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Born in 1974 in Utah, USA
Studied Biology, Chemistry, Neurosciences, and Oncological Sciences at the University of Utah and Neurophysiology at the Otto von Guericke University Magdeburg

PROJECT

How Memory Circuits in the Brain Use Information about the Past to Inform Future Choices

Learning and memory are core cognitive functions that are supported by complex neural circuits in the brain. The key region for the formation of new autobiographical memories is the hippocampus. Within the hippocampus, the dentate gyrus (DG) is a highly specialized brain region with unique properties. First, the DG has particularly expanded in the mammalian lineage and is the subregion with the highest number of neurons. Second, neurons in the DG continue to be born in the adult brain, which is unique among brain regions and is thought to convey a heightened level of plasticity. Third, neurons in the DG have large specialized synapses, such that activity in target neurons can be elicited by one or just a few inputs. While the many specializations point to the hippocampal DG network as a key region for memory-related computations, the function of the DG remains understudied and poorly understood compared with other modules in memory networks. Understanding DG network computations is essential for therapeutic intervention in disease, as cellular changes in the DG are among the first to be identified in aging, depression, and epilepsy. My previous work has shown that neuronal activity patterns in the DG have a pivotal role in pattern separation. Pattern separation is an essential neural computation that allows for similar memories to be stored in distinct subpopulations of neurons, such that memories do not interfere with each other. More recently, I have discovered that neuronal activity in the DG not only distinguishes among similar patterns, but may also contribute to the planning of future actions. However, it remains unknown how the computations in the DG are integrated into a broader network that processes the outcome of past actions to inform future memory-guided choices. My goal is to experimentally and conceptually advance our understanding of the neural mechanisms for memory and decision making by focusing on computations that originate in dentate networks.

Recommended Reading

Leutgeb, Jill K., Stefan Leutgeb, May-Britt Moser, and Edvard I. Moser (2007). “Pattern Separation in the Dentate Gyrus and CA3 of the Hippocampus.” Science 315: 961–966. https://doi.org/10.1126/science.1135801.
Mankin, Emily A., Fraser T. Sparks, Begum Slayyeh, Robert J. Sutherland, Stefan Leutgeb, and Jill K. Leutgeb (2012). “Neuronal Code for Extended Time in the Hippocampus.” Proceedings of the National Academy of Sciences 109: 19462–19467. https://doi.org/10.1073/pnas.1214107109.
Sasaki, Takuya, Verónica C. Piatti, Ernie Hwaun, Siavash Ahmadi, John E. Lisman, Stefan Leutgeb, and Jill K. Leutgeb (2018). “Dentate Network Activity Is Necessary for Spatial Working Memory by Supporting CA3 Sharp-Wave Ripple Generation and Prospective Firing of CA3 Neurons.” Nature Neuroscience 21: 258–269. https://doi.org/10.1038/s41593-017-0061-5.

TUESDAY COLLOQUIUM, 06.02.2024

The Biology of Memory and the Special Role of the Dentate Gyrus

Memories can be retained as briefly as a few seconds or as long as a lifetime. What is the biological foundation or change in the brain that collects the elements of an experience such that it can be recreated again at a later time in our conscious mind as memory? What endows the brain with the capacity to not just generate exact recollections of past events but to store information in a way that can be flexibly and creatively used? Answers to these questions depend on deciphering the function of a highly specialized brain region, the dentate gyrus. Before zooming in on the dentate gyrus, we will look at the building blocks of the brain and the tools that researchers are using to measure the computations of neural networks while the brain creates, stores, and retrieves particular memories. With an understanding of the basic components, we will appreciate the limitations of brain areas that process sensory inputs in also contributing to the formation of conscious memories that combine different modalities, such as what we smell, see, hear, touch, and feel. The need for the brain to utilize specialized neural circuits for memory formation will become apparent and that the circuits for the formation and retrieval of memories include a specialized brain structure – the dentate gyrus. The neurons and the plasticity of the connections between neurons of the dentate gyrus are highly specialized to solve several computing problems. For example, the ability to store information about one event as a distinct memory from another is solved in a manner similar to how our governments identify individual cars. Like a unique license plate number, each memory is encoded as a distinct pattern of network activity, a process only made possible by the unusually large number of strongly inhibited dentate cells. However, like license plate numbers, unique combinations are easily exhausted without a scheme for increasing possible combinations. Thus, memory capacity has a limit that is set by the functional properties of the dentate gyrus. Memory loss is therefore often the consequence of initial degeneration of the dentate gyrus, such as with aging and in temporal lobe epilepsy. With our expanding knowledge on the function of the dentate gyrus, the cellular biology of memory encoding and retrieval are now better understood, as evident by the ability of scientists to implant, delete, and express specific memories artificially in animal models. In addition, new observations are starting to reveal mechanisms for how stored memories are used to inform future decisions, and I will provide new unexpected findings that the imagination and the planning of future actions requires the dentate gyrus. I am currently working on theories and artificial neural networks to better inform future biological experiments by identifying key mechanisms for this cognitive flexibility.

PUBLICATIONS FROM THE FELLOWS' LIBRARY

Leutgeb, Jill K. (New York, NY,2021)

Precisely timed theta oscillations are selectively required during the encoding phase of memory

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1853688436

Leutgeb, Jill K. (New York, NY Nature America,2018)

Dentate network activity is necessary for spatial working memory by supporting CA3 sharp-wave ripple generation and prospective firing of CA3 neurons

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1853690090

Leutgeb, Jill K. (Washington, DC,2012)

Neuronal code for extended time in the hippocampus

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=1853066427

Leutgeb, Jill K. (Washington, DC,2007)

Pattern separation in the dentate gyrus and CA3 of the hippocampus

https://kxp.k10plus.de/DB=9.663/PPNSET?PPN=185306548X