Saccadic eye movements in head-fixed mice, and the underlying changes in visual cortical activity

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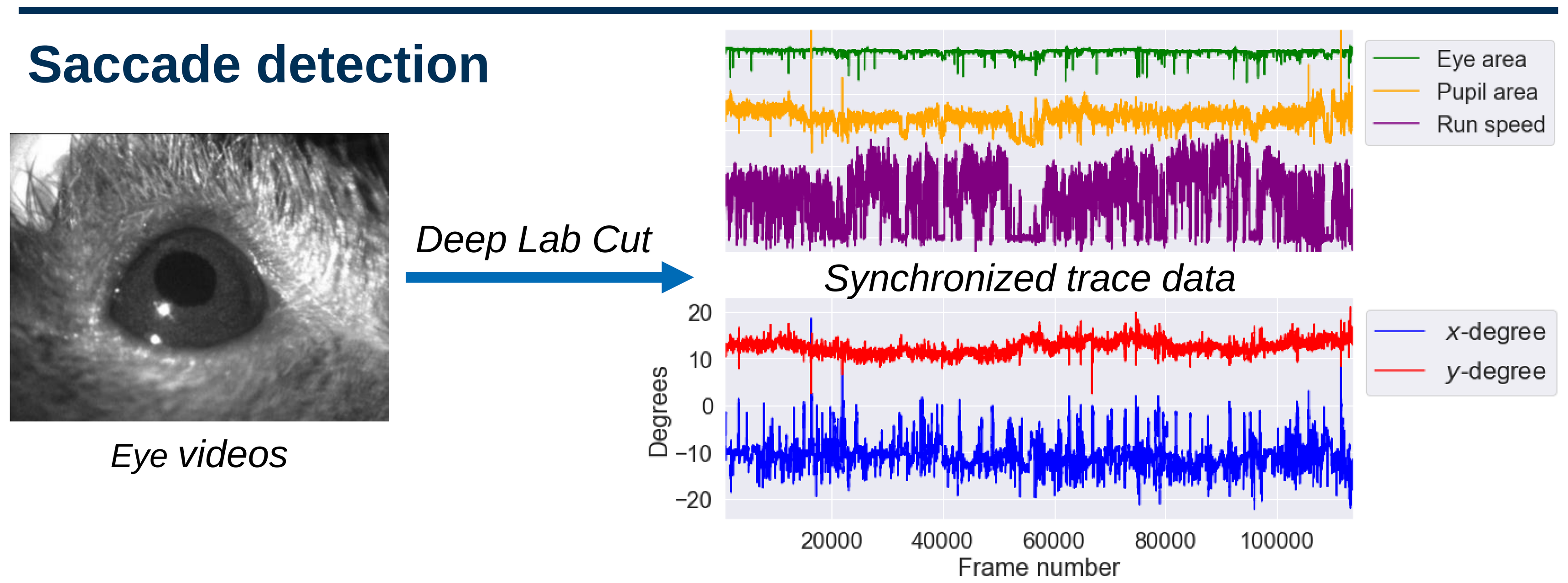
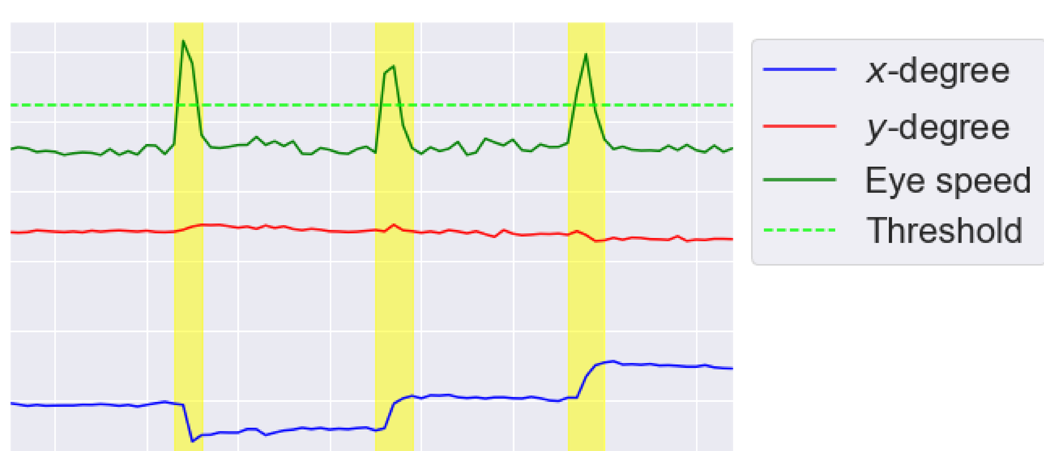
Introduction

