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Supplemental Information

Enhanced Neural Processing by Covert Attention only during Microsaccades Directed toward the Attended Stimulus

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SUPPLEMENTAL INFORMATION

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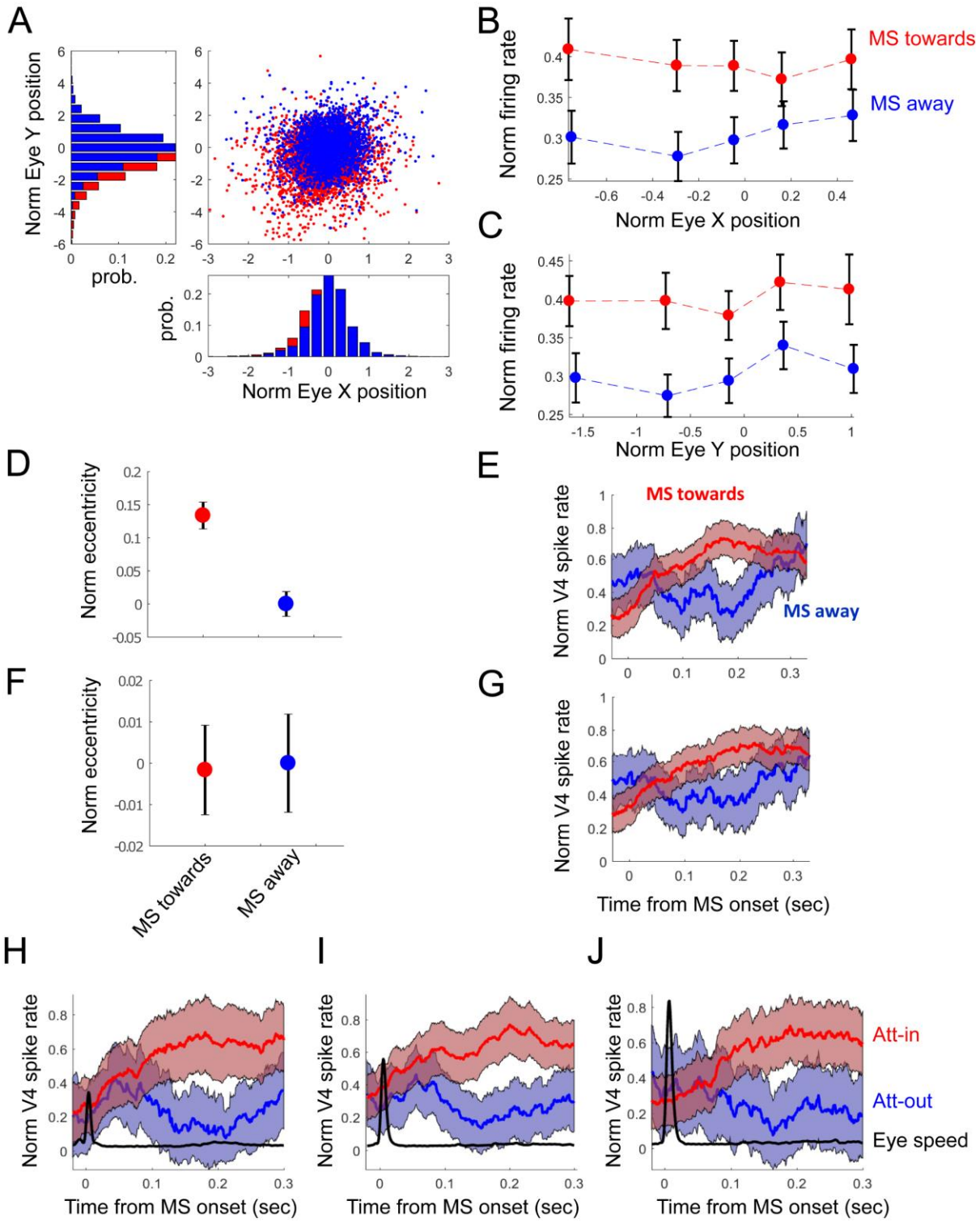

Figure S1. **Related to Figure 2.** Control for eye position comparing MS directed towards or away from cued stimulus. **A**) The marginal and joint population distribution of X and Y eye position for MS towards (red) and MS away (blue) from cued stimulus (attention-in condition, which is attending to the stimulus covering V4 RF located in the lower left quadrant). (**B-C**)

