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Review

One-trial object recognition in rats and mice: Methodological and theoretical issues

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ABSTRACT

The one-trial object recognition task involves memory of a familiar object in parallel with the detection and encoding of a novel object. It provides the basis for the study of a wide range of cognitive and neuropsychological functions and processes in rats and mice. However, unlike in humans, primate and pigeon studies, object recognition in rats and mice has been mostly limited to memory while little is known about object perception, affordances and acquisition of a representation of an object. In the present paper, we addressed some of these issues. We also described novelty preference models and hypotheses that account for one-trial object recognition and question the validity of the novelty preference concept. In addition, we discussed whether one-trial object recognition involves working memory and how it involves memory of an episode.

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1. Introduction

When exposed to a familiar object alongside a novel object, young and adult rats and mice approach frequently and spend more time exploring the novel than the familiar object. This apparent 'unconditioned preference' for a novel object is considered as an indication that a representation of the familiar object exists in memory; it forms the basis of the one-trial object recognition task in the study of memory functions in rodents [48,49,58,59] which has been extended to cover various aspects and types of memory [35–37,43,51,50,54,58,88,103].

Recent reviews have described the use of the one-trial object recognition task and its variants in various experimental manipulations (i.e. lesions, pharmacological and genetics) [38,148]. Here we will examine some methodological and theoretical issues that emerged from the adaptation and extension of the object recogni-

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tion task to include other memory types and processes. Some issues are related to the testing conditions under which object recognition is assessed, mostly concerning perception and motor affordances. Other issues relate to the conceptual and theoretical framework under which object recognition have been considered and evaluated. We will examine the novelty preference models [11–13,136] and novelty-bias hypothesis [106,107] which have been proposed to account for object recognition memory. We will also examine whether object recognition involves working memory, and how object recognition involves memory of episodes.

2. Object affordances

In a recent publication, Chemero and Heyser [27] raised the issue of object affordances which they described as "relations between the abilities of animals and the properties of objects". According to these authors this issue was raised when they observed that ethanol withdrawal did not impair recognition memory but rather increased exploration of novel objects when compared to controls. They report that closer examination of the data revealed "that the findings were greatly influenced by the properties of the objects, with rats preferring objects they could climb onto to those they could not. That is, the rats showed a preference for objects that have affordances for common rat activities". While the issue of affordances merits serious consideration when selecting objects as suggested by the authors, serious concerns must be raised in regard to the design of the experiment that led to this issue. It seems to us that the role of the short and the tall object were not randomly alternated between animals during the test. Hence, the withdrawal group benefited from having the short object as the novel one. It is however surprising that control animals did not benefit from such affordance. Furthermore, in all our publications it is repeated verbatim that climbing on the objects is not recorded as an exploration of the objects unless the snout of a rat or a mouse is directed towards these objects by no more than 2 cm.

In the one-trial object recognition task, the issue of affordances can be applied to what animals are able to perceive, recognize and memorize. It can also include reaching and grasping-like actions when objects are presented inside arms or alleyways and they need to be displaced for access to a reward. For instance, rats and mice may not be able to discriminate between objects based on a sole difference in the color of vertical stripes on their surface, but they would discriminate if one of the objects has horizontal stripes instead; then the color becomes irrelevant as the orientation of the stripes determine the difference between the two objects. The perception of differences in the orientation of stripes, however, does not necessarily imply that these objects are suitable for assessing memory of objects using variable retention intervals. Memory in rodents may not be able to afford such limited discriminative features between objects as these can be subject to high level of interferences than objects with redundant features. It may not be able also to afford large similarities between objects for the same reasons. Under these conditions, a deficit in object recognition can be observed as soon as a delay is interposed between the sample phase and the test phase. For instance, in Mumby et al.'s experiments [107,108,109], a glass jar (6 cm high) is attached to the bottom of each object. These objects can be viewed differently if they are placed at a set distance apart directly on the floor or on a common stand. The glass jar and the object on the top constitute one compound. Rats' exploration is not limited to the top part of the object compound, particularly from a close distance, and if rearing is reduced by an experimental manipulation then it is possible that exploration would be limited mostly to the lower part the object compound. The elevation of objects on top of a jar or any other support reduces the differences between novel and familiar object. It is also possible that an increased similarity in local features can shift preference from novel to familiar stimuli [98,134] because any shared commonalities between two objects introduces some form of uncertainty about the features of the previously explored objects which then require updating and consolidation at the expense of the novel stimulus.

Objects are accessible along various dimensions such as shapes, textures, odor, color and brightness. All these dimensions can be involved in the discrimination and memory of an object in rats and mice. Efforts are made to equate the pairings of objects in order to avoid any unintentionally induced preference bias. Most attention has been paid to the object odors. Therefore, in any single session, multiple copies of the sample objects have been made available and each copy is used once only for the same animal. The objects are also carefully cleaned before being used for another animal. Haptic perception can be involved in the discrimination between objects. In this case, the main issue is the presence of protrusions/intrusions on the surface of the objects which may advantage the exploration of these objects when exposed alongside objects with a plain surface. There are other aspects of the objects which are accessible through vision, and most studies on object recognition in rats and mice seem to rely heavily on the visual aspects of objects. However, it appears that vision in rats and mice is poor; therefore shapes, colors and brightness of objects need to be carefully selected. About 97% of the rat retina consists of rods, and the remaining consists of cones [23,87]. Rods are generally used for low-light vision; hence, they are responsible for the peripheral and the night vision. Cones are used for daylight, bright-colored vision; they perceive and recognize colors, but for this they need a bright light falling on them. Rats and mice have limited color vision which is determined by two cones (dichromatic vision) as opposed to three cones (trichromatic vision) in humans [21,84,85]. Recent evidence show that rats perceive ultraviolet light, can discriminate between ultraviolet and visible light, and between different colors in the blue–green range [85]. Accordingly, rats and mice are able to discriminate between stimuli which differ in brightness but proved difficult to train in color discrimination [85]. Objects with similar brightness, which differ mostly in colors in the eyes of a human observer, may look identical in the eyes of a rat or a mouse.

Rats and mice are thought to be shortsighted but this view has been challenged by Dean [32] in an experiment where the size and distance of the stimuli to be detected by rats were varied independently. It was found that distance (range: 30–160 cm) produced relatively slight effects on the smallest detectable visual angle. However, the smallest targets that could be detected were large. Rats required considerable training to run reliably to targets subtending less than 5–10° of visual angle. Accordingly, it is unlikely that rats are able to see anything lying on the ground at some distance but can use their vibrissae and their sense of smell. If odors are eliminated from objects, then we can assume that animals used vision to move towards distant objects which need to be of large size otherwise small objects (nuts, bolts or bottle caps) laid on the floor need first to be discovered when animals are sniffing on the ground of the open-field. However, small objects may not require too much attention due to their limited features that animals can explore.

As we do not know much about object invariance in rats and mice, there is a case where results are not reproduced due mainly to a poor attention paid by the experimenter to the orientation of objects in both phases of a one-trial object recognition test. A sample object with asymmetrical features can induce some spatial ambiguity in the choice phase of the test. In relation to this, there are some concerns about the validity of behavioral tests used in the study of discrimination and memory of reconfigured objects. In these tests, the reconfigured object can be selected because of the novel orientation of some of its parts (due to its asymmetrical aspect) relative to the original object, and most importantly