



Litmus test of rich episodic representations: Context-induced false recognition

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ABSTRACT

Context-dependent episodic memory is typically investigated using tasks in which retrieval occurs either in the reinstated context of encoding or in a completely new context. A fundamental question of episodic memory models is the level of detail in episodic memory representations containing contextual information about the encoded event. The present study examined whether memory is affected when the contexts of encoding and retrieval are highly similar but not exactly the same. At encoding, participants saw unique object images presented on the background of unique context scene images. On a surprise recognition test, the objects were either old or visually similar to ones seen at encoding (lure stimuli). The objects were presented on either the old or a lure context image; the lure context image was visually similar to the corresponding object's encoding context. Context reinstatement increased the hit rate for the old objects, but also increased the false alarm for the lure objects. This latter finding indicates that the presence of the encoding context at test does not always aid recognition memory decisions. These results suggest that slight visual differences between the contexts of encoding and retrieval matter, as context reinstatement leads to a tendency to respond Old even in case of small differences in the old and lure contexts.

1. Introduction

The study of context-dependent memory effects has been of particular scientific interest since it has significant implications and provides important suggestions for a variety of applied areas, e.g., eyewitness testimony, psychotherapy, and educational practice (for an overview, see [Smith and Vela, 2001](#)). Context-dependent memory refers to the improvement in memory performance when the contexts (information aside from the focal, target information) of encoding and retrieval match ([Tulving, 1974](#); for overviews, see e.g., [Isarida and Isarida, 2014](#); [Smith, 1994](#); [Smith and Vela, 2001](#)). The presence/re-representation of the encoding context at test helps to remember by providing a set of cues at retrieval ([Thomson and Tulving, 1970](#); [Tulving and Thompson, 1973](#)).

The operationalization and the definition of context are crucial to better understand differential effects of context among studies and among experimental circumstances. Some studies define context that persists and gradually changes over time (e.g., [Yonelinas, Ranganath,](#)

[Ekstrom, and Wiltgen, 2019](#)), whereas other studies define context as information that is task-irrelevant or at least incidental to the task being performed (e.g., [Hayes, Nadel, and Ryan, 2007](#)). Others prefer to make a distinction between global and local contexts instead (see [Dalton, 1993](#)). While global contextual elements (such as elements of the environmental context) are associated with a set of focal stimuli, local contextual elements are associated with only one or a few stimuli (such as when a focal stimulus is presented on a unique background scene image). In the latter case, therefore, the focal stimulus and the contextual features together form a unique association (see [Davenport and Potter, 2004](#); [Hayes et al., 2007](#); [Tsivilis, Otten, and Rugg, 2001](#)). Global and local context effects on memory are not necessarily associated with the same processes. For example, some stimulus parameters (such as stimulus novelty) affect context-dependent memory but not for all types of context (see e.g., [Dalton, 1993](#); [Russo, Ward, Geurts, & Scheres, 1999](#)).

The most frequently used method to assess context-dependent memory is the so-called reinstatement paradigm in which retrieval

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occurs within either the context of encoding or another context. Memory performance is shown to be better when the original context is reinstated, especially when testing occurs in the form of a recall task (e.g., Godden and Baddeley, 1975; Isarida and Isarida, 2007; Smith, Glenberg, and Bjork, 1978). For recognition memory, the empirical findings are more controversial (for an overview, see Smith and Vela, 2001). Numerous studies found no or weak contextual effects on the correct recognition of previously studied (old) items (e.g., Godden and Baddeley, 1980; Jacoby, 1983; Smith et al., 1978). One explanation for this observation is that a recognition memory test in itself provides enough non-contextual cues that aid remembering (see Smith and Vela, 2001). Despite these negative findings, several studies demonstrated context-dependent effects for recognition memory (e.g., Dalton, 1993; Davenport and Potter, 2004; Geiselman and Bjork, 1980; Murnane and Phelps, 1994; Tsivilis et al., 2001), and a meta-analysis of 75 studies also showed a reliable context-dependent recognition memory enhancement (Smith and Vela, 2001).

Importantly, context-dependent enhancement of recognition memory is typically measured by the amount of correctly recognized target items. However, it is a question of the utmost importance whether/how the presence of the encoding context affects the correct rejection of non-studied (new) stimuli in a recognition memory task. The answer to this question seems to be essential, because recognition memory decisions require the detection of a studied old item in a noisy environment (see Mickes, Johnson, and Wixted, 2010; Wixted, 2020). Interestingly, context reinstatement not only improves the correct recognition of the studied stimuli, but it also increases the false alarm rate for the non-studied stimuli (e.g., Hockley, 2008; Murnane, Phelps, and Malmberg, 1999). In other words, as the result of context reinstatement, there is a general bias towards Old responses (see also Feenan and Snodgrass, 1990). Hockley (2008) concluded that this effect is probably due to an increase in familiarity which stems from the re-presentation of the encoding context at retrieval.

Discriminating between studied and new items in a recognition memory task is particularly difficult in case of overlapping stimuli that share similar features. The reduction of interference between such similar sensory inputs is supported by a specific computational mechanism of the hippocampus, called pattern separation (for overviews, see Hunsaker and Kesner, 2013; Keresztes, Ngo, Lindenberger, Werkle-Bergner, and Newcombe, 2018; Rolls, 2013; Yassa and Stark, 2011). The findings of patient studies (Kirwan et al., 2012) and structural/functional neuroimaging studies of children (Keresztes et al., 2017) as well as of young (Bakker, Kirwan, Miller, and Stark, 2008) and older adults (Yassa et al., 2011) pointed out that pattern separation is supported by the dentate gyrus and CA3 subregions of the hippocampus (for reviews, see Rolls, 2013; Yassa and Stark, 2011).

