

Mixed selectivity in mouse V1 revealed with visual stimulation in freely moving virtual reality

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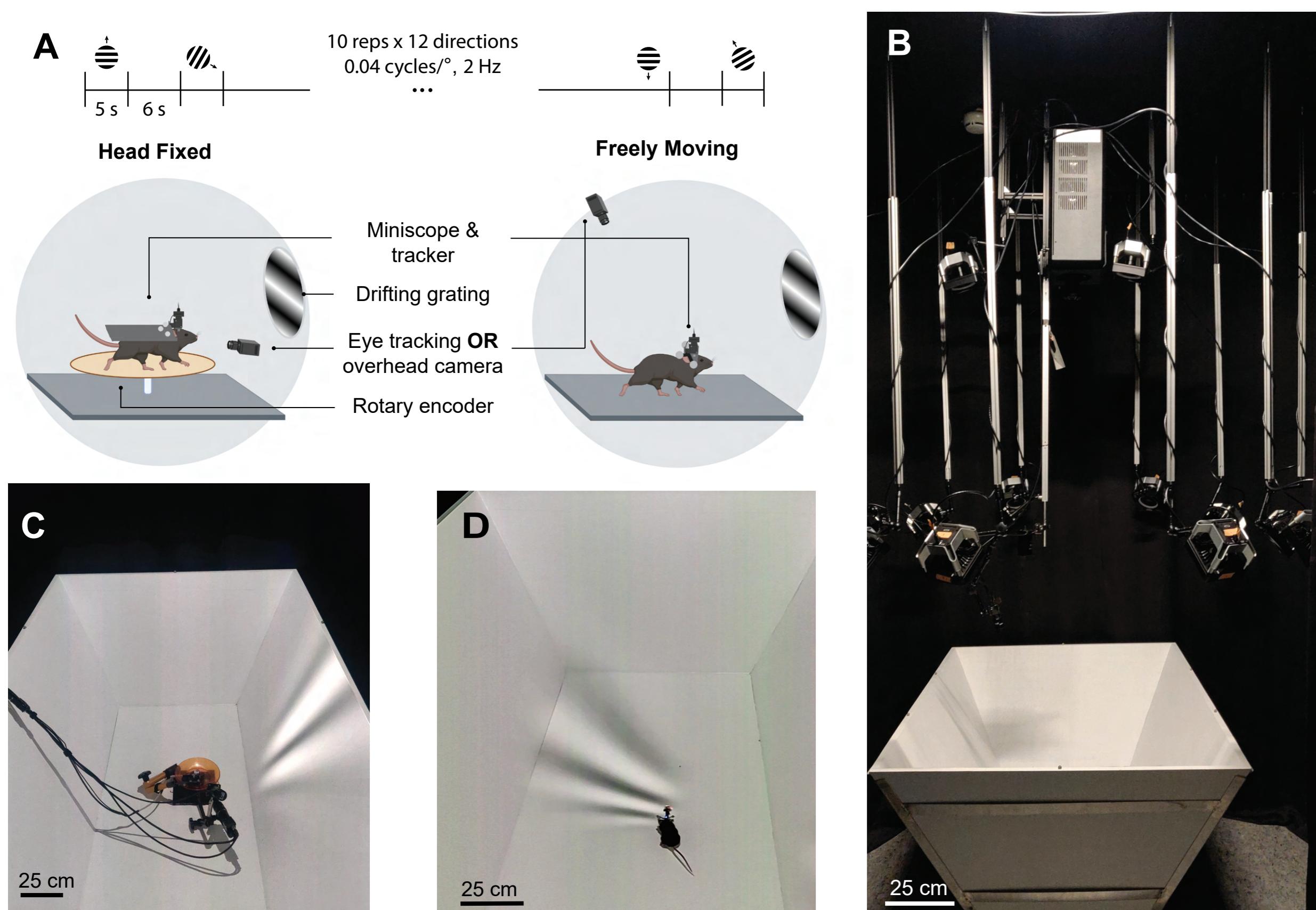


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INTRODUCTION

- Neurons in V1 are classically described by selectivity for visual stimulus features or non-visual variables during head-fixed experiments.
- Recent work has examined luminance selectivity and visual receptive field structure in freely behaving rodents [1-4], but to date no other visual tuning properties have been analyzed in unrestrained contexts.
- We present a method to measure neuronal activity in response to visual stimuli and motor activity during free behavior. We use wireless minisscopes while presenting drifting grating Gabor patches to mice in an immersive virtual reality (VR) arena.
- We find similar distributions of direction and orientation selectivity in both cells matched and not matched between head fixed and freely moving sessions. Cells matched between sessions are dominated by visual tuning, with smaller numbers modulated by self-motion.

