Exploring the neural basis of visual processing in the freely-moving mouse

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Introduction

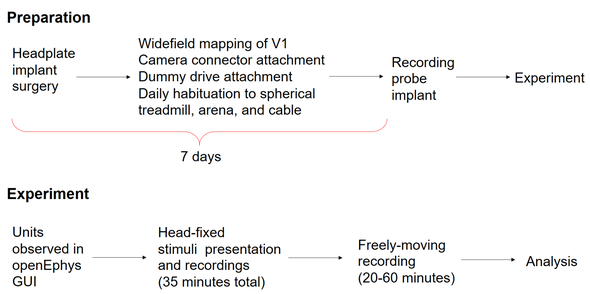
- Neurons in primary visual cortex (V1) are tuned to respond to visual stimuli with specific properties
- V1 is known to respond to non-visual signals, including signals related to movement of the body, head, and face
- Previous work investigating V1 is limited by experimental technique – it is difficult to record both brain activity and movements of a freely-moving animal, and analysis of this data is challenging given the lack of control over sensory input and action
- **We developed a novel technique to record and analyze electrophysiology data, as well as head/eye movements, body movements, and the animal's visual scene in order to investigate the integration of signals from multiple modalities in mouse V1**

How are movement signals integrated into the primary visual cortex?

Background

- V1 plays a role in important natural behaviors in mice, such as navigation and prey capture (Hoy et al., 2016), as it is known to process both visual and non-visual information (Parker et al., 2020)
- Locomotor activity modulates response magnitudes and spatial integration in V1 neurons (Niell & Stryker, 2010; Ayaz et al., 2013)
- Eye movements signals in V1 (Musall et al., 2019)
- Head movement signals are integrated into V1 (Guitchounts et al., 2020) and are dependent on environmental luminance (Bouvier et al., 2020)
- Mismatch signals between optic flow and running speed in V1 (Saleem et al. 2013; Keller et al., 2012)

Methods



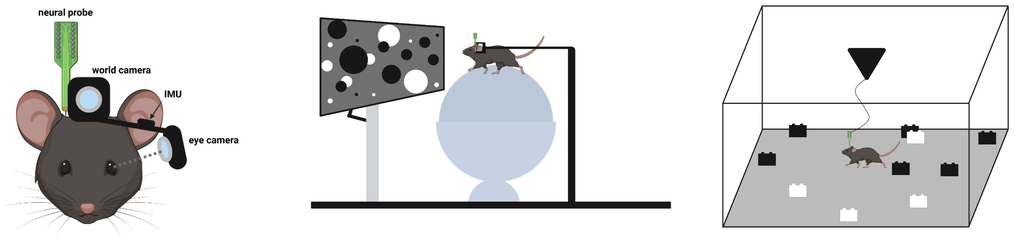


Figure 1. **Head attachments and head-fixed and freely-moving experimental setups. Left**: Electrode, world camera, IMU, and eye camera attachment. **Middle**: Schematic of head-fixed experimental setup. **Right**: Schematic of freely-moving experimental setup.

Results

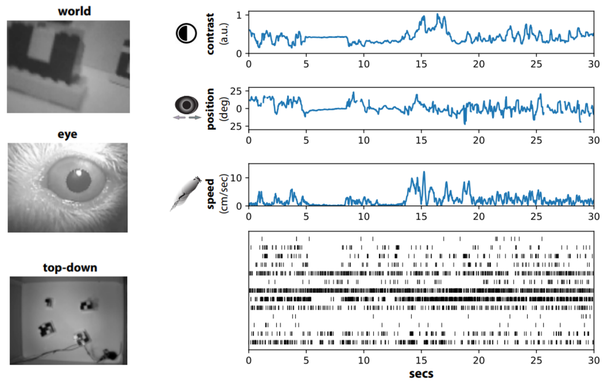


Figure 2. Frames from worldview camera, eye camera, and top-down arena camera; traces of worldview camera contrast, pupil position, and running speed during recording, aligned with raster plot of all recorded units

