Parsing the electrophysiological signatures of spatially selective versus distributed attention in neuronal population data

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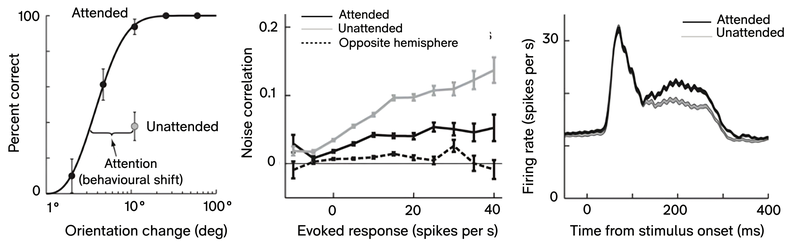
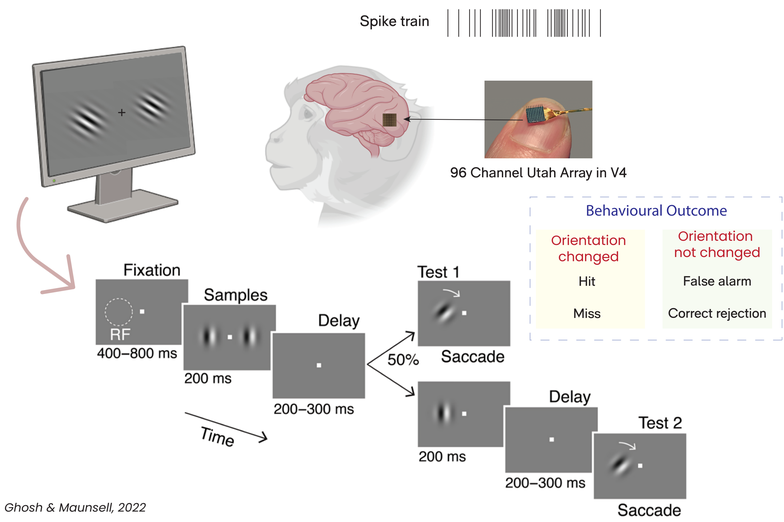
Shifting attention from spatially selective to spatially distributed engages distinct neuronal population dynamics in visual area V4 via normalization circuits.

Neural and Behavioural Correlates of Attention



Cohen & Maunsell, 2009

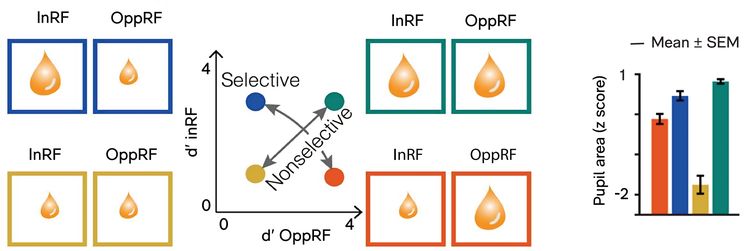
Visual Spatial Attention Task



Ghosh & Maunsell, 2022

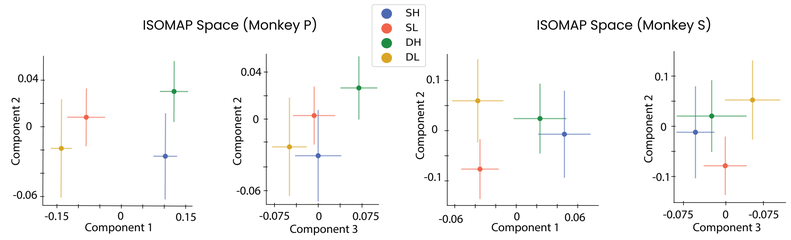
Controllling The Locus and Extent of Attention

High Selective d' InRF
High Selective d' OppRF
High Distributed
Low Distributed



Ghosh & Maunsell, 2022

Distinct Population Signatures Are Associated with Selective Versus Distributed Attentio