1 Visual stimulation in freely moving VR & wireless Ca^{2+} imaging of V1 neurons

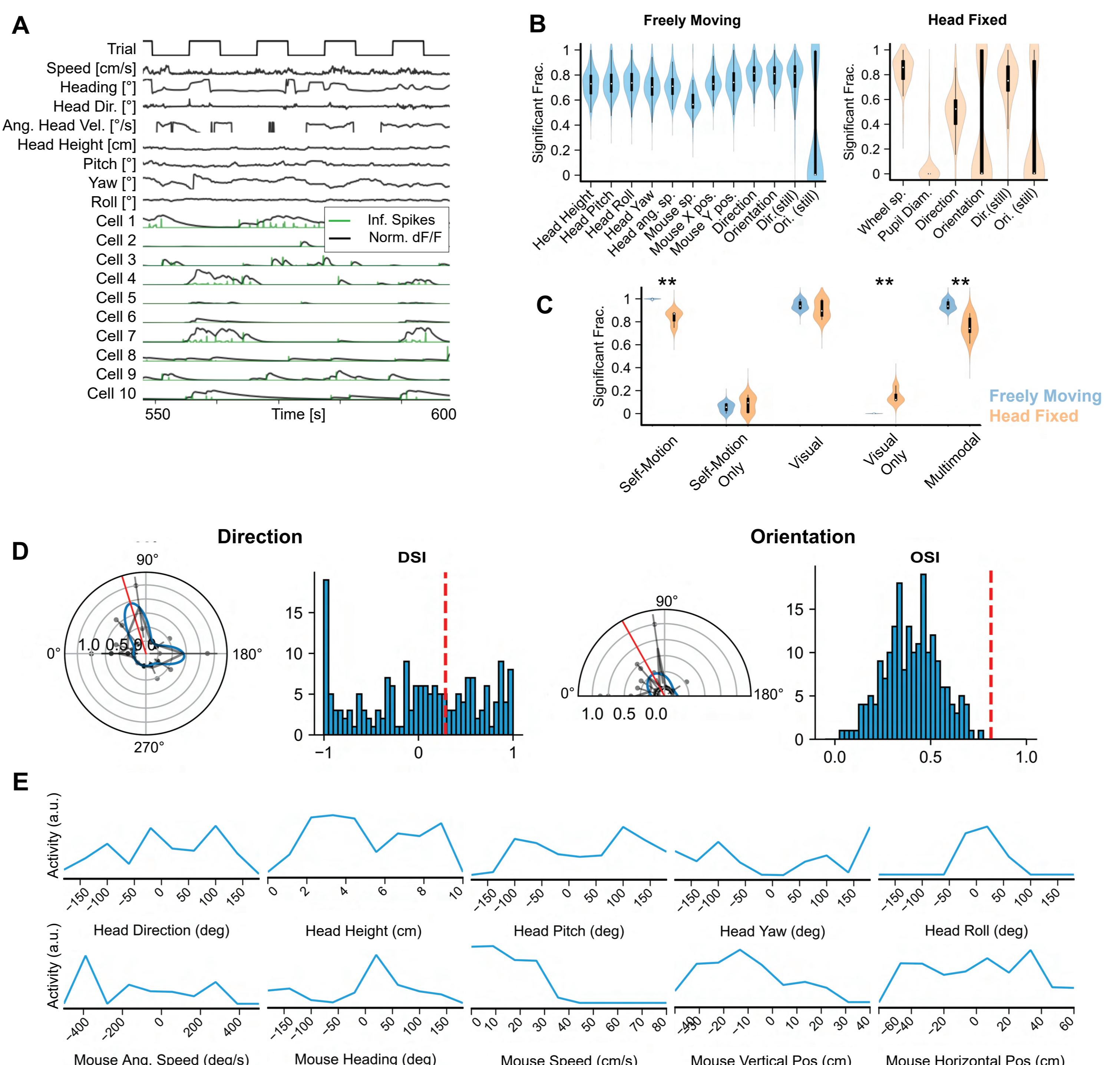


A. Experimental schematic for comparing visual and self-motion tuning between head fixed and freely moving sessions. **B.** VR arena. Mouse head position and rotation were tracked by 12 IR motion capture cameras. Visual stimuli were rendered in Unity3D. **C.** Drifting Gabor patch presented during a head fixed experiment. **D.