# Eye Movements Temporally Organize Spatial Representations in the Primate Hippocampus

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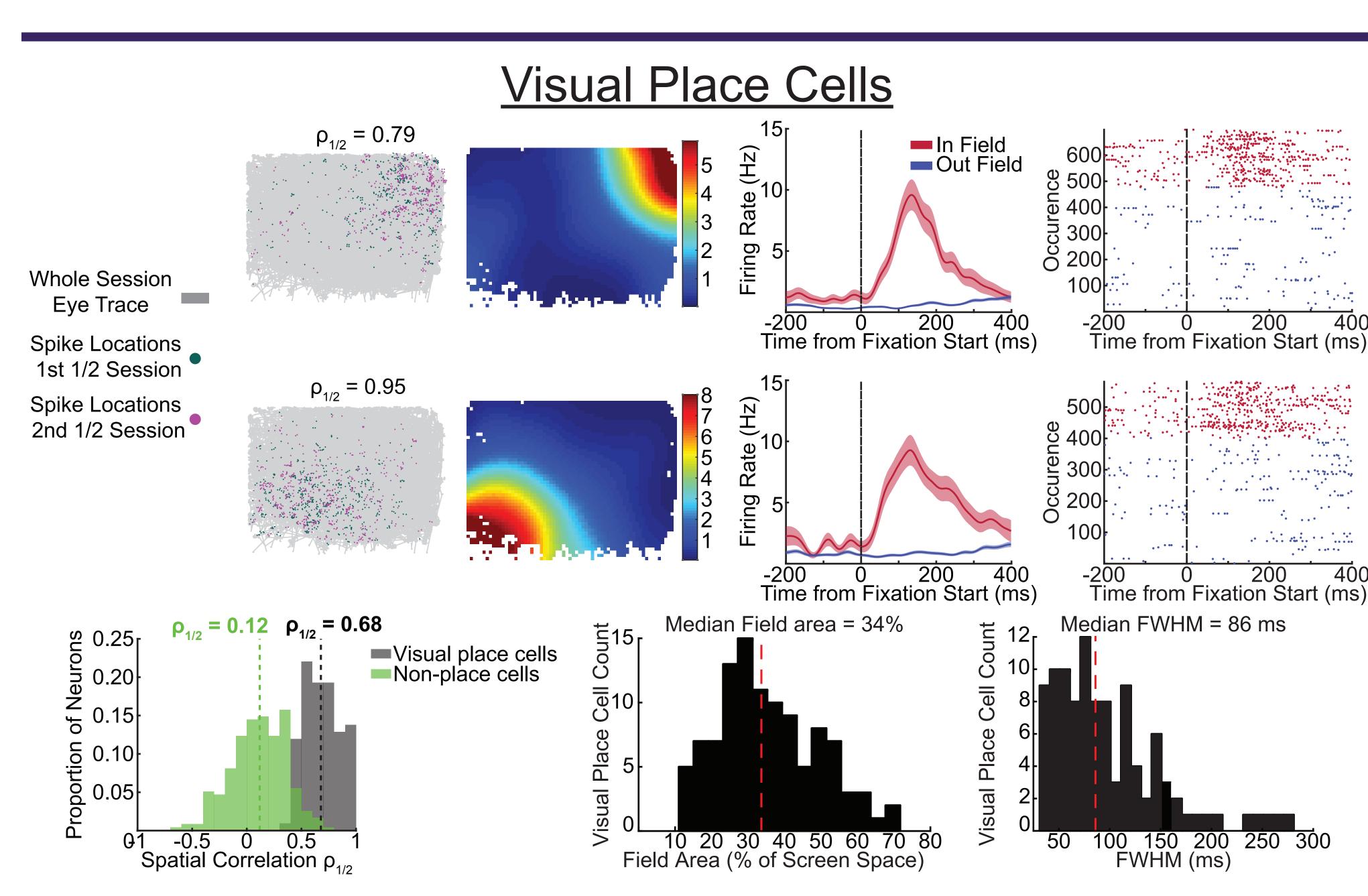
