A Free-moving Virtual Reality System to Probe Interactions between Head Direction Cells and Visual Inputs

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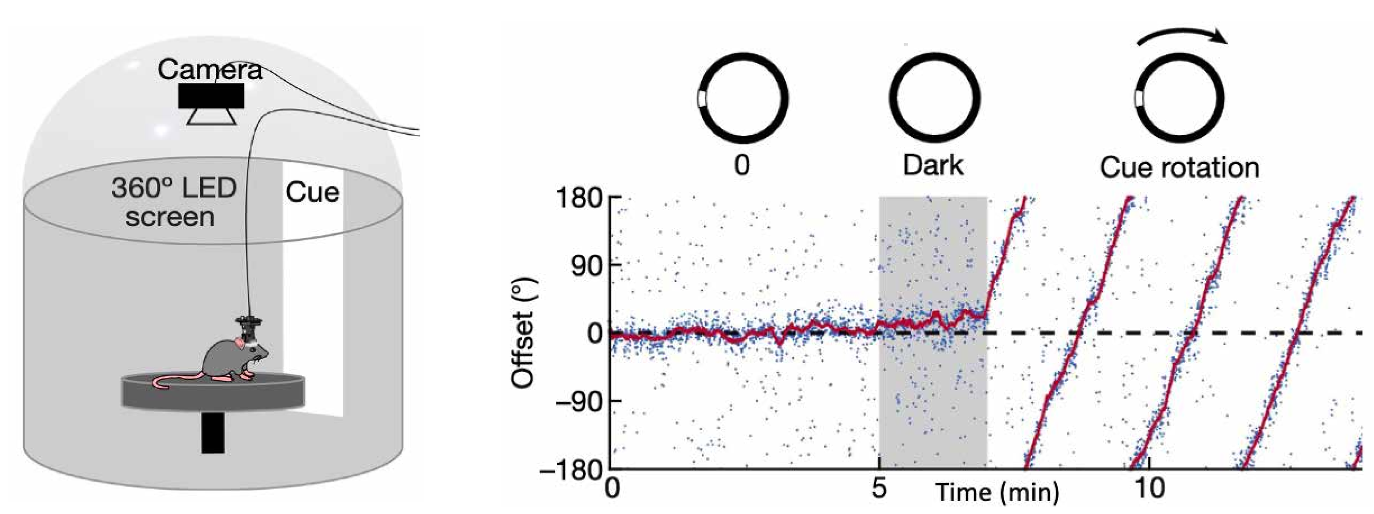
1. Background

Accurate navigation requires maintaining an estimate of allocentric heading while animals move through the environment, despite noisy self-motion signals and changing sensory inputs. Head direction (HD) cells provide a robust neural representation of heading in freely moving rodents and have been identified in cortical structures such as the postsubiculum, the anterior dorsal thalamic nucleus (ADN), and several other brainstem areas. HD representations are updated by integrating self-motion signals and are anchored to surrounding visual landmarks. However, a key question remains: how does the brain integrate visual and motor signals to update its HD representation during active scanning of the environment? During scanning behaviors, such as head orienting, sensory and motor signals must be integrated coherently to construct an internal cognitive map of the external world.



