CA3 and Memory/Introduction

Preface

Raymond P. Kesner

It has been suggested that the CA3 subregion of the hippocampus is a critical substrate of hippocampal memory function, including the operation of short-term memory, pattern separation, pattern completion, encoding, and retrieval as well as mediation of a match-mismatch process, sequential learning, spatial processing, path integration, and learning of arbitrary associations. Furthermore, it has been suggested that most if not all of the above-mentioned functions are based on CA3 recurrent collateral associative connections, suggesting that the CA3 system may operate as an attractor network. In this special issue, the aims are to describe the anatomical neural substrate of the CA3 subregion of the hippocampus, to present a variety of computational approaches to the modeling function of the CA3 network, and to present molecular, physiological, and behavioral evidence for the functions of the CA3 region.

Menno Witter has presented an excellent review elaborating further on an anatomical analysis of the CA3-to-CA3 connectivity, CA3-to-CA1 projections, connections between CA3 and the dentate gyrus, and connections between CA3 and the septal complex. In general, the data presented imply that within the CA3 complex there are many architectural differences and that the contribution of connections other than the CA3-CA3 collaterals are also likely to be of functional importance.

Edmund Rolls has presented a quantitative computational theory of the operation of the CA3 system as an attractor or autoassociation network in support of a variety of process and behavioral functions of the CA3 network. In addition, he has presented a computational analysis of how different inputs and outputs to the CA3 region can affect the CA3 network and how this network interacts with other subregions of the hippocampus and through backprojections with the neocortex.

Gergely Papp, Menno Witter, and Alessandro Treves have elaborated further on the autoassociation network of CA3 by introducing an evolutionary perspective that could underlie the organization of CA3 in mammalian systems and by discussing the development of specific mathematical models for the CA3 network that can give direction as to the constraint of storage capacity. Furthermore, they emphasize the importance of spatial representations.

Michael Hasselmo presents a different model of the CA3 network function by computational simulations of electrophysiological data associated with encoding of sequences and temporal processing of information. The model is based primarily on interference between theta frequency oscillations in encoding the position within a sequence based on spatial arc and length or time. It is proposed that this model can be incorporated in episodic memory based on encoding and retrieval sequences of states and actions.

Licurgo de Almeida, Marco Idiart, and John Lisman present a more extensive model for CA3 function based on the develop-

ment of gamma oscillations that are created by rapid periodic feedback inhibition. They further suggest that their model is compatible with an autoassociative network function for CA3. Finally, they suggest that the key to recalling episodic memory may be a function of interactions between the dentate gyrus and CA3.

Stefan Leutgeb and Jill Leutgeb present an extensive review of the single unit recording data of the subregions of the hippocampus as it relates to the processing of spatial and temporal information. They suggest that the CA3 network is intimately associated with the processing of spatial information, but because of its responsiveness to novelty it may play an important role in rapid integration of spatial and nonspatial information. The single unit data from the CA3 region appears to be quite compatible with the behavioral functions assigned to CA3. In contrast, the CA1 region is more responsive to the processing of temporal information.

Inah Lee and James Knierim present data in support of differential firing dynamics of the CA3 and CA1 place cells. They report that CA3 place cells when exposed to a rearrangement of familiar cues rotate primarily with proximal cues and shift their firing locations backward over time when presented for the first time, but not on subsequent exposures. In contrast, CA1 place cells when exposed to a rearrangement of familiar cues rotate with different sets of cues or remap and shift their firing locations backward over time on repeated exposures, but not on the first exposure.

Stepan Kubik, Teiko Miyashita, and John Guzowski present a comprehensive review of the role of immediate early gene expression patterns as it relates to the dynamics of CA3 and CA1 function and the subregional contributions to memory acquisition, consolidation, and retrieval. They also elaborate on the immediate early gene contribution to the potentially dissociative functions of the dorsal and ventral hippocampus.

Raymond Kesner presents a comprehensive review of the mnemonic functions of CA3 guided in part by an autoassociative function of the CA3 network. He suggests that the CA3 mediates the encoding and retrieval of spatial information (episodic) within short-term memory. The CA3 is also involved in constructing relational representations and utilizes a pattern completion process. He further presents a review of the functions of the major intrinsic and extrinsic input and output pathways of the CA3 region.

In general, based on a multiple level of analysis there appears to be some consensus as to the function of CA3, while recognizing the complexity of the CA3 network, the diversity of computational models, the complexity of single unit recording and early gene analysis and the multitude of mnemonic processes that are supported by the CA3 region.

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Article is online at <http://www.learnmem.org/cgi/doi/10.1101/lm.786407>.

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Learn. Mem. 2007, **14**:

Access the most recent version at doi:[10.1101/lm.786407](https://doi.org/10.1101/lm.786407)

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