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Electrophysiological evidence for context reinstatement effects on object recognition memory

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ABSTRACT

Reinstating the context present at encoding during the test phase generally enhances recognition memory compared with changing the context when specific item–context associations are established during encoding. However, it remains unclear whether context reinstatement improves the performance in differentiating between old and similar items in recognition memory tests and what underlying cognitive processes are involved. Using the context reinstatement paradigm together with event-related potentials (ERP), we examined the context-dependent effects of background scenes on recognition discrimination among similar objects. Participants were instructed to associate intentionally specific objects with background scenes during the encoding phase and subsequently complete an object recognition memory task, during which old and similar new objects were presented superimposed over the studied old or similar new background scenes. Electroencephalogram was recorded to measure the electrophysiological manifestations of cognitive processes associated with episodic retrieval. Behavioral results revealed enhanced performance in differentiating old from similar objects in the old context, as opposed to the similar context condition. Importantly, ERP results indicated a more pronounced recollection-related parietal object old/new effect in the old context compared to the similar context condition. This suggests that the ability to distinguish between old and similar objects in recognition memory is primarily driven by recollection rather than familiarity, particularly when the encoding context is reinstated during the test phase. Our findings are in line with the account that the impact of context reinstatement on object recognition memory is attributable to the enhanced recollection of specific item–context associations during retrieval and provides evidence for the specificity of episodic associative representations.

1. Introduction

Context plays a crucial role in episodic memory. Reinstating the encoding context in the test phase may enhance memory retrieval relative to changing the context (Hockley & Bancroft, 2015; Isarida & Isarida, 2014; Roediger et al., 2017; Smith, 2014). For example, going back to an old place such as our university campus often brings back memories of the past that might never be remembered in other places. Numerous studies have previously established the positive effects of context reinstatement on episodic memory, particularly in recall tasks (Godden & Baddeley, 1975; Smith, 1985; Smith & Vela, 2001; Smith et al., 1978). According to the encoding specificity principle (Tulving & Thomson, 1973), context information presented concurrently with the to-be-remembered information at study can serve as a retrieval cue for accessing the target information from stored memory traces during the test phase.

It is noteworthy that context reinstatement effect is less consistent in recognition memory tasks (Isarida & Isarida, 2014; Roediger et al., 2017). The contextual dependence of recognition discrimination, which pertains to the ability to distinguish between old and new test items in memory, was not supported in early studies (Godden & Baddeley, 1980; Murnane & Phelps, 1995, 1994, 1993; Smith et al., 1978). Specifically,

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these studies generally revealed higher rates of both hit and false alarm responses to test items when the test context was old relative to the new context, which is commonly referred to as the concordant effect. There were no notable discrepancies in memory discrimination accuracy between the conditions of the old and new contexts. The global matching model (e.g., Clark & Gronlund, 1996) explains the concordant effect by assuming that the context automatically acts as a retrieval cue to match with the memory traces, thus augmenting the familiarity of both old and new test items. Fortunately, subsequent research has demonstrated reliable context reinstatement effects on recognition discrimination accuracy, especially when the context is intentionally encoded together with the to-be-remembered items (Hanczakowski et al., 2014; Hockley, 2008; Hockley et al., 2012; Isarida et al., 2020; Murnane et al., 1999; Shahabuddin & Smith, 2016). Therefore, it is possible that reinstated context in a test is more likely to improve recognition memory when individuals successfully associate the study items with their contexts during encoding (Hockley & Bancroft, 2015).

However, the neurocognitive mechanisms underlying context reinstatement effects in recognition memory are not yet clear. It is well-accepted that recognition memory can be underpinned by two dissociable cognitive processes, namely familiarity and recollection (Yonelinas, 2002). While familiarity is a rapid process that occurs without the need for retrieval of specific details of a previously experienced event, recollection is a conscious process that necessitates the retrieval of relevant event details. To date, two competing views have attempted to explain which cognitive processes support the beneficial impacts of context reinstatement on memory performance.

The item, associated context, and ensemble (ICE) model, an extended version of the global matching model, proposes that not only the context itself but also the ensemble information influences the recognition memory performance (Murnane et al., 1999). Ensemble information, as a unique memory representation formed by integrating the study item with context during encoding, would additionally increase the hit rates to study items when the context is reinstated at test, thus resulting in a recognition discrimination advantage in the old context owing to the enhanced familiarity-based recognition judgments during the test.

The dual-process account offers an alternative perspective (Gruppuso et al., 2007; Macken, 2002). It proposes that the beneficial effects of context reinstatement on item recognition memory are driven by facilitated recollection during retrieval. Specifically, individuals are more likely to recognize the study items when the exact context paired with the item during encoding is reinstated during the test because they have bound the study items to their contexts during encoding and subsequently consciously recollect the specific item–context associations. Several studies support this account by showing that context effects in recognition tests are accompanied by recollection-based rather than familiarity-based recognition judgments using the remember/know procedure (Diana et al., 2013; Hockley, 2008; Gruppuso et al., 2007; Macken, 2002).

Notably, most of the previous studies investigating context effects in recognition memory have used recognition tests containing studied and completely new items (Ensor et al., 2023; Hanczakowski et al., 2015; Isarida et al., 2020; Shahabuddin & Smith, 2016). It remains unclear whether context reinstatement effects also occur for recognition discrimination between old items and physically similar new items. It is relatively difficult to discriminate among similar items in recognition memory, which is thought to depend on pattern separation, a neurocomputational process by which similar items sharing overlapping features with old items are transformed into less similar ones (Leal & Yassa, 2018; Yassa & Stark, 2011). To date, three studies have addressed this question by examining the impacts of background scene pictures on object recognition memory (Doss et al., 2018; Racsmány et al., 2021; Szőllősi et al., 2023). All these studies found that picture context reinstatement increased both correct responses to old objects and false alarm rates for similar objects, while not affecting recognition discrimination between old and similar objects.

The lack of beneficial outcomes of context reinstatement on the ability to distinguish between old and similar objects in these studies may be attributed to several methodological issues. On the one hand, participants were engaged in an incidental encoding task during the study phase and were unaware of the memory test that would be conducted in the future (Doss et al., 2018; Racsmány et al., 2021; Szőllősi et al., 2023). On the other hand, participants were directed to concentrate solely on the objects during encoding (Racsmány et al., 2021; Szőllősi et al., 2023). These manipulations may have impeded participants from establishing unique object–context associations during encoding, thus potentially diminishing the memory advantage in the old context condition. Interestingly, despite Doss et al. (2018) instructing participants to create associations between the objects and their contexts during the study phase, no context reinstatement effects on the ability to discriminate between old and similar objects were observed. This may be due to the contextual manipulation by which a particular context had to be linked with multiple study items instead of exclusively linking it with one study item, thus compromising the benefits of context reinstatement on recognition memory because of the interference caused by competing associations. In support of this view, it has been shown that it becomes more difficult for participants to retrieve specific associations as the number of associations between different study items and the same context increases (Hockley & Bancroft, 2015; Reder et al., 2013).

The first objective of the present study was to examine the contextual influence of background scenes on recognition memory in situations that require differentiation between old and similar objects, using the context reinstatement paradigm. We used common and familiar objects as study items and semantically unrelated background pictures of real-world scenes as contexts (see Fig. 1 for example). Each object was paired with a unique background scene during encoding. Critically, the participants were required to associate objects with background scenes intentionally during encoding. Afterward, they undertook a recognition memory task that comprised of studied objects and similar objects that were physically and conceptually similar to the studied objects (e.g., two different suitcases) regardless of their background contexts. In the old context condition, the test objects were presented with pictures of the old background scene from the study phase. Notably, we manipulated the new context condition by presenting the test objects together with new background scenes that were physically and categorically similar to the scenes from the study phase (e.g., two different bookshelves).

It has been suggested that representations of associative information in episodic memory can be remembered at different levels of specificity (Greene, et al., 2022; Greene & Naveh-Benjamin, 2020; Greene & Naveh-Benjamin, 2022; Greene & Naveh-Benjamin, 2023). The highly specific representation of an association refers to a representation that retains precise information about which specific components had been associated together during encoding (e.g., remembering that the helmet had been paired with the particular desert scene). The gist representation of an association refers to a representation of association at a less specific or detailed level (e.g., remembering that the helmet had been paired with a desert scene, but not remembering specifically which desert scene). In the present study, it is supposed that highly specific representations of associative information would be retrieved for the old objects in the old context condition, while less specific or gist representations of associative information would be retrieved for the old objects in the similar context condition. As a result, by taking the similar context as a control condition, we can examine the effects of the specificity of object-context associations on recognition memory.

