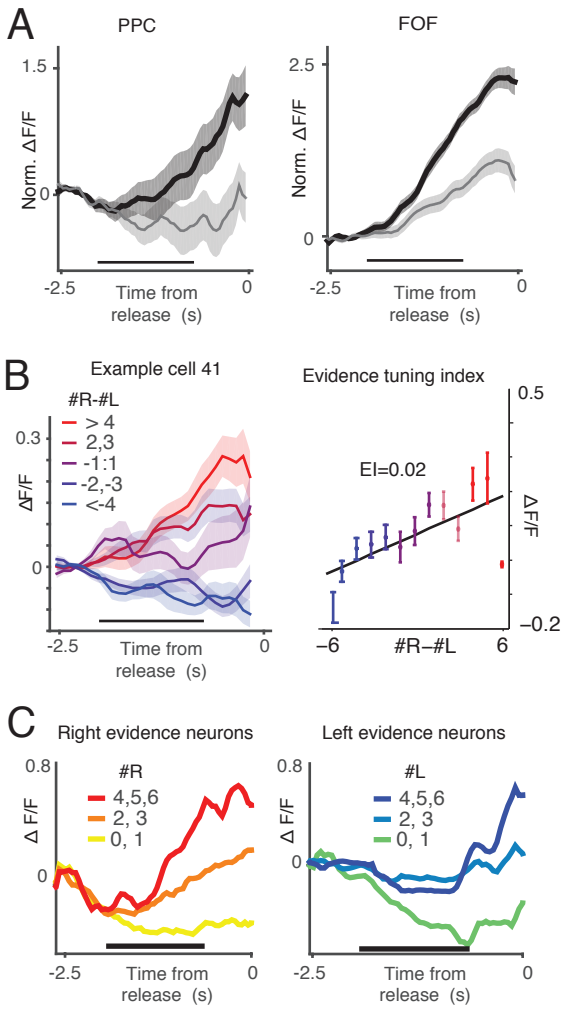

Figure S3 Related to Figure 5. (A) Averaged choice responses made to the preferred (black) and non-preferred (gray) sides for all active neurons recorded in PPC (left panel) and FOF (right panel). Shaded region indicates s.e.m. (B) (left panel) Example of a side-selective neuron in FOF that exhibited graded response to accumulated evidence during the delay period. Colored lines indicate the mean response on trials of different amounts of evidence, using correct trials only. Black lines indicates the cue period. (right panel) The average ΔF/F during the delay period on trials with different amounts of evidence. The slope of the line fit to these points was termed the "evidence index." (C) The average ΔF/F on trials with different amounts of right (left) evidence for all neurons with a positive (negative) evidence index. Black lines indicate the cue period.

