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Research report

# Neural circuitry for rat recognition memory

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## HIGHLIGHTS

- We present a summary of findings from object recognition memory tasks revealing the roles played by cortical, hippocampal and thalamic regions.
- We report a neural circuit for object–location association recognition memory and temporal order recognition memory.
- The neural circuit involves the perirhinal cortex, medial prefrontal cortex and hippocampus.
- Experimental evidence shows that all structures in the circuit play critical roles in memory formation which can potentially be differentiated.

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## ABSTRACT

Information concerning the roles of different brain regions in recognition memory processes is reviewed. The review concentrates on findings from spontaneous recognition memory tasks performed by rats, including memory for single objects, locations, object–location associations and temporal order. Particular emphasis is given to the potential roles of different regions in the circuit of interacting structures involving the perirhinal cortex, hippocampus, medial prefrontal cortex and medial dorsal thalamus in recognition memory for the association of objects and places. It is concluded that while all structures in this circuit play roles critical to such memory, these roles can potentially be differentiated and differences in the underlying synaptic and biochemical processes involved in each region are beginning to be uncovered.



## 1. Introduction

The process of recognition memory, which is our ability to judge the prior occurrence of stimuli, is fundamental to our ability to record events, but also to guide prospective behaviour. Different types of information can be used to establish whether a stimulus or set of stimuli have been encountered before and thus it may be argued that recognition memory has multiple component aspects. For example, judgments can be made on whether an individual item is novel or familiar and/or whether an item has been previously associated with another item, a particular location or context. In addition judgments can be made using an item's relative familiarity or the recency of the last encounter with that item [1]. It is possible to measure recognition memory in rodents, in particular through the use of object recognition memory tasks based on measuring the spontaneous preference for novelty in either an arena or maze [1–4]. It is thereby possible to explore the neural basis of such memory in greater detail than is currently possible in humans. Using these tasks in rodents has resulted in the widely accepted view that recognition memory judgments for individual items depend on the perirhinal cortex in the medial temporal lobe [5–9], while judgments concerning the spatial location of a previously encountered item involves the hippocampus [9,10]. These findings suggest that different brain regions may make different contributions to recognition memory. Here we present extensions to these findings, in particular, discussing evidence that associative recognition memory judgments that require a subject to remember that an item was associated with a particular place, or recency memory judgments depend on a network of brain regions working in concert that include the perirhinal cortex (PRH), the medial prefrontal cortex (medial prefrontal cortex), the hippocampus (HPC) and medial dorsal thalamus (MD). The potential contributions of the different regions to such memory are considered.

### 1.1. Assessing recognition memory in the rat

As this review will focus on experimental evidence from rodent studies, we will briefly outline object recognition paradigms in the