Furthermore, the present study aimed to elucidate the cognitive mechanisms that underlie the beneficial effects of context reinstatement on memory performance. To this end, electroencephalogram (EEG) was captured, and event-related potentials (ERP) were extracted during the test phase. The ERP technique is widely recognized for its ability to offer a reliable measure of the subprocesses involved in the retrieval of episodic memory (Rugg et al., 1998). Two ERP old/new effects have been identified in previous ERP studies, which can be viewed as

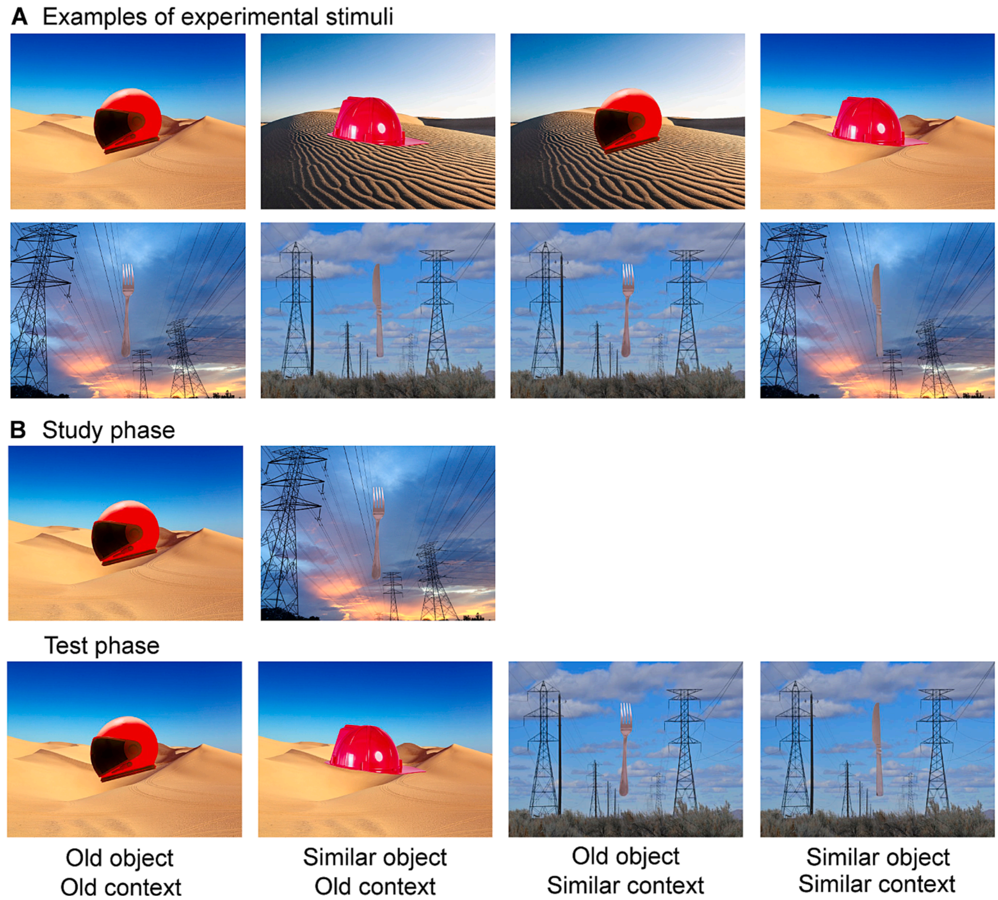

Fig. 1. Panel A shows examples of the quadruples; each quadruple contains two similar objects and two similar background scene pictures and thus, four object–scene arrangements. Panel B shows the context reinstatement task. At study, objects were presented superimposed on a unique background scene picture. At test, the old and similar new objects were presented superimposed on a restated background scene picture (i.e., old context) or a similar new background scene picture (i.e., similar context), resulting in four different experimental conditions.

potential indicators of familiarity and recollection, respectively. The early mid-frontal old/new effect that occurs approximately 300 ms after stimulus onset—maximal at frontal recording sites—is associated with familiarity-based recognition (Mecklinger & Bader, 2020; Rugg & Curran, 2007). The late parietal old/new effect that emerges around 500 ms post-stimulus is indicative of recollection-based remembering (Friedman & Johnson, 2000; Rugg & Curran, 2007). The topography of this effect exhibits a parietal maximum for words but is more widespread for pictures (Gutchess et al., 2007; Höltje & Mecklinger, 2020). By comparing the ERP old/new effects between reinstated and similar contexts, we can explore the specific cognitive processes underlying the advantages of context reinstatement in discrimination among similar items in recognition memory. Of importance, we can investigate the electrophysiological correlates of the specificity of object-context associations in episodic memory.

Behaviorally, we predicted that reinstatement of the encoding context relative to the similar context during retrieval would lead to an enhanced ability to distinguish between old and similar objects. According to the ICE model, context reinstatement effects on object recognition would be accompanied by an increased mid-frontal old/new effect related to familiarity during object recognition in the old context in comparison to the similar context condition. Conversely, according to the dual-process account and specificity principle of memory, if individuals successfully recognized the study objects because they recollected highly specific details about object–context associations under the old context condition, there would be a more pronounced parietal old/new effect indexing recollection during object recognition in the old context as opposed to the similar context condition.

2. Methods

2.1. Participants

G*Power (v. 3.1; Faul et al., 2007) was utilized to determine sample size. The results of a priori power analysis indicated that 27 participants would be necessary to achieve 80% power in detecting a higher discrimination accuracy in the old relative to the similar context condition, assuming a medium effect size of 0.5 and a significance level of 0.05. However, a larger sample size was ultimately employed for the purpose of counterbalancing.

A total of thirty-one university students who were in a state of good health were recruited for the experiment. All of these individuals were native speakers of the Chinese language and had normal or corrected-to-normal vision. Furthermore, they did not exhibit any signs of neurological or psychiatric disorders. Due to an inadequate number of artifact-free trials (<15) for the purpose of computing the averaged ERP in at least one experimental condition, data from one participant were eliminated, leading to a final cohort of 30 participants (15 females, mean age = 21.93 years, standard deviation (SD) = 2.97). The Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences gave their approval for the experimental procedures. All participants provided informed consent and were paid for their participation.

2.2. Materials

Stimuli were selected from the Official Rating of Complex Arrangements (ORCA) picture database developed for cross-cultural cognitive research (Weigl et al., 2023). Specifically, in this database, there were 180 common and familiar object pairs (e.g., two pictures of a suitcase) and 180 indoor and outdoor scene pairs (e.g., two pictures of a field) with high physical and conceptual similarities. The pictures of an object pair were separately placed in the center of the pictures of one scene pair, resulting in 180 quadruples, each containing four object–scene combinations. Examples of quadruples are presented in Fig. 1A. In Weigl et al. (2023), 24 young Chinese participants (12 females, mean age 21.83 years, SD = 2.40) were enlisted to rate the familiarity of objects and semantic fit of object–scene associations using a 6-point self-report scale. Familiarity refers to the extent to which one experiences an object in one's personal life. Semantic fit refers to the extent to which one can associate the depicted object with the scene depicted in the background. The ratings of familiarity of objects ranged from 1 (not familiar at all) to 6 (completely familiar), and the ratings of semantic fit of object-scene associations ranged from 1 (not associated at all) to 6 (completely associated). The mean familiarity for the two pictures in each object pair and the mean semantic fit for the four object–scene associations in each quadruple were calculated. We selected 120 quadruples from the database based on the criteria of mean familiarity $\geq$ 3.5 and mean semantic fit $\leq$ 3.5. The results showed that the object pictures had a high familiarity (5.11 $\pm$ 0.41) and the object–scene associations had a low semantic fit (1.59 $\pm$ 0.49).

In the present experiment, an object picture selected at random from an object pair was presented during the study phase and later utilized as an old item. Another picture in this object pair served as a new item during the test phase. Similarly, one picture randomly selected from a scene pair was presented during the study phase and later employed as an old background context. Another picture in this scene pair served as a new background context during the test phase. Object–scene combinations during recognition were always from predetermined quadruples. To ensure equal presentation of each object picture and scene picture in a quadruple, the recognition status and context condition assignments were counterbalanced. This ensured that every picture was presented with equal frequency as an old or similar item and as an old or similar context.