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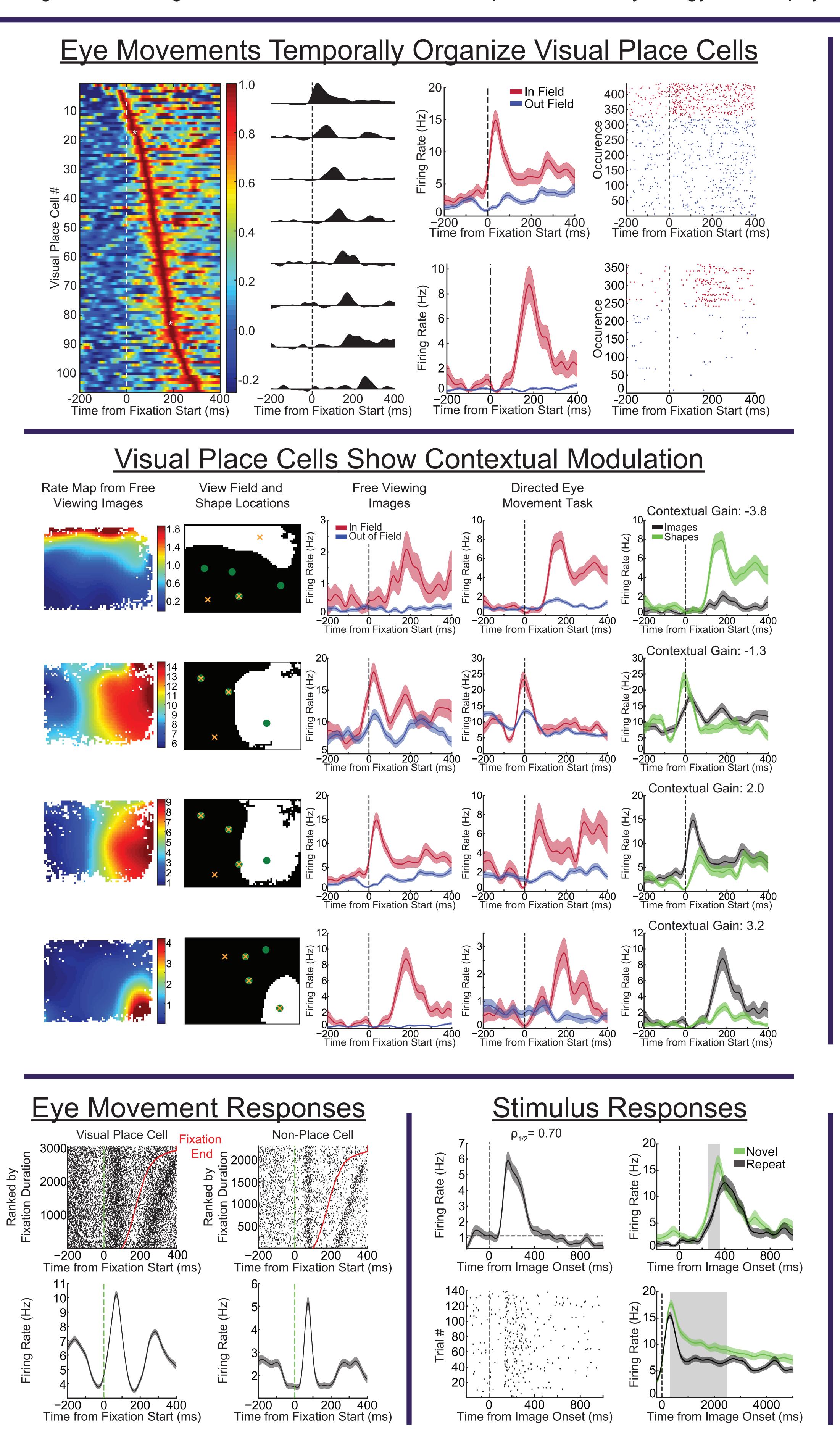
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#### Introduction