- The Allen Brain Observatory Visual Coding datasets consist of neural recordings from thousands of neurons across 6 cortical areas, 4 layers, and 14 transgenically defined cell types in the mouse visual cortex [1; observatory.brain-map.org].
- Simultaneous video recordings of eye positions yields an additional unexplored eye position dimension to this dataset.
- It is unclear how saccades (rapid eye movements between points of fixation) play a role in visual processing.
- By studying the effects of saccades on neural activity, we hope to gain insight into their functional and computational roles in the brain.

Methods

Saccade detection



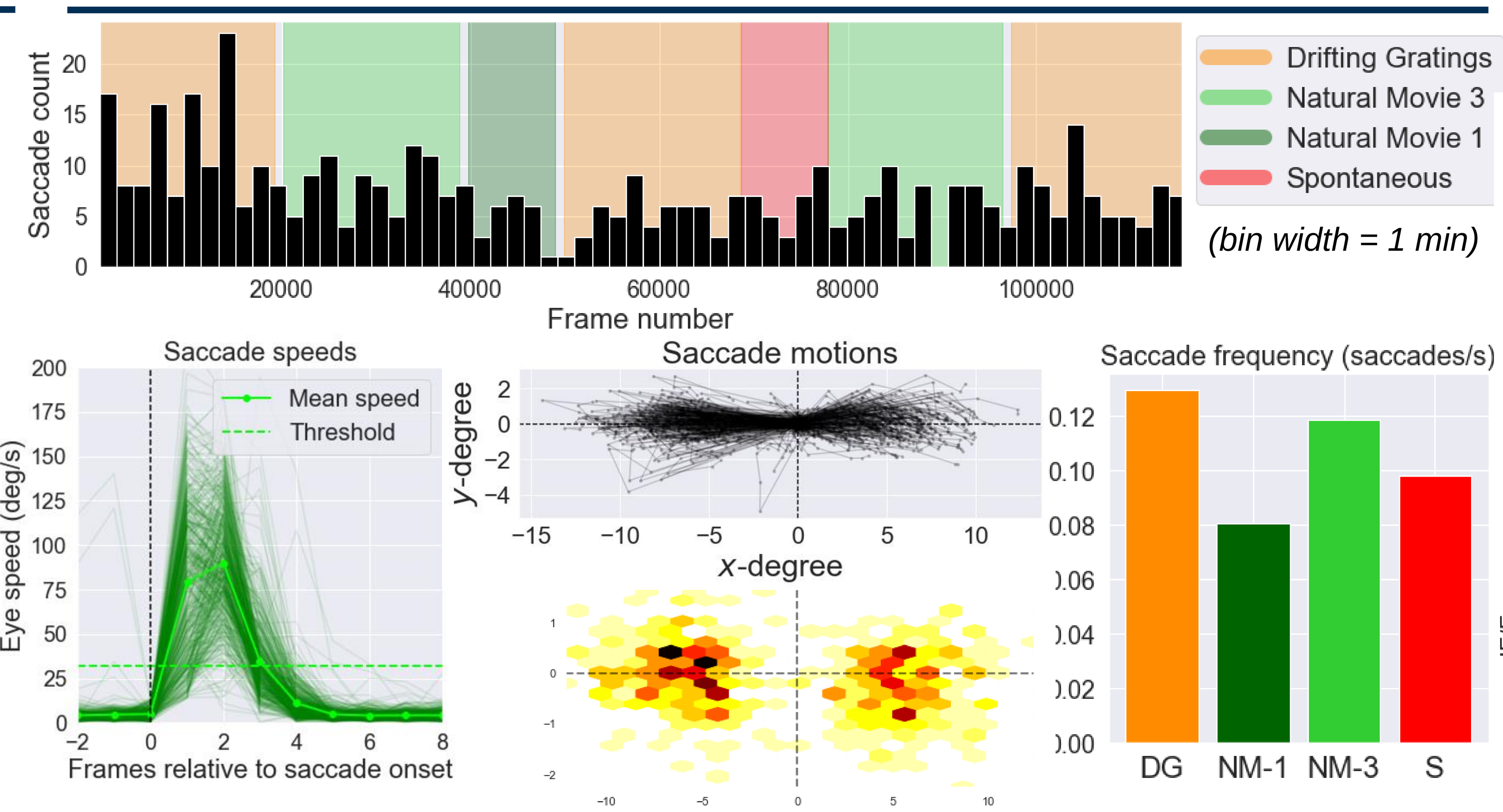


Saccade detection using eye-speed-threshold (3σ) [2]; filtering only >1.5-degree saccades

Neural activity analysis

We sought to characterize the extent to which neural activity changed in response to saccades. To do this, we used bootstrapping methods to compute percentiles and p-values to quantify the responsiveness of cells to saccades. Specifically, the mean dF/F trace for a cell around each saccade was compared to a $N = 1000$ bootstrapped distribution, and p-values for each time point around saccade onset were computed representing likelihood of the saccade-induced mean trace falling near baseline activity. Cells responding significantly to saccades were determined by investigating those that maximize the number of post-saccade significant p-values ($p < 0.05$). (See Figure 3.)

Figure 1: Experimental analysis of saccades



Session 595273803 (A), VISam, Rbp4, 375 μm, 466 saccades.