The formal experiment involved four study-test blocks. Each study list comprised 30 object–scene associations. Each test list consisted of 30 studied object pictures and 30 non-studied similar object pictures that were similar in physical and categorical attributes to the old objects, superimposed over an old or new background scene picture. Of the 30 studied objects, 15 were displayed on the original background scene picture as paired at study, and 15 were displayed on a new background scene picture physically and categorically similar to the background pictures as paired at study. Of the 30 non-studied similar objects, 15 were tested with an old background scene picture presented at study and 15 were tested with a similar background scene picture not presented at study (see Fig. 1B). The arrangement of the study-test blocks was counterbalanced among the participants. Across the four test lists, 240 trials were executed, including 60 associations for each of the following: old object–old context, old object–similar context, similar object–old context, and similar object–similar context.

2.3. Procedures

The E-Prime 2.0 software (Psychology Software Tools, Inc.) was utilized to design the experiment, while the participants employed a keyboard to provide their responses. All pictures (object: 256 $\times$ 256 pixels; scene: 640 $\times$ 480 pixels) were presented in a central position on a white background. The viewing distance was approximately 100 cm, and all images were digitally calibrated to maintain uniformity in terms of brightness and contrast.

The experimental procedures for the study and test phases are depicted in Fig. 2. In the study phases, a trial was initiated with the presentation of a fixation cross (+) in the middle of the screen for a duration of 500 ms. An object picture superimposed over a background scene picture was then presented in a randomized sequence for 5,000 ms. To motivate the participants to engage in active encoding of each object-context association, a rating interface was provided to prompt them to rate whether the object spatially fits with the background scene picture. The scale ranged from 1 (lowest fit) to 6 (highest fit), and the participants were allowed to rate at their own pace. Subsequently, the next trial was initiated.

A distraction task was implemented between the study and test phases, wherein participants were required to undertake a novelty oddball task for a duration of 150 s. The participants were instructed to press the space key in response to a target stimulus (i.e., "X") and not to respond to a standard (i.e., "O") or a novel (e.g., "ψ") stimulus.

During the test phases, every trial was initiated with a fixation cross displayed for 500 ms, succeeded by the presentation of an object picture superimposed over a background scene picture presented in random order with a maximum duration of 2,000 ms. An "old/new" prompt under the picture background was used to instruct the participants to indicate whether the object had been previously presented during the study phase, regardless of the background scene picture. They were instructed to respond as accurately as possible. The prompt was

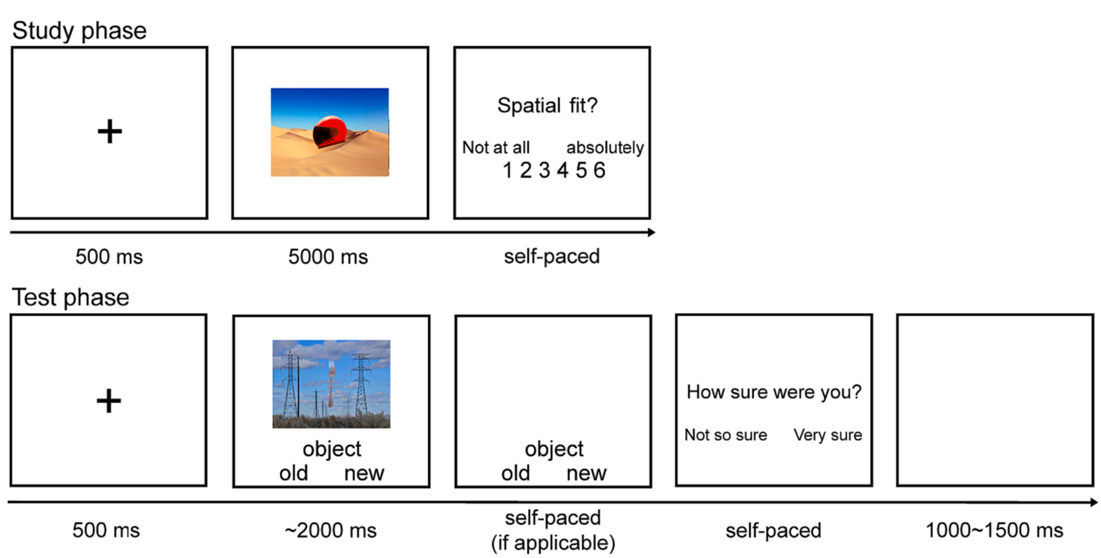

Fig. 2. Schematic representing a trial at the study and test phases during the context reinstatement task.

displayed until a response was obtained. Thereafter, a confidence rating screen was presented to direct the participants to assess their level of certainty in their recognition decision by means of a two-alternative, forced-choice examination (i.e., not so sure or very sure). Once the participants had provided their response, a blank screen was exhibited for a period of 1,000 ~ 1,500 ms, after which the next trial was initiated.

Preceding the initiation of the formal experiment, each participant was subjected to a brief practice session aimed at familiarizing them with the procedures. To reduce EEG artifacts, the participants were advised to sustain gaze fixation, remain calm, and abstain from making any head or eye movements aside from blinking.

2.4. EEG recording and processing

An elastic cap containing 62 Ag/AgCl electrodes was utilized to record the EEG in a continuous manner, following the extension of the international 10–20 system. Electrodes were positioned above and below the left eye, as well as on the outer canthi of both eyes, in order to obtain vertical and horizontal electrooculograms. The electrode impedances were maintained below 5 kΩ. Amplification of the EEG was carried out through a Neuroscan Synamps amplifier (https://www.neuroscan.com) operating within a frequency range of 0.05 to 100 Hz, with a sampling rate of 500 Hz. The electrodes were initially referenced to the left mastoid during online recording, and subsequently re-referenced to the average of the left and right mastoids during offline analysis.

The EEG data obtained from the test phase was subjected to an offline analysis using the Neuroscan v. 4.3 software package. The ocular artifact reduction algorithm, which employs a regression-based approach, was utilized to automatically rectify eye blink artifacts (Semlitsch et al., 1986). The data was filtered through a low-pass zero-phase shift FIR filter with a cutoff frequency of 30 Hz (12 dB/octave). Segments were extracted from −200 to 2000 ms relative to the stimulus onset. Baseline correction of the segments was carried out based on activity during the 200 ms preceding to the stimulus onset. Any segments with amplitudes exceeding ± 100 μV were removed to eliminate any artifacts that may have been caused by eye movements, muscle activity, electrode drift, or other sources of interference.

To obtain sufficient segments for averaging the ERP, the ERP recordings for accurately recognized old objects and properly rejected similar objects in both old and similar context conditions were combined across the two confidence levels. Each participant had to produce at least 15 artifact-free segments in each experimental condition to guarantee an acceptable signal-to-noise ratio. One participant was eliminated because of limited valid segments. Henceforth, the dataset comprises 30 participants who were included for further statistical analyses. The mean number of segments (mean ± SD and range) contributing to the grand average ERP in each condition was as follows: old context: old object (47 ± 8; 18–58) and similar object (47 ± 8; 29–58); similar context: old object (44 ± 8; 19–58) and similar object (47 ± 7; 29–59). According to the results of a one-way repeated-measures analysis of variance (ANOVA), there were no significant disparities in the number of trials among the four conditions ($F(3,87) = 1.84$, $p = .169$, partial $\eta^2 = 0.06$).

2.5. Statistical analyses

2.5.1. Behavioral data

To examine context reinstatement effects on object recognition memory, we analyzed the recognition performance collapsed across two confidence levels.

The mean proportions of old responses were subjected to a repeated-measures ANOVA with the within-subjects factors of Context (old, similar) and Object (old, similar). In addition, we calculated the discrimination accuracy ($d' = z$(hit rates to old objects) – z(false alarm rates to similar objects)) and response bias [C = - [z(hit rates to old objects) + z(false alarm rates to similar objects)]/2] according to signal detection theory to obtain a bias-free measure of recognition performance for each context condition. Paired-samples t-tests were then employed to examine the differences in d' and C between the old and similar context conditions. Given our hypothesis that discrimination accuracy would exhibit an increase in the old context conditions as opposed to the similar context conditions, we employed a one-tailed test of significance to investigate this effect.

The mean response times data of correct responses were subjected to a repeated-measures ANOVA with the within-subjects factors of Context (old, similar) and Object (old, similar).

