A locomotor rhythm organizes directional firing of neurons in the superior colliculus

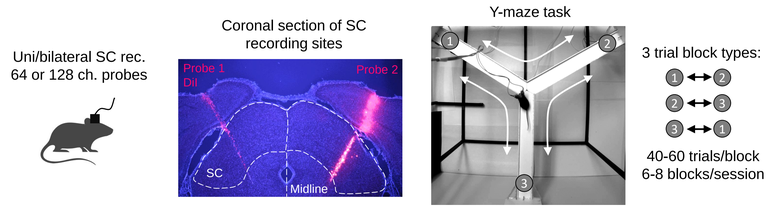
Cameron Wilhite [1], Loren Frank [2,3,4,5], Massimo Scanziani [2,4,5]

1) Neuroscience Graduate Program, 2) Department of Physiology, 3) Department of Psychiatry, 4) Howard Hughes Medical Institute, 5) Kavli Institute for Fundamental Neuroscience, UCSF, San Francisco, CA

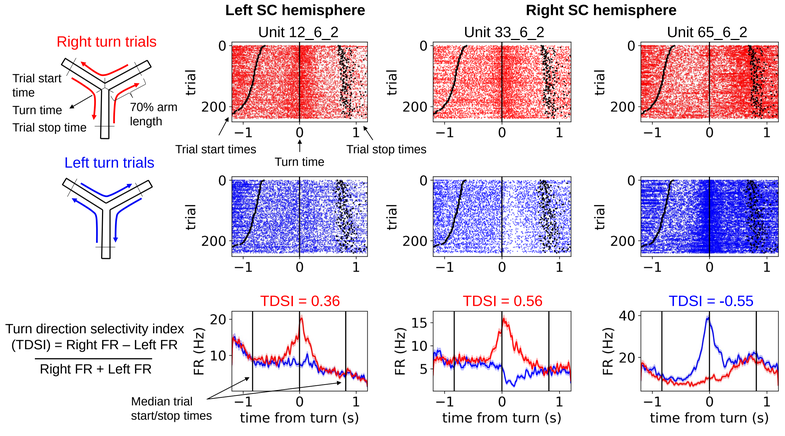
Abstract

Studies investigating the role of the superior colliculus (SC) in orienting behavior have traditionally involved partially restrained animals performing orienting movements toward external stimuli. Accordingly, how neural activity in SC is organized during freely moving, internally driven behaviors is unknown. Here we record SC neurons in freely moving mice during a Y-maze spatial foraging task and identify neurons that preferentially fire during either left or right turns at the bifurcation of the maze. Remarkably, we show that a subset of these neurons fires rhythmically, in phase with a ~6 Hz left/right head oscillation that is characteristic of locomotion. Strikingly, a neuron's turn direction preference on the Y-maze (i.e., selective firing during left or right turns) largely determines its preferred firing phase relative to the locomotor rhythm. During this preferred firing phase, the preferred turn direction of SC neurons matches the direction of the ongoing head oscillation. As a result, rhythmic neurons in SC that prefer opposite turn directions are segregated into two populations that fire during opposite phases/directions of the locomotor head rhythm. In summary, neural activity in mouse SC involves distinct populations whose firing alternates such as to represent rhythmic directional movements of the animal as it locomotes through space.

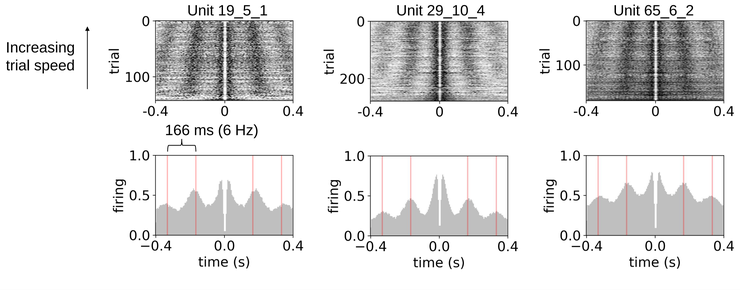
SC recordings during a Y-maze spatial foraging task



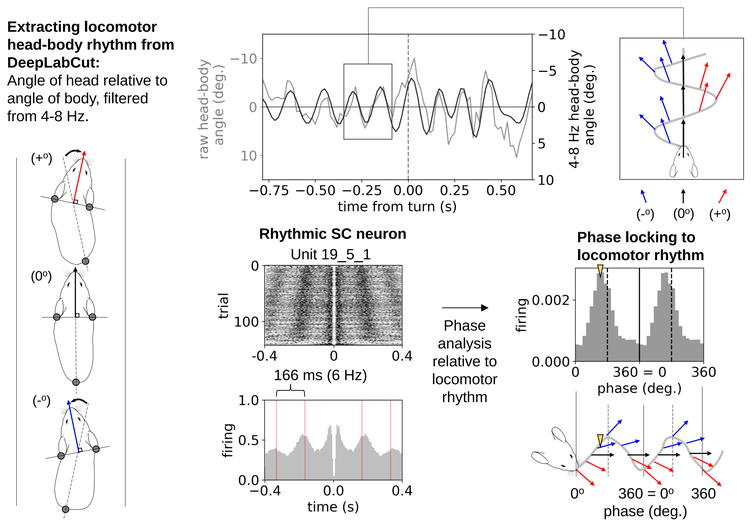
Neurons in SC are selective for turn direction on Y-maze



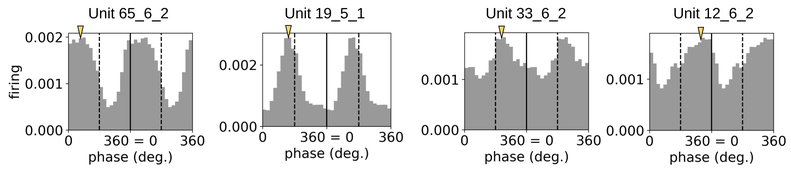
A subset (30%) of SC neurons fire at ~6 Hz during locomotion