- Single unit recordings in the rodent hippocampus have revealed place cells (O'Keefe, 1971) and time cells (MacDonald et al., 2011; Pastalkova et al., 2008) that are hypothesized to support the spatial and temporal aspects of episodic memories.
- Neurons recorded in the primate hippocampus selectively respond when a monkey views portions of an environment, independent of the monkey's physical position (Rolls et al., 1997).
- Recent work in our lab identified visual grid cells in the primate entorhinal cortex which responded in a grid-like pattern reflecting gaze location during the free-viewing of images (Killian et al., 2012).
- Building upon this recent work, we recorded from 347 neurons in the hippocampus of 2 monkeys during the free-viewing of images and a directed eye movement task.
- Here we analyzed the spatial, temporal, and contextual properties of these hippocampal neurons.

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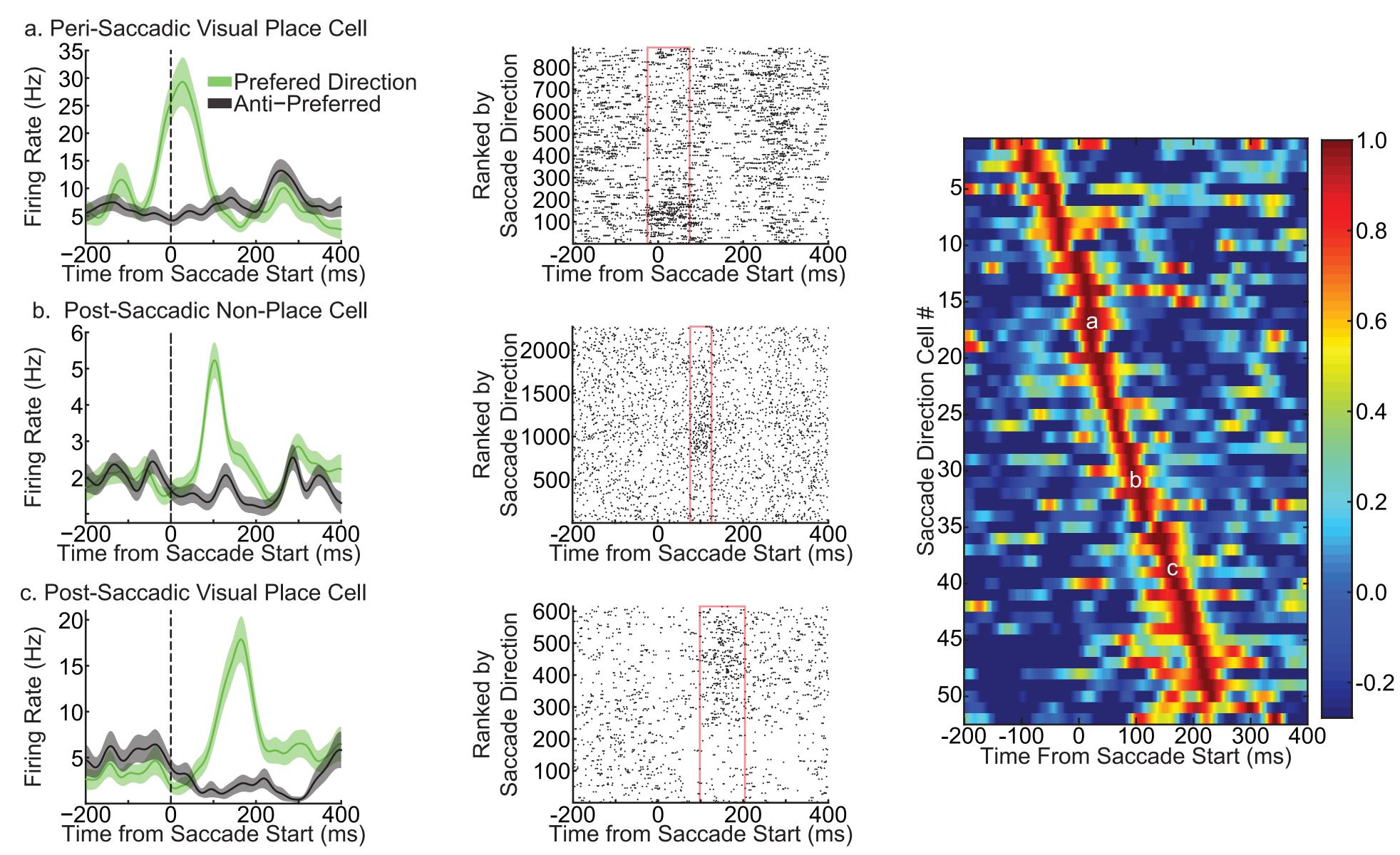