2.5.2. ERP data

The mean amplitude data relative to the pre-stimulus baseline period was subjected to repeated-measures ANOVAs. The ERP old/new effect was quantified by computing the mean amplitudes during the time intervals of 300–600 ms and 800–1,200 ms, which were determined based on visual examination of the grand average waveforms and previous research (Diana et al. 2011; Mecklinger & Bader, 2020; Rugg & Curran, 2007). These specific time windows were selected to characterize the early mid-frontal and late parietal old/new effects, respectively. A relatively late onset time window for the parietal old/new effect was chosen predominantly based on visual examination of the grand average waveforms, which is in line with a prior investigation that focused on the retrieval of source memory (Diana et al. 2011). The data from three electrode sites in each of the four scalp regions were averaged and subjected to ANOVAs. These regions include the left frontal region (F1, F3, and F5), the right frontal region (F2, F4, and F6), the left parietal region (P1, P3, and P5), and the right parietal region (P2, P4, and P6).

The initial analysis involved conducting repeated-measures ANOVAs with the within-subjects factors of Context (old, similar), Object (old, similar), Region (frontal, parietal), and Hemisphere (left, right) on the average amplitudes of each time window. In cases where there were significant interactions involving the Object and Context factors, further investigation was carried out through secondary ANOVA. These analyses were conducted separately for the old and similar Context conditions, with the aim of assessing the old/new differences in different context conditions. Pairwise comparisons were employed to evaluate the old/new differences at the frontal and parietal locations for significant interactions that involved the Object factor in each context condition. For statistically reliable old/new effects, between-context condition comparisons were directly carried out through planned t-tests on the old/new difference waveforms (old minus similar objects), where appropriate. Topographical maps illustrating the old/new effects for each context condition were generated through the subtraction of the ERP of similar objects from the ERP of old objects.

The statistical analysis was carried out utilizing SPSS 21.0 (IBM Corporation, Somers, NY), with the application of the Greenhouse-Geisser correction in cases of non-spherical data. Uncorrected degrees of freedom, corrected p-values, and effect size (Cohen's d and partial η^2) are reported. A significance level of 0.05 was established for all analyses.

3. Results

3.1. Behavioral results

The mean proportions of old responses (i.e., hit rates to old objects

Table 1
Mean hit rates, false alarm rates, discrimination accuracy (d'), and response biases (C) as a function of context conditions (standard error of the mean).

	Hit rates	False alarm rates	d'	C
Old context	0.842 (0.020)	0.167 (0.022)	2.192 (0.154)	−0.007 (0.049)
Similar context	0.790 (0.026)	0.155 (0.020)	2.045 (0.135)	0.126 (0.069)

and false alarm rates to similar objects), *d'*, and *C* for each context condition are presented in Table 1.

The repeated-measures ANOVA with the within-subjects factors of Context and Object on the proportion of old responses revealed a significant main effect of Context (F(1,29) = 4.64, p =.04, partial η^2 = 0.14), suggesting higher hit and false alarm rates in the old context compared to the similar context condition. There was a significant main effect of Object (F(1,29) = 388.08, p <.001, partial η^2 = 0.93), revealing higher hit than false alarm rates in both the old and similar context conditions. The interaction between Context and Object did not reach significance (F(1,29) = 3.19, p =.08, partial η^2 = 0.10).

Paired-samples *t*-tests revealed a marginally significant higher *d'* in the old context compared to the similar context condition (t(29) = 1.70, p =.05, Cohen's d = 0.31). In addition, there was a higher *C* in the similar context than that in the old context condition (t(29) = 2.09, p =.045, Cohen's d = 0.38), suggesting a more conservative response bias in the similar context condition.

An analysis of the response times (see Table 2) using a repeated-measures ANOVA with the within-subjects factors of Context and Object revealed a significant main effect of Object (F(1,29) = 5.04, p =.03, partial η^2 = 0.15), indicating that response times were faster for old objects than similar objects in both the old and similar context conditions. The interaction between Context and Object did not reach significance (F(1,29) = 3.78, p =.06, partial η^2 = 0.12).

In summary, the results revealed that the hit and false-alarm rates for test objects in the old context were higher than the rates for those in the similar context condition. There was a trend towards a discrimination advantage in the old context condition compared to the similar context condition, suggesting that context reinstatement may be beneficial in distinguishing between old and similar objects during recognition.

3.2. ERP results

The grand average ERP evoked by correct responses to old and similar objects in the old and similar context conditions are presented in Figs. 3 and 4, respectively. ERP data from the time windows of 300–600 ms and 800–1,200 ms at the bilateral frontal and parietal regions of interest were used to quantify the early mid-frontal and late parietal old/new effects, respectively. As shown in Fig. 5, even though the ERP waveforms were slightly more positive for old objects in the similar context condition at frontal recording sites in the early time interval, no noticeable old/new differences were observed in both the old and similar context conditions in this time window. At approximately 800 ms after stimulus onset, a noticeable divergence between the ERP waveforms for "old" and "new" objects occurs. Specifically, the waveforms for old objects exhibit a more positive trend compared to those for similar objects. This positivity is observed across both anterior and posterior sites, regardless of whether the context is old or new. However, the parietal positivity is more pronounced in the old context condition than in the similar context condition.

3.3. 300–600 ms

In the initial ANOVA analysis, which incorporated the within-subjects factors of Context, Object, Region, and Hemisphere, a significant three-way interaction was observed between Context, Object, and Region (F(1,29) = 5.12, p =.031, partial η^2 = 0.15). Subsidiary ANOVA conducted for the old context demonstrated no significant main effect or interactions that involved the Object factor. This finding indicates that object recognition evoked no apparent old/new differences at any scalp region in the old context condition (see Fig. 5). A subsidiary ANOVA for the similar context indicated a marginally significant interaction between Object and Region (F(1,29) = 4.19, p =.05, partial η^2 = 0.13). Pairwise comparisons revealed no significant old/new effects at either the frontal (t(29) = 1.73, p =.094, Cohen's d = 0.32) or parietal regions (t(29) = 0.44, p =.661, Cohen's d = 0.08), despite the numerically greater old/new differences at the frontal region (0.71 μV) compared with those at the parietal region (0.13 μV; see Fig. 5).

To summarize, there was a lack of reliable mid-frontal old/new effects detected in the 300–600 ms time window in both the old and similar context conditions.

Table 2
Mean response times (in milliseconds) for correctly recognized old objects and correctly rejected similar objects as a function of context conditions (standard error of the mean).

	Old object	Similar object
Old context	1516 (60)	1649 (64)
Similar context	1596 (69)	1645 (71)

3.4. 800–1200 ms

In the initial ANOVA analysis, which incorporated the within-subjects factors of Context, Object, Region, and Hemisphere, a main effect of Context (F(1,29) = 17.70, p <.001, partial η^2 = 0.38), a main effect of Object (F(1,29) = 32.89, p <.001, partial η^2 = 0.53), and a Context × Object × Region interaction (F(1,29) = 7.44, p =.011, partial η^2 = 0.20) were observed.

A Subsidiary ANOVA for the old context revealed a main effect of the Object (F(1,29) = 37.69, p <.001, partial η^2 = 0.57). Meanwhile, no significant interactions with regards to the Object factor were identified (Fs < 1), indicating widespread old/new effects at the frontal and parietal scalp regions for correctly recognized old objects during this time interval (see Fig. 5). A subsidiary ANOVA for the similar context revealed a main effect of Object (F(1,29) = 8.48, p =.007, partial η^2 = 0.23) as well as a marginally significant interaction between Object and Region (F(1,29) = 4.19, p =.05, partial η^2 = 0.13). Pairwise comparisons revealed a trend for more prominent old/new differences at the frontal scalp region (t(29) = 3.07, p =.005, Cohen's d = 0.56) than at the parietal scalp region (t(29) = 2.20, p =.036, Cohen's d = 0.40), as shown in Fig. 5. The topographical maps of the old minus the similar difference waveforms for each context condition during this time window are illustrated in Fig. 6A.

In an additional analysis, we directly contrasted the old/new difference waveforms in the old and similar context conditions. This analysis revealed comparable old/new differences at the bilateral frontal region (collapsed over six frontal electrodes F1/3/5/2/4/6) for both context conditions (t(29) = 0.32, p =.749, Cohen's d = 0.06). At the bilateral parietal region (collapsed over six parietal electrodes P1/3/5/2/4/6), there was a more pronounced old/new effect for the old than for the similar context condition (t(29) = 2.50, p =.018, Cohen's d = 0.46). The mean amplitudes of the old/new effect (old minus similar objects) observed at the bilateral frontal and parietal regions for each context condition are shown in Fig. 6B.