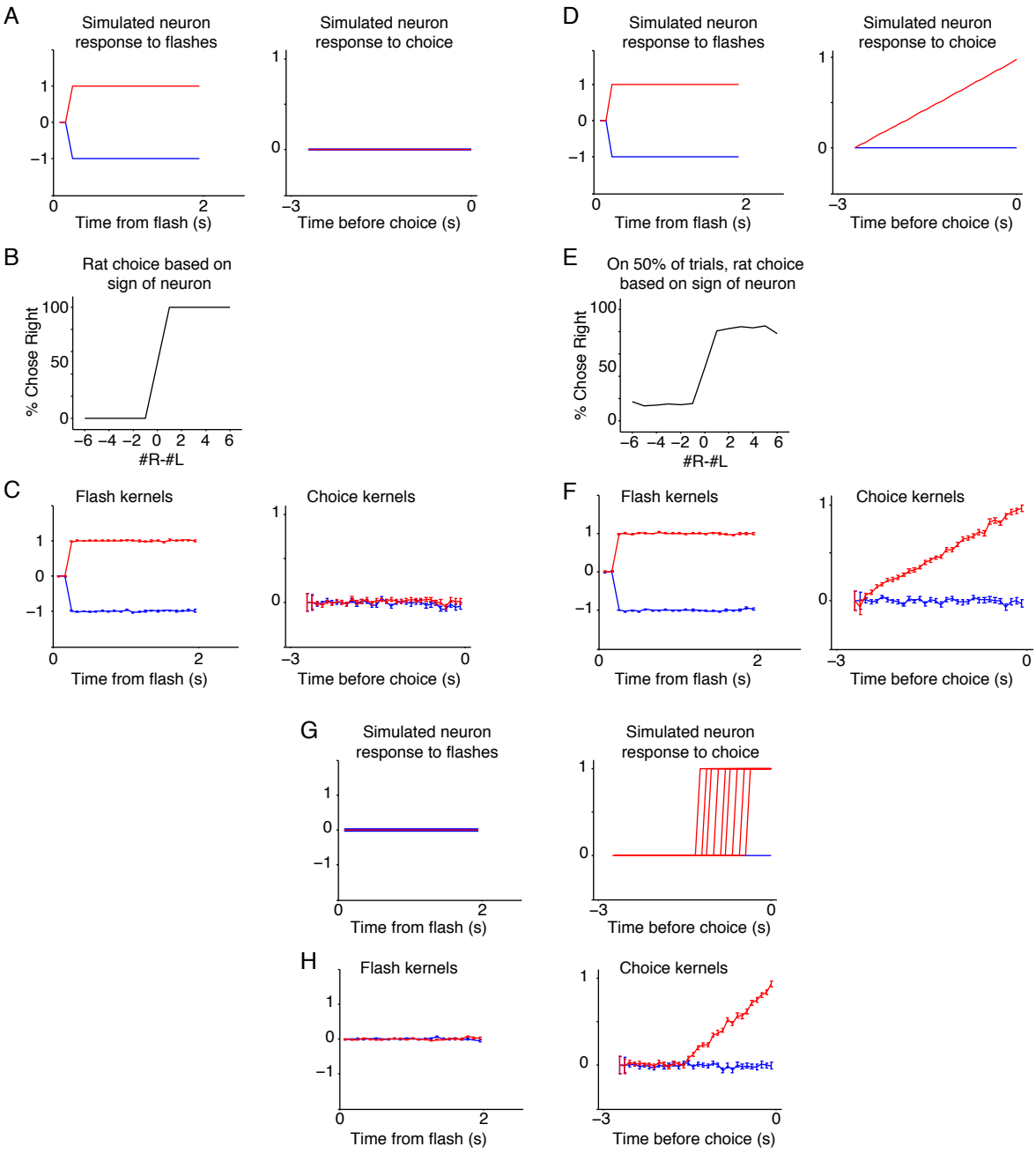

Figure S4. Related to Figure 6. Response kernels from simulated neurons.
(A) A simulated neuron was a perfect accumulator of flashes, and responded to ipsilateral (right, red) and contralateral (left, blue) flashes with positive and negative step functions, respectively. This neuron did not respond to choice, but the simulated rat made his choice based on the sign of this neuron. (B) The psychometric performance of the simulated rat in this case. Here, the choice of the animal is perfectly correlated with the flash responses of the neuron, because the simulated rat makes his choice based on the sign (positive or negative) of the neuron's activity at the end of the trial. (C) Despite this correlation, the regression correctly derives the flash and choice components of the response. (D) A simulated neuron with flash and choice kernels. (E) The psychometric performance of the simulated rat in this case. In this simulation, the rat makes his choice based on the activity of the neuron on 50% of the trials; on the other 50%, the rat chooses at random. Here, the choice of the animal is partially correlated with both the flash and choice-associated responses of the neuron. (F) Regression derives the flash and choice kernels. (G) A simulated neuron that does not respond to flashes, but exhibits a randomly timed stepping response on right choice trials. The step times are drawn from a uniform distribution with a minimum latency of 1.5s from trial start. (H) Regression derives the flash and choice kernels .

