

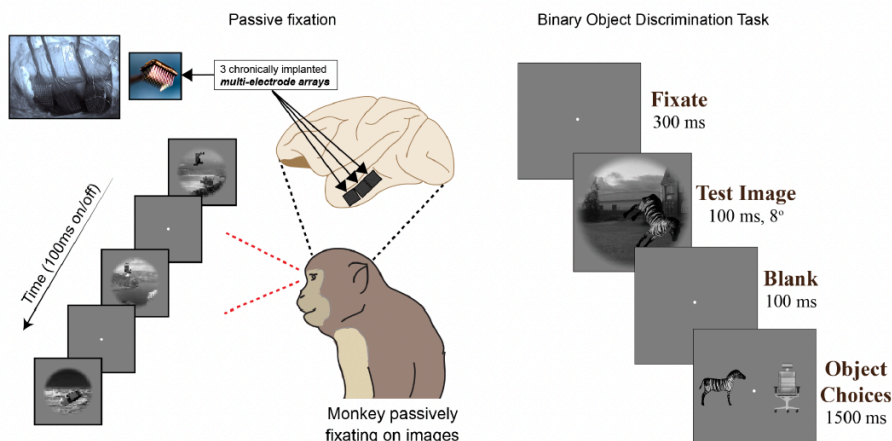
Temporal and Geometric Signatures of Excitatory and Inhibitory Population Codes in Primate Object Representation

Distributed population activity in macaque inferior temporal (IT) cortex supports core object recognition, yet the contributions of excitatory (Exc) and inhibitory (Inh) neurons remain unclear. We recorded large-scale neural activity using implanted Utah arrays across IT cortex in three macaques (8 object types \times 80 exemplars) and identified 124 Exc (broad-spiking) and 37 Inh (narrow-spiking) neurons via waveform clustering. We asked how the temporal evolution and geometric structure of Exc and Inh representations contribute to object coding. Inh neurons responded earlier and more reliably (Δ latency \approx 15 ms), achieving linearly separable stimulus representations before Exc neurons (start $<$ 100 ms: $Z=3.0$, $p = 0.001$). This early inhibitory recruitment is consistent with rapid stabilization and gain control predicted by balanced-network models, in which inhibition dynamically constrains excitatory drive before category-specific manifolds emerge. Over time (\sim 150–250 ms), Exc and Inh populations reached comparable decoding accuracies ($t(11) = 0.009$, $p = 0.993$), but Exc decodes predicted monkeys' image-level behavior significantly better ($Z=67.0$, $p = 0.004$). Geometric analyses revealed the basis of this divergence. Although Inh manifolds exhibited modest between-category radius (mean = 0.3), they showed disproportionately high within-category radius (mean = 0.78), reducing categorical separability ($Z = 46.5$, $p=0.003$). Exc manifolds were more compact both within (0.60) and across categories (0.24), yet became higher-dimensional over time (150–200 ms: Exc = 14, Inh = 11; $t(24) = 9.9$, $p < 0.001$). Thus, inhibition expands and stabilizes variance early, while excitation consolidates high-dimensional, behaviorally aligned manifolds. Consistent with this view, deep networks predict Exc responses significantly better than Inh ($Z = 24.0$, $p < 0.001$), suggesting that current models capture the excitatory backbone of IT computation while missing inhibitory control dynamics. Together, these results identify complementary temporal and geometric roles for excitation and inhibition in shaping robust visual object codes.

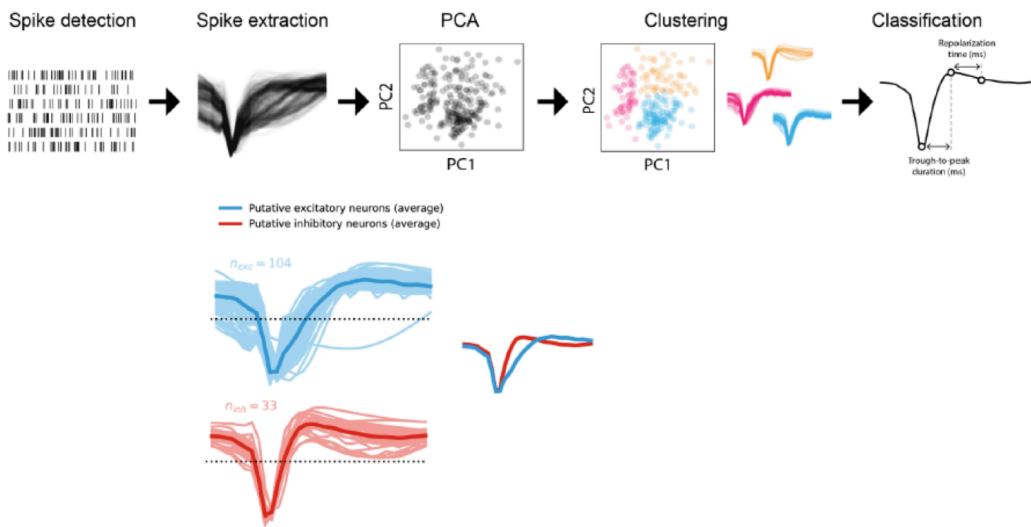
Additional Details

Significance and Relevance: This work uncovers how excitation and inhibition jointly shape object representations in macaque IT cortex across time and geometry. By combining large-scale Utah-array recordings with cell-type-specific manifold analysis, we show that inhibition acts early to stabilize and expand population variance, while excitation consolidates high-dimensional, behaviorally aligned object manifolds that best match both behavior and model representations. These results provide the first geometric account of how E/I interactions sculpt representational structure in a high-level visual area, bridging neural dynamics, population geometry, and computational modeling. The study's cell-type-resolved, geometry-based framework directly engages Cosyne's core themes—linking circuit dynamics to population coding principles and informing next-generation network models that integrate inhibitory control into object recognition.