At the behavioural level, as the result of pattern separation, one becomes able to discriminate between the encoded information and a similar (lure) stimulus (see e.g., Stark, Kirwan, and Stark, 2019). The Mnemonic Similarity Task is a modified object recognition memory task and is frequently used to assess the behavioural outcome of pattern separation (for a recent overview, see Stark et al., 2019; see also Stark, Yassa, Lacy, and Stark, 2013). In this task, participants are shown photographs of everyday objects usually in an incidental encoding situation. This phase is followed by a memory test in which participants are presented with a mixture of old and new stimuli. Crucially, participants see critical lure images as well, that are visually similar items to ones presented at encoding. The so-called Lure Discrimination Index (i.e., the correct rejection of the visually similar lure stimuli) is shown to be more sensitive to hippocampal integrity, rather than the correct recognition of studied old stimuli (e.g., Huffman and Stark, 2017; Stark, Stevenson, Wu, Rutledge, and Stark, 2015; for an overview, see Stark et al., 2019).

In relation with object recognition, most previous studies focused on the semantic consistency between the presented objects and their contexts (e.g., Bar and Ullman, 1996; Davenport and Potter, 2004). It is also crucial, however, how the visual context affects memory for a specific

object when there is no systematic semantic relationship between the focal information and its context. One important study in this line of research examined the effect of visually complex background scenes (as contexts) on the recognition of object images (Hayes et al., 2007). In a series of five experiments the authors demonstrated better recognition memory performance as the result of context reinstatement.

An important aspect of the study of Hayes et al. (2007) is that they investigated recognition memory using a paradigm in which participants were presented with old and completely new focal stimuli. At the same time, discriminating between stimuli that share similar features is often needed in everyday life. Accordingly, a recent study used not only old and completely new object images but visually similar lure focal stimuli as well in a modified version of the Mnemonic Similarity Task (Racsmany, Bencze, Pajkossy, Szöllösi, and Marián, 2021). The main goal of this study was to examine whether the presence of incidentally encoded (visually complex) background scenes at test affects memory for studied old objects and the rejection of visually similar lure items. In accordance with the results of previous studies, the re-presentation of the encoding context at test increased the hit rate for the old objects. Interestingly though, context reinstatement increased the false alarm rate for the lure objects. In other words, it can be assumed that context reinstatement diminished the efficiency of pattern separation at a computational level.

Another study using a very similar experimental design also found an increase in false alarms (as the result of context reinstatement) for lures that shared features with the studied items (Doss, Picart, and Gallo, 2018). In this study, participants were instructed to make conceptual associations between the objects and the background contexts scene images at encoding. The authors concluded that context reinstatement prompted the recall of these conceptual associations at test and the conceptual fluency of the object-context binding led to an increase in hit rates for the old objects and an increase in false alarm rates for the lure objects. Another important finding of this study is that the false recognition of the lure objects was associated with high confidence. Doss et al. (2018) suggested that these high confidence ratings indicated false recollection (see also Doss, Weafer, Gallo, and de Wit, 2020).

1.1. Study objectives

In brief, a couple of findings pointed out that the reinstatement of the encoding context does not always aid recognition memory decisions. When there is a need for interference resolution between highly similar focal stimuli, the re-presentation of the encoding context at retrieval leads to an increase in false recognition (Doss et al., 2018, 2020; Racsmany et al., 2021). Following the same line of reasoning, it also seems to be essential to investigate context-dependent memory when the context of retrieval is similar to but not exactly the same as the encoding context. In fact, the term context refers to a complex set of information, and it rarely happens in everyday life that the contexts of encoding and retrieval are exactly the same or that they are completely different. Instead, there are good reasons to assume that the contexts of encoding and retrieval generally have similar features, while at the same time always have unique properties making them distinguishable. Therefore, we designed an experiment to investigate recognition memory for interfering object stimuli and to examine whether performance is affected when the contexts of encoding and retrieval are similar but not exactly the same. The definition of context in the present study is close to that of Hayes et al. (2007) since these authors defined context as information that is task-irrelevant (or at least incidental) to the task being performed.

As a first step, we collected and validated a set of scene images. Specifically, we collected a set of 91 scene image pairs. Each image had a visually similar corresponding (lure) pair. These images were used in two stimulus validation tasks. The first task was a recognition memory task, whereas in the second task, participants rated the visual similarity of the image pairs. In other words, the first task was conducted to

validate the mnemonic discriminability of the images, whereas the second task was conducted to validate the perceptual discriminability of the images. This stimulus set was then used as background images in an experimental task (see below).

Since the context of encoding is typically incidental to a given task (see Smith and Vela, 2001), we used an incidental learning paradigm, a modified version of the Mnemonic Similarity Task (Stark et al., 2013; Stark et al., 2019). Participants were presented with photographs of everyday objects at encoding; each object was seen on the background of a unique context scene image. There were two groups of participants; they differed only in the instructions presented before the encoding phase. The rationale for these two instruction types was as follows. In the encoding phase of the original version of the Mnemonic Similarity Task (Stark et al., 2013), participants are presented with object images and are required to make Indoor/Outdoor decisions. However, we used not only object images but (indoor and outdoor) scene images as stimuli as well. To assess whether there are confounding encoding effects due to the nature of the encoding task, we used an additional instruction type (Pleasant/Unpleasant decision), and not only the Indoor/Outdoor decision. These two instructions both prompt the semantic processing of the stimuli. We assumed no difference between them in terms of subsequent memory performance, we only aimed to avoid the possible effects of congruence/incongruence between the Indoor/Outdoor decision and the type of the scene image (indoor or outdoor).

