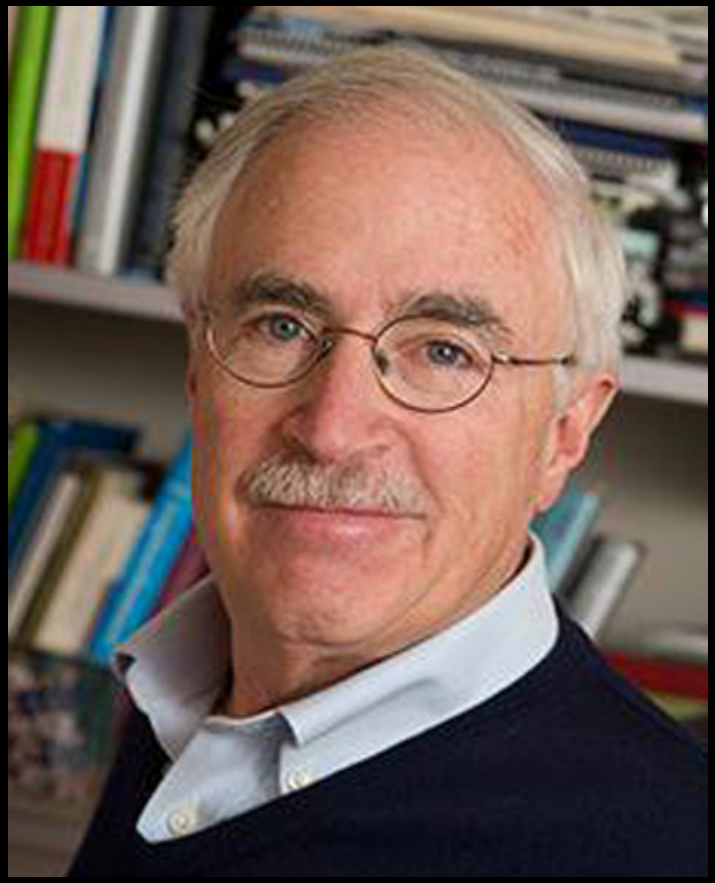
Howard B. Eichenbaum



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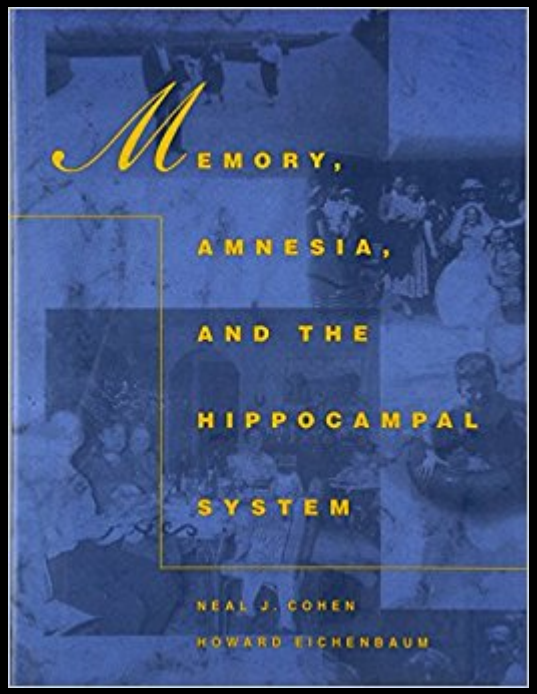
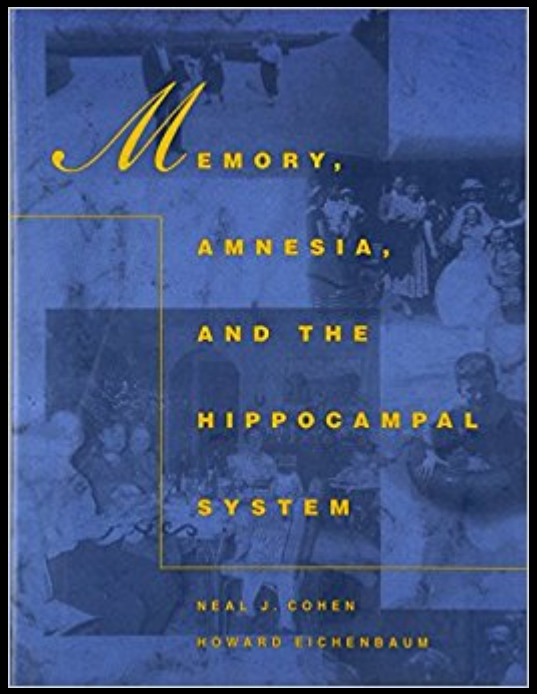


(1993)

"To really understand memory, amnesia and the hippocampal system it would be very important to bring the cognitive and neuropsychological work on humans together with the behavioral, neuroanatomical, and neurophysiological work on animals."