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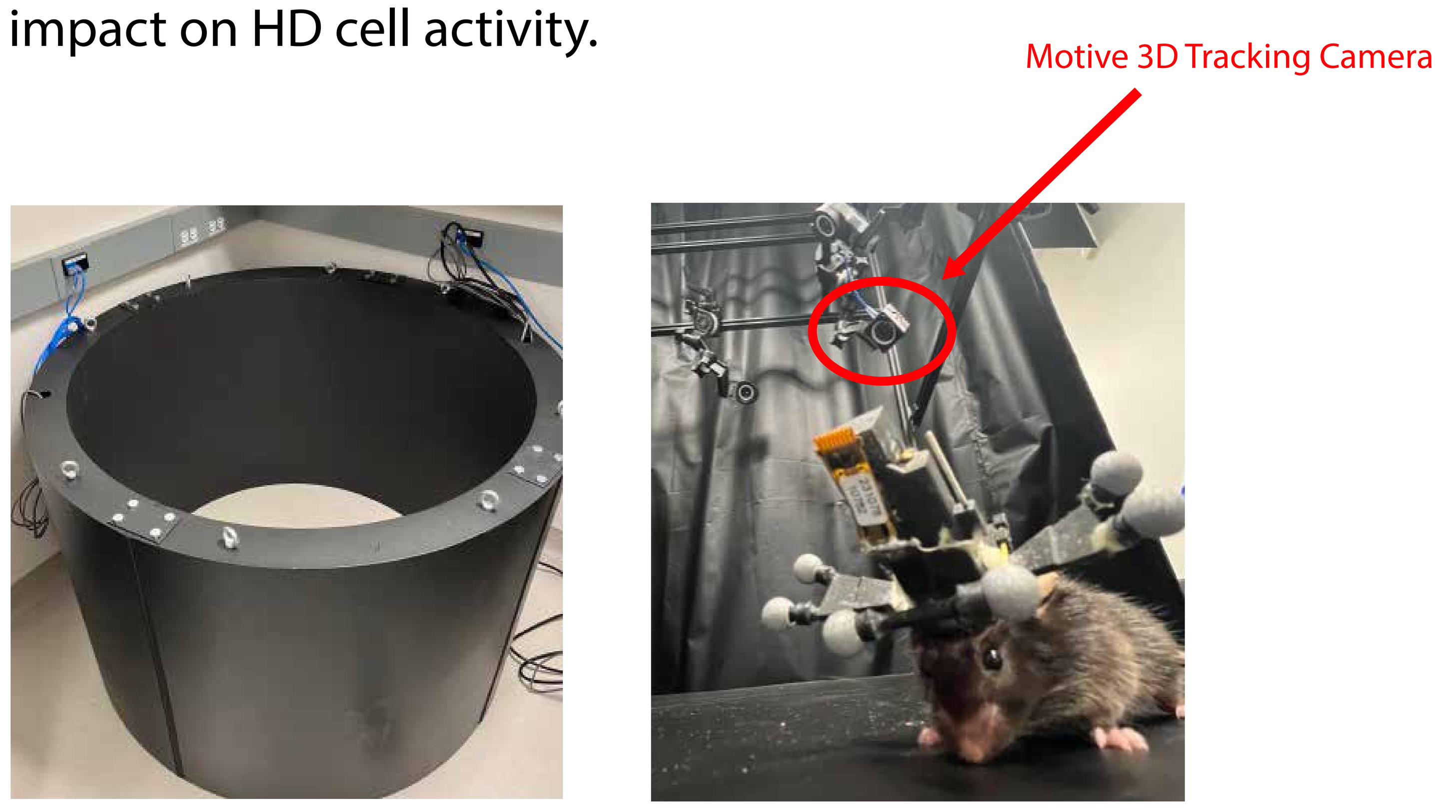
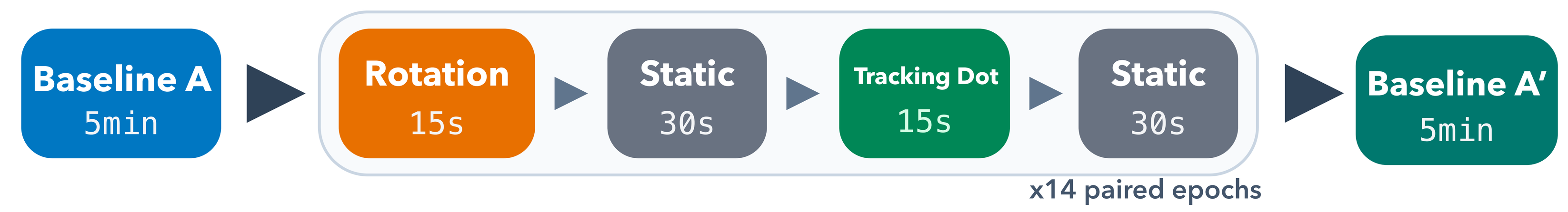
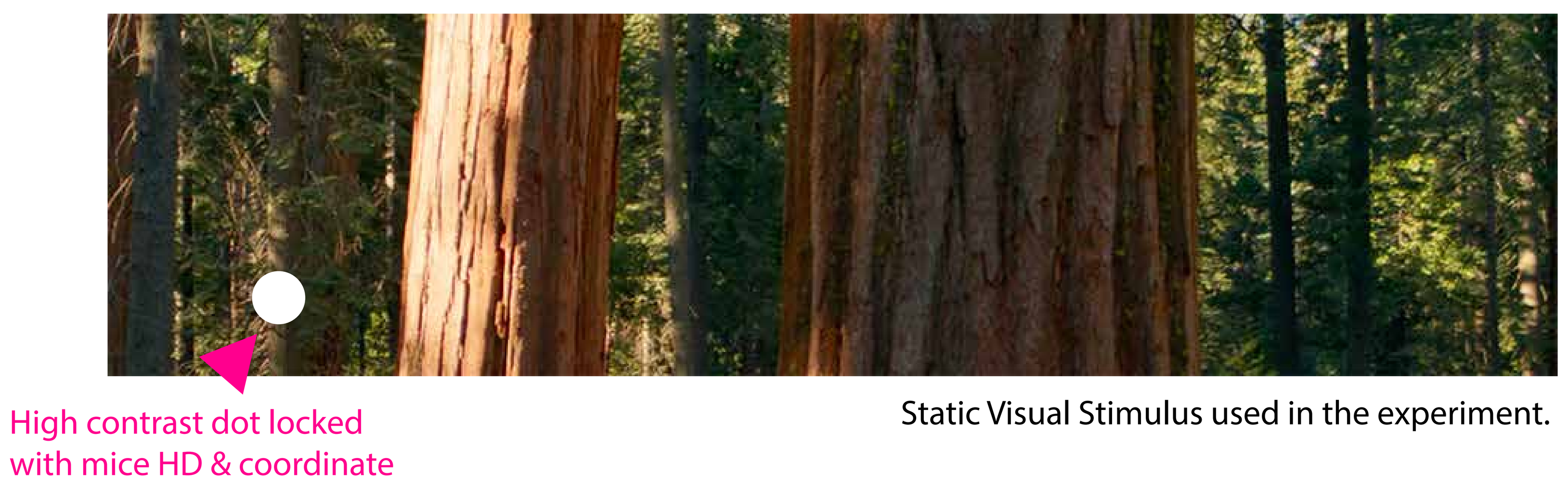
To address this question, we require an experimental system that allows manipulation of surrounding visual landmarks during scanning behaviors. To this end, we developed a free-moving virtual reality system in which real-time 3D tracking of the animal dynamically updates visual stimuli on a surrounding 360° LED display. Using this platform, we aim to introduce controlled visuo-motor mismatches during scanning behaviors and probe their impact on HD cell activity.