The encoding phase was followed by a recognition memory test; participants' task was to decide whether they had seen the object image before or not. There are different variants of the MST. Some authors prefer to use only Old and New as response options, whereas others prefer to use an additional Similar response option (for an overview, see Stark et al., 2019). On the one hand, when participants have three response options, incorrect New responses and correct Similar responses can be separated (see Kirwan and Stark, 2007). On the other hand, the use of only two response options reduces task difficulty. Crucially, it has been demonstrated that both of the two variants of the MST are sensitive for the same influencing factors including hippocampal integrity, age, task instructions, etc. (see Stark et al., 2015). Finally, following the tradition of some previous studies (e.g., Berron et al., 2018; Leal, Tighe, and Yassa, 2014; Stark et al., 2015), we decided to use only Old and New as response options.

The objects on the recognition test were either exact repetitions of the objects presented at encoding (old objects) or visually similar to ones seen in the encoding phase (lure objects). Also, the context scene stimuli were either old or lure images. The lure context stimulus was visually similar to the corresponding object's encoding context image. Confidence ratings were also collected following each Old/New response (for similar experimental designs and procedures, see e.g., Bencze, Szöllösi, and Racsomány, 2021; Szöllösi, Bencze, and Racsomány, 2020).

It can be assumed that participants have a sense of familiarity with the lure context stimuli in our experiment (at least to some extent) resulting from the similarity between the encoded context images and the lure images. Strongly related to this assumption, a couple of studies investigated the effect of different-but-familiar context on recognition (e.g., Hockley, 2008; Murnane and Phelps, 1994). In these experiments, a context stimulus was presented at encoding and then it was shown at test as well, but was not paired with the same focal item at encoding and test. Memory performance was better in the different-but-familiar condition than it was in the condition when the focal stimulus was presented on a completely new context. More importantly, there was no difference in memory performance between the different-but-familiar condition and the condition where the focal stimulus was presented together with its encoding context (same-old context condition). Additionally, the study of Macken (2002) showed a higher false alarm rate in the different-but-familiar condition as compared to the completely new context condition. This pattern of findings indicates that the familiarity of a context in itself can affect recognition memory decisions. Based on this observation, it seems plausible that due to their familiarity, lure

contexts can affect recognition performance in our task, similar to the old contexts. However, if there is still a difference in recognition decisions between the old and lure contexts, it can be concluded that slight (visual) differences between the contexts of encoding and retrieval matter.

In sum, the experimental design of the present study allows us to investigate whether a focal stimulus and its unique context together form a detailed memory representation in an incidental encoding situation. If this set of information still forms a meaning-based (gist) representation, small visual changes (from study to test) in the context should not affect memory for the focal object. In addition, since only the visual details make the old and lure contexts distinguishable, semantic (or conceptual) cues cannot account for possible context-dependent memory effects in the present experiment. Finally, as we use old and visually similar focal object stimuli, we can draw conclusions about whether (small) differences in the encoding and test contexts selectively affect memory performance that is suggested to be hippocampus-dependent and is assumed to be related to the computation called pattern separation.

2. Materials and methods

2.1. Participants

Participants were undergraduate students. They received either course credit or money for participation and gave written informed consent. Participants had no history of psychiatric/neurological disorders and had normal or corrected-to-normal vision. The study had been approved by the United Ethical Review Committee for Research in Psychology (Hungary) and was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Altogether 76 individuals participated in the study. First, 35 participants completed two stimulus validation tasks. Then we used G-Power (Version 3.1.9.2.; Faul, Erdfelder, Lang, and Buchner, 2007) to calculate required sample size for the experimental task. We used the effect size value of $d = 0.947$ (observed in Racsomány et al., 2021, who had a very similar experimental design to the present experiment's design), a power of 95%, and an alpha error probability of 0.05. Required sample size was a minimum of $n = 17$. We had two groups in the present experiment. The two groups differed only in the instructions before the encoding phase of the memory task. Participants in the first group made Indoor/Outdoor decisions, whereas participants in the second group made Pleasant/Unpleasant decisions in the encoding phase. To ensure that we can detect any possible moderating effect of instruction, the experiment was conducted with the minimum required sample size in each group. We also expected some drop out, so finally we collected data from 41 participants ($n_{\text{Indoor/Outdoor}} = 21$; $n_{\text{Pleasant/Unpleasant}} = 20$).

We did not analyse the data of two participants in the first stimulus validation task. These exclusions were due to a technical error and because one participant gave no response in 44 trials (in 32% of the trials) which was >3 SDs from the mean of the sample ($M_{\text{no response}} = 7.0$ trials, $SD = 11.3$). One participant was excluded from the sample of the experimental task, because this participant gave no response in 12 trials (in 10% of the trials) of the memory task (which was >3 SDs from the mean of the sample, $M_{\text{no response}} = 2.7$ trials, $SD = 2.1$).