(1993)

"To really understand memory, amnesia and the hippocampal system it would be very important to bring the cognitive and neuropsychological work on humans together with the behavioral, neuroanatomical, and neurophysiological work on animals."

"What was required in order to really work simultaneously on humans and rodents was an articulation of the functional role of the hippocampal system in memory, and of the nature of the memory impairment in amnesia, that would permit experimental predictions for studies performed on any species and that would permit us to make contact with and contribute to work ranging from cognitive processes to neural mechanisms."

Declarative memory in the rat: behavior

articles

Critical role of the hippocampus in memory for sequences of events

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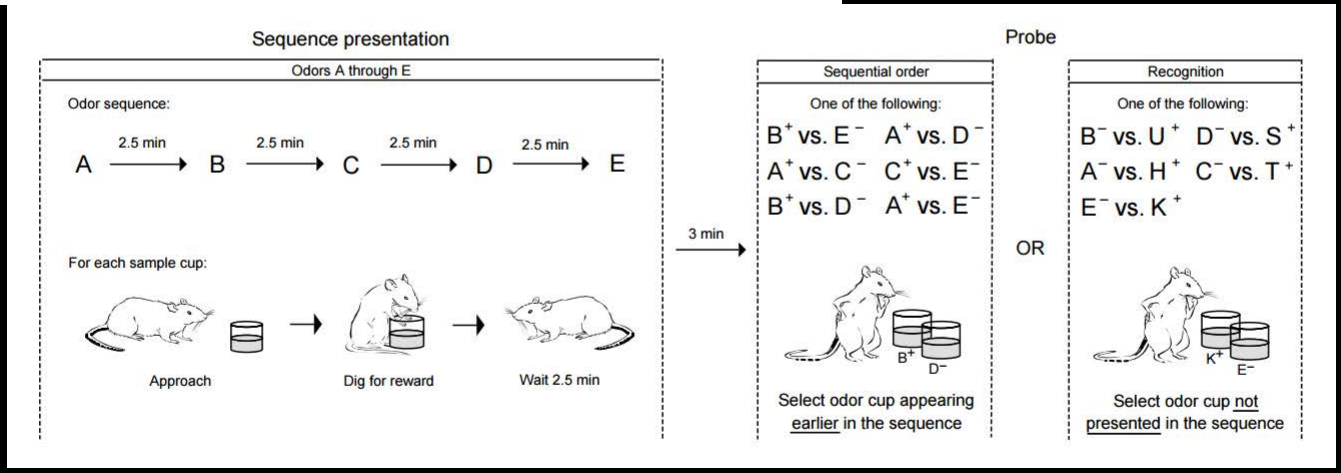
Recent models of hippocampal function emphasize the potential role of this brain structure in encoding and retrieving sequences of events that compose episodic memories. Here we show that hippocampal lesions produce a severe and selective impairment in the capacity of rats to remember the sequential ordering of a series of odors, despite an intact capacity to recognize odors that recently occurred. These findings support the hypothesis that hippocampal networks mediate associations between sequential events that constitute elements of an episodic memory.