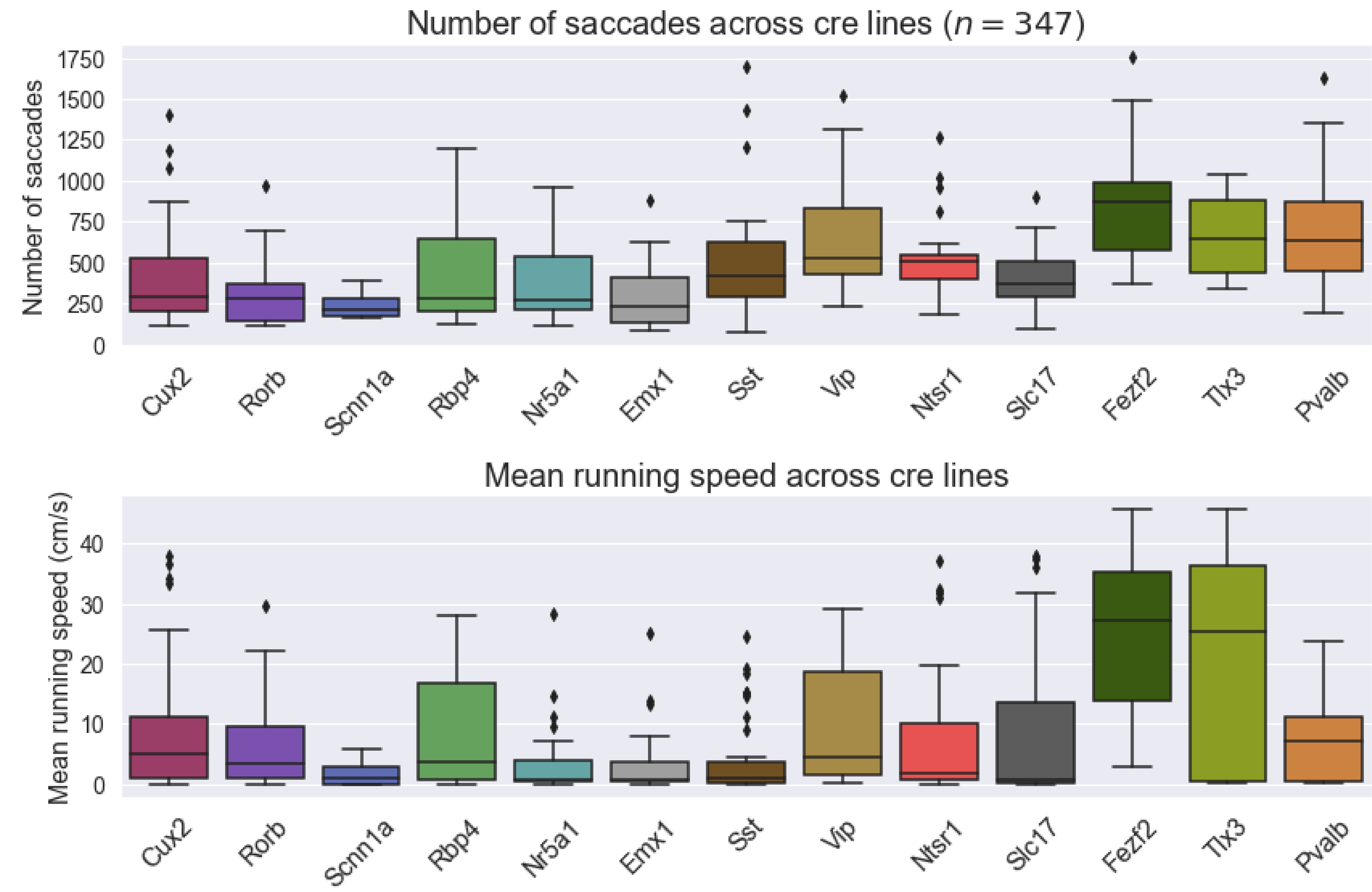


Figure 2: Mice make saccades more frequently when running faster

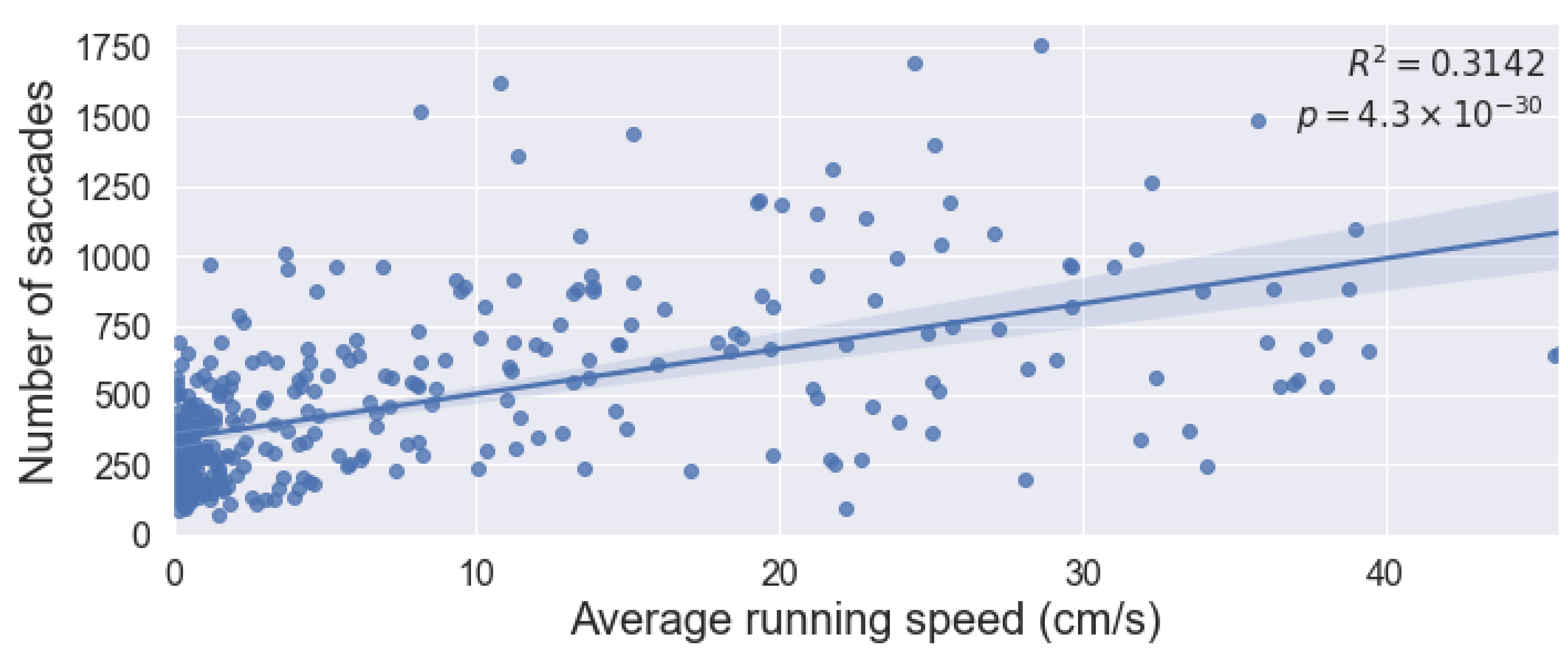
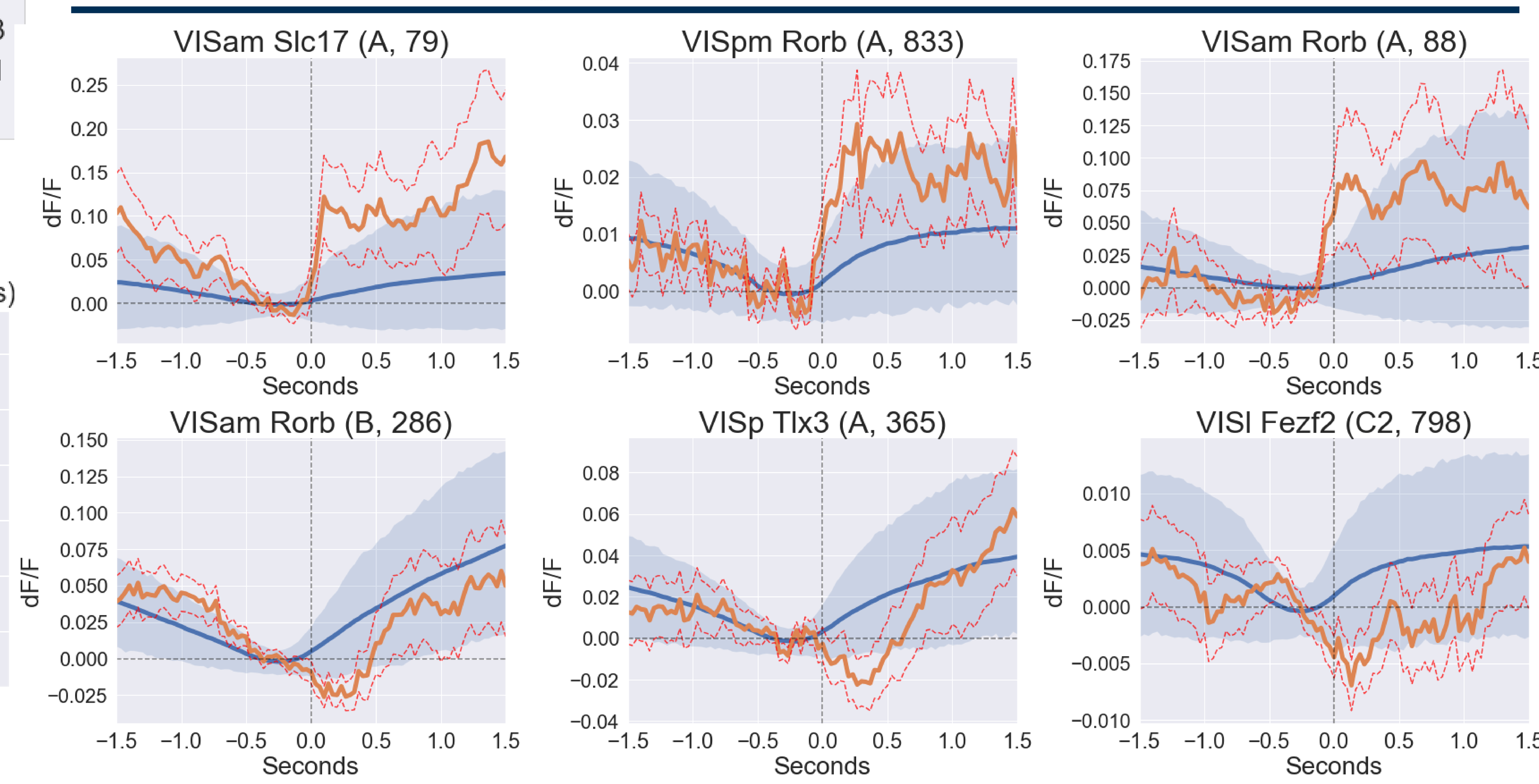
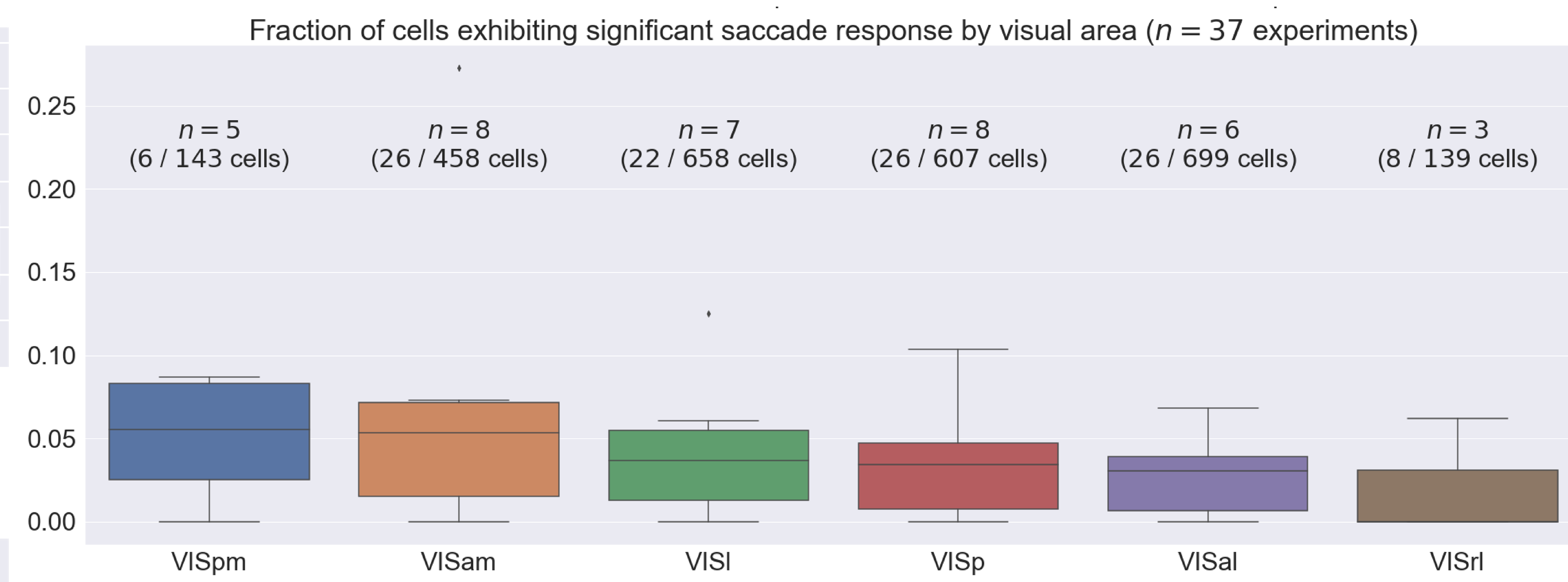


Figure 3: Cells exhibit diverse responses to saccades throughout visual cortex



Orange trace = mean across all saccades; blue = bootstrap mean; title includes session type and # saccades.



Conclusions

- Saccades occur preferentially in the horizontal direction, with a peak velocity on the order of 100 degrees/s.
- Fezf2, Tlx3, and Pvalb Cre lines yielded the highest numbers of saccades. Interestingly, these three Cre lines also yielded the highest mean mouse running speeds.
- There are visual cortical neurons that respond to saccades, either by increasing or decreasing activity. With our small sample size, saccade-responding cells were found mostly in PM and AM.

References

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