Fine grain eye position analysis of MS-direction dependent V4 attentional modulation. X and Y eye positions were subtracted and normalized by the mean and variance of positions from MS away windows. (**B**) Population-averaged V4 firing rate for time-windows 100ms-250ms after MS either directed towards (red) or away (blue) from cued stimulus. Population data was grouped into 5 groups (20% percentile steps) dividing equally the X eye position distribution (**C**) Same as (B), but for Y eye position. (**D-G**) Eye position eccentricity is computed by taken the squared distance of X and Y eye position during stimulus presentation relative to X and Y in the fixation baseline. The eye position eccentricities were computed for MS towards and MS away from the cued stimulus. The values were normalized to the mean value of the MS away population to reduce variability between sessions and monkeys. (**D**) The averaged normalized eye position eccentricity (sessions=20), for MS towards and away from the cued stimulus. (t-test, $p = 1.5 \times 10^{-6}$). (**E**) The population-averaged V4 firing rate for the two different MS directions (t-test for interval 150-300ms after MS, $p = 8.27 \times 10^{-8}$, neurons =253). Shaded area is ±SE. (**F**) The averaged normalized eccentricity after equalization (t-test, p =0.75). (**G**) Despite the equalization for eccentricity, the firing-rate modulation persisted (t-test for interval 100-200 ms after MS, p =0.0024). (**H-J**) Effect of MS amplitude on attention effect. (**H**) Normalized population averaged V4 firing rate for MS towards the cued stimulus. Only MSs that were between the 5^{th} and 35^{th} percentile of the MS amplitude distribution we chosen. (**I**) Same as (H), but for MS lying between the 35^{th} and 65^{th} percentile of the MS amplitude distributions. (**J**) Same as (H), but for MSs lying between the 65^{th} and 95^{th} percentile of the MS amplitude distributions.