To summarize, during the time window of 800–1,200 ms, object recognition evoked widespread old/new effects in the old context condition. In the similar context condition, object recognition also evoked significant old/new differences that were broadly distributed across the scalp, with the most prominent effect appearing to be over the frontal scalp region. The between-context condition contrasts revealed a greater parietal old/new effect associated with recollection in the old context condition than in the similar context condition (see Fig. 6C).

4. Discussion

Context dependency is a key characteristic of episodic memory. Reinstating the exact context paired with the study items during encoding in a recognition test may boost recognition performance when the study items are intentionally encoded in association with their contexts. However, it remains unclear whether there are context reinstatement effects on the ability to differentiate between old and similar

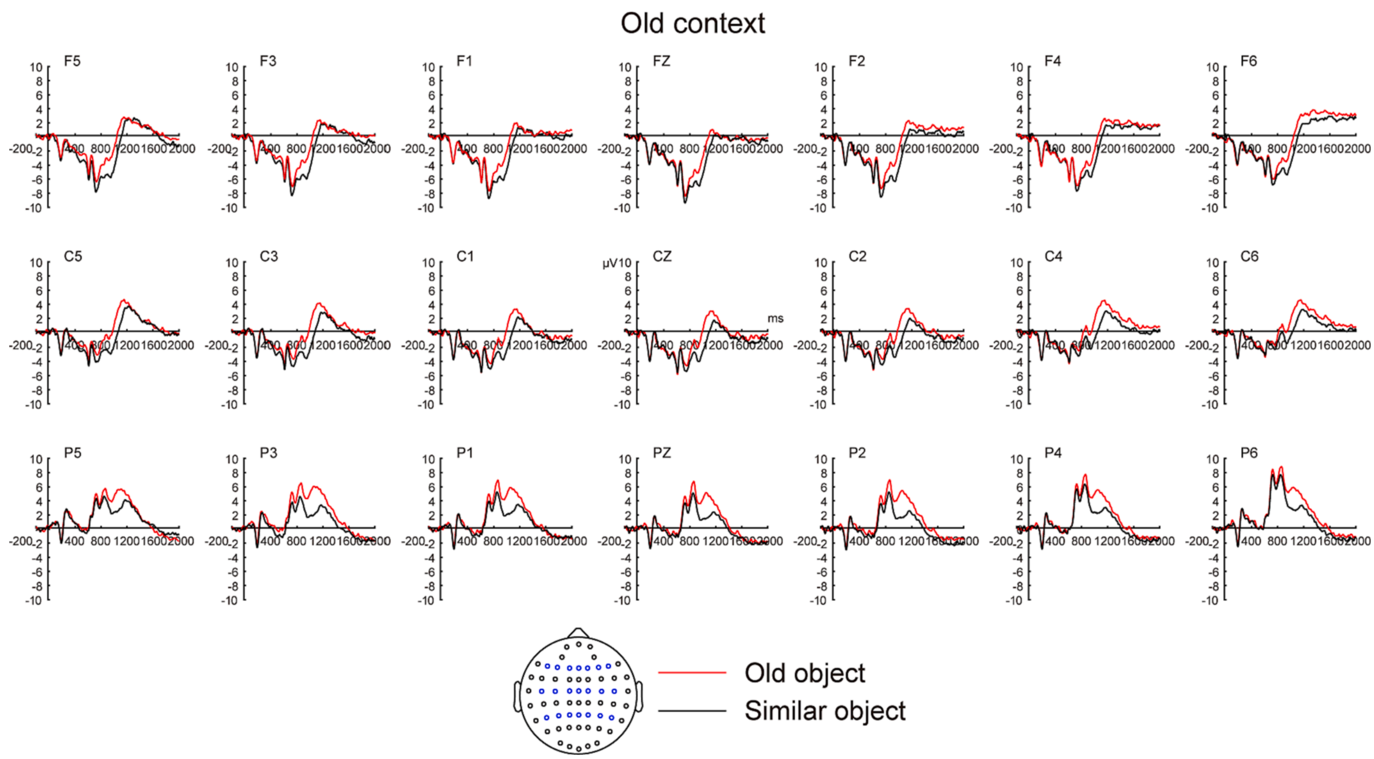

Fig. 3. The grand average ERP waveforms for old (red) and similar (black) objects in the old context condition, showing from − 200 to 2,000 ms at selected electrodes. Positive voltages are depicted upwards in the graph, with the electrode sites indicated in the inserted montage.

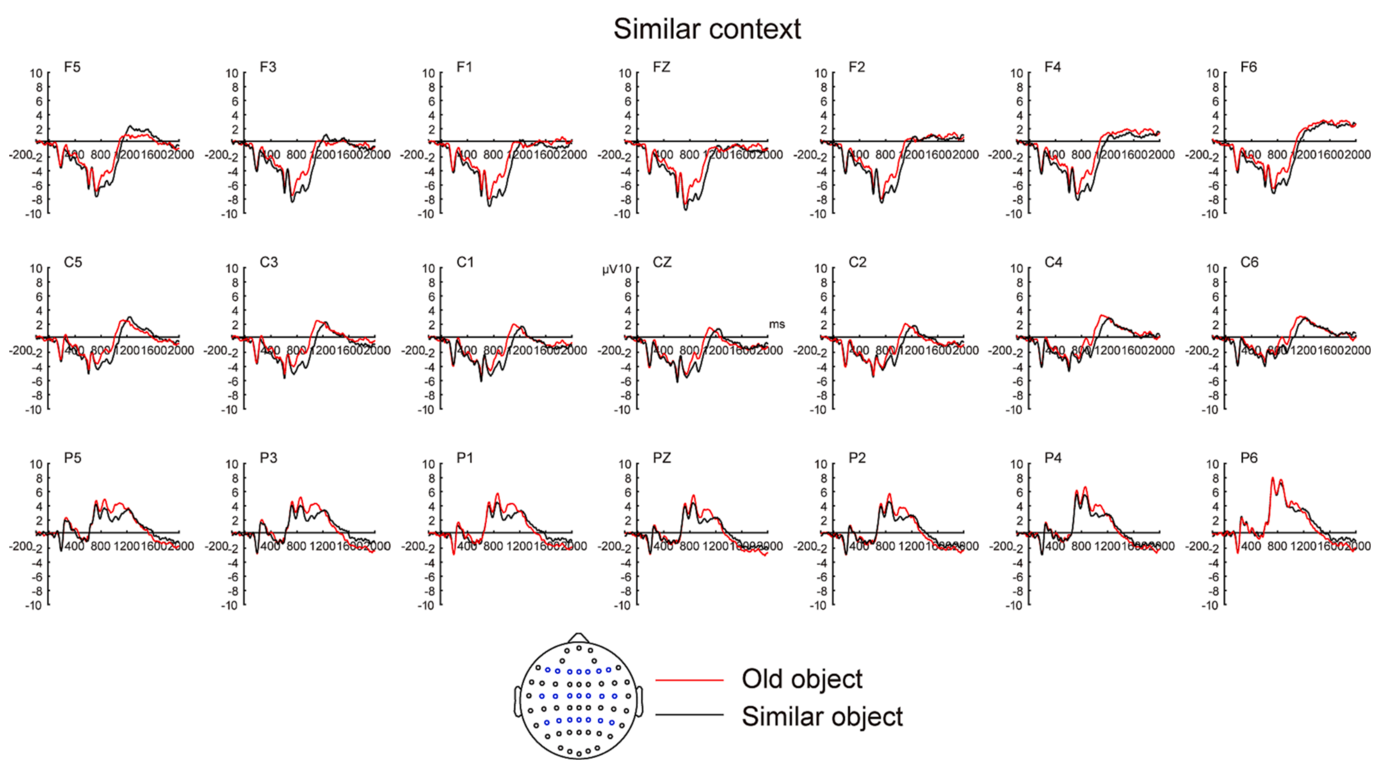

Fig. 4. The grand average ERP waveforms for old (red) and similar (black) objects in the similar context condition, showing from − 200 to 2,000 ms at selected electrodes. Positive voltages are depicted upwards in the graph, with the electrode sites indicated in the inserted montage.

items in recognition. In addition, the exact cognitive mechanisms underlying the favorable effects of context reinstatement on recognition memory have not been elucidated. The present study endeavors to provide direct answers to these questions by investigating whether reinstated background scenes affect the discrimination between studied objects and physically and conceptually similar objects. To examine the relative contribution of familiarity and recollection to episodic retrieval, EEG data was collected during the object recognition memory test and