Declarative memory in the rat: behavior

letters to nature

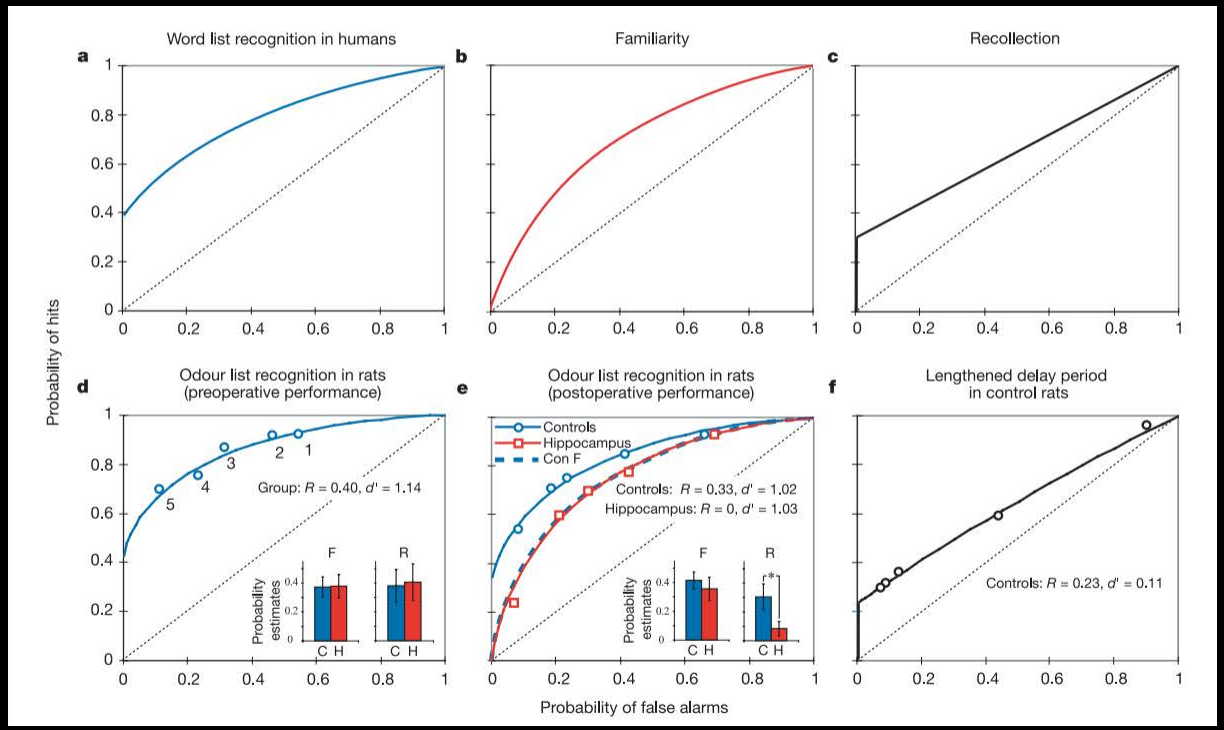
Recollection-like memory retrieval in rats is dependent on the hippocampus

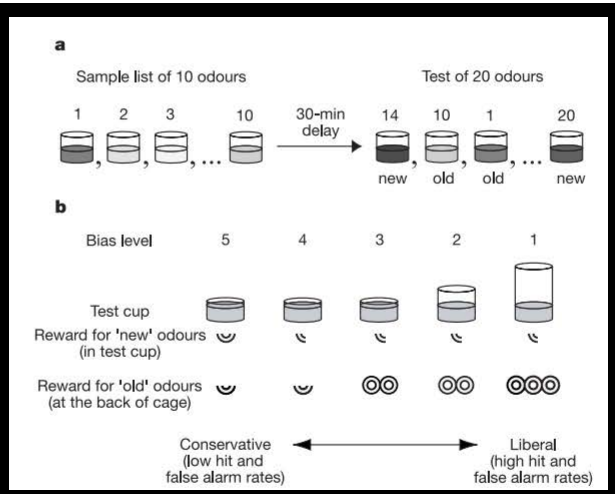
Norbert J. Fortin, Sean P. Wright & Howard Eichenbaum

Center for Memory and Brain, Boston University, 2 Cummington Street, Boston, Massachusetts 02215, USA

Recognition memory may be supported by two independent types of retrieval, conscious recollection of a specific experience and a sense of familiarity gained from previous exposure to particular stimuli[1,2]. In humans, signal detection techniques have been used to distinguish recollection and familiarity, respectively, in asymmetrical and curvilinear components of their receiver operating characteristic (ROC) curves, standard curves that represent item recognition across different levels of confidence or bias. To determine whether animals also employ multiple processes in recognition memory and to explore the anatomical basis of this distinction, we adapted these techniques to examine odour recognition memory in rats. Their ROC curve had asymmetrical and curvilinear components, indicating the existence of both recollection and familiarity in rats. Furthermore, following selective damage to the hippocampus the ROC curve became entirely symmetrical and remained curvilinear, supporting the view that the hippocampus specifically mediates the capacity for recollection.

When meeting people on a second occasion, we sometimes recall





Declarative memory in the rat: behavior

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Episodic recollection in animals: "If it walks like a duck and quacks like a duck…"

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Center for Memory and Brain, Boston University, Boston, MA 02215, USA

Received 28 February 2005
Available online 8 April 2005

Abstract

In humans, episodic memory is most commonly defined as the subjective experience of recollection, presenting a major challenge to the identification of episodic memory in animals. Here we take the position that episodic memory also has several other distinctive qualities that can be assessed objectively in animals, as well as humans, and the examination of these properties provides insights into underlying mechanisms of episodic memory. We focus on recent evidence accumulated in this laboratory indicating that recognition in rats involves a threshold retrieval process, similar to that observed in human episodic recall. Also, rats can remember the temporal order of unique events, characteristic of the replay of vivid episodic memories in humans. Furthermore, rats combine elements of "when" and "where" events occur, as well as the flow of events within a memory, to distinguish memories that share overlapping features, also characteristic of human episodic memory. Finally, all of these capacities are dependent on the hippocampus, which also plays a critical role in human episodic memory. This combination of findings strongly suggests that animals have the same fundamental information processing functions that underlie episodic recall in humans.