Following the exclusions, the final samples were as follows: $n = 33$ (23 females; age range: 19–38 years, $M = 23.7$, $SD = 4.3$) in the first stimulus validation task and $n = 35$ (24 females; age range: 19–38 years, $M = 23.7$, $SD = 4.2$) in the second stimulus validation task. There were two groups in the experimental task with 21 participants in the first (Indoor/Outdoor) group (18 females; age range: 18–31 years, $M = 21.5$, $SD = 2.8$) and 19 participants in the second (Pleasant/Unpleasant) group (17 females; age range: 18–24 years, $M = 21.2$, $SD = 2.0$).

2.2. Stimuli

The stimuli were object-background image pairs. The object images were adapted from Stark et al. (2013, 2019). This stimulus set consists of color photographs of everyday objects and each object image has a visually similar (lure) version. The similarity level of these object image pairs was determined by Lacy, Yassa, Stark, Muftuler, and Stark (2011) on the basis of false alarm judgments in a recognition memory task. The background images (color photographs of scenes) were either selected from freely available internet data sources or taken from a commercial stock-photo database. Each image belonged to a unique semantic category. We refer to these background scenes as contexts in the following.

2.3. Stimulus validation: Background context scene images

2.3.1. Stimulus validation task 1: Methods and results

The scene image pairs were tested in two groups in the first stimulus validation task. The reason for this is that in the recognition task we are only able to gather data on the similarity of half of the images that are used as lures in the test phase. Therefore, we systematically used a different half of the images as lures for the two groups of participants to gather enough data for each image (Group 1, $n = 18$: 46 target, 45 lure, 45 foil images; Group 2, $n = 17$: 45 target, 46 lure, 45 foil images).

The procedure of the first stimulus validation task is illustrated in Fig. 1a. Participants were presented with the 91 scene images in the encoding phase (for 4 s each with an inter-stimulus interval [ISI] of 1 s). They were required to make Pleasant/Unpleasant decisions (the response buttons were N and V, respectively). The encoding phase was followed by a surprise recognition memory test where participants were presented with 136 scene images. In the test phase, there were old, new, and (visually similar) lure images. Participants had 4 s in each trial to make an Old/New decision, i.e., to decide whether they had seen the image before or not (the response buttons were F and K, respectively). The ISI was 1 s.

For the individual data, Old response rates ranged between 47.8 and 100% for the old images, between 0 and 55.6% for the lure images, and between 0 and 8.9% for the new images. The results of the first stimulus validation task are illustrated in Fig. 1b. For the Old responses we conducted a repeated measures analysis of variance (ANOVA) with three levels; the ANOVA indicated a significant difference between the stimulus types, $F(1.56, 49.83) = 627.843, p < .001, \eta_p^2 = 0.952$. The simple contrast analysis showed that the ratio of Old responses was higher for the old stimuli than it was for the lures, $F(1,32) = 444.774, p < .001, \eta_p^2 = 0.933$. In addition, the ratio of Old responses was higher for the lures than it was for the new stimuli, $F(1, 32) = 71.953, p < .001, \eta_p^2 = 0.692$. Altogether, these results indicate that visual similarity affected memory performance.

2.3.2. Stimulus validation task 2: Methods and results

The procedure of the second stimulus validation task is illustrated in Fig. 2a. The scene images were tested in two groups in the second stimulus validation task; therefore, each participant was presented with only half of the images in this task (46 images in Group 1, $n = 18$; 45 images in Group 2, $n = 17$). The reason for testing only half of the images was to avoid fatigue effect due to the combined length of the two stimulus validation tasks (exceeding one hour).

Each trial consisted of the successive presentation of two images. Each trial started with the presentation of a scene image (4 s/stimulus with an ISI of 0.1 s during which a visual noise mask was presented). The second image in the trial was either the repetition of the first image in the trial (old image) or a corresponding visually similar (lure) image or a completely new stimulus. Each image was presented three times, once in an old trial, once in a lure trial, and once in a new trial. The order of the three trial types of the same image was randomized, and a lag of 3–6 trials was implemented between each two trials belonging to the same image. Participants' task was to rate the visual similarity of the two images presented in one trial. The scale ranged from 1 (Completely different) to 6 (Exactly the same). There was no time limit to respond, the ISI was 1 s.

For the individual data, mean similarity ratings ranged between 5.4 and 6.0 for the old-old image pairs, between 1.3 and 4.7 for the old-lure image pairs, and between 1.0 and 1.8 for the old-new image pairs. The results of the second stimulus validation task are illustrated in Fig. 2b. We calculated the median ratings for the individual data and for all types of image pairs (old-old, old-lure, and old-new). For these similarity ratings, we conducted a repeated measures ANOVA with three levels; the ANOVA indicated a significant difference, $F(1.01, 34.28) = 517.151, p < .001, \eta_p^2 = 0.938$. The simple contrast analyses showed that the old-old pairs were given higher ratings, as compared to the old-lure pairs, $F(1, 32) = 122.268, p < .001, \eta_p^2 = 0.782$. In addition, the old-lure pairs were given higher ratings, as compared to the old-new pairs, $F(1, 32) = 229.935, p < .001, \eta_p^2 = 0.871$. In sum, with two tasks we validated the old-lure scene image pairs by demonstrating that they are similar and at the same time discriminable from each other (both perceptually and mnemonically).