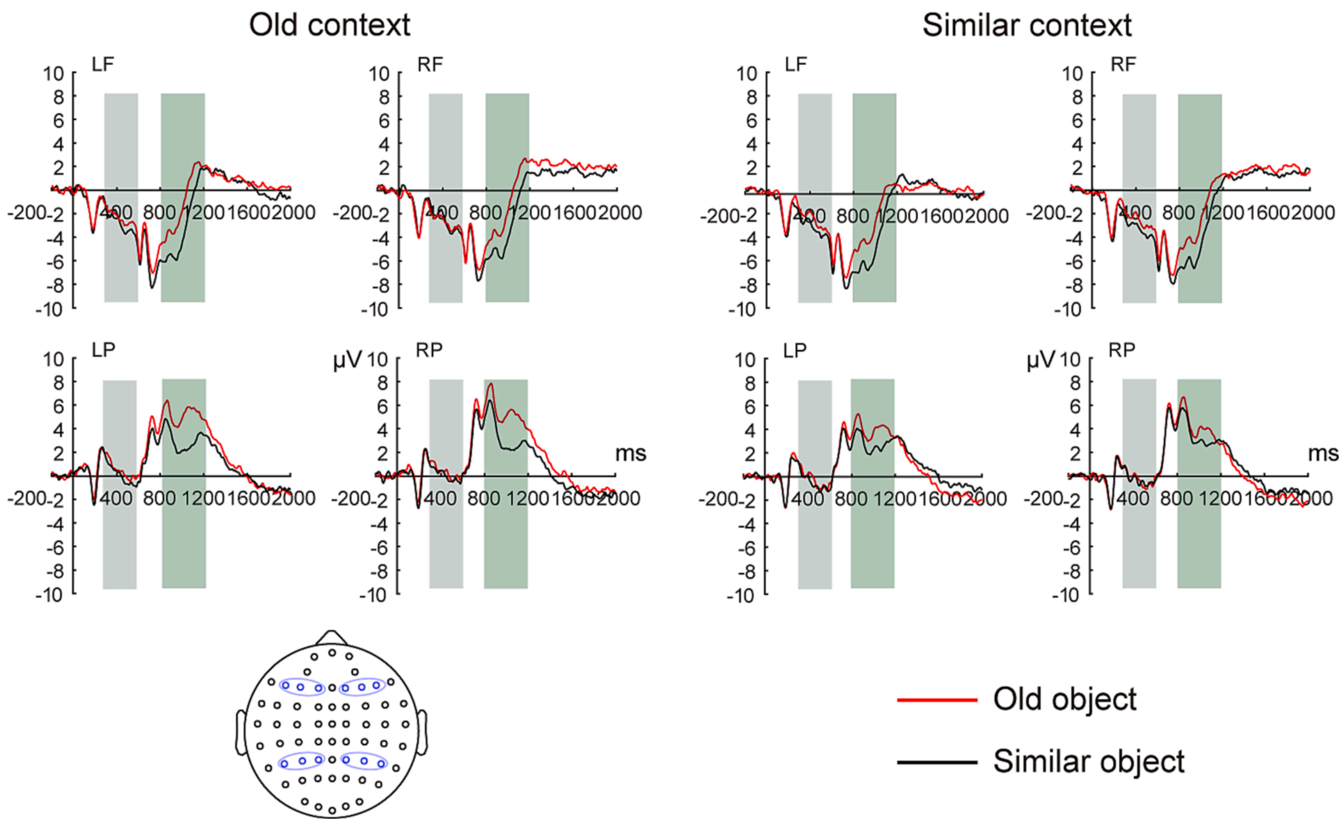

Fig. 5. The grand average ERP waveforms evoked by old (red) and similar (black) objects as a function of context conditions are shown at the scalp regions of LF (left frontal: F1, F3, F5), RF (right frontal: F2, F4, F6), LP (left parietal: P1, P3, P5), and RP (right parietal: P2, P4, P6). Each scalp region is composed of the average of the data from three electrode sites. The positive voltages are plotted in an upward direction. The montage indicates the locations of the electrode sites, while the scale bars denote the time windows utilized for statistical analyses, namely 300–600 ms and 800–1,200 ms.

ERP old/new effects were computed. As far as we are aware, this is the first investigation to explore how reinstated contexts influence ERP indicators of the retrieval process underlying object differentiation between old and similar objects during recognition.

Behaviorally, we anticipated that the reinstated context condition would demonstrate a discrimination advantage over the similar context condition. Overall, the present results lend support to our hypothesis, revealing that participants exhibited a trend towards superior discrimination accuracy in the old context as compared to the similar context conditions. As noted, prior research addressing similar question have not shown any evidence of context reinstatement effects on recognition discrimination between old and similar objects (Doss et al., 2018; Racsmány et al., 2021; Szőllősi et al., 2023). This may be because that, in the present study, the participants were instructed to focus intentionally on the relationship between objects and their background scenes during encoding for a subsequent recognition test, which might have encouraged them to integrate the objects with their context to a greater extent. In addition, rather than pairing multiple study items with one picture context (e.g., Doss et al., 2018), we paired each object with a unique background scene picture during encoding. These manipulations might have made it more likely for participants to form and retrieve unique item–context associations. Taken together, our behavioral results extend previous studies (Doss et al., 2018; Ensor et al., 2023; Hanczakowski et al., 2015; Isarida et al., 2020; Racsmány et al., 2021; Szőllősi et al., 2023; Shahabuddin & Smith, 2016) by showing that a reinstated context relative to a similar context may enhance the participants' ability to distinguish old objects from similar lures during recognition.

In addition, theoretical explanations regarding the neurocognitive mechanisms underlying context reinstatement effects of recognition memory remain controversial. Regarding the cognitive process that supports the differentiation between old and similar objects in the reinstated context, global matching models suggest that the reinstated context would leads to a rise in both the hit and false alarm rates while leaving memory discrimination accuracy unaffected because old contexts augment the familiarity of both the old and new items during the test phase (Murnane & Phelps, 1993, 1994, 1995). The ICE model extends traditional global matching models by proposing that when study items and their contexts are integrated as unique mnemonic traces, the ensemble information enhances memory discrimination by additionally increasing the familiarity of old items when the context is reinstated at test (Murnane et al., 1999). In the present study, during the early time window of 300–600 ms, our ERP results did not reveal significant early mid-frontal ERP old/new effects related to familiarity in either the old or similar context conditions. These results indicate that familiarity does not play a role when discrimination between studied objects and similar objects is required. Moreover, the present ERP results fail to corroborate the ICE model, since our findings suggest that familiarity does not contribute to discriminating among similar items in both the old and similar context conditions.

An alternative account is that the memorial benefits of context reinstatement in distinguishing old and new objects are due to the recollection of the unique object–scene associations established during encoding in the old context in recognition (Diana et al., 2013; Gruppuso et al., 2007; Macken, 2002). In the present study, during a later time window of 800–1,200 ms, we found broadly distributed old/new effects for correctly identified old objects versus correctly rejected similar objects in both the old and similar contexts. The broad topographic distribution of the old/new differences in the current study aligns with previous recognition memory research that investigate the recollection-based remembering process using pictures as experimental stimuli (Gutchess et al., 2007; Höltje & Mecklinger, 2020). The present findings suggest that the recollection process greatly supports discrimination