Keywords: Episodic memory; Animal model; Recollection; Familiarity; Temporal order; What-where-when; Sequence disambiguation; Rat

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Neural coding in the rodent hippocampus

Neuron, Vol. 27, 623–633, September, 2000, Copyright ©2000 by Cell Press

Hippocampal Neurons Encode Information about Different Types of Memory Episodes Occurring in the Same Location

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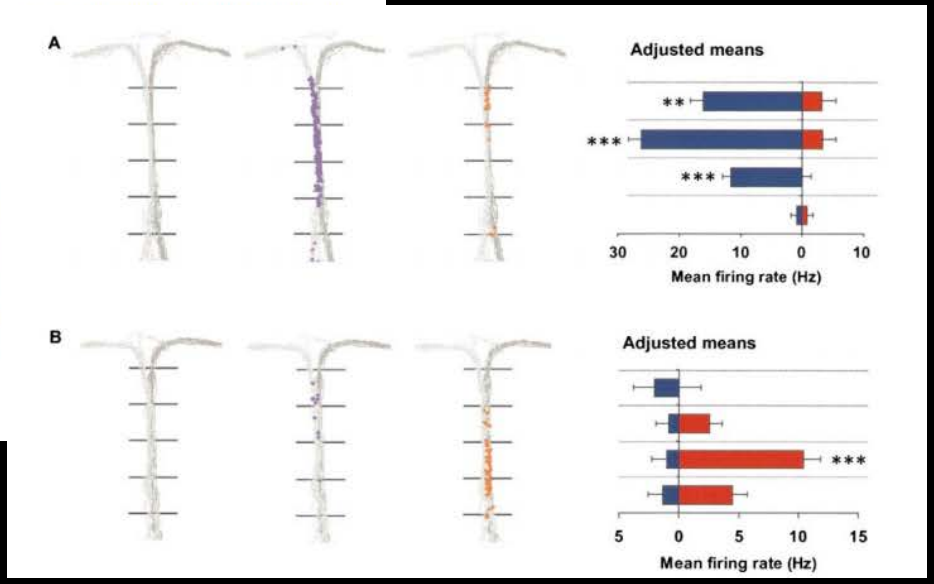
R. Jonathan Robitsek, and Howard Eichenbaum
Laboratory of Cognitive Neurobiology
Boston University
Boston, Massachusetts 02215

Summary

Firing patterns of hippocampal complex-spike neurons were examined for the capacity to encode information important to the memory demands of a task even when the overt behavior and location of the animal are held constant. Neuronal activity was recorded as rats continuously alternated left and right turns from the central stem of a modified T maze. Two-thirds of the cells fired differentially as the rat traversed the common stem on left-turn and right-turn trials, even when potentially confounding variations in running speed, heading, and position on the stem were taken into account. Other cells fired differentially on the two trial types in combination with behavioral and spatial factors or appeared to fire similarly on both trial types. This pattern of results suggests that hippocampal representations encode some of the information necessary for representing specific memory episodes.



The global record of memory in hippocampal neuronal activity

Emma R. Wood, Paul A. Dudchenko & Howard Eichenbaum

Laboratory of Cognitive Neurobiology, Department of Psychology, Boston University, 64 Cummington Street, Boston, Massachusetts 02215, USA

In humans the hippocampal region of the brain is crucial for declarative[1] or episodic[2] memory for a broad range of materials. In contrast, there has been controversy over whether the hippocampus mediates a similarly general memory function in other species, or whether it is dedicated to spatial memory processing[3–6]. Evidence for the spatial view is derived principally from the observations of 'place cells'—hippocampal neurons that fire whenever the animal is in a particular location in its