2.4. Experimental task: Design and procedure

The experimental design and the procedure of the task are illustrated in Fig. 3. The task consisted of an incidental encoding phase and a subsequent recognition memory test (with no delay between them). The stimuli were 120 object-context image pairs at encoding (4 s/stimulus pair, ISI = 1 s), and each object was seen on the background of a unique context scene image (i.e., each object stimulus was presented only once and each context stimulus was presented only once). The objects and the context images were randomly assigned into pairs for each participant. The objects were placed in the same location on the background of the

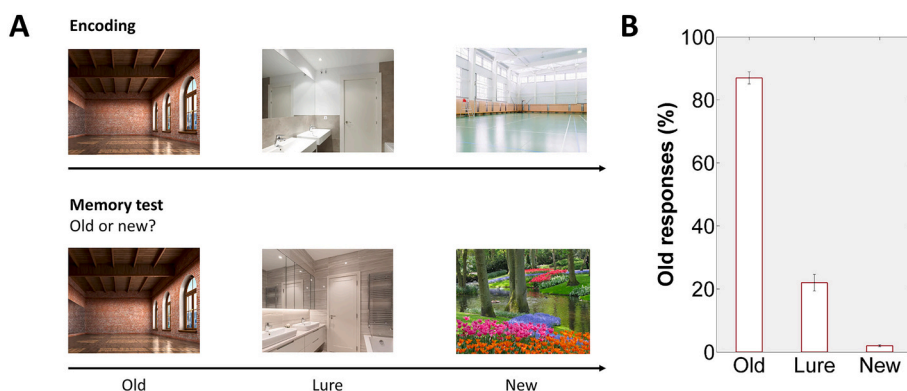


Fig. 1. First stimulus validation task: Procedure (A) and results (B).

Figure notes. (A) Participants were presented with scene images at encoding; on the recognition test, they were presented with exact repetitions of images seen at encoding (old stimuli), completely new images, and visually similar lure images to ones seen at encoding. (B) The ratio of Old responses differed between the stimulus types: old > lure > new (all $ps < 0.001$). (The error bars represent the standard error of the mean.)

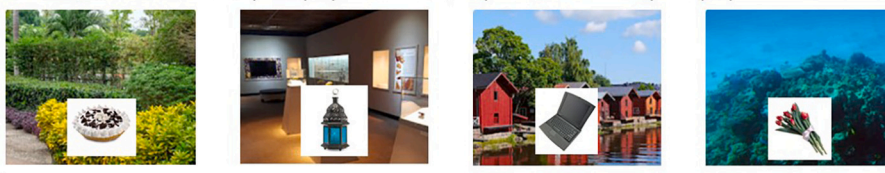


Fig. 2. Second stimulus validation task: Procedure (A) and results (B).

Figure notes. (A) In each trial, participants were presented with a scene image followed by the presentation of a visual noise mask. The second image in the trial was the exact repetition of the first image (old stimulus), or a completely new image, or a visually similar lure image to the first stimulus in the trial. (B) Similarity ratings differed between the stimulus pairs: old-old > old-lure > old-new (all p s < 0.001). (Error bars represent standard error of the mean.)

Encoding

Indoor/Outdoor decision (Group 1) or Pleasant/Unpleasant decision (Group 2)



Memory test

Old or new object?



Fig. 3. The procedure of the experimental task.

Figure notes. Participants were required to make either Indoor/Outdoor (Group 1) or Pleasant/Unpleasant (Group 2) decisions with respect to the objects in the encoding phase. On the recognition test, a 2×2 (object [old and lure] x context [old and lure]) experimental design was used. The old images (of the objects and contexts) were exact repetitions of images presented at encoding, whereas the lure images (of the objects and contexts) were visually similar stimuli to ones presented at encoding. Participants were asked to decide whether they had seen the object image before or not, followed by a judgment of their confidence in making the right decision.

contexts in each trial (at the bottom center of the screen). The objects' presentation size was 250 pixels in height and the backgrounds' height was 800 pixels.

There were two groups of participants; they differed only in the instructions presented before the encoding phase. Specifically, participants in Group 1 made Indoor/Outdoor decisions with respect to the objects, whereas participants in Group 2 were required to make Pleasant/Unpleasant judgments (again, with respect to the objects). The response options (Group 1: F = Indoor and K = Outdoor; Group 2: F = Pleasant and K = Unpleasant) remained on the screen for the duration of the encoding phase.

The two groups' tasks were the same in the recognition memory test phase. On the recognition test, a 2×2 (object [old and lure] x context [old and lure]) experimental design was used. There were 60 old objects and 60 lure objects. Previously, object images were classified into five categories (bins) based on their similarity (bin 1 = most similar; bin 5 = least similar) (see Lacy et al., 2011; Stark et al., 2019). We used lure bins 2 and 3 in our experiment and the number of lure object images per bin was the same in all context conditions. In addition, there were old and lure contexts. Specifically, half of the old objects (30 items) appeared on

old contexts and the remaining old objects (30 items) appeared on lure contexts. The lure objects were also presented either on old or on lure contexts. The lure context image was visually similar to the corresponding object's encoding context. Participants were not informed that they will be presented with old and lure scene images. The 60 old-lure image pairs were randomly selected from a larger pool of 91 old-lure context pairs. The rest of the image pairs in the pool had one member of each pair used in the other conditions.

Participants were asked to make Old/New decisions with respect to the object images (they had 4 s to respond with an ISI of 0.5 s), and then to make a secondary decision confidence judgment. Specifically, they were required to rate after each Old/New response how confident they were that they had made the right decision. The scale ranged from 1 (Not at all sure) to 6 (Very sure). There was a 90-s practice phase before the recognition test while participants were presented with the labels of the Old/New decision, followed by the confidence scale (e.g., Old, then Very sure) and were required to press the corresponding response button. Participants were asked to focus on the object only (and not on the whole image together with the context) on the recognition test.