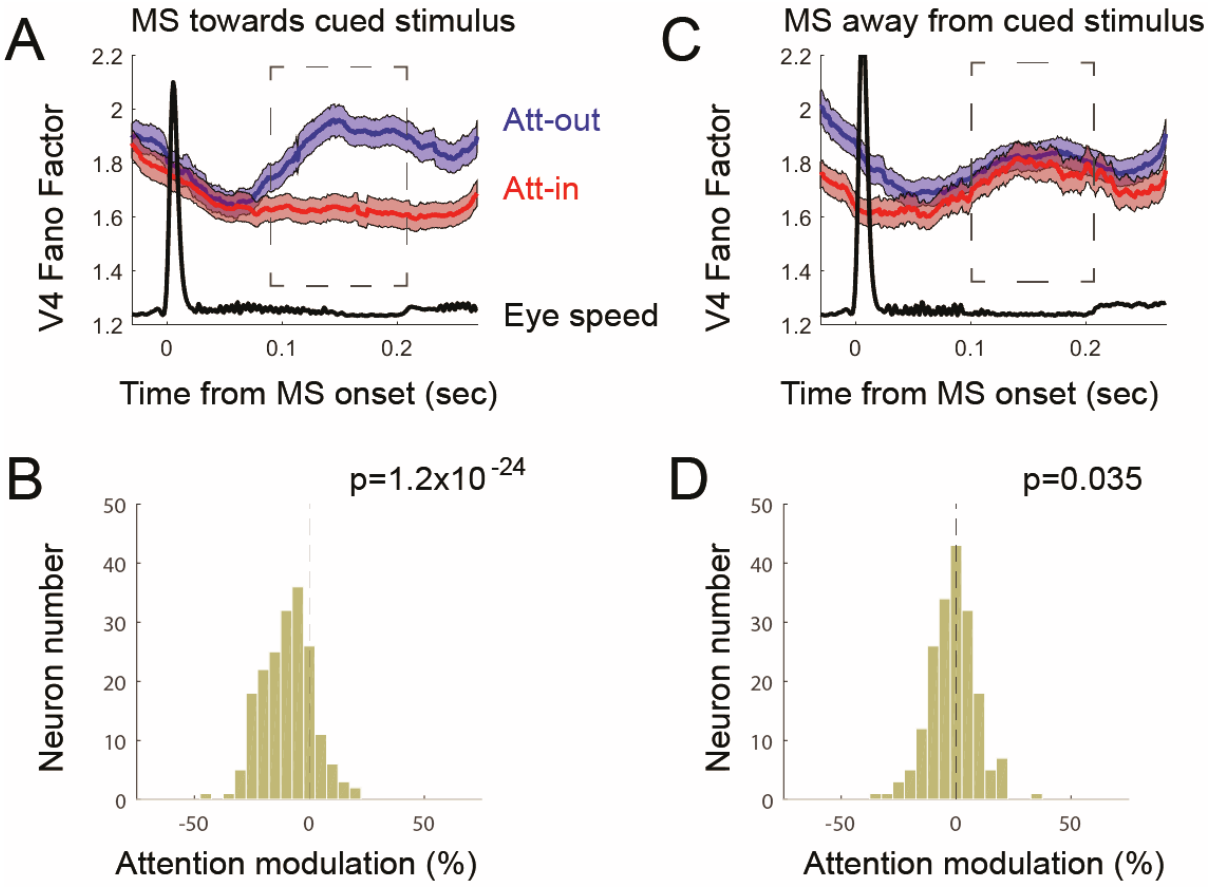

Figure S2. **Related to Figure 2.** Attention and MS modulation of the Fano-factor. (**A-B**) MS towards cued stimulus. (**A**) Population-averaged V4 firing rate over time references to MS onset. Att-in (red) is if cue was directed to the stimulus covering RF, whereas att-out (blue) is if cue was directed to stimulus outside RF. Black line is trial-averaged eye speed. Shaded area is ±SE. Dashed rectangular window represents the time period for quantifying attentional modulation. (**B**) Attention modulation (A-U)/(A+U) expressed in percent for each neuron (n=253) computed 100-200 ms after MS onset. Statistics were computed using t-test. (**C-D**) Same as (A-B), but for MS directed away from cued stimulus.