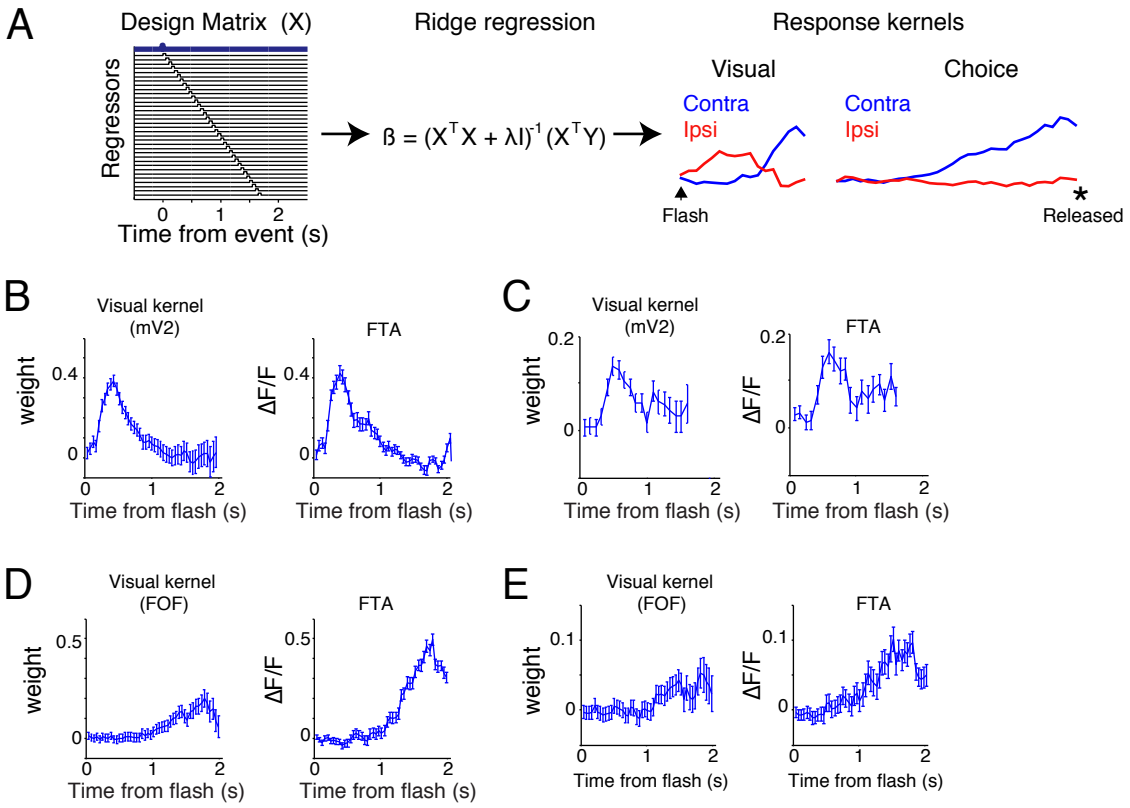

Figure S5 Related to Figure 6. Linear encoding model reveals visual and choice components. (A) Schematic of the linear encoding model. Each model component (left flash, right flash, left choice, right choice) was parameterized by a series of regressors at different lags relative to the task event. The regressors were delta functions, in steps of the frame rate of the imaging session (usually ~22 Hz, but sometimes ~11 Hz). The flash components spanned 2 seconds following each flash, and the choice components spanned the maximum trial duration preceding the end of the trial (when the rat was released from head-restraint and free to make a choice). The model components, or kernals, were fit using ridge regression. Visual and choice kernels for an example FOF cell are shown (right). The blue lines correspond to the contralateral (left) model components, and the red lines correspond to the ipsilateral (right) components. (B) Comparison of the model-derived contralateral (left) visual kernel for a neuron in mV2, with the flash-triggered average obtained by model-free analysis (error bars are s.e.m.). Flash-triggered averages (FTAs) were computed as follows: we selected trials which had identical flash times for all flashes except one. Subtracting the neural response on the trial with one fewer flash from the response on the trial with one extra flash isolates the effect of that flash on the neural response. Trials were aligned to the onset of the isolated flash and averaged. (C) Comparison of contralateral visual kernel and FTA of a different mV2 neuron. (D,E) Comparison of visual components and FTAs for two neurons from FOF. Note the difference in magnitude reflects the coefficient penalty imposed by ridge regularization in the regression model.