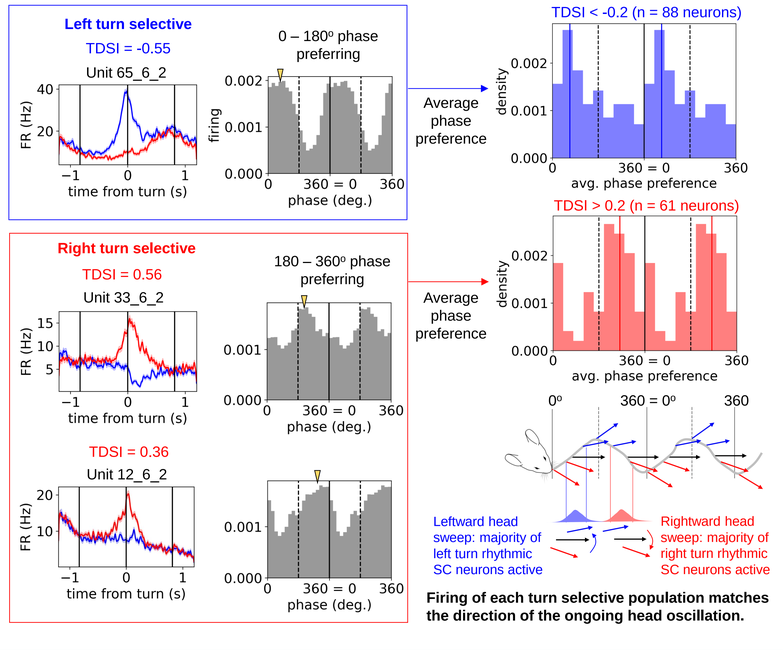
Rhythmic neurons in SC fire in phase with a locomotor head-body rhythm



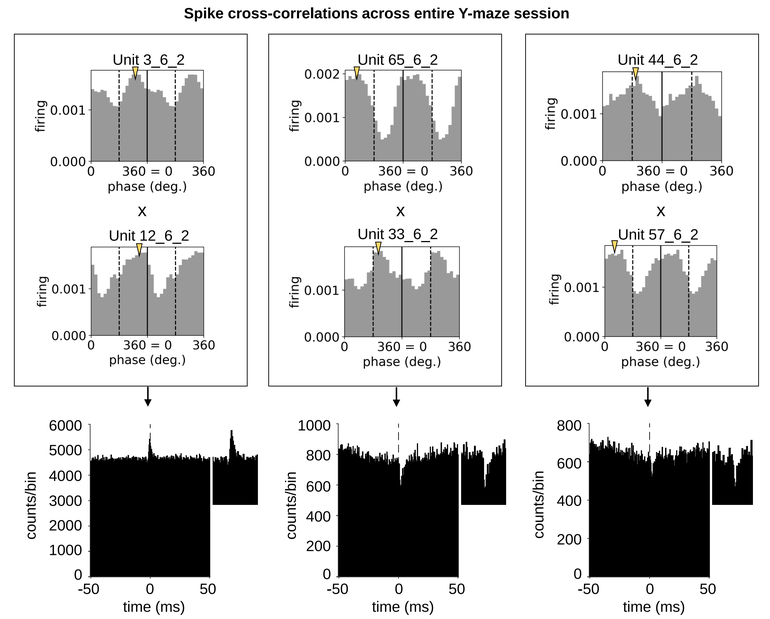
Rhythmic neurons in SC have a variety of preferred firing phases relative to the locomotor rhythm



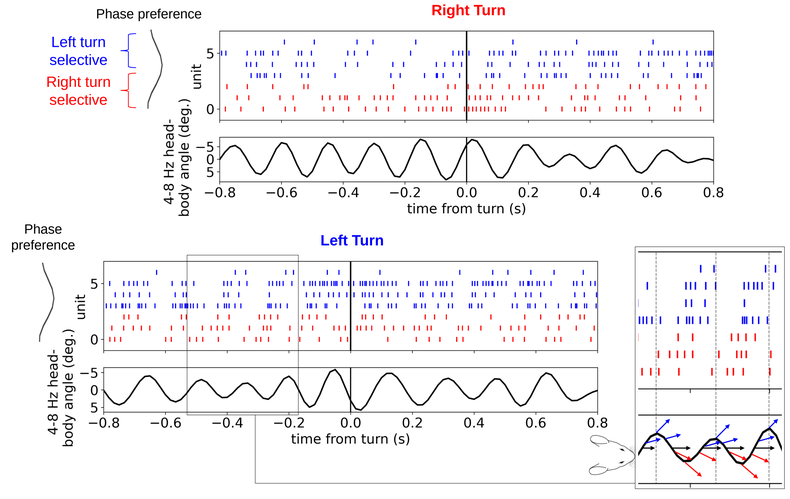
Turn direction preference on Y-maze determines preferred firing phase relative to the locomotor rhythm



Relative phase preference predicts functional connectivity between rhythmic neuron pairs



Locomotion is associated with population-level cycling of directional sequences in SC



Conclusions

- Neurons in mouse SC fire in phase with a ~6 Hz locomotor head-body rhythm.
- SC neuronal sequences that are selective for opposite turn directions alternate such as to represent distinct phases of the animal's head-body rhythm during locomotion.
- **Mouse SC is continuously active during locomotion.**
- **Neural activity in mouse SC may specify a 'motor set' of potential orienting actions to be used for the control of spatial behavior.**

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