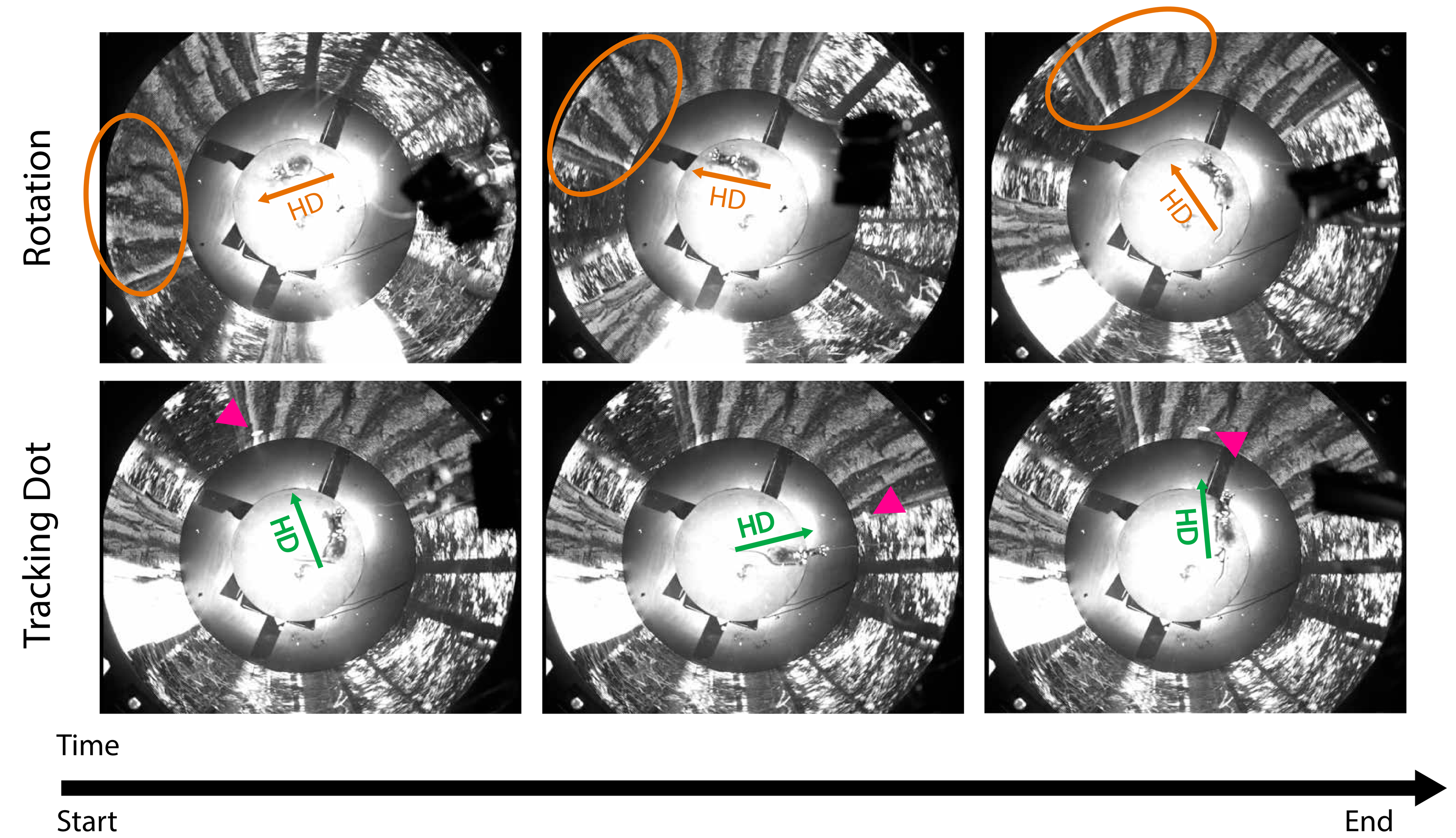


2. Experimental Design

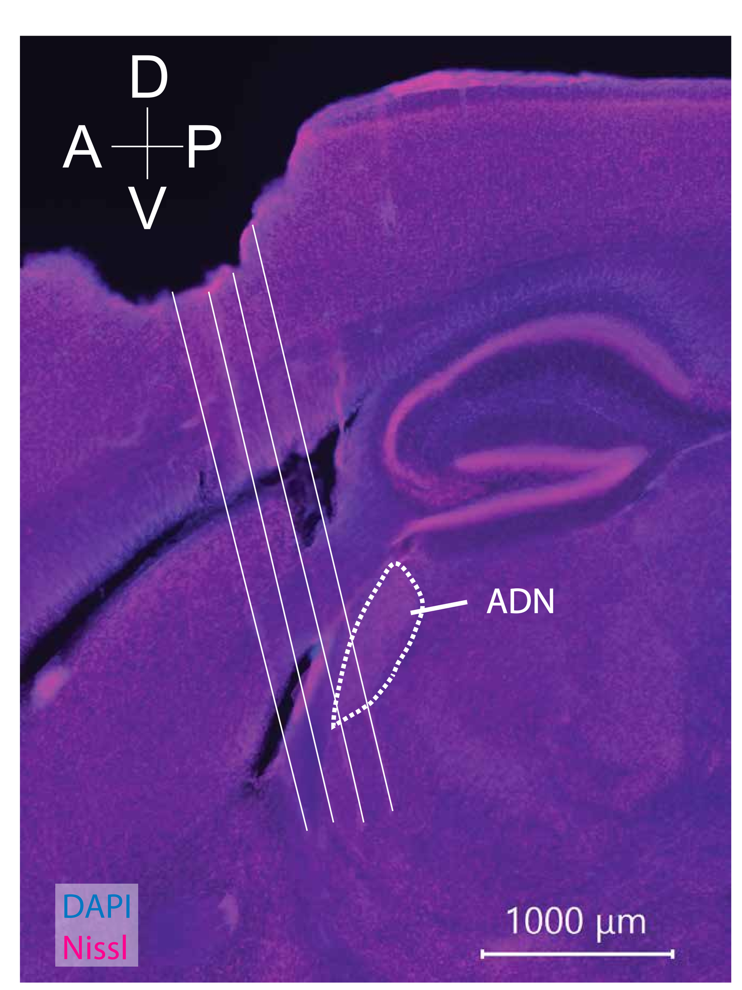