Neural coding in the rodent hippocampus

Neuron
Article

Hippocampal "Time Cells" Bridge the Gap in Memory for Discontiguous Events

Christopher J. MacDonald,[1] Kyle Q. Lepage,[1] Uri T. Eden,[1] and Howard Eichenbaum[1,*]
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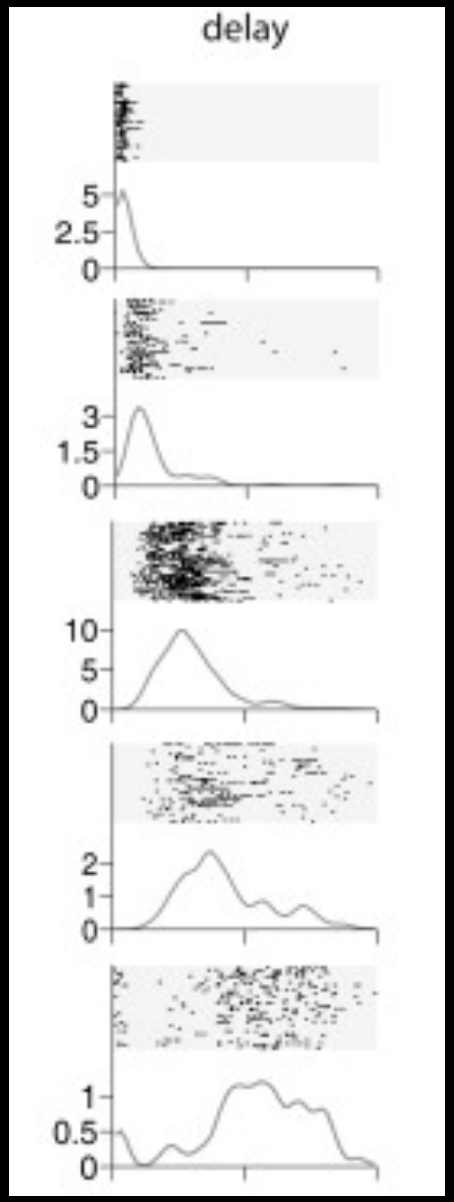
DOI 10.1016/j.neuron.2011.07.012

SUMMARY

The hippocampus is critical to remembering the flow of events in distinct experiences and, in doing so, bridges temporal gaps between discontiguous events. Here, we report a robust hippocampal representation of sequence memories, highlighted by "time cells" that encode successive moments during an empty temporal gap between the key events, while also encoding location and ongoing behavior. Furthermore, just as most place cells "remap" when a salient spatial cue is altered, most time cells form qualitatively different representations ("retime") when the main temporal parameter is altered. Hippocampal neurons also differentially encode the key events and disambiguate different event sequences to compose unique, temporally organized representations of specific experiences. These findings suggest that hippocampal neural ensembles segment temporally organized memories much the same as they represent locations of important events in spatially defined environments.

How do hippocampal neurons represent the temporal organization of extended experiences and bridge temporal gaps between discontiguous events? To investigate these issues, we recorded hippocampal neural activity as rats distinguished sequences composed of two events separated by a temporal gap (Figure 1) (Kesner et al., 2005). Each trial began with the rat sampling one of two objects, followed by a 10 s empty delay, then as the delay ended, finished with presentation of one of two odors mixed with playground sand in a flowerpot. Each odor was associated with one of the objects, such that if the odor followed its paired object, the rat could dig in the sand to retrieve a buried reward (go response). Alternatively, if the odor followed the object with which it was not paired, no reward was available in the odor pot; but if the animal withheld digging (nogo response), a reward could be obtained at a separate location. Importantly, even though the sequences were presented repeatedly, on each trial the rat had to remember the initial object in order to respond correctly to the odor presented at the end of the sequence. This paradigm provides the opportunity to examine whether hippocampal neurons encode sequential events and to explore how hippocampal neuronal activity bridges and disambiguates the identical empty delay between the object and odor that compose each sequence.



Neural coding in the rodent hippocampus

CellPress

Neuron
Article

Hippocampal Representation of Related and Opposing Memories Develop within Distinct, Hierarchically Organized Neural Schemas

