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Distinct episodic contexts enhance retrieval-based learning

John Schwoebel, Acasia K. Depperman and Jessica L. Scott

Department of Psychology, Utica College, Utica, NY, USA

ABSTRACT

Spaced retrieval practice results in better long-term retention than massed retrieval practice. The episodic context account of this effect suggests that updated representations of the more distinct temporal contexts associated with spaced retrievals facilitate later recall. We examined whether environmental context, in addition to temporal context, may also play a role in retrieval-based learning. Participants studied and then attempted to retrieve the English translations of Swahili words during four acquisition blocks of trials. They were then randomly assigned to practice retrieving items three more times in one of the following conditions: massed practice with the same environmental context scene; massed practice with different environmental context scenes; spaced practice with the same environmental context scene; or spaced practice with different environmental context scenes. After a one-week delay, measures of recall, forgetting, and the joint probabilities between study session recall and final recall performance all indicated enhanced retention for both the spaced and different environmental context conditions. Indeed, after retrieving items in the study session, forgetting them during final recall was 371% more likely in the same context than in the different context conditions. These findings redefine and refine previous accounts of the episodic context model of retrieval-based learning.

I mean that in learning by heart (for example), when we almost know the piece, it pays better to wait and recollect by an effort from within, than to look at the book again” (James, 1890, p. 686). James’s insight that retrieval practice improves retention has been supported by a wealth of research over the last decade (Karpicke, 2017). In addition to the mediated effects of retrieval practice (e.g., guiding further studying), the process of retrieving information itself, without feedback or restudying, directly enhances long-term retention (Roediger & Karpicke, 2006).

One key finding relevant to evaluating models of retrieval-based learning is that repeated spaced retrieval practice results in substantial improvements in long-term retention relative to retrieving information only once (Karpicke & Roediger, 2007, 2008; Soderstrom, Kerr, & Bjork, 2016), or to repeated massed retrieval practice (Carpenter & DeLosh, 2005; Karpicke & Bauernschmidt, 2011). For example, Karpicke and Bauernschmidt (2011) presented participants with a list of Swahili-English word pairs to study and then tested their ability to recall the English translations when presented with the Swahili words in one of several conditions. Participants practiced retrieval (with feedback) until they correctly retrieved each English word once, then either practiced retrieval on the next three consecutive trials (i.e., massed retrieval practice), or retrieved each English word on three additional spaced trials which were separated by 15, 30, or 90 intervening trials. No feedback was provided after the repeated retrieval practice trials. One week later, participants were asked to recall the English translation of each Swahili word presented. No recall advantage was observed for the massed retrieval practice condition (M = 25%) compared to the single retrieval condition (M = 26%), but there were significant advantages for all three spaced retrieval practice conditions (15 trials M = 49%, 30 trials M = 64%, 90 trials M = 75%) relative to the massed condition and the single retrieval condition.

The episodic context account of retrieval-based learning has received substantial empirical support (Karpicke, Lehman, & Aue, 2014; Lehman, Smith, & Karpicke, 2014). The account suggests that an item to be remembered is encoded along with its temporal context, which then serves as a retrieval cue when later attempting to retrieve the item. If retrieval is successful, the temporal context associated with the item is updated so that it includes both the original temporal context at encoding and the context at the time of retrieval. This theory provides a mechanistic account of the findings summarised above which suggest an advantage in favour of spaced retrieval practice versus massed retrieval practice, insofar as massed retrieval practice results in very similar or redundant updated temporal context information that would not likely facilitate future memory searches for the item. In contrast, during spaced retrieval practice conditions,
the temporal contexts associated with the item during retrieval would be more distinct and thus more likely to aid future recall of the item by restricting the search set. Thus, the encoding of distinctive temporal contexts plays a key role in the episodic context account. Karpicke et al. (2014) posit:

The term "context" can refer to a variety of aspects of an event, including the external environment (e.g., Smith, 1979) and a person's mental state (Klein et al., 2007). The episodic context account focuses on the importance of temporal context, a representation of context that changes with the passage of time (Howard & Kahana, 2002). (p. 259)

However, there is some evidence suggesting that, in addition to time, there may be another aspect of episodic memory – place or environmental context – that plays a role in retrieval-based learning. An important recent finding (Smith & Handy, 2014) suggests that while it may be more difficult to retrieve information in different environmental contexts than in the same contexts (i.e., context-dependent memory; Godden & Baddeley, 1975; for a review, see Smith & Vela, 2001), successful retrieval in different contexts enhances long-term retention. Smith and Handy (2014) presented participants with 20 face-name pairs superimposed on unique video backgrounds during an initial study session. Five retrieval practice blocks of trials with feedback were then completed in which only the faces were presented on the background scenes and participants were asked to write down the associated names. The background scenes were manipulated between-subjects during the retrieval practice blocks so that each face was presented either with the same context presented at study or with a different context during each retrieval practice trial. Consistent with the context-dependent effects mentioned above, an initial recall advantage was observed for the same context condition compared to the different context condition during the retrieval practice trials. For example, on the fifth retrieval practice block of Experiment 1, significantly better recall was observed in the same context condition (M = 93%) than in the different context condition (M = 63%). Compellingly, on a final recall test two days later, there was an advantage for the different context condition (M = 61%) compared to the same context condition (M = 43%), suggesting that retrieval practice in different environmental contexts enhances long-term retention.