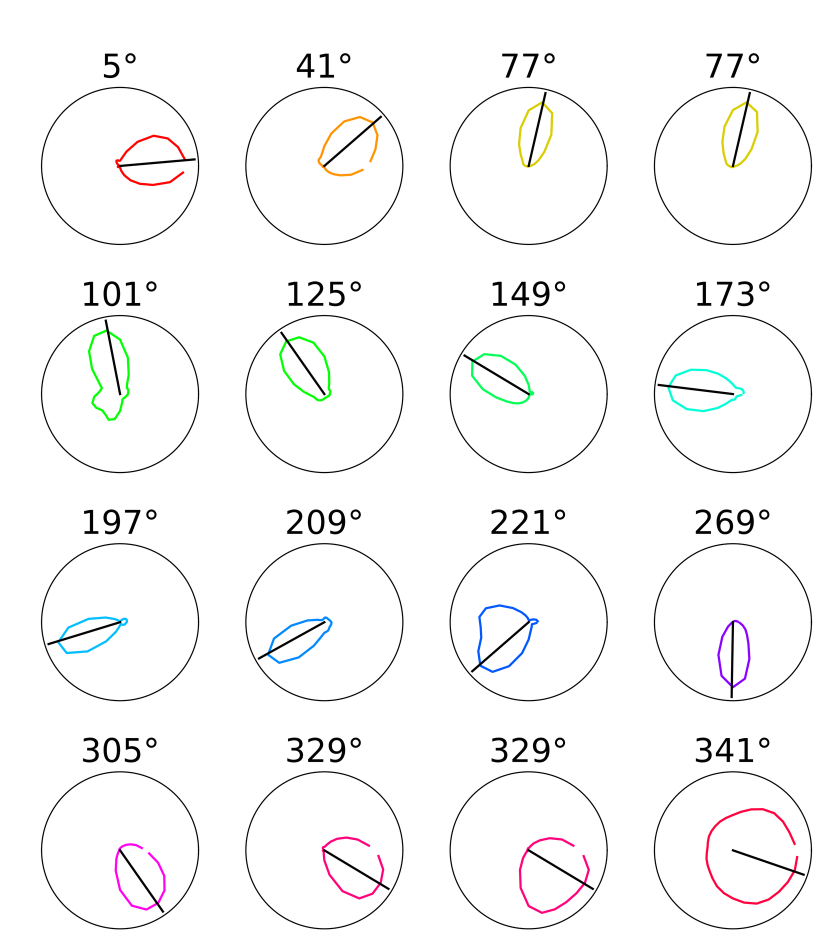
Static Visual Stimulus used in the experiment.