** Same as C, but freely moving. **E.** Mouse with headbar, head tracker, and UCLA wire-free miniscope V3. **F.** Max projection and ROIs (green, CNMF-E [5]) from an example field of view. soma-GCaMP7f was expressed in superficial V1 either via injections or using silk fibroin films [6].

References

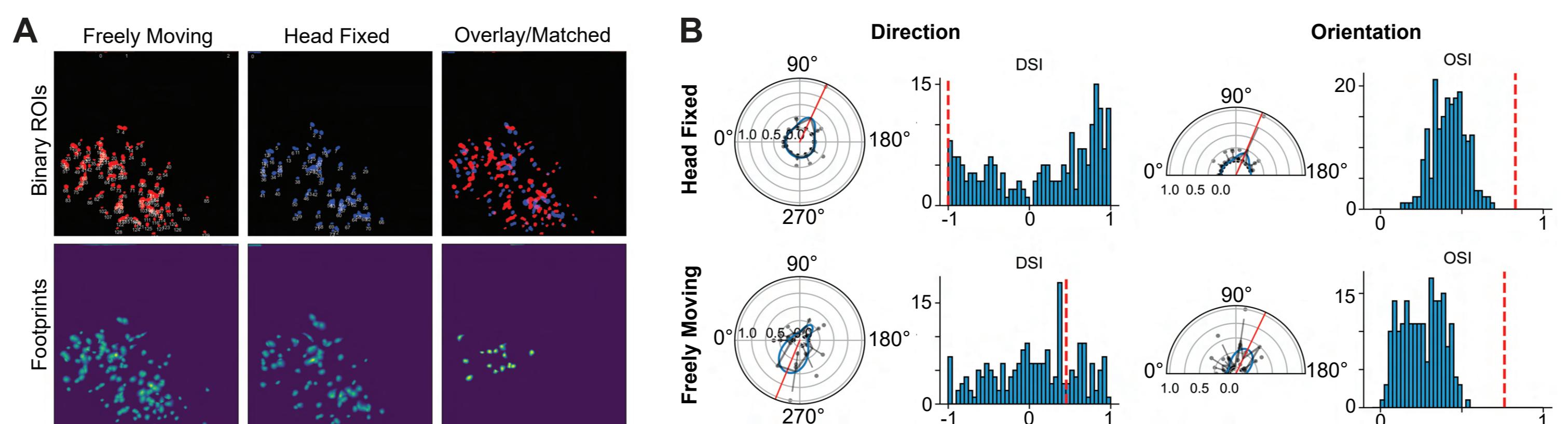
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2 V1 neurons respond to visual stimulus direction/orientation and self-motion



