Interdisciplinary Technical Journal Club: special series on Laboratory Animal Science

Mapping the neuronal circuits underlying spatial navigation

Yingjun Liu 06.02.2018 Spatial navigation: The capacity to plan and execute a goal-directed path

- Map
- Your location
- Your destination
- Sense of direction



The cognitive map hypothesis





Edward Chace Tolman (April 14, 1886 – November 19, 1959)

Martin Muller and Rudiger Wehner, 1988, PNAS Edvard I Moser, May-Britt Moser and Bruce L McNaughton, 2017, Nature Neuroscience TOLMAN, E. C., Cognitive maps in man and animals, 1948, Psychological Review

The neuronal basis of spatial cognition

Place cell



O'Keefe, J. & Dostrovsky, 1971, Brain research JS Taube and JB Ranck et al., 1990, Journal of Neuroscience Torkel Hafting, Marianne Fyhn and Edvard I. Moser et al. 2005 Nature Trygve Solstad and Edvard I. Moser et al., 2008, Science Emilio Kropff and Edvard I. Moser et al., 2015, Nautre Edvard I Moser, May-Britt Moser and Bruce L McNaughton, 2017, Nature neuroscience

Mapping of a non-spatial dimension by the hippocampal-entorhinal circuit

Dmitriy Aronov¹, Rhino Nevers¹ & David W. Tank¹

¹Princeton Neuroscience Institute, Princeton University, Princeton, New Jersey 08544, USA.



Images from Thomas RECORDING Wikipedia.org Edvard I Moser, May-Britt Moser and Bruce L McNaughton, 2017, Nature neuroscience Jon W. Rueckemann and Elizabeth A. Buffalo, 2017, Nature

Sound modulation task (SMT)



Recording sites and stability of the recordings



1s avg 1 s avg

2,208 units were recorded in the dorsal CA1 hippocampal region and 1,164 units in the dorsal MEC. 40.0% and 51.3% of cells in these regions, respectively, had firing rates that were significantly modulated during the SMT

CA1 and MEC activity in the SMT



Activity depends on behavioral context



SMT-modulated and spatially modulated cells overlap



SMT-modulated and spatially modulated cells overlap





Linking neuronal structure to function in cognitive navigation: methodologies



500 µm

Patricia Preston-Ferrer and Andrea Burgalossi, 2017, Cell and Tissue Research



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Inhibitory and excitatory synapses

MF en passant synapses

Patricia Preston-Ferrer and Andrea Burgalossi, 2017, Cell and Tissue Research Grzegorz Wiera and Jerzy W. Mozrzymas, 2015, Frontiers in Cellular Neuroscience YutaSenzai and György Buzsáki, 2017, Neuron



Patricia Preston-Ferrer and Andrea Burgalossi, 2017, Cell and Tissue Research Nathan B.Danielson and Attila Losonczy et al., 2017. Neuron



Patricia Preston-Ferrer and Andrea Burgalossi, 2017, Cell and Tissue Research Douglas GoodSmith and James J.Knierim et al., 2017, Neuron

The cognitive map in humans: Using fMRI to interrogate neural codes





Virtual navigation, Imagined navigation, Spatial memory recall viewing of navigationally relevant stimuli.

Network of brain regions involved in spatial navigation

Neurosynth.org Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.

It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:





An automated meta-analysis of 901 studies of working memory

Neurosynth.org

Soojin Park and Marvin M. Chun, 2009, Neuroimage Daniel D. Dilks and Nancy Kanwisher et al., 2013, Journal of Neuroscience Russell A Epstein and Hugo J Spiers, 2017, Nature Neuroscience

z = 0













Parahippocampal place area (PPA) Retrosplenial cortex (RSC) Occipital place area (OPA)

Temporal and spatial coding in humans



Lindsay K. Morgan and Russell A. Epstein et al., 2011, Journal of Neuroscience Dylan M. Nielson and Per B. Sederberg et al., 2015, PNAS Russell A Epstein and Hugo J Spiers, 2017, Nature Neuroscience

Grid-like coding of navigable space in human entorhinal cortex



Christian F. Doeller, and Neil Burgess et al., 2010, Nature Russell A Epstein and Hugo J Spiers, 2017, Nature Neuroscience

Head-direction coding in human parietal cortex

fMRI adaptation (also known as fMRI repetition suppression) occurs when repeated presentation of the same stimulus leads to a reduction in the fMRI signal. Adaptation across different stimuli two provides evidence for a neural common representation, while an absence of adaptation (or 'recovery from adaptation') is evidence that the two stimuli are representationally distinct.



Oliver Baumann and Jason B. Mattingley, 2010, Journal of Neuroscience Steven A Marchette and Russell A Epstein et al., 2014, Nature Neuroscience Russell A Epstein and Hugo J Spiers, 2017, Nature Neuroscience

Limitations of fMRI

Major problems with BOLD signal

- The relationship between neural activity and blood flow to the region is not a linear relationship.
- The BOLD signal was found to better model the local field potential rather than the neural action potential.

