Figure S1. Stability of behavioral performance and effect of cueing on reaction time; related to Figure 2.

To compare behavior across sessions, we computed the mean reaction times on validly and invalidly cued trials. Since this effect was so large on average (Figure 2B), it could be estimated from just the few correctly performed, invalidly cued trials on each session, and therefore served as a useful index of the animal's use of the cue to orient attention and generate saccade plans. Only correctly performed trials with similar change magnitudes (45˚) and blank durations (>200ms) were included in this analysis. The mean reaction time for both validly cued trials (cyan) and invalidly cued trials (purple) is plotted as a function of recording session in chronological order for each monkey. For each invalidly cued point, the inset number indicates the number of trials averaged for that point. Faded lines in plots for sessions 1-3 for Monkey G and 1-9 for Monkey B indicate sessions in which little or no appropriate invalidly cued trials were presented. The mean RT on validly cued trials was consistently faster than the mean on invalidly cued trials (monkey G, 19 out of 21 sessions; monkey B, 11 out of 12 sessions).

Figure S2. Firing rate modulation by cue direction for correctly and incorrectly performed trials; related to Figure 4.

To ask whether the attention-related and saccadic modulations we observed depended on the correct performance of the task, we computed the modulation indices for each neuron on incorrectly performed trials. A. Histograms of post-cue period firing rate modulation indices (MIs) between cue-RF and cue-orthogonal trials. MIs were computed separately for firing rates recorded on correctly (top panel) and incorrectly (bottom panel) performed trials. Distribution for correct trials is identical to Figure 4A. The triangle marker indicates median value of the distribution. B. As in A, but for MIs between firing rates on cue-opposite and cue-orthogonal trials. For neither cue-RF versus cue-orthogonal MIs nor cue-opposite versus cue-orthogonal MIs were the medians of the correct and incorrect distributions significantly different from each other (cue-RF, $p = 0.074$; cue-opposite, $p = 0.84$, Wilcoxon signed rank test).

Figure S3. Fano factor effects for neurons with different median firing rates; related to Figure 6. We asked whether the FF differences we observed between cue conditions depended on the firing rate of the neurons. The Fano factor for each of the three conditions (cue-RF, cyan; cue-opposite, red; cue-orthogonal, purple) is shown for four independent quartiles of the population, split by firing rate. The x-axis value of each point is the median firing rate of the neurons in that quartile across all three conditions. Though there was a clear dependence of absolute FF on firing rate, the FF differences between conditions were statistically indistinguishable across the range of firing rates. Furthermore, we computed a regression of the cue-RF minus cue-orthogonal FF difference against firing rate for each neuron, and likewise for cue-opposite minus cue-orthogonal. In both cases, the slope of this regression was not different from zero (95% confidence intervals of slope, cue-RF vs. cue-orth.: -0.001 to 0.002, n.s.; cue-Opp vs. cue-orth.: -0.002 to 0.001, n.s.), indicating no dependence of the FF effect on firing rate. Asterisks indicate that comparison of cue-RF vs. cue-orthogonal (cyan) or cue-opposite vs. cue-orthogonal (red) was significant ($p<0.05$, Wilcoxon signed rank test) for only the neurons in that quartile.

Figure S4. Modulation during covert attention in neurons significantly modulated during saccade preparation; related to Figure 7.

Similar to the analysis of cue-opposite MIs for neurons significantly modulated during cue-RF trials (Figure 7), we also asked whether neurons significantly modulated during cue-opposite trials (n=56, 38 enhanced and 18 suppressed) were modulated on cue-RF trials. Indeed, of the 56 neurons significantly modulated during cue-opposite trials, 25 (45%) were also significantly modulated during cue-RF trials (19 enhanced during both and 5 suppressed during both). The 38 neurons enhanced during cue-opposite trials were also enhanced during cue-RF trials (median cue-RF vs. cue-orthogonal MI = 0.076). This cue-RF MI was greater than that of the overall population ($p<0.001$, Wilcoxon ranked sum test) and greater than that of the 18 neurons significantly suppressed during cue-opposite trials ($p=0.009$). Shown are overlaid histograms of modulation indices during attention (cue-RF condition) for neurons significantly enhanced (blue) and significantly suppressed (black) during saccade preparation (cue-opposite condition).

Figure S5. Firing rate modulation during the saccadic period; related to Figure 3.

To determine whether neuronal firing rates were modulated in the perisaccadic period (-75ms to +25ms relative to saccade onset), we computed modulation indices between the cue-opposite (i.e. saccade to RF) and cue-orthogonal conditions. A. Example PSTHs aligned to saccade onset for three example neurons. PSTHs are shown for the cue-opposite (i.e. saccades to the RF) and cue-orthogonal (saccades also orthogonal) conditions. PSTHs indicate responses around the time of correctly executed saccades following reappearance of the stimulus array and an orientation change of the cued stimulus. B, Histogram of the modulation indices between cue-opposite and cue-orthogonal trials for perisaccadic firing rates across the population of V4 neurons. Consistent with previous findings, we observed a robust enhancement of firing rates during this period (median MI = 0.16, $p<10^{-49}$, Wilcoxon signed rank test). Red portion of the histogram corresponds to individually significantly modulated neurons. Black triangle indicates median of the distribution.

Conflict of Interest form