Research report

Relative recency influences object-in-context memory

Shu K.E. Tam [1], Charlotte Bonardi*, Jasper Robinson*

School of Psychology, University of Nottingham, University Park, Nottingham NG7 2RD, United Kingdom

HIGHLIGHTS

- Results of object-in-context experiments can be influenced by relative recency.
- Data from two experiments presented supporting this suggestion.
- This may complicate interpretation of results of object-in-context experiments.
- Recommendations are made on how to address this.
- Results consistent with an associative account of recognition memory.

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ABSTRACT

In two experiments rats received training on an object-in-context (OIC) task, in which they received preexposure to object *A* in context *x*, followed by exposure to object *B* in context *y*. In a subsequent test both *A* and *B* are presented in *either* context *x* or context *y*. Usually more exploration is seen of the object that has not previously been paired with the test context, an effect attributed to the ability to remember *where* an object was encountered. However, in the typical version of this task, object *A* has also been encountered less recently than object *B* at test. This is precisely the arrangement in tests of 'relatively recency' (RR), in which more remotely presented objects are explored more than objects experienced more recently. RR could contaminate performance on the OIC task, by enhancing the OIC effect when animals are tested in context *y*, and masking it when the test is in context *x*. This possibility was examined in two experiments, and evidence for superior performance in context *y* was obtained. The implications of this for theoretical interpretations of recognition memory and the procedures used to explore it are discussed.

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1. Introduction

The phenomenon of spontaneous object recognition (SOR)—the observation that animals show a preference for exploring a novel object rather than one that has been previously encountered

[1–3]—underlies a variety of tasks designed to examine memory processes in rats and mice. One version of this, the object-in-context (OIC) task, is used to assess rodents' ability to remember *where* they have encountered a specific object. In one typical variant of this task the rodent is allowed first to freely explore one type of object, *A*, in one context, *x*, and subsequently a different type of object, *B*, in another context, *y* (see Fig. 1). Each context-object pairing usually consists of a single trial. After a delay, a test with objects *A* and *B* is given in one or other of the two contexts. It is typically reported that normal animals show a preference for the object that has *not* been encountered in the test context [4–12]. It has been proposed that this task relates to the 'where' component of episodic memory (e.g., [11,12]), context memory (e.g., [6]), recollection (e.g., [8]) or, more generally, contextual processing [7,9,10].

Another variant of the SOR procedure, the relative recency (RR) task, is designed to evaluate learning about *when* an object was experienced, by examining the animal's ability to discriminate objects based on how long ago they have been encountered. Here

	Sample 1	Sample 2	Test	OIP	RR	Net Effect
Group x	A in x	B in y	A versus B in x	B is unpredicted & surprising	older A is surprising	OIP & RR in opposition
Group y			A versus B in y	A is unpredicted & surprising		OIP & RR act together

Fig. 1. Design of Experiment 1 and example of specific objects and contexts presented in the sample phases of an OIC recognition trial. A rat is allowed to freely explore one type of object (*A*) in one visual context (*x*), and subsequently, a different type of object (*B*) in a different visual context (*y*). Following these two sample phases animals are given a choice between *A* and *B*, either in the less recent context x, or in the more recent context y. Note that object *A* has been encountered earlier than object *B*, and thus, at the time of test, the memory trace of object *A* would be relatively weaker than that of object *B*.

the rat is allowed to freely explore one type of object, *A*, and subsequently a different type of object, *B*, in the same apparatus. After a delay, the animal receives a test with the objects *A* and *B* presented simultaneously [13–18]. Animals show a preference for object *A*, the object that has been encountered earlier in the series. Relative recency has been described as a form of *temporal memory* in which events are remembered in sequence through a *higher-order mnemonic function* (e.g., [13,14]). This description implies that the mechanism underlying RR is likely to be quite distinct from that responsible for OIC learning—indeed the learning mechanisms involved in the OIC and RR versions of the task are regarded as independent [19].