Pairwise Correlations Differ for Selective Versus Distributed Attention

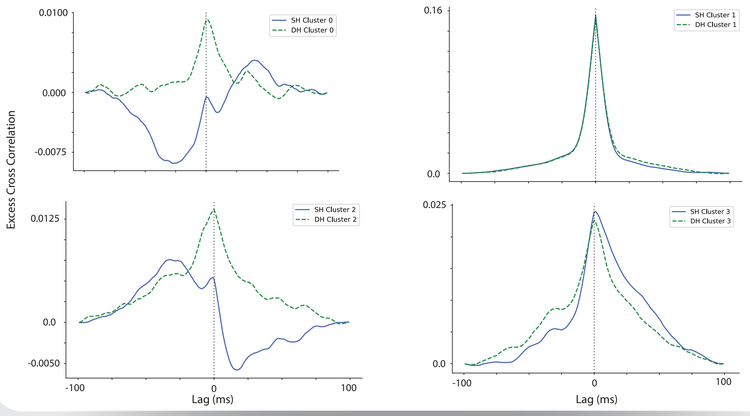
Excess Cross Correlation Suggests Different Population Dynamics During Attentional Shifts

$$\mathrm{ccg}_j(\tau) = \frac{\mathrm{ccg}(\tau)}{\sqrt{\mathrm{acg}_1(0)\,\mathrm{acg}_2(0)}}$$ normalized with autocorrelations at zero time lag

$$\mathrm{ccg}^{\mathrm{inv}}_{j,p}(\tau) = \frac{1}{2K}\sum_{\tau=-K}^{K} f_j(t_k) g_p(t_k+\tau)\Delta t_k, \quad j \neq i$$ common input captured by trial-invariant correlation function

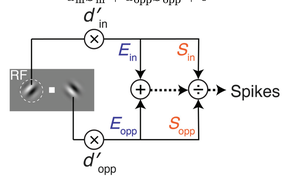
$$\mathrm{ccg}^{\mathrm{noise}}(\tau) = \frac{1}{J}\sum_{j=1}^{J}\left(\mathrm{ccg}_j(\tau) - \mathrm{ccg}^{\mathrm{inv}}_j(\tau)\right)$$ trial-specific correlation (i.e., the "noise correlation")

Cluster pairs on SH correlations, examine clusters in DH



Changes in Pairwise Correlations Depend on Normalization Mechanisms

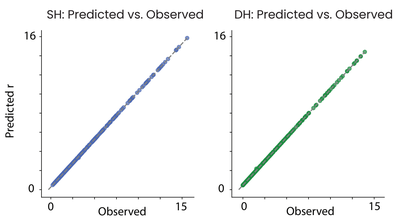
$$r_{\mathrm{in,opp}} = \frac{d_{\mathrm{in}}E_{\mathrm{in}} + d_{\mathrm{opp}}E_{\mathrm{opp}}}{d_{\mathrm{in}}S_{\mathrm{in}} + d_{\mathrm{opp}}S_{\mathrm{opp}} + \sigma}$$ (sample)



Spatially tuned normalization model with d' and background display

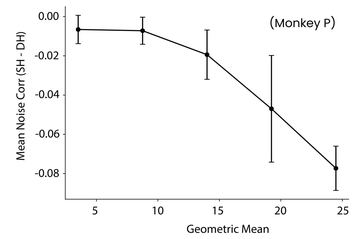
$E_{\mathrm{in}}\ E_{\mathrm{opp}}\ S_{\mathrm{in}}\ S_{\mathrm{opp}}$	represent excitation and suppression in/opposite RF
$d_{\mathrm{in}}\ \ d_{\mathrm{opp}}$	behavioural d' at the RF and opposite RF locations
$r_{\mathrm{in,opp}}$	Trial-averaged spike counts over 200 ms across attentional states

4-Fold Cross Validation
Least-squares Problem



The differences in correlation by attentional state arise from normalization mechanisms

Geometric Mean = $\sqrt{\frac{E_{\mathrm{in}_i}}{S_{\mathrm{in}_i}} \cdot \frac{E_{\mathrm{in}_j}}{S_{\mathrm{in}_j}}}$



Future Directions

- Relate normalization model parameters to cluster identities in cross-correlation cluster analyses.
- Relate ISOMAP coordinate space to trial outcomes.

Implications

- Distributing attention to both visual hemifields engages neuronal mechanisms that differ considerably from established signatures of selective attention in visual area V4.
- Changes in neuronal correlations appear to depend on differential engagement of normalization circuitry.
- Prior work suggests that decorrelation of neuronal population activity plays an important role in the signatures of spatially selective attention that arise from attention. This work suggests that divergent population dynamics can yield equivalent levels of behavioural performance at the receptive field location of the recorded neurons.

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