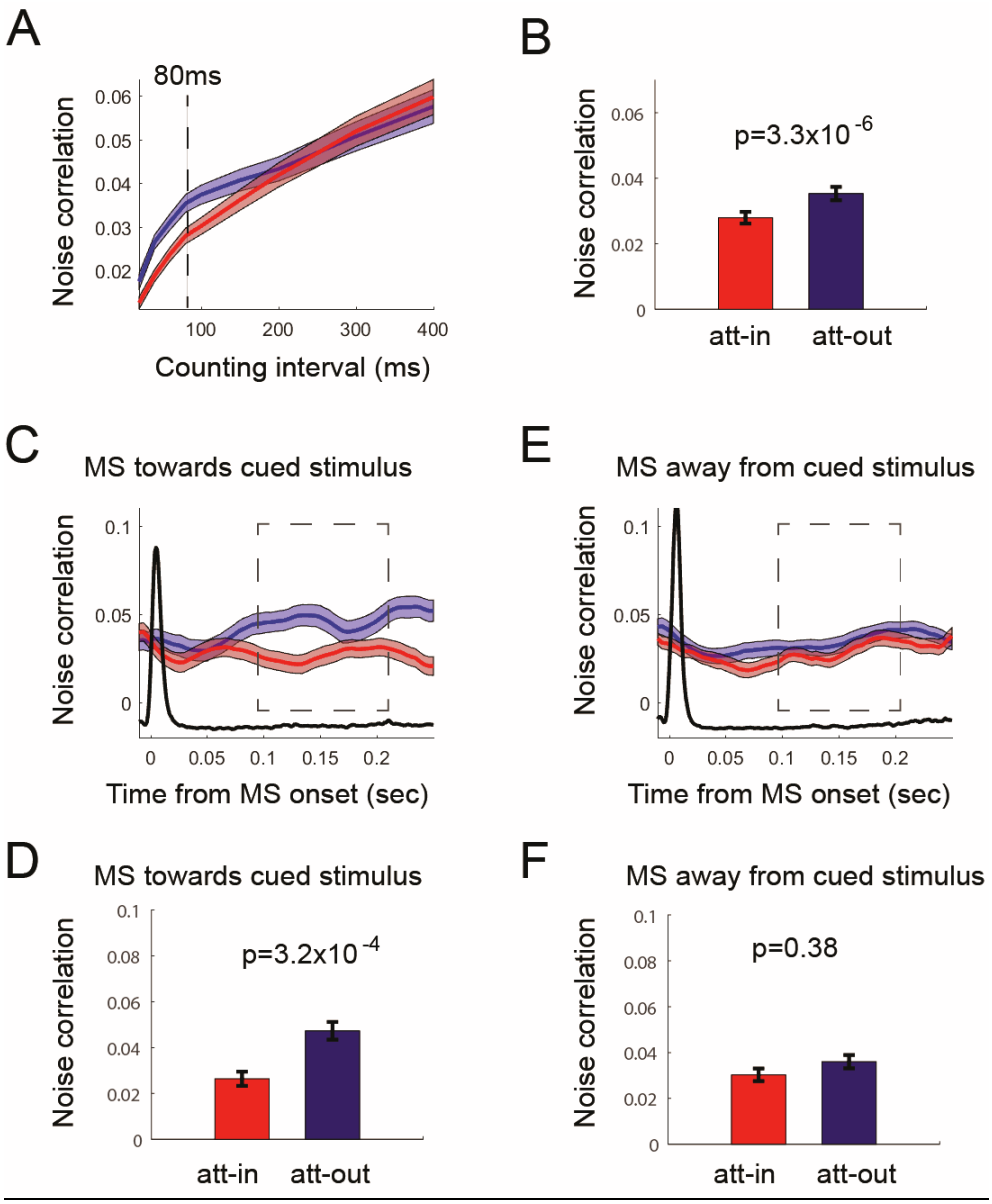

Figure S3. **Related to Figure 2.** Attention and MS modulation of noise correlation. (**A**) V4 neuronal noise correlation (NC) (n=460) as a function of counting interval. Red line is att-in and blue line is att-out. Shaded area is ±SE. (**B**) The attention effect (t-test) for counting interval 80 ms. (**C**) Time-resolved NC for MS-locked windows directed towards cued stimulus. (**D**) Attentional effect (t-test) for time period 100-200 ms after MS directed towards cued stimulus. (**E-F**) Same as (C-D), but for MS directed away.