The suggestion that RR and OIC tasks rely on independent mechanisms has, however, been challenged. For example, the most obvious analysis of SOR (e.g., [1–3]) is that exposure to object *A* leaves a memory trace that is present during the test, but absent for the new object, *B* [18,20–23]. Performance on RR tasks can be explained in similar terms, by arguing that the preference for the less recent *A* stems from its memory trace being weaker than that of the more recent *B*. Moreover, as the delay between the sample trials and testing increases, the difference in preference between *A* and *B* declines [18]. This may be understood by assuming that the difference in the trace strength of *A* and *B* is greatest at short delays when *A*'s memory trace has had an opportunity to decay but *B*'s remains active; as the delay increases, the memory traces for both objects will eventually decline to some negligible value (for discussion see, e.g., [23,24]). For ease of exposition, we describe the decline in memory performance over time as '*decay*' though we acknowledge here that it might be the result of a more active process of *interference* (see, e.g., [25]). That is, the memory trace of the target stimulus may be supplanted by the accumulated memory traces of interfering stimuli that are present during the retention interval. Interfering stimuli may be explicitly added by the experimenter (see, e.g., [25,26]) but even when they are not, non-specific events in the laboratory may create the same effect (see, e.g., [27]).

An alternative, but related, analysis of SOR maintains that apparatus cues enter into an excitatory association with the pre-exposed *A*—the process assumed to underlie Pavlovian conditioning. At test, the excitatory association activates the memory of the pre-exposed object, reducing the degree to which it is explored. In contrast the novel *B*, not being associated with the apparatus cues, is unexpected in that apparatus; thus its memory is not activated and normal exploration is maintained (e.g., [20,28–30]). The same explanation can be used to explain OIC learning: Although both objects will become associated with their respective contexts, only the memory of the object that has been previously encountered in the test context will be subject to this associative activation, and this is why it is explored less than the alternative object.

This view assumes that while RR depends on differential decay of the memory trace (cf. [15–17]), OIC stems from differences in associative activation of the memory trace [18,20–23,28–30], and both processes may contribute to SOR performance. This analysis of performance on both OIC and RR tasks in terms of the same underlying mechanism raises the possibility that they might interact. For example, in the OIC procedure originally described by Dix and Aggleton [5], animals received two exposures to each of the objects, *A* and *B*, in their respective contexts in a double alternation procedure (*A*, *B*, *B*, *A*); however in most OIC reports animals received only one preexposure to each of *A* and *B* [4,6–8,11,12,31]. This arrangement is problematic, because it renders interpretation of performance ambiguous (cf. [7,12]). For example, consider the case where *A* is pre-exposed in context *x*, and then *B* in context *y* (Fig. 1). When recognition is tested in the first, less recent context, *x*, the presence of *x* should result in a preference for object *B* because it has never been presented in *x*. But on the basis of relative recency one would anticipate the opposite—a preference for object *A*, because it has been encountered earlier in the series. As a result, the two processes would counteract each other when the test is conducted in the first context. In contrast, when recognition is tested in the second, more recent context, *y*, the context would lead to a preference for object *A*, which is the same object that would be preferred on the basis of relative recency. Thus here *both processes* would lead to a preference for object *A*. This would predict that OIC recognition should appear stronger when the test is conducted in *y*—the second and more recent context—than in *x*.

The preceding analysis does not deny the reality of the OIC effect; but it does suggest that, especially in this one-sample-trial variant, OIC performance can in part be attributed to the mechanism underlying RR. Moreover, although this suggestion is consistent with the proposal that both RR and OIC can be explained in terms of the same underlying mechanism, it does not require it: Provided one accepts the existence of both OIC and RR effects, the possibility that both might operate in the same task remains. This in turn implies that deficits in OIC performance produced by neural manipulations are ambiguous (e.g., [6–12,31])—a neural manipulation that affects OIC performance may indeed be the result of a