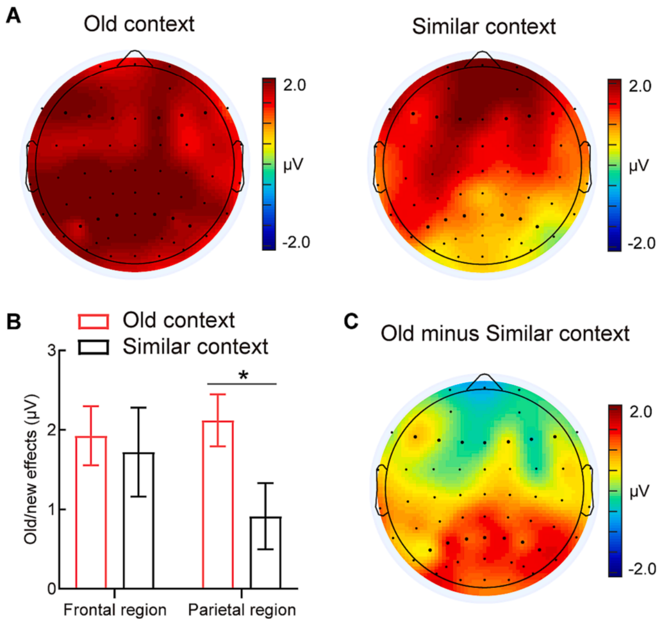

Fig. 6. Panel A displays the topographical maps of the old/new effects (800–1,200 ms) for old and similar context conditions, which were created by subtracting the ERP for correctly rejected similar objects from the ERP for correctly recognized old objects. The amplitude range is indicated by the scale bar. In Panel B, the mean amplitudes of the old/new effects are presented for both the old and similar context conditions. These effects were measured at bilateral frontal and parietal scalp regions, which were determined by averaging data from six electrodes each. Specifically, the electrodes used were F1/3/5/2/4/6 for the frontal region and P1/3/5/2/4/6 for the parietal region. The error bars denote the standard error of the mean. $^*p < .05$. Panel C exhibits the topographical map of the difference in old/new effects between the old and similar context conditions.

among similar items in recognition memory, which is consistent with a previous behavioral study examining cognitive processes involved in the object pattern separation task (Kim & Yassa, 2013). Critically, our results indicated greater old/new differences at the parietal regions in the old context than in the similar context conditions, suggesting a greater contribution of recollection rather than the familiarity process to object recognition memory in the old relative to the similar context condition. Consequently, we provide direct evidence for the dual-process account that the favorable impacts of context reinstatement on the differentiation between old objects and similar objects in memory are attributed to recollecting particular item–context associations during retrieval.

The present findings also provide evidence for the levels of specificity in episodic memory (Craik, 2002), which suggests that episodic memories can be accessed at a highly specific level of representation (e.g., remembering the exact object one has previously experienced) or at a less specific level of representation (e.g., remembering a similar object to those one has previously experienced). Recent studies demonstrate that levels of specificity of item memory can be extended to the associations between items and contexts in episodic memory, meaning that representations of associative information in episodic memory can be retrieved at different levels of specificity (Greene, et al., 2022; Greene & Naveh-Benjamin, 2020; Greene & Naveh-Benjamin, 2022; Greene & Naveh-Benjamin, 2023). Evidence supporting this account indicates that older adults experience a greater decrease in retrieving highly specific representations of associations compared to remembering gist representations of associations (Greene, et al., 2022; Greene & Naveh-Benjamin, 2020). In the present study, highly specific representations of object-context associations would be retrieved during recognition of old objects in the old context condition, while gist representations of associations would be retrieved during recognition of old objects in the similar context condition. As a result, the present findings suggest that the creation of specific representation of object-context associations is beneficial to discriminate between old and similar objects when making recognition memory judgements. Of importance, our ERP results point to the fact that recollection plays a greater role when remembering highly specific associative representations in the old context condition than when remembering gist representations in the similar context condition.

Overall, the ERP results in the current study extend previous behavioral studies (Diana et al., 2013; Gruppuso et al., 2007; Hockley, 2008; Macken, 2002) that employ a remember–know paradigm to examine the roles of familiarity and recollection in context effects on recognition memory based on individuals' subjective feelings. In addition, the present study also extends previous ERP studies investigating the cognitive processing that underlie context reinstatement effects on recognition memory (Bramão & Johansson, 2017; Bramão et al., 2017). These studies report significant ERP old/new effects related to recollection by contrasting the ERP responses linked to memory retrieval in the old context with those observed in the no-context condition. Our study is unique in that it reveals recollection-related electrophysiological evidence for the memorial benefits of context reinstatement in discriminating among similar items in recognition tests when the original contexts are reinstated, with similar contexts as a control condition. Finally, the present study has important implications for research on the neural basis of context reinstatement effects on recognition memory. Previous studies have identified that the parahippocampal/hippocampal cortex is associated with the memory recollection process for context information and item–context associations (Diana et al., 2007) and may have a crucial role in reinstating the studied context to mediate successful episodic memory retrieval in recognition memory (Diana et al., 2013; Hayes et al., 2007; Hayes et al., 2010). It is plausible to assume that these brain regions and related brain networks are especially involved in the memorial benefits of context reinstatement on recognition memory for discriminating among similar items.

5. Conclusion

In summary, we observed that the old contexts, relative to similar contexts, tentatively boost the ability to distinguish between old and similar objects in recognition memory. ERP results demonstrated a more pronounced parietal old/new effect in relation to recollection process during object recognition in the old contexts, as opposed to the similar contexts. These findings suggest that recollection supports context reinstatement effects on recognition memory for discriminating among similar items, which may further our understanding of the context dependency of episodic memory. In addition, the present study provides evidence for the specificity of episodic associative representations.

CRediT authorship contribution statement

Jingwen Miao: Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing, Project administration. **Michael Weigl:** Methodology, Writing – review & editing, Project administration. **Nuo Kong:** Methodology, Writing – review & editing, Project administration. **Min-Fang Zhao:** Methodology, Writing – review & editing, Project administration. **Axel Mecklinger:** Conceptualization, Validation, Methodology, Writing – review & editing, Funding acquisition. **Zhiwei Zheng:** Conceptualization, Formal analysis, Validation, Methodology, Visualization, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision. **Juan Li:** Conceptualization, Validation, Methodology, Resources, Writing – review & editing, Funding acquisition, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Bramão, I., & Johansson, M. (2017). Benefits and costs of context reinstatement in episodic memory: An ERP study. *Journal of Cognitive Neuroscience, 29*(1), 52–64. https://doi.org/10.1162/jocn_a_01035

Bramão, I., Karlsson, A., & Johansson, M. (2017). Mental reinstatement of encoding context improves episodic remembering. *Cortex, 94*, 15–26. https://doi.org/10.1016/j.cortex.2017.06.007

Clark, S. E., & Gronlund, S. D. (1996). Global matching models of recognition memory: How the models match the data. *Psychonomic Bulletin and Review, 3*(1), 37–60. https://doi.org/10.3758/bf03210740

Craik, F. I. M. (2002). Levels of processing: Past, present and future? *Memory, 10*(5–6), 305–318. https://doi.org/10.1080/09658210244000135

Diana, R. A., Van den Boom, W., Yonelinas, A. P., & Ranganath, C. (2011). ERP correlates of source memory: unitized source information increases familiarity-based retrieval. *Brain Research, 1367*, 278–286. https://doi.org/10.1016/j.brainres.2010.10.030

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2007). Imaging recollection and familiarity in the medial temporal lobe: A three-component model. *Trends in Cognitive Sciences, 11*(9), 379–386. https://doi.org/10.1016/j.tics.2007.08.001

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2013). Parahippocampal cortex activation during context reinstatement predicts item recollection. *Journal of Experimental Psychology: General, 142*(4), 1287–1297. https://doi.org/10.1037/a0034029

Doss, M. K., Picart, J. K., & Gallo, D. A. (2018). The dark side of context: Context reinstatement can distort memory. *Psychological Science, 29*(6), 914–925. https://doi.org/10.1177/0956797617749534

Ensor, T. M., Surprenant, A. M., Neath, I., & Hockley, W. E. (2023). Using preexperimental familiarity to compare the ICE and cue-overload accounts of context-dependent memory in item recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 49*(4), 533–546. https://doi.org/10.1037/xlm0001169

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/bf03193146

Friedman, D., & Johnson, R., Jr (2000). Event-related potential (ERP) studies of memory encoding and retrieval: A selective review. *Microscopy Research and Technique, 51*(1), 6–28. https://doi.org/10.1002/1097-0029(20001001)51:1<6::AID-JEMT2>3.0.CO;2-R

Godden, D. R., & Baddeley, A. D. (1975). Context-dependent memory in two natural environments: On land and underwater. *British Journal of Psychology, 66*, 325–331. https://doi.org/10.1111/j.2044-8295.1975.tb01468.x

Godden, D. R., & Baddeley, A. D. (1980). When does context influence recognition memory? *British Journal of Psychology, 71*(1), 99–104. https://doi.org/10.1111/j.2044-8295.1980.tb02735.x

Greene, N. R., Chism, S., & Naveh-Benjamin, M. (2022). Levels of specificity in episodic memory: Insights from response accuracy and subjective confidence ratings in older adults and in younger adults under full or divided attention. *Journal of Experimental Psychology: General, 151*(4), 804–819. https://doi.org/10.1037/xge0001113