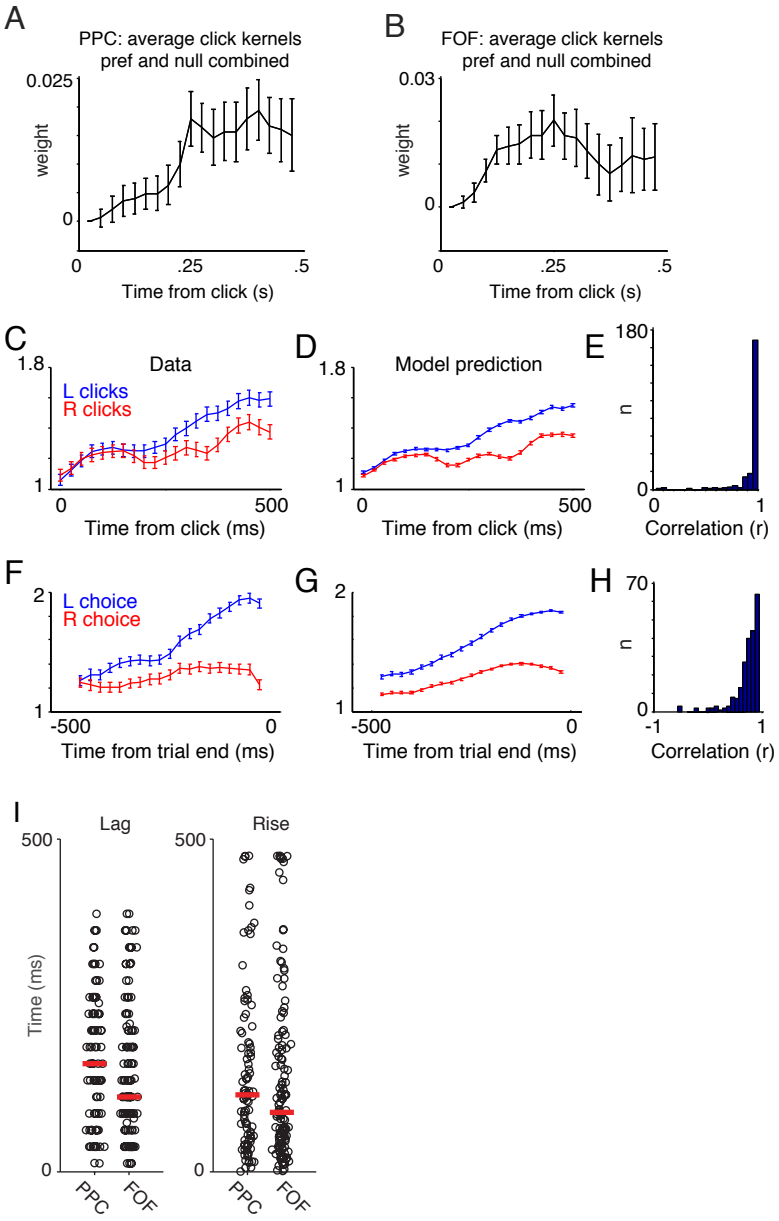

Figure S6. Related to figure 6. Impulse response functions of PPC and FOF neurons recorded during the auditory "Poisson clicks" task. (A) Average click kernels from the model for neurons in PPC. To directly compare with a previous model-free analysis from Figure 1E,F of Hanks et al., (2015), the click component from the non-preferred side was inverted, and then averaged with the component from the preferred side. The plot in A is the average across all PPC neurons, and is similar to the click-triggered average reported in Hanks et al. (2015). (B) The average click components from FOF neurons. (C) The average firing rate triggered off of all left (blue) and right (red) clicks for a neuron recorded in PPC. (D) The average model prediction triggered off all left (blue) and right (red) clicks for the neuron shown in C. (E) Histogram of the correlation between these click-triggered averages of the data and the model for all PPC and FOF neurons (Pearson's correlation coefficient). (F) The average firing rate from trials when the animal subsequently oriented to the left (blue) and right (red) for a neuron recorded in FOF. (G) The average model prediction on left/right choice trials for the cell in F. (H) Histogram of the correlation between the choice-averaged data and model predictions for all PPC and FOF neurons. (I) Comparison of lag (left panel) and rise times (right panel) for each cell across PPC and FOF. Black circles indicate the best-fit parameters for each neuron. Red line indicates the mean across each group. Note that PPC and FOF exhibited a wide range of best-fit parameters and that parameters were largely overlapping between the two areas.

