Supporting Information

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SI Materials and Methods

Neurophysiological Recordings. We recorded single-cell activity from the lateral prefrontal cortex (PFC) (left hemisphere, around the principal sulcus) of both monkeys. The location of the recording sites and the placement of the recording chambers were reconstructed in stereotactic coordinates by using magnetic resonance images of individual monkey brains (Fig. 2*A*). Electrodes were inserted each recording day by using a grid with 1-mm spacing. Neurons were selected at random in every recording session; no attempt was made to preselect neurons according to response properties. Signal acquisition, amplification, filtering, digitalization, and spike sorting (offline) were accomplished by using the Plexon system (Plexon).

Stepwise Linear Regression (SLR) Analysis. Neuronal responses during the rule cue were analyzed in the period starting 200 ms before the rule cue onset and ending 300 ms after the rule cue onset. Sliding SLR analysis was calculated for analysis windows of 100-ms duration, slid in steps of 10 ms for the factors intensity (INT), decision (*D*), action (*A*), and rule cue (*R*). The number of neurons significantly encoding each factor in each analysis window was convolved with a Gaussian kernel (bin width 10 ms; step 1 ms) for the plot (Fig. 5*C*).

To test for the presence of multicollinearity, we calculated the variance inflation factor (VIF) $\mathrm{VIF} = 1/(1 - R^2)$, where R is the coefficient of the correlation of both explanatory variables decision and intensity. As a common rule of thumb VIF > 5 are used as cut off values for too high multicollinearity (1, 2). None of the VIF values calculated for every neuron exceeded the cutoff value.

Receiver Operating Characteristic (ROC) Analysis. To characterize how neurons represent the abstract decision across time, we applied sliding ROC analysis (3) to consecutive overlapping time windows of 300 ms moved in 50 ms steps across the trial. We compared the discharge rates of salient (≥2.4% visual contrast) hit trials to discharge rates of correct rejections. Further, hit trials of threshold stimuli (2.0%, 1.7%, 1.4%, and 1.1% of visual contrast) were compared to miss threshold trials. To exclude possible stimulus intensity biases in the analysis of four different intensities of hit or miss trials, equal numbers of trials of each stimulus intensity were included in the comparison for each cell.

To estimate the extent to which neuronal activity in both phases was influenced by the decision, we calculated the choice probability index (4) (area under the ROC curve). Values of 0.5 indicated chance-level discrimination; values >0.5 denoted neurons with higher firing rates for hits compared with misses or correct rejections; choice probability indices <0.5 signified cells with higher discharge rates for misses and correct rejections. We used bootstrapping to assess whether the indices were significantly different from 0.5. For this analysis, we constructed 1,000 resamples of the observed discharge rates, each of which was obtained by random sampling with replacement keeping the original number of trials for each condition. Then, we calculated the choice probability index for each resample, and compared the resulting distribution of the indices to the value of the original dataset. If 95% of the bootstrapped values were higher/lower than the original value, it was considered statistically significant ($P < 0.05$). Confidence intervals, depicted in Figs. 3 and 4, were calculated by using the bootstrap technique for each interval.

To calculate the response latency of the neurons, sliding ROC analysis with time windows of 50 ms slid by 1 ms was used. We defined the latency for each cell as the time after stimulus onset, but no later than 500 ms, for which the choice probability index exceeded for 50 consecutive windows the 95% threshold of the bootstrapped data. If no value could be determined, a default latency corresponding to the 75th percentile of the response latency distribution of a given recording was used (179 ms).

Population Analysis and Normalization. For the group analysis of each cell class, we normalized and averaged responses of all significantly selective cells. Normalized activity was calculated by subtracting the mean baseline activity and dividing by the SD of the baseline activity (300 ms period before stimulus onset). Spike density histograms for single neurons were averaged over trials and convolved with a Gaussian kernel (bin width 150 ms; step size 1 ms) for illustrative purposes only.

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2. O'Brien RM (2007) A caution regarding rules of thumb for variance inflation factors. *Qual Quant* 41:673–690.
3. Green DM, Swets JA (1966) *Signal Detection Theory and Psychophysics* (Wiley, New York).
4. Britten KH, Newsome WT, Shadlen MN, Celebrini S, Movshon JA (1996) A relationship between behavioral choice and the visual responses of neurons in macaque MT. *Vis Neurosci* 13:87–100.

Table S1. Number of neurons classified as "yes" and "no" decision neurons

	"Yes" neurons		"No" neurons	
	↑	↓	↑	↓
Stimulus phase	34	23	1	0
Delay phase	79	25	21	3

↑, increasing firing rate; ↓, decreasing firing rate.