3. Results

3.1. Recognition accuracy

Since there were two response options (Old and New), the ratio of Old responses mirrors the ratio of New responses in each condition. Therefore, in order to analyse the two object types (old and lure) in one model, we analyzed only the Old responses (hit rate for the old objects and false alarm rate for the lure objects). We conducted a $2 \times 2 \times 2$ mixed design ANOVA with Object (old and lure) and Context (old and lure) as within-subjects variables and Encoding type (indoor/outdoor and pleasant/unpleasant) as a between-subjects factor. For descriptive statistics, see Fig. 4a and Fig. 4b (for the two groups separately).

Encoding type had no effect on performance. Specifically, the main effect of Encoding type, $F(1, 38) = 1.757, p = .193, \eta_p^2 = 0.044$, the Encoding type x Object interaction, $F(1, 38) = 0.188, p = .667, \eta_p^2 = 0.005$, the Encoding type x Context interaction, $F(1, 38) = 0.772, p = .385, \eta_p^2 = 0.020$, and the Encoding type x Object x Context interaction, $F(1, 38) = 0.125, p = .725, \eta_p^2 = 0.003$, were not significant.

Both Object, $F(1, 38) = 119.361, p < .001, \eta_p^2 = 0.759$, and Context, $F(1, 38) = 14.134, p < .01, \eta_p^2 = 0.271$, had significant main effects on mnemonic performance. The Object x Context interaction was not significant, $F(1, 38) = 0.125, p = .725, \eta_p^2 = 0.003$.

In sum, as expected, the results showed a higher Old response ratio given to the old objects, as compared to the lure objects (as indicated by the main effect of Objects). More importantly, the main effect of Context indicates that the re-representation of the old context increased the hit rate for the old objects and increased the false alarm rate for the lure objects (as compared to the lure context condition).

3.2. Confidence decisions

Due to technical difficulties, two participants' confidence ratings were not recorded. Therefore, we analyzed the data of 38 participants.

For accuracy data, we analyzed the Old responses. In a subsequent analysis, we calculated the mean confidence ratings for these Old responses. Then we conducted a $2 \times 2 \times 2$ mixed design ANOVA with Object (old and lure) and Context (old and lure) as within-subjects factors and Encoding type (indoor/outdoor and pleasant/unpleasant)

as a between-subjects variable. For descriptive statistics, see Fig. 4c and Fig. 4d (for the two groups separately).

Encoding type had no effect on the confidence ratings. Specifically, the main effect of Encoding type, $F(1, 36) = 0.011, p = .919, \eta_p^2 < 10^{-3}$, the Encoding type x Object interaction, $F(1, 36) = 0.011, p = .917, \eta_p^2 < 10^{-3}$, the Encoding type x Context interaction, $F(1, 36) = 0.038, p = 846, \eta_p^2 = 0.001$, and the Encoding type x Object x Context interaction, $F(1, 36) = 0.071, p = .791, \eta_p^2 = 0.002$, were not significant.

Object had a main effect on the confidence ratings, $F(1, 36) = 36.605, p < .001, \eta_p^2 = 0.504$, i.e., the ratings were higher for the old objects, as compared to the lure objects. This difference was expected, since the Old responses were the correct responses for the old objects but not for the lure objects. More importantly, Context also had a main effect on the confidence ratings, $F(1, 36) = 5.053, p = .031, \eta_p^2 = 0.123$. This latter finding indicates that the ratings were higher in the old context condition, as compared to the lure context condition, and this difference was present for both the old and lure object types. The Object x Context interaction was not significant, $F(1, 36) = 0.222, p = .640, \eta_p^2 = 0.006$.

The ratio of New responses for the old objects was very low (17.1% averaged across conditions), therefore, we did not analyse confidence ratings for these responses. We analyzed, however, confidence ratings for the correct rejections. Means of these confidence ratings in the old context condition were as follows: $M_{Indoor/Outdoor} = 4.5, SE = 0.2$; $M_{Pleasant/Unpleasant} = 4.9, SE = 0.2$. Means of these confidence ratings in the lure context condition were as follows: $M_{Indoor/Outdoor} = 4.9, SE = 0.2$; $M_{Pleasant/Unpleasant} = 5.0, SE = 0.1$. We conducted 2×2 mixed-design ANOVA with Context (old and lure) as a within-subjects factor and Encoding type (indoor/outdoor and pleasant/unpleasant) as a between-subjects variable. Encoding type had no main effect on the ratings, $F(1, 36) = 0.874, p = .356, \eta_p^2 = 0.024$, and the Context x Encoding type interaction was also not significant, $F(1, 36) = 0.874, p = .356, \eta_p^2 = 0.024$. Importantly though, there was a trend towards significance for the main effect of Context, $F(1, 36) = 4.009, p = .053, \eta_p^2 = 0.100$. This latter result might indicate that when a lure object was presented on a lure context, confidence ratings were higher for correct rejections (as compared to the old context condition).