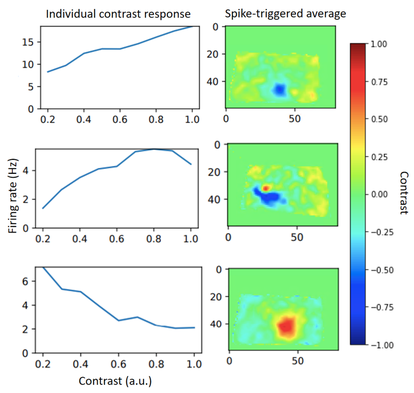


Figure 3. Individual contrast response plots and spike-triggered averages of three V1 units.

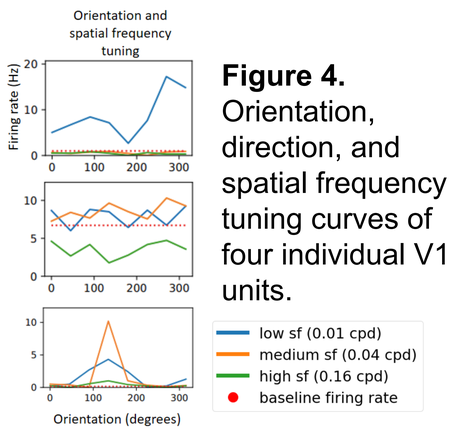


Figure 4. Orientation, direction, and spatial frequency tuning curves of four individual V1 units.

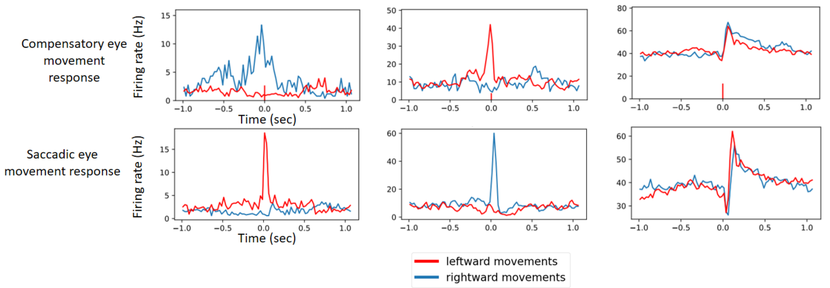


Figure 5. Individual responses of V1 neurons to compensatory eye movements and saccadic eye movements.

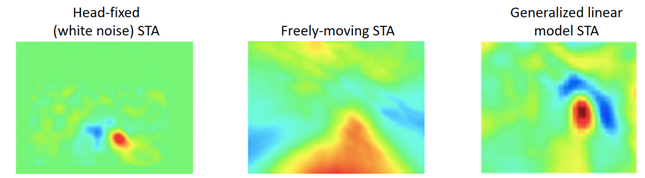


Figure 7. Head-fixed STA, freely-moving STA, and STA generated from generalized linear modeling (GLM) of freely-moving data.

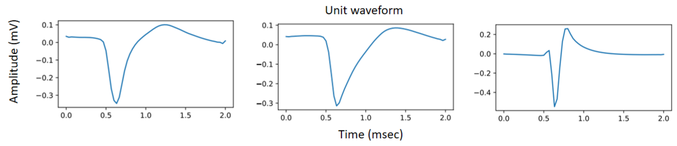


Figure 6. Action potential waveforms of three individual V1 units.

Future Work

- Next, we will perform population-level analyses of the response of V1 neurons to head movements and eye movements, as well as determine the relationship between visual and non-visual signals in V1.
- Our novel technique of aligning electrophysiology data with other signals can be used to investigate the activity of other brain regions, and we can introduce trained behaviors into the paradigm to determine the neural correlates underlying behavior.

Acknowledgments

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