Sam McKenzie,[1] Andrea J. Frank,[1] Nathaniel R. Kinsky,[1] Blake Porter,[1] Pamela D. Rivière,[1] and Howard Eichenbaum[1,*]
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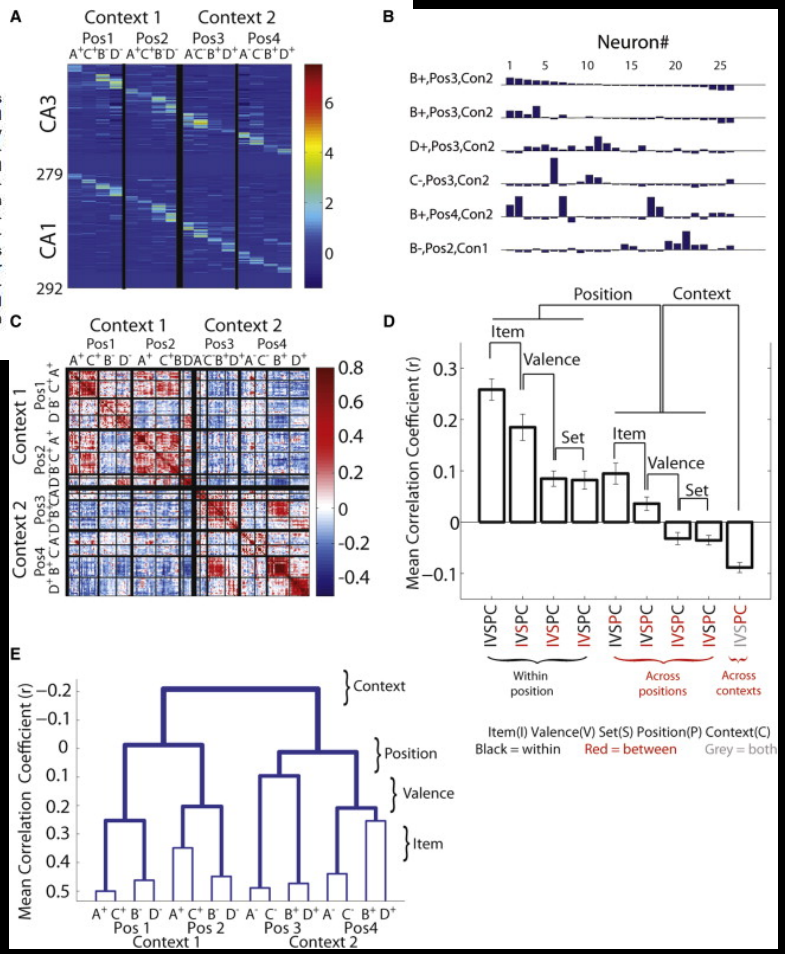
http://dx.doi.org/10.1016/j.neuron.2014.05.019

SUMMARY

Recent evidence suggests that the hippocampus may integrate overlapping memories into relational representations, or schemas, that link indirectly related events and support flexible memory expression. Here we explored the nature of hippocampal neural population representations for multiple features of events and the locations and contexts in which they occurred. Hippocampal networks developed hierarchical organizations of associated elements of related but separately acquired memories within a context, and distinct organizations for memories where the contexts differentiated object-reward associations. These findings reveal neural mechanisms for the development and organization of relational representations.



theory

CellPress

Neuron

Perspective

Can We Reconcile the Declarative Memory and Spatial Navigation Views on Hippocampal Function?

Howard Eichenbaum[1,*] and Neal J. Cohen[2]
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http://dx.doi.org/10.1016/j.neuron.2014.07.032

Some argue that hippocampus supports declarative memory, our capacity to recall facts and events, whereas others view the hippocampus as part of a system dedicated to calculating routes through space, and these two contrasting views are pursued largely independently in current research. Here we offer a perspective on where these views can and cannot be reconciled and update a bridging framework that will improve our understanding of hippocampal function.