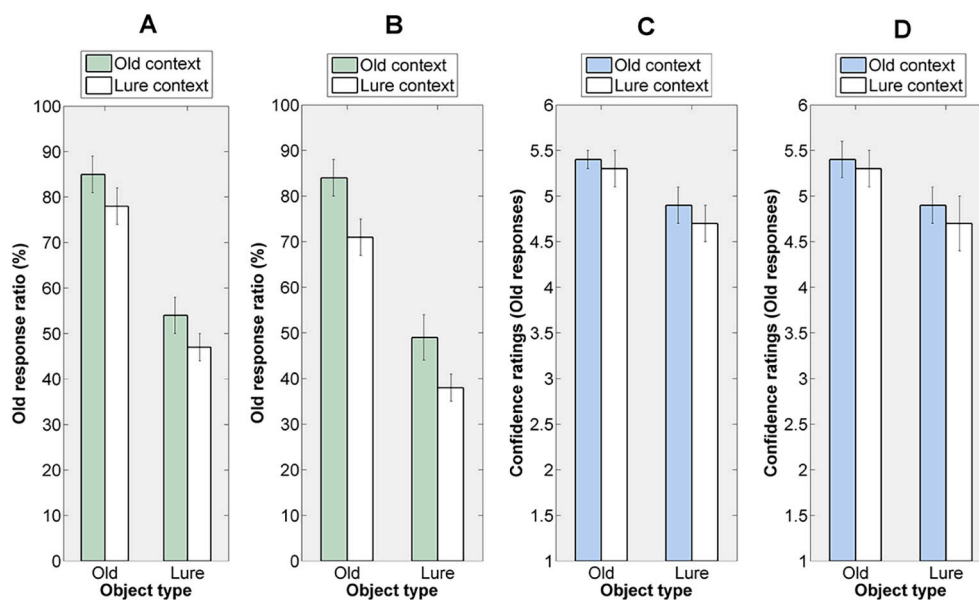


Fig. 4. The ratio of Old responses (A, B) and confidence ratings for the Old responses (C, D) in the experimental task for the two groups separately. Figure notes. A and C: Group 1 (Indoor/Outdoor decision at incidental encoding); B and D: Group 2 (Pleasant/Unpleasant decision at incidental encoding). The error bars represent the standard error of the mean.

3.3. The effect of context similarity on object recognition

We analyzed on a post hoc basis whether similarities between the lure context scenes and their corresponding (old) context scene images affected object recognition. Based on the ratio of Old responses given in the first stimulus validation task, we made three stimulus categories: less similar, middle range, and more similar scene stimuli. Stimuli with <12% Old response ratio belonged to the less similar category ($Mdn_{Old\ responses} = 5.9\%$; 32 stimuli), whereas stimuli with at least 25% Old response ratio belonged to the more similar category ($Mdn_{Old\ responses} = 37.5\%$; 32 stimuli). Then based on this classification, we re-analyzed the data of the experimental task (when these scene images were used as context stimuli). Specifically, hits for the old objects and false alarms for the lure objects were compared between the less and more similar context image categories. Hit rate was $M = 75.3\%$ ($SE = 2.3$) for the less similar context images and $M = 76.8\%$ ($SE = 2.1$) for the more similar context images. There was no significant difference between these two values, $t(60.44) = 0.504$, $p = .616$, $d = 0.127$. False alarm rate was $M = 41.6\%$ ($SE = 2.1$) for the less similar context images and $M = 43.9\%$ ($SE = 2.7$) for the more similar context images. These two values did not differ significantly either, $t(57.07) = 0.684$, $p = .497$, $d = 0.173$.

4. Discussion

The aim of the present study was to investigate the effect of context reinstatement on object recognition with a novel paradigm, a modified version of the Mnemonic Similarity Task (Stark et al., 2013; Stark et al., 2019). The paradigm used in the present study allowed us to examine the possible effect of slight visual differences between the encoding and test contexts on memory for a set of focal information. Participants were presented with object images in an incidental encoding situation, and each stimulus was presented on a unique context scene image. On the subsequent recognition memory test, the object was seen on either an old or a lure context image; the latter was a visually similar image to the corresponding object's encoding context.

Our findings showed that context reinstatement increased the hit rate for the old objects and that the effect of context reinstatement was not restricted to memory for the old objects. Specifically, when a lure object was presented on its corresponding object image's unique encoding context, there was an increase in false alarms, as compared to the lure context condition. On the one hand, our finding is a replication of several previous studies' results, since a couple of previous works have also shown that the re-presentation of the encoding context at test increases hits and false alarms (e.g., Hayes et al., 2007; Murnane and Phelps, 1994; Racsomány et al., 2021). On the other hand, our finding is an extension of the results of former studies, since in previous experiments the test contexts were either old or completely new, and consequently, these context stimuli did not share (a large number of) common features. In brief, we have extended the previous results by demonstrating that small visual differences between the encoding and test contexts affect recognition memory decisions.

It has been demonstrated previously that the semantic associations between a focal information and its context can affect memory by providing a set of conceptual cues at retrieval (e.g., Bar and Ullman, 1996; Davenport and Potter, 2004; Doss et al., 2018). In our experiment, however, there was no semantic difference between the old and lure contexts. Therefore, conceptual cues could be present in both context conditions, but because these cues were the same they could not lead to a difference in memory performance between these conditions. Our finding seems to be especially important as we used an incidental learning paradigm; consequently, participants had no consistent strategy for memorizing the stimuli. Moreover, the instructions at encoding (Indoor/Outdoor and Pleasant/Unpleasant decisions) were exclusively related to the focal information. Thus the context was irrelevant with respect to the task in the encoding phase. This type of instruction does not prompt the formation of associations between the objects and their

backgrounds, further providing ground to our claim that it was not semantic associations that influenced participants' recognition performance.