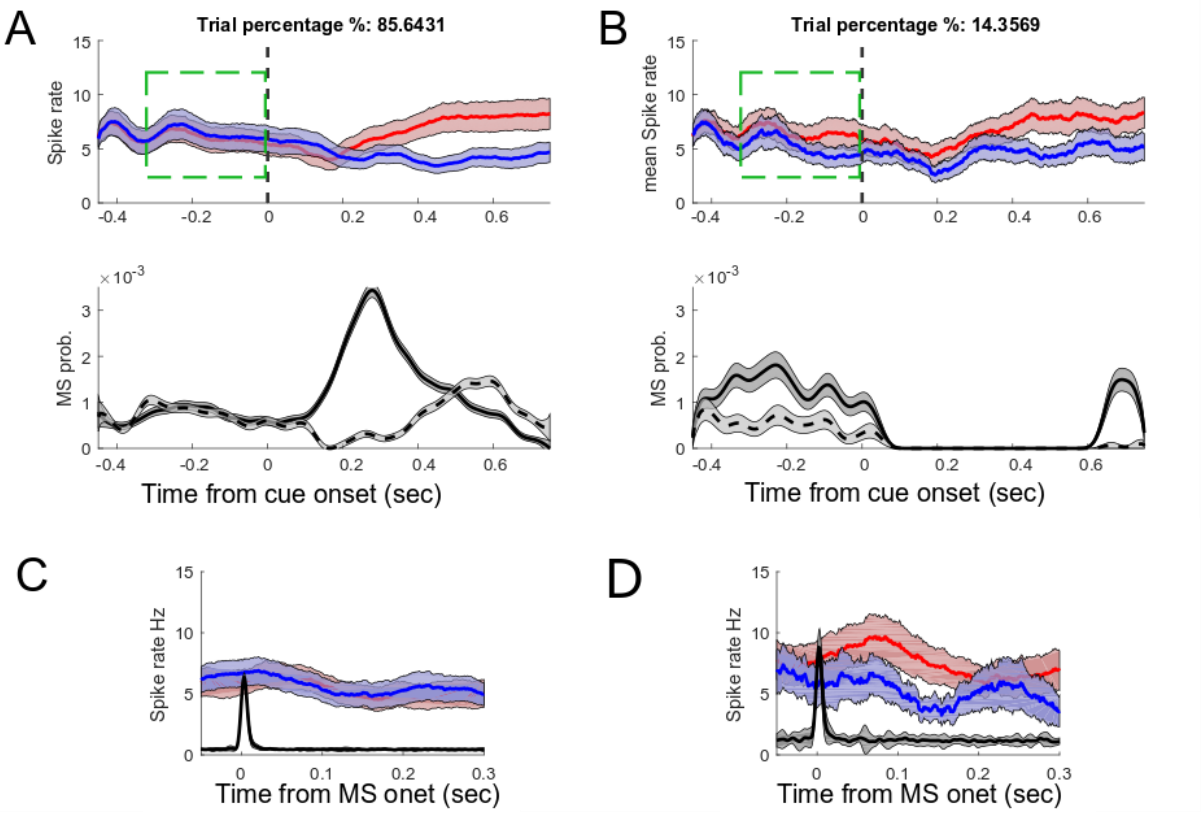

Figure S4. **Related to Figure 4.** Related to Figure 4. Comparison of trials with or without MS within 600 ms window after cue. (**A**) Trials with a MS after the cue (~83% of total number of trials). Upper plot: Red line is att-in and blue line is att-out population spike rate. Shaded area is ±SE. The green dashed line represents the period used to detect MS for subplot B). Black dashed line represents cue onset. Lower plot: Dark line is the occurrence probability of MS towards the cued stimulus and lighter line is the occurrence probability of MS away from the cued stimulus. Black line is eye speed. Shaded area is ±SE. (**B**) The population averaged spike rate for att-in (red line) and att-out (blue line) as a function of MS onset towards the to-be-attended stimulus in the period before the cue onset (green dashed box in A), from -300 ms to 0 ms). Only trials were considered if a MS was detected after the cue (*MS before cue + MS after cue*). (**C**) as in (A), but only trials with no MS after the cue (~17% of total number of trials). (**D**) As in (B), but only trials where considered if no detected MS after the cue (*MS before cue + no MS after cue*).

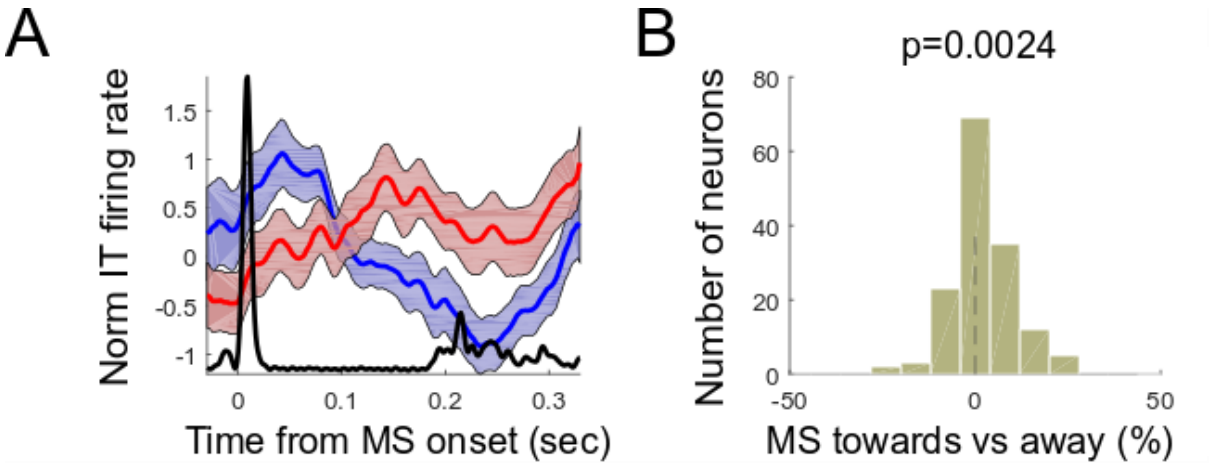

Figure S5. Related to Figure 5. Modulation of IT firing rate by MS. **(A)** IT firing rate modulation with MS towards or away from attended stimuli (averaged across attention conditions). IT firing rate was normalized using the mean rate from MS away time windows. Shaded area is ±SE. Black line is averaged eye speed. (**B**) Averaged from 100ms to 250 after MS onset, the firing rate modulation $(MS_{towards} - MS_{away})/(MS_{towards} + MS_{away})$ for each neuron is computed and shown in a population histogram. The firing rate modulation histogram deviated significantly from a zero distribution (t-test, p=0.0024) with increased firing rate probability for time windows after a MS towards attended stimuli.