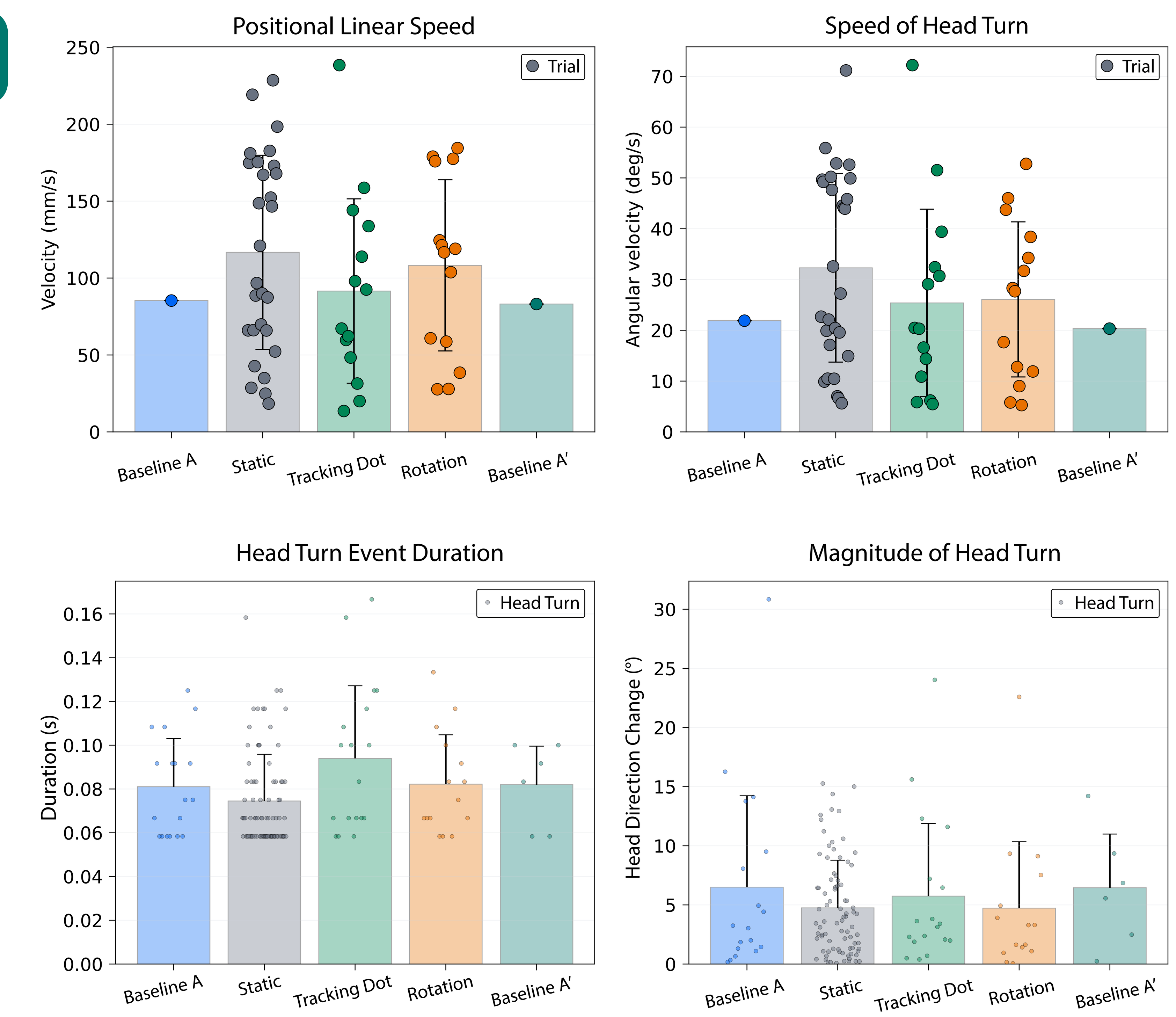
3. Recorded HD cells from ADN via Neuropixels



Tuning Curves of ADN HD Cells



4. Behavioral Data from 360º LED display



5. Summary and Discussion

We have developped a free-moving virtual reality system by combining a multi-camera 3D positioning system and real-time visual rendering on a 360º LED display.

With this system, we have created an integrative mismatch between the execution of motor command (i.e. head turns) and visual feedback within the arena.

This visuo-motor mismatch impacts the animal’s behavior minimally.

We will test how the HD cells in the ADN respond to visuo-motor mismatch.

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