Another important aspect of our experimental design is the nature of context presentation at encoding. Numerous previous studies investigated context-dependent memory by using the same context for a set of focal stimuli at encoding, e.g., by manipulating the global environmental context of stimulus presentation (for overviews, see Isarida and Isarida, 2014; Smith, 2013; Smith and Vela, 2001). In contrast, in the present study, each object stimulus was seen on a unique context scene image during encoding, i.e., we manipulated the local contexts of the focal stimuli (see Dalton, 1993). That is, each object was presented once, and accordingly, each context scene image was presented only once. Therefore, as context reinstatement affected memory under these conditions, it can be concluded that the specific association between the focal information and its own context affected memory performance, including hits and false alarms. Importantly though, since global and local context effects on memory are not necessarily associated with the same processes (see Dalton, 1993; Russo et al., 1999), future studies are needed to test whether our findings can be generalized to the effects of global context.

Several authors suggest that the tendency to respond Old as a consequence of context reinstatement is due to an increase in the sense of familiarity (e.g., Hockley, 2008; Murnane and Phelps, 1994). Our findings seem to reinforce this idea. In other words, our results indicate that familiarity signals can support memory for item-context associations, and therefore, recollection might be not necessary for the retrieval of contextual information (as suggested by e.g., Macken, 2002; Yonelinas, 1997). The global activation model provides a plausible explanation for our findings (see Murnane and Phelps, 1994). This model proposes that a test cue activates a set of items in memory, and this global activation provides a basis for recognition decisions. The response criterion does not change between the same and different context conditions, and therefore, it leads to a general tendency towards Old responses, and consequently, to an increase in hit rate and also in false alarms.

The familiarity plus corroboration account (Lampinen, Ryals, and Smith, 2008; Odegard and Lampinen, 2004) also presents a good explanation for our results. According to this model, the similarity of an encoded item and its lure pair leads to a strong feeling of familiarity that is associated with a biased search to find episodic details that would corroborate the increased familiarity. This latter model claims that familiarity signals can support memory for item-context associations (see also e.g., Ngo and Lloyd, 2018) but does not rule out that recollection may also play a key role in context reinstatement effects (see also Yonelinas, 1997).

It should be highlighted that the Old responses were associated with higher confidence decisions when the object stimuli were presented on old contexts (as compared to the lure context condition). Specifically, not only the correct responses (Old for the old objects) but the incorrect decisions (Old for the lure objects) were associated with relatively high confidence. Some authors suggest that recollection is associated with the highest level of confidence (Yonelinas, 2001, 2002), whereas others propose that not only the highest, but relatively high confidence decisions are associated with recollection (Gardiner and Java, 1990; Tulving, 1985). Relatedly, familiarity-based decisions can be associated with high confidence as well (Gardiner and Java, 1990). Therefore, it is difficult to conclude from the confidence ratings whether the false recognition of the lures stems from recollection or from familiarity-based decisions in the present experiment. However, our findings clearly indicate that increased false alarm rates for the lure objects could not be the consequence of reduced confidence.

4.1. Future plans

It has been suggested previously that context reinstatement leads to a bias towards pattern completion (Doss et al., 2018). The computational

mechanism of pattern completion refers to when a memory is retrieved in response to degraded or partial cues (Hunsaker and Kesner, 2013; Keresztes et al., 2018; Rolls, 2013; Yassa and Stark, 2011). For the studied (old) items, this pattern completion bias can lead to an increase in hit rate, whereas for the lure items, the bias towards pattern completion can be associated with incorrect responses (an increase in false alarms) when the encoded representations are not sufficiently distinct. Our results seem to reinforce this idea, future neuroimaging studies are needed, however, to clarify this question.

Interestingly though, there was no difference in object recognition depending on the level of similarity between the lure context images and their corresponding image pairs in the present study. In other words, small differences between the scene images affected memory when these images were the focal stimuli (in our stimulus validation task) but not when features of these images served as contextual information (in our experimental task). On the one hand, this finding might indicate that while small differences between the old and lure contexts affect recognition memory for the focal information, smaller differences between the lure contexts do not. On the other hand, we believe that future studies are needed to investigate whether parametric changes in perceptual features of the context stimuli influence memory for the focal information. Such an experimental manipulation of context similarity could answer the question as to what degree of visual similarity between the context images affects memory for the focal objects.

It should be also stressed that there was no condition in the present experiment where the object image was paired with an old scene image that was not the object's original pair. In the absence of such a condition, it is difficult to conclude whether it was the unique association between an object and its context that affected memory performance, or just the familiarity of the scene image itself.

Finally, it should be also highlighted that there was no explicit memory test for the scene images in the experimental task we used. Such an experiment can answer the question whether detailed representations of the scene images are indeed encoded and whether the re-presentation of the focal information affects memory for the context images (see Shahabuddin and Smith, 2016). Relatedly, the results of our stimulus validation tasks cannot fully translate to the results of our experimental task. First, the scene images were the focal information in the validation task. Second, only the scene images were presented in the validation task, and consequently, they were not masked by the object images as in the experimental task. This latter aspect of the experimental design further strengthens the idea that investigating memory explicitly for the scene images can be a possible aim of future studies.

CRedit authorship contribution statement

Ágnes Szöllösi: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization. **Péter Pajkossy:** Conceptualization, Methodology, Writing – review & editing, Project administration. **Dorottya Bencze:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Visualization. **Miklós Marián:** Conceptualization, Methodology, Writing – review & editing. **Mihály Racsmány:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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