A

	FOF	PPC
Active neurons	62 (100%)	38 (100%)
Side selective neurons	23 (37%)	6 (16%)
Prev. choice selective neurons	14 (23%)	8 (21%)

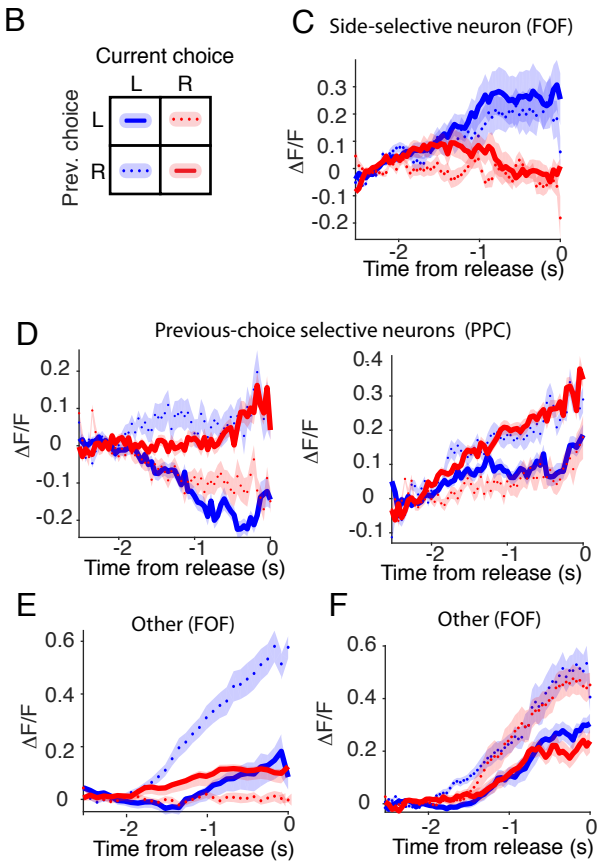

Figure S7 related to Figure 8. Modulation of responses in FOF and PPC by the animal's choice on the previous trial. (A) Table indicating the number of neurons in FOF and PPC that exhibited side-selectivity and previous choice selectivity. Previous choice selectivity was computed similar to side selectivity. The distribution of responses during the delay period on trials in which the animal responded to the left was compared to the distribution of responses on trials in which the animal responded to the right. If the distributions were significantly different (two sided t-test $p < 0.05$) that neuron was defined as previous choice selective. (B) Legend for the panels C-F which show the dynamics of example neurons. For each panel (C-F) the responses of an example neuron were averaged across four types of trials. Solid blue line represents the average on trials in which the current choice was left and the previous trial was left. Dotted blue line represents trials in which current choice was left and the previous trial was right. Dotted red line represents trials in which current choice was right and the previous trial was left. Solid red line represents trials in which current choice was right and the previous trial was left. Shaded area represents s.e.m. (C) Example of a side-selective neuron in FOF that was not selective for previous trial. This neuron responded more strongly when the current choice was left regardless of the choice on the previous trial. (D) Examples of two previous-side selective neurons in PPC. (E) Example of a neuron in FOF that was identified as both side-selective and previous side selective. F) Example of a neuron in FOF that exhibited interesting choice history responses but was not identified either as side-selective or previous choice selective. This neuron responded more strongly when the animal switched its choice between the last and the current trial, regardless of the side it chose.