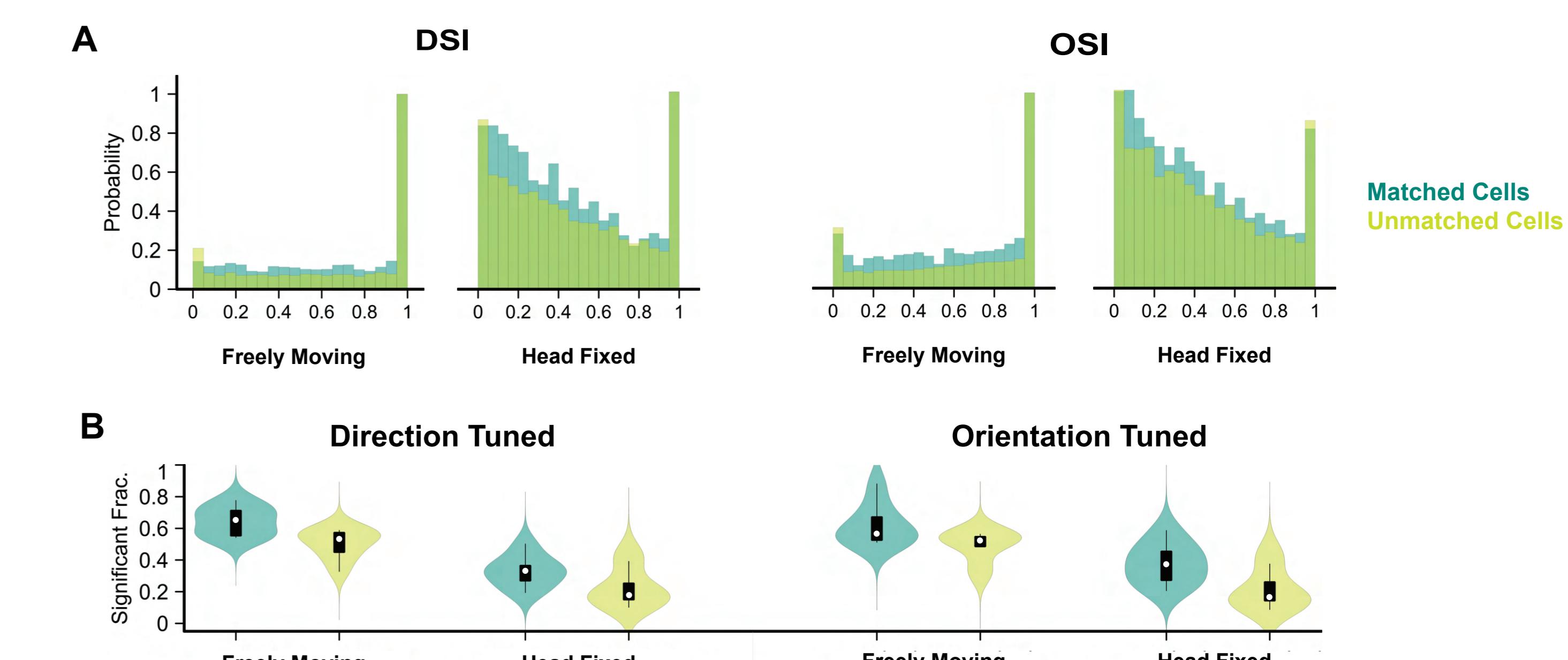
A. Ethogram from 50s of a freely moving experiment. **B.** Fraction of cells across mice ($n=8$) significantly tuned to self-motion or visual stimulus variables. **C.** Fraction of cells across all mice significantly tuned to at least one self-motion or visual feature, or to a combination of features. **D.** Direction and orientation tuning (polar plots) for an example cell under freely moving conditions. Direction and orientation selectivity (red line) compared to a bootstrapped distribution (histogram). **E.** Self-motion tuning curves for the same cell as in D.