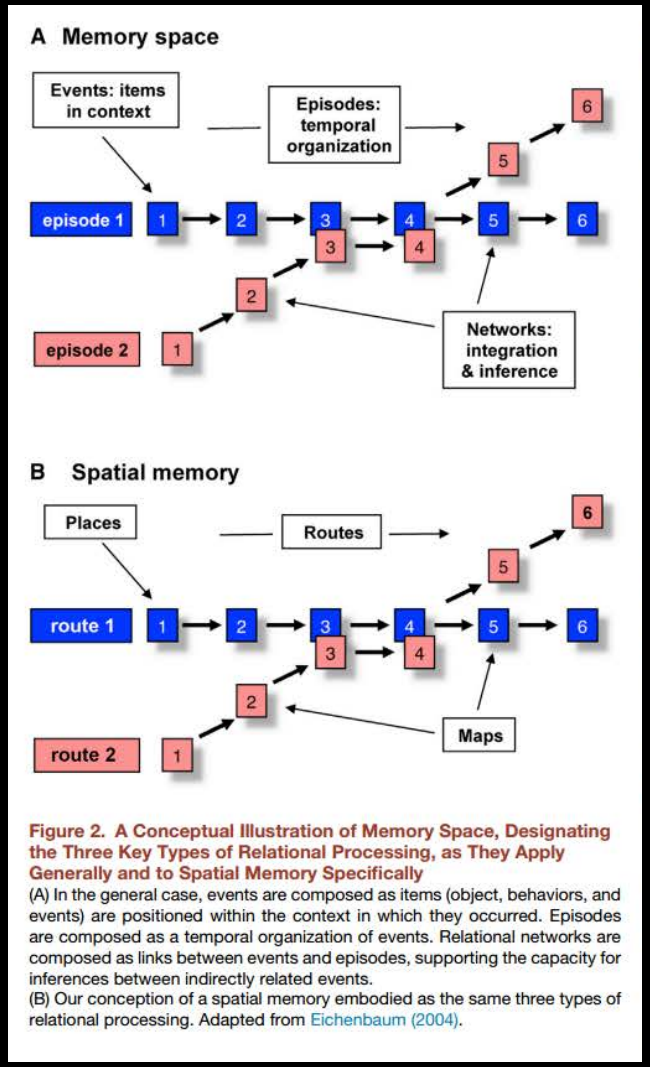


Figure 2. A Conceptual Illustration of Memory Space, Designating the Three Key Types of Relational Processing, as They Apply Generally and to Spatial Memory Specifically

(A) In the general case, events are composed as items (object, behaviors, and events) are positioned within the context in which they occurred. Episodes are composed as a temporal organization of events. Relational networks are composed as links between events and episodes, supporting the capacity for inferences between indirectly related events.

(B) Our conception of a spatial memory embodied as the same three types of relational processing. Adapted from Eichenbaum (2004).

Neural coding in the rodent hippocampus

The Nobel Prize in Physiology or Medicine 2014

Fig. 1

John O'Keefe

John O'Keefe discovered, in 1971, that certain nerve cells in the brain were activated when a rat assumed a particular place in the environment. Other nerve cells were activated at other places. He proposed that these "place cells" build up an inner map of the environment. Place cells are located in a part of the brain called the hippocampus.

May-Britt Moser and Edvard I. Moser

May-Britt och Edvard I. Moser discovered in 2005 that other nerve cells in a nearby part of the brain, the entorhinal cortex, were activated when the rat passed certain locations. Together, these locations formed a hexagonal grid, each "grid cell" reacting in a unique spatial pattern. Collectively, these grid cells form a coordinate system that allows for spatial navigation.

Fig. 2

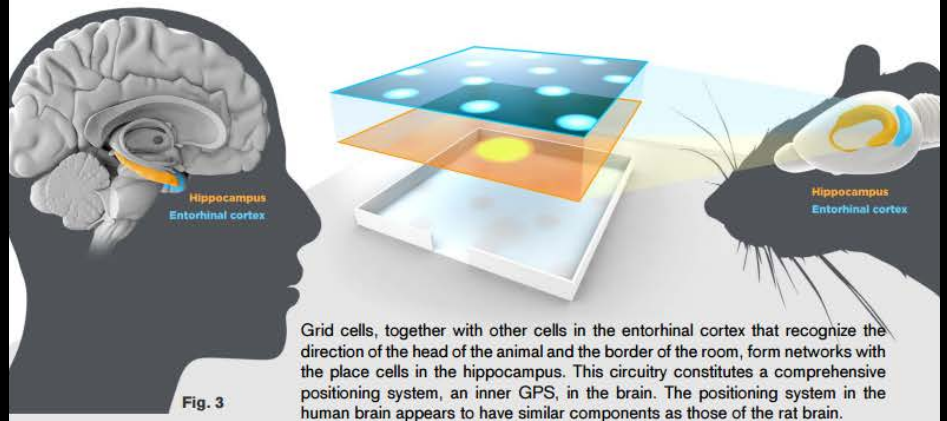
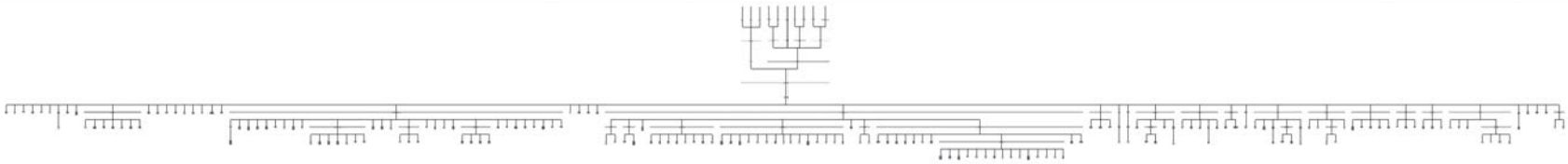


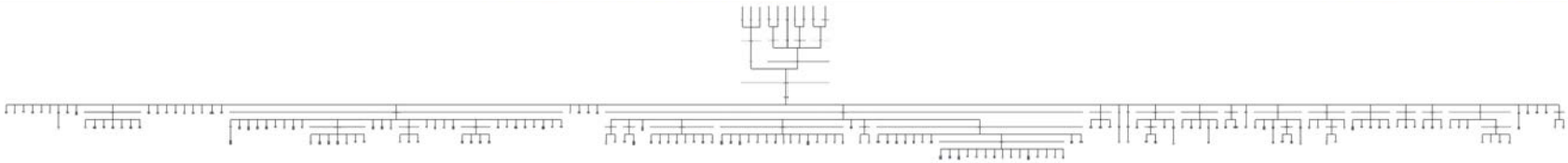
Fig. 3

Grid cells, together with other cells in the entorhinal cortex that recognize the direction of the head of the animal and the border of the room, form networks with the place cells in the hippocampus. This circuitry constitutes a comprehensive positioning system, an inner GPS, in the brain. The positioning system in the human brain appears to have similar components as those of the rat brain.