Main experimental methods

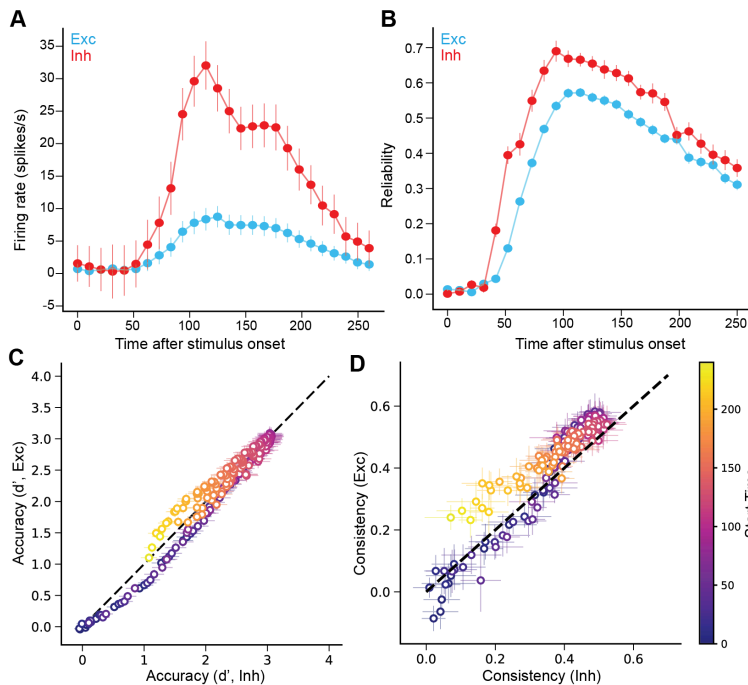


We chronically implanted Utah arrays to perform large-scale neural recording in passively fixating (100 ms presentation of images, followed by a 100 ms blank screen) monkeys ($n=3$). Monkeys ($n=3$) also performed a binary object discrimination task, where each sample image was followed by two choice token (target and distractor) and monkeys had to saccade to the target to get rewarded.

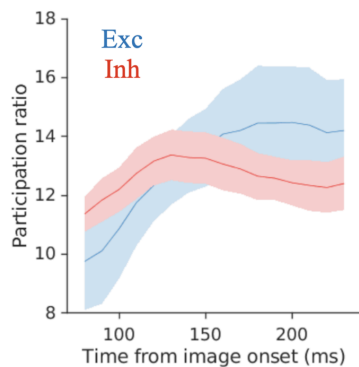


To classify neurons as excitatory and inhibitory we performed a series of steps. First we detected spike events via threshold crossings. We then used PCA to cluster the spike waveforms into individual neurons. We then used repolarization time and trough-to-peak duration based measures to classify the neurons into putative excitatory

(broad spiking) and inhibitory (narrow spiking) cell types.

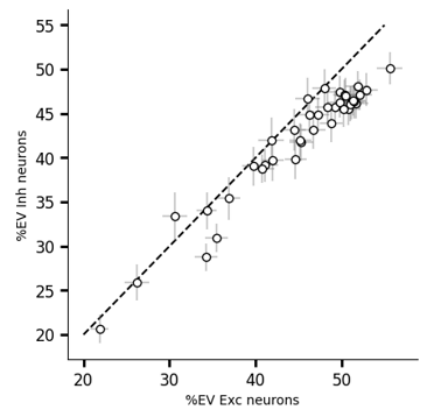
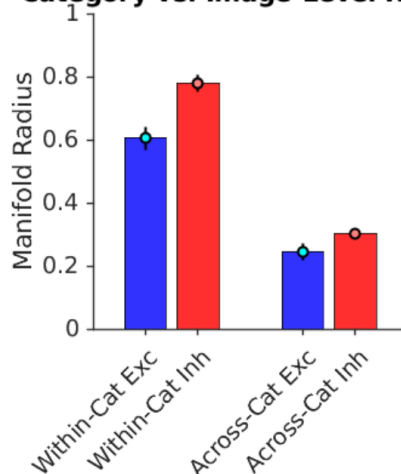


A. Firing rate of Exc and Inh neurons. **B.** Reliability of image responses (Exc and Inh). *Inh* shows reliability earlier than *Exc*. **C.** Decoding accuracy comparison. Each dot represents a choice of a temporal decoder (color shades indicate an increase in the start time of integration). *Inh* leads *Exc*, but they match in accuracy at a late phase. **D.** Consistency of decodes with monkey behavior. *Exc* > *Inh*.



Dimensionality across time. *Inh* leads *Exc*. At the end, *Exc* > *Inh*

Category vs. Image-Level Radius



Comparison of ANN IT predictivity. Each dot is an ANN (e.g. ResNet-50)