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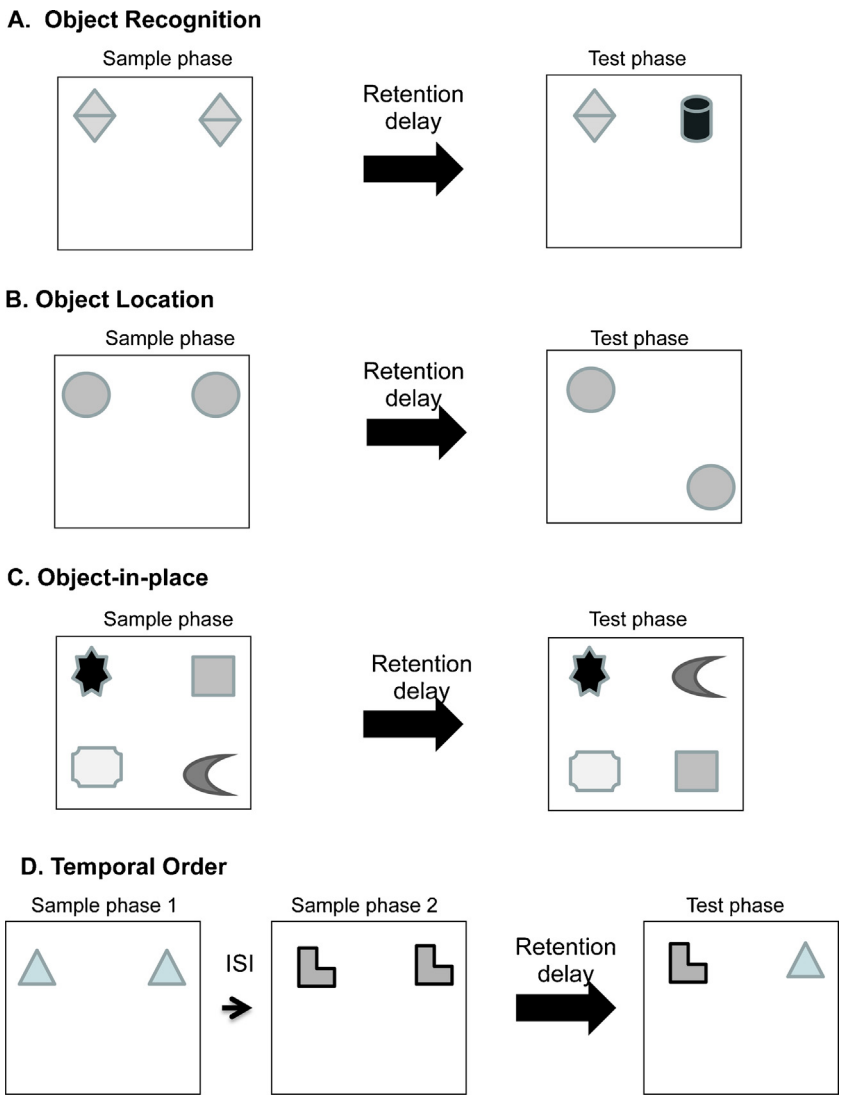


**Fig. 1.** Diagram of the four object recognition memory tasks. (A) Novel object preference task, (B) object location task, (C) object-in-place task, (D) temporal order task.

rat. Object recognition memory tasks depend on the use of this species' instinctive tendency to explore novel items or a novel location. These tasks thus avoid lengthy training regimes or reinforcement schedules [11,12]. Four recognition memory procedures have been used in our studies, to explore the effects of specific neural manipulations of different aspects of recognition memory. These recognition memory procedures all involve an acquisition (sample) phase, in which a rat familiarises itself with one or more objects, or objects in a particular places. After a delay, the sample phase is followed by a choice (test) phase. In the test phase, the time spent exploring what has been encountered in the sample phase is compared with the time spent exploring a new object or object–location configuration. The four recognition memory tasks (shown in Fig. 1) are: (a) *novel object preference (OR)*, in which the rats' exploration of a novel object is compared with that of a familiar object; (b) *object location (OL)*, which tests the animals' ability to detect the movement of a familiar object to a novel location; (c) *object-in-place (OiP)* in which animals' discriminate between familiar objects that have been previously associated and those that are newly associated with particular places; (d) *temporal order (TO)* which examines the animals' ability to differentiate between familiar objects presented at different times previously.

## 2. Perirhinal cortex in recognition memory

There is now overwhelming evidence demonstrating that the perirhinal cortex plays a critical role in judging the prior occurrence of individual items; relevant work from both behavioural and electrophysiological studies has been reviewed extensively elsewhere [1,13–15]. However a summary of these findings is presented here and then the importance of the perirhinal cortex in other recognition memory processes such as object-in-place and temporal order recognition memory will be considered.

### 2.1. Perirhinal cortex and novel object recognition

A number of studies have revealed the essential role of the perirhinal cortex in novel object recognition. Thus tasks in which the subject must discriminate between novel and the prior occurrence of infrequently repeated individual items, as for example, visual delayed matching or non-matching to sample tasks with 'trial unique' stimuli, in monkeys [16–20], or tasks that rely on the spontaneous preference of a rat for novel objects, are significantly impaired following lesions in the perirhinal cortex [4,5,21–23].