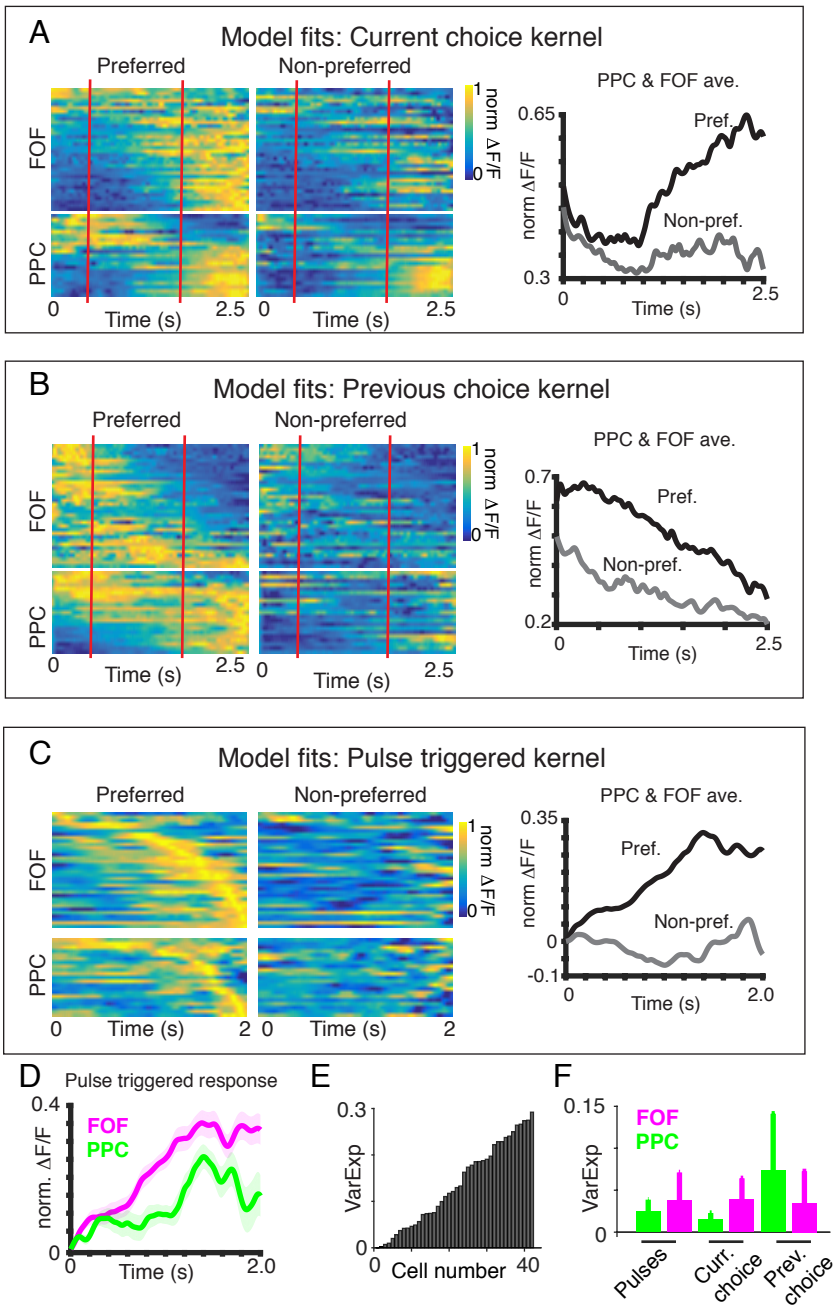

Figure S8 Related to Figure 8. Regression based analysis of calcium dynamics related to current choice, previous choice and sensory evidence in FOF and PPC.

A-C) Regression-based estimates of neuronal responses to task related events, which include the current choice of the animal (A), the previous choice of the animal (B) and the timing of the left and right pulses (C). Each row represents the estimated response of an individual neuron aligned to the time of the event. Columns indicated the response of neurons in FOF and PPC for events on the preferred (left) and non-preferred (middle) sides. Neurons are sorted based on the response center of mass (A-B) or peak response (C) to events on the preferred side. Right column shows the average response to task events on the preferred (black) or non-preferred aligned to the time of the event. D) Comparison of average estimated pulse triggered responses between PPC (green) and FOF (magenta). Solid line indicates the average response of neurons to pulses on the preferred side, shaded area indicates standard error. E-F) Evaluation of the linear regression fits using cross validation. E) Improvement in variance explained between fits based on task-related events and scrambled regressors. F) Contribution of different task events to the model's variance explained in FOF (magenta) and PPC (green). Note that in FOF sensory evidence, current choice and previous choice explain the variance in neuronal responses equally well. In PPC however, the previous choice of the animal explains significantly more of the variance then the current choice (t-test, $p<0.05$).