3 Direction/orientation tuning in matched cells



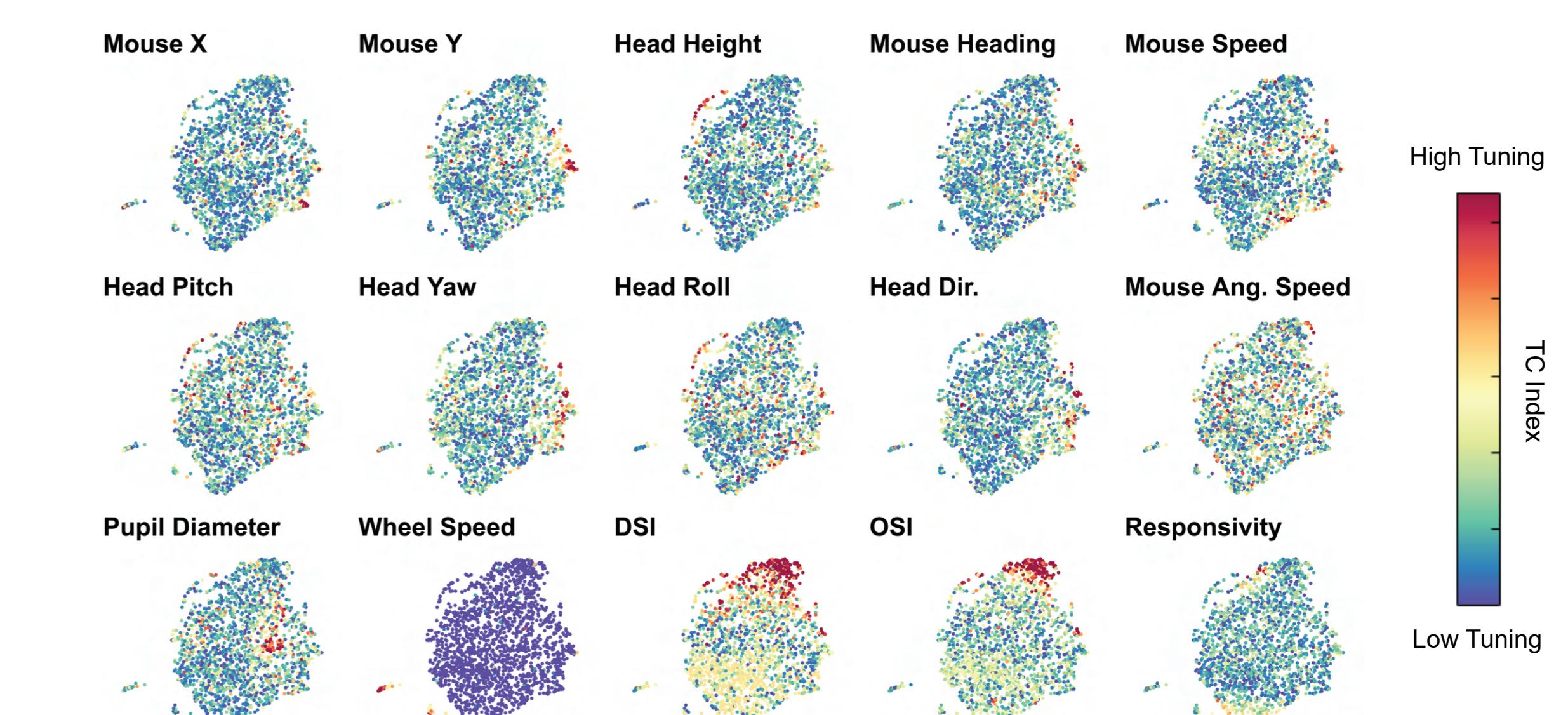
A. Example cell matching between freely moving and head fixed experiments. Briefly, an intersection over union metric and the Hungarian metric for optimal matching are applied for all ROIs between paired sessions. ROIs are considered matched if their centroids are within 15px. **B.** Example visual tuning curves as in Fig. 2D.

4 Visual selectivity is similarly distributed between matched and unmatched cells



A. Distributions of direction and orientation selectivity indices (DSI and OSI) for matched ($n=1948$) and unmatched ($n=28,930$) cells. **B.** Significant fraction of moderate to strongly tuned cells ($|DSI| > 0.5$) for matched and unmatched cells.

5 Matched cell tunings are dominated by direction & orientation with clusters modulated by self-motion



UMAP embedding of all matched cells ($n=1948$) for all recorded variables across both freely moving and head fixed sessions.

OUTLOOK

- We present a VR experimental paradigm that allows for precisely controlled presentation of visual stimuli to freely behaving mice with simultaneous wireless miniscope recordings.
- V1 neurons exhibit tuning to both visual and self-motion variables during free behavior and head fixation.
- DSI and OSI distributions are similar between matched and unmatched cells.
- Matched cell tunings are dominated by direction and orientation with clusters modulated by self motion.
- Ongoing analysis is focused on determining the relative weights of visual stimuli and postural variables on neural activity.



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