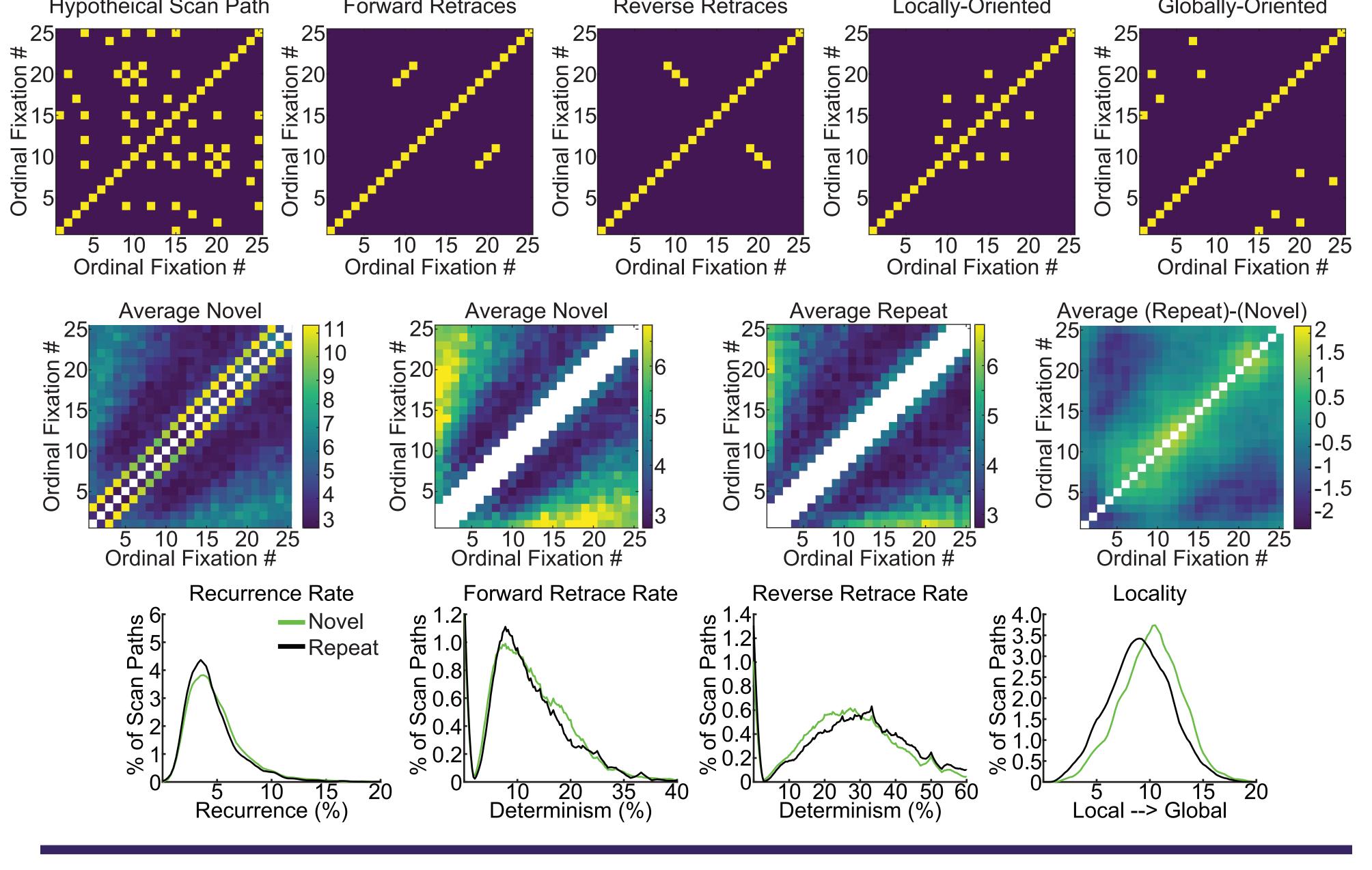
#### Conclusions

- · We identified 109 (31%) visual place cells in the primate hippocampus which selectively responded when the monkey fixated particular locations on the computer monitor.
- Eye movements temporally organized visual place cells with each neuron responding at a particular time relative to fixation onset. The population fully tiled the duration of the fixation.
  Visual place cells were modulated by context and fired ~2x faster for their preferred task.
- · 72% (78/109) of visual place cells responded to the presentation of the image stimulus and 51% of these neurons also differentiated between novel and repeated stimuli.
- 26% of neurons were modulated by saccade direction including 36% of visual place cells.
   Direction tuning was observed outside the place field in 72% of these neurons.
- Taken together, our results show that hippocampal neurons conjunctively code spatial, temporal, contextual, and stimulus information. These conjunctive response properties may support episodic memory formation.

### Saccade-Direction Modulation is also Temporally Organized



## Using Eye Movements to Build Spatial Relationships



#### **Acknowledgments**

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