Mentorship



Mentorship



Sidney Wiener
Matthew Shapiro
Heikki Tanila
Geoffrey Schoenbaum
Paul Abbas
Tim Otto
Paul Dudchenko*
Emma Wood*
Aras Petrulis
Laure Rondi-Reig
Josh Berke
Amy Griffin
Norbert Fortin

**met in Howard's lab & subsequently married*

Howard Eichenbaum

- Rats forage, sniff, and dig…

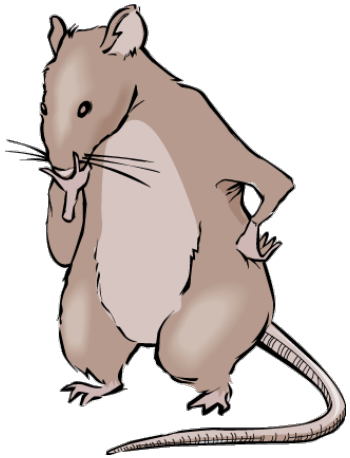


Photo by John Lisman

Hippocampal function

Neuron, Vol. 23, 209–226, June, 1999, Copyright ©1999 by Cell Press

Review

The Hippocampus, Memory, and Place Cells: Is It Spatial Memory or a Memory Space?

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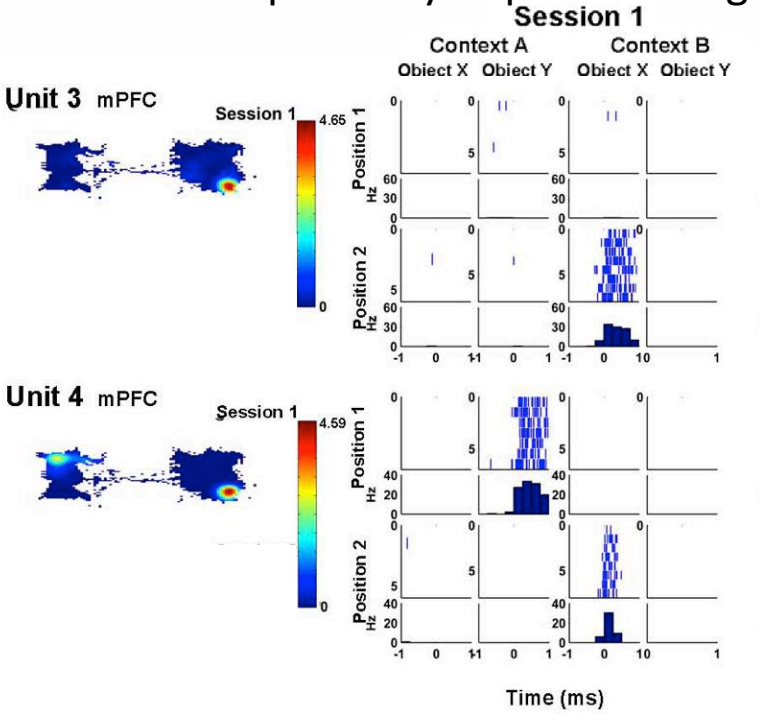
in humans and nonhuman primates. A major source of this limitation has been the contention that hippocampal processing is dedicated to spatial memory in rodents, in contrast to the global memory deficits observed following damage to the hippocampal region in humans and more recently in animals as well (Eichenbaum, 1997). Furthermore, several recent electrophysiological studies have revealed properties of hippocampal neuronal firing patterns that are inconsistent with the notion of a cognitive map and indicate a broader scope of information processing. This paper will focus on these studies, reviewing some of the history and basic properties of place cells, and considering both early and recent findings that shed light on the content and organization of information encoded within hippocampal neuronal

Maps in the hippocampus

- Place cell activity in the context guided discrimination task
  - Place cell activity is cue and context sensitive
  - Inactivating mPFC reduces the cue specificity of place coding



Navawongse and Eichenbaum (2013) *J Neurosci*