Researching Local and Long-Distance Circuits in the Mouse Visual Cortex

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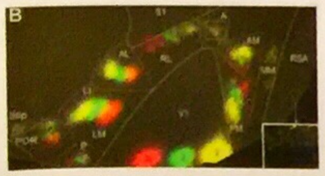
Introduction

The Life Sciences Summer Institute (LSSI) connects high school students with life science industries in San Diego. As part of the program, students complete a one-week pre-internship "boot camp" followed by a 7-week paid internship at a premier research institute.

Following the course, I joined the Systems Neurobiology Laboratory under the direction of Dr. Edward Callaway. The lab explores the various connections between cortical neurons and works to map cortical circuits.

Background

Anatomical and Functional Organization of Mouse Visual Cortex

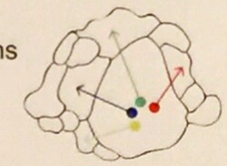


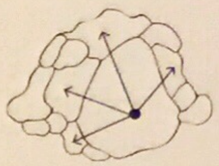
(Wang and Burkhalter, 2007)

Neurons in the primary visual cortex (V1) project to different higher visual areas (HVAs). Projections from V1 carry distinct visual information to the HVAs.

Two Extreme Models of V1 Projection Neurons

Solitary Projection: V1 projection neurons project to a specific HVA individually.



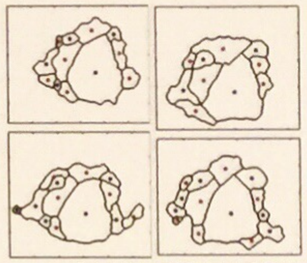


Manifold Projection: V1 projection neurons project to multiple HVAs.

Do V1 projection neurons project to a single area or to multiple areas?

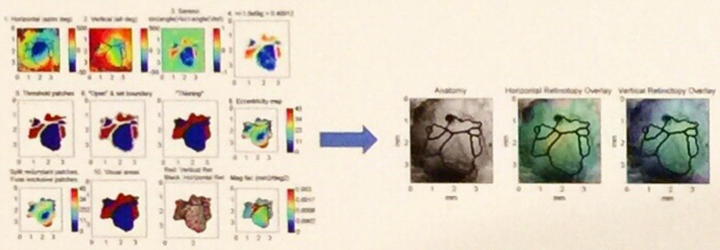
Methods

Intrinsic Imaging Signaling (ISI)



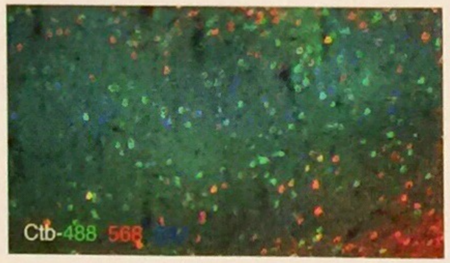
(Garrett and Nauhaus, 2014)

Because there are differences in cortical layout between individual mice, a brain atlas with a diagram of the visual cortex cannot be use. Instead, ISI is needed to create area maps for each specific mouse brain.



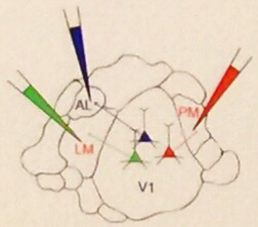
ISI creates blood flow maps by measuring the relative concentration of hemoglobin in different regions of the brain as the mouse's eyes are exposed to a stimulus. This information is translated into area maps by using a computer segmentation algorithm.

Cholera Toxin Subunit B Tracing



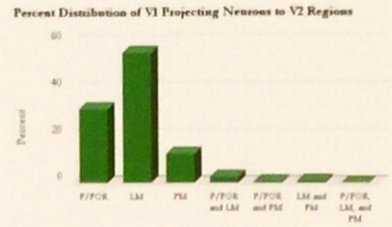
Cholera Toxin Subunit B (CTb) is a retrograde tracer, meaning that it travels in the opposite manner to that of a regular neuronal signal. CTb can be used to quantify the number of connections between cells in V1 and cells in the HVAs.

Injections of the dye are made directly into the various HVAs as shown. The dye is swept up by the V1 projection neurons, effectively labeling cells in V1 with the corresponding dye. Cells in V1 that project to multiple HVAs will show co-localization of dyes.

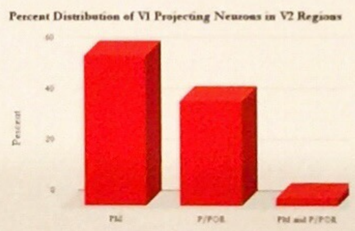


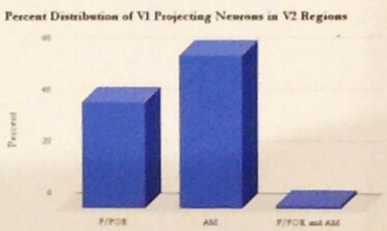
Results

The majority of V1 projection neurons project to a single area



Data from 3 different brains are shown, all traced with CTb. The data shows most V1 projection neurons project to individual HVAs instead of multiple HVAs, as evidenced by the lower columns showing co-localization.





Most V1 projection neurons are "solitary", projecting to only one area, and are thus labeled by a single CTb tracer.

Discussion

The CTb tracing data shows that the majority of V1 projection neurons are solitary. However, manifold projection seems to be the more efficient method for cell communication as one neuron can communicate with cells from many HVAs. One theory concerning the prevalence of solitary projection is that primitive neuronal networks may have had no evolutionary pressure for neurons to project to many HVAs since solitary projection is an inherently simpler model. A future area for research that arises from the conclusion that V1 projections are solitary is on the functional and morphological differences in V1 cells that allow a specific cell to communicate to a certain region and not another. This question is the next logical step for this investigation.

References

Wang, Q, and A Burkhalter. "Area Map of Mouse Visual Cortex." *The Journal of Comparative Neurology*, U.S. National Library of Medicine, 20 May 2007.

Garrett, M E, et al. "Topography and Areal Organization of Mouse Visual Cortex." *The Journal of Neuroscience*, U.S. National Library of Medicine, 10 Sept. 2014.

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