DANDRITE LECTURE

Insights gained from watching the construction of a cognitive map

Cognitive maps confer animals with flexible intelligence by representing spatial, temporal, and abstract relationships that can be used to shape thought, planning, and behavior. Cognitive maps have been observed in the hippocampus, but their algorithmic form and the processes by which they are learned remain obscure. Here, we employed large-scale, longitudinal two-photon calcium imaging to record activity from thousands of neurons in the CA1 region of the hippocampus while mice learned to efficiently collect rewards from two subtly different versions of linear tracks in virtual reality. The results provide a detailed view of the formation of a cognitive map in the hippocampus. Throughout learning, both the animal behavior and hippocampal neural activity progressed through multiple intermediate stages, gradually revealing improved task representation that mirrored improved behavioral efficiency. The learning process led to progressive decorrelations in initially similar hippocampal neural activity within and across tracks, ultimately resulting in orthogonalized representations resembling a state machine capturing the inherent structure of the task. We show that a Hidden Markov Model (HMM) and a biologically plausible recurrent neural network trained using Hebbian learning can both capture core aspects of the learning dynamics and the orthogonalized representational structure in neural activity. In contrast, we show that gradient-based learning of sequence models such as Long Short-Term Memory networks (LSTMs) and Transformers do not naturally produce such orthogonalized representations. We further demonstrate that mice exhibited adaptive behavior in novel task settings, with neural activity reflecting flexible deployment of the state machine. These findings shed light on the mathematical form of cognitive maps, the learning rules that sculpt them, and the algorithms that promote adaptive behavior in animals. The work thus charts a course toward a deeper understanding of biological intelligence and offers insights toward developing more robust learning algorithms in artificial intelligence.

Title and abstract are from our bioRxiv preprint, Sun et al. 2023
doi: https://doi.org/10.1101/2023.08.03.551900

Host: Chao Sun

Read more about Nelson Spruston's research here:

https://www.janelia.org/people/nelson-spruston

Nelson Spruston

Senior Director of Scientific Programs
& Laboratory Head
Janelia Research Campus
Howard Hughes Medical Institute
United States

Date: **Wednesday 12 June 2024**
Time: **11:00 – 12:00**
Venue: **1170-347**
Address: **Ole Worms Allé 3**
8000 Aarhus C

OPEN TO ALL INTERESTED.

DANDRITE
Danish Research Institute of Translational Neuroscience
Nordic EMBL Partnership for Molecular Medicine

AARHUS UNIVERSITY

NORDIC EMBL PARTNERSHIP FOR MOLECULAR MEDICINE

LUNDBECKFONDEN