Greene, N. R., & Naveh-Benjamin, M. (2020). A specificity principle of memory: Evidence from aging and associative memory. *Psychological Science, 31*(3), 316–331. https://doi.org/10.1177/0956797620901760

Greene, N. R., & Naveh-Benjamin, M. (2022). Effects of divided attention at encoding on specific and gist representations in working and long-term memory. *Journal of Memory and Language, 126*, Article 104340. https://doi.org/10.1016/j.jml.2022.104340

Greene, N. R., & Naveh-Benjamin, M. (2023). Adult age-related changes in the specificity of episodic memory representations: A review and theoretical framework. *Psychology and Aging, 38*(2), 67–86. https://doi.org/10.1037/pag0000724

Gruppuso, V., Lindsay, D. S., & Masson, M. E. (2007). I'd know that face anywhere! *Psychonomic Bulletin & Review, 14*(6), 1085–1089. https://doi.org/10.3758/BF03193095

Gutchess, A. H., Ieuji, Y., & Federmeier, K. D. (2007). Event-related potentials reveal age differences in the encoding and recognition of scenes. *Journal of Cognitive Neuroscience, 19*(7), 1089–1103. https://doi.org/10.1162/jocn.2007.19.7.1089

Hanczakowski, M., Zawadzka, K., & Coote, L. (2014). Context reinstatement in recognition: Memory and beyond. *Journal of Memory and Language, 72*, 85–97. https://doi.org/10.1016/j.jml.2014.01.001

Hanczakowski, M., Zawadzka, K., & Macken, B. (2015). Continued effects of context reinstatement in recognition. *Memory & Cognition, 43*(5), 788–797. https://doi.org/10.3758/s13421-014-0502-2

Hayes, S. M., Nadel, L., & Ryan, L. (2007). The effect of scene context on episodic object recognition: Parahippocampal cortex mediates memory encoding and retrieval success. *Hippocampus, 17*(9), 873–889. https://doi.org/10.1002/hipo.20319

Hayes, S. M., Baena, E., Truong, T. K., & Cabeza, R. (2010). Neural mechanisms of context effects on face recognition: Automatic Binding and context shift decrements. *Journal of Cognitive Neuroscience, 22*(11), 2541–2554. https://doi.org/10.1162/jocn.2009.21379

Hockley, W. E. (2008). The effects of environmental context on recognition memory and claims of remembering. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(6), 1412–1429. https://doi.org/10.1037/a0013016

Hockley, W. E., & Bancroft, T. D. (2015). Context dependent memory. In J. D. Wright (Ed.), *International Encyclopedia of the Social and Behavioural Sciences* (Vol. 2, pp. 787–795). Elsevier Limited. https://doi.org/10.1016/B978-0-08-097086-8.51028-9.

Hockley, W. E., Bancroft, T. D., & Bryant, E. (2012). Associative and familiarity-based effects of environmental context on memory. *Canadian Journal of Experimental Psychology, 66*(2), 81–89. https://doi.org/10.1037/a0027136

Höltje, G., & Mecklinger, A. (2020). Feedback timing modulates interactions between feedback processing and memory encoding: Evidence from event-related potentials. *Cognitive, Affective & Behavioral Neuroscience, 20*(2), 250–264. https://doi.org/10.3758/s13415-019-00765-5

Kim, J., & Yassa, M. A. (2013). Assessing recollection and familiarity of similar lures in a behavioral pattern separation task. *Hippocampus, 23*(4), 287–294. https://doi.org/10.1002/hipo.22087

Isarida, T., & Isarida, T. K. (2014). Environmental context-dependent memory. In A. J. Thirnton (Ed.), *Advances in Experimental Psychology Research* (pp. 115–152). New York: NOVA Science Publishers.

Isarida, T., Isarida, T. K., Kubota, T., Nakajima, S., Yagi, K., Yamamoto, A., & Higuma, M. (2020). Video context-dependent effects in recognition memory. *Journal of Memory and Language, 113*, Article 104113. https://doi.org/10.1016/j.jml.2020.104113

Leal, S. L., & Yassa, M. A. (2018). Integrating new findings and examining clinical applications of pattern separation. *Nature Neuroscience, 21*(2), 163–173. https://doi.org/10.1038/s41593-017-0065-1

Macken, W. J. (2002). Environmental context and recognition: The role of recollection and familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(1), 153–161. https://doi.org/10.1037/0278-7393.28.1.153

Mecklinger, A., & Bader, R. (2020). From fluency to recognition decisions: A broader view of familiarity-based remembering. *Neuropsychologia, 146*, Article 107527. https://doi.org/10.1016/j.neuropsychologia.2020.107527

Murnane, K., Phelps, M. P., & Malmberg, K. (1999). Context-dependent recognition memory: The ICE theory. *Journal of Experimental Psychology: General, 128*, 403–415. https://doi.org/10.1037/0096-3445.128.4.403

Murnane, K., & Phelps, M. P. (1993). A global activation approach to the effect of changes in environmental context on recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 882–894. https://doi.org/10.1037/0278-7393.19.4.882

Murnane, K., & Phelps, M. P. (1994). When does a different environmental context make a difference in recognition? A global activation model. *Memory & Cognition, 22*(5), 584–590. https://doi.org/10.3758/BF03198397

Murnane, K., & Phelps, M. P. (1995). Effects of changes in relative cue strength on context-dependent recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 158–172. https://doi.org/10.1037/0278-7393.21.1.158

Racsmány, M., Bencze, D., Pajkossy, P., Szőllősi, Á., & Marián, M. (2021). Irrelevant background context decreases mnemonic discrimination and increases false memory. *Scientific Reports, 11*(1), 6204. https://doi.org/10.1038/s41598-021-85627-2

Reder, L. M., Victoria, L. W., Manelis, A., Oates, J. M., Dutcher, J. M., Bates, J. T., … Gyulai, F. (2013). Why it's easier to remember seeing a face we already know than one we don't. *Psychological Science, 24*(3), 363–372. https://doi.org/10.1177/0956797612457396

Roediger III, H. L., Tekin, E., Uner, O. (2017) Encoding–Retrieval interactions. In: Wixted, J. T. (ed.), *Cognitive Psychology of Memory, Vol. 2 of Learning and Memory: A Comprehensive Reference, 2nd edition*, Byrne, J. H. (ed.). pp. 5–26. Oxford: Academic Press. https://doi.org/10.1016/B978-0-12-809324-5.21036-5.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature, 392*(6676), 595–598. https://doi.org/10.1038/33396

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11*, 251–257. https://doi.org/10.1016/j.tics.2007.04.004

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology, 23*(6), 695–703. https://doi.org/10.1111/j.1469-8986.1986.tb00696.x

Shahabuddin, S. S., & Smith, S. M. (2016). Asymmetric reinstatement effects in recognition. *Journal of General Psychology, 143*(4), 267–280. https://doi.org/10.1080/00221309.2016.1214100

Smith, S. M. (1985). Background music and context-dependent memory. *The American Journal of Psychology, 98*(4), 591–603. https://doi.org/10.2307/1422512

Smith, S. M. (2014). Effects of Environmental Context on Human Memory. In T. J. Perfect, & D. S. Lindsay (Eds.), *The SAGE Handbook of Applied Memory* (pp. 162–182). London: SAGE Publications Ltd.. https://doi.org/10.4135/9781446294703

Smith, S. M., Glenberg, A., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition, 6*(4), 342–353. https://doi.org/10.3758/BF03197465

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review, 8*(2), 203–220. https://doi.org/10.3758/BF03196157

Szőllősi, Á., Pajkossy, P., Bencze, D., Marián, M., & Racsmány, M. (2023). Litmus test of rich episodic representations: Context-induced false recognition. *Cognition, 230*, Article 105287. https://doi.org/10.1016/j.cognition.2022.105287

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352–373. https://doi.org/10.1037/h0020071

Weigl, M., Pietsch, J., Kapsali, E., Shao, Q., Zheng, Z. W., Li, J., Kray, J., & Mecklinger, A. (2023). ORCA: A picture database of object-scene arrangements for cross-cultural and aging research. *Behavior Research Methods*. https://doi.org/10.3758/s13428-023-02064-x

Yassa, M. A., & Stark, C. E. (2011). Pattern separation in the hippocampus. *Trends in Neurosciences, 34*(10), 515–525. https://doi.org/10.1016/j.tins.2011.06.006

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*(3), 441–517. https://doi.org/10.1006/jmla.2002.2864