These findings, however, are ambiguous with respect to the unique contributions of environmental context to retrieval-based learning for two reasons: first, Smith and Handy (2014) provided feedback (i.e., correct face-name pairs) after each retrieval practice trial, so it is impossible to discern the unique contribution of retrieval processes to increased retention from the effects of re-exposure to the items to be remembered; second, only environmental context was manipulated by Smith and Handy (2014), so it is impossible, based on their findings, to disentangle the contributions of temporal spacing and environmental context to retrieval-based learning.

Hence, the current experiment has two main goals: first, to replicate the study reported by Karpicke and Bauernschmidt (2011), which provided key evidence for the role of temporal context in retrieval-based learning and provided support for the episodic context account; second, to clarify Smith and Handy’s (2014) findings in order to determine whether environmental context plays a unique role in retrieval-based learning. Toward these ends, we did not provide feedback after retrieval practice trials in order to examine the effects of retrieval practice in the absence of re-exposure to items. We also manipulated both environmental and temporal contexts in a 2 × 2 factorial design, to examine the unique effects of these variables on long-term retention. Therefore, we examined whether retrieving information in distinct environmental contexts – like distinct temporal contexts – increases long-term retention. Positive findings would support expansion of the episodic context account of retrieval-based learning to include environmental context.

**Method**

**Participants**

Eighty-four Utica College undergraduates participated for course credit. Nine additional students participated in the study session, but failed to return for the testing session and were thus excluded from the analyses. Two additional participants were excluded because they failed to follow instructions during the study session (i.e., recording responses during feedback trials). This research was approved by the Utica College Institutional Review Board and all participants signed consent forms prior to participating.

**Materials**

Twenty Swahili-English word pairs were selected from Nelson and Dunlosky (1994). Eighty naturalistic scenes (e.g., beach, classroom, kitchen, waterfall) were selected from Konkle, Brady, Alvarez, and Oliva (2010) and randomly-paired with the Swahili-English word-pairs with the constraint that there be no obvious relationship between the scene and the words. Stimuli were projected onto a white screen at the front of the room. The scenes appeared in colour and were 41 inches wide by 31 inches high. Word stimuli were centred approximately 2.5 inches below the scenes in a 72-point black Times New Roman font (5 inch maximum height).

**Design**

All participants studied the Swahili-English word pairs once and then practiced retrieving the English words when presented with the Swahili words and scenes during a series of four acquisition blocks of trials, with feedback after each trial (Karpicke & Smith, 2012). The acquisition trials were
included in an effort to maximise initial recall across all conditions, so that we could examine the effects of additional successful retrieval practice trials on long-term retention. Participants were randomly assigned to one of five retrieval practice conditions. In the acquisition-only condition, no further study or testing occurred after the study and acquisition trials. The remaining four retrieval practice conditions resulted from a 2(environmental context: same vs. different) × 2(temporal context: massed vs. spaced) between-subjects design (i.e., same context massed (SCM), same context spaced (SCS), different context massed (DCM), and different context spaced (DCS) retrieval practice conditions).

In all four of the retrieval practice conditions, participants attempted to retrieve each of the 20 English translations three times. In the SCM condition, each Swahili word was presented three consecutive times with the same scene that was presented during the study and acquisition trials. In the SCS condition, each retrieval attempt was separated by 19 intervening trials. For the DCM and DCS conditions, each time a Swahili word was presented, it appeared along with a unique scene (e.g., the Swahili word for horse, “farasi,” was presented with an amusement park scene during the study and acquisition trials and with an iceberg, kitchen, and library scene on the three retrieval practice trials). The order of presentation was randomly determined for the massed retrieval practice trials. For the spaced conditions, the first block of 20 retrieval practice trials was randomly determined and then repeated for blocks two and three in order to maintain the 19 intervening trials between each retrieval practice attempt for each item.

Procedure

Participants were tested in groups of 5–15 during a study session, then again in a final recall session one week later. Prior to the initial study block, participants were told that on each trial they would see a Swahili-English word pair presented below a scene, and that their goal was to learn the English translations of the Swahili words so that they could recall them later when only the Swahili words would be presented. Stimuli were presented for 5 s with a 1 s interstimulus interval.

For acquisition trials, only the Swahili words were presented below the scenes. Participants were told to write down a one-to-two word description of the scene and the English translation of the Swahili words on their response sheets, and to cover up their responses with another sheet of paper after each trial. Instructions to write down scene descriptions prompted participants to attend to the scene on each trial. Four blocks of 20 acquisition trials were presented for 10 s each with 1 s interstimulus intervals. Each trial was immediately followed by a 5 s feedback trial in which both the scene and the associated Swahili-English word-pair were presented.

During each of the repeated retrieval practice trials, a scene and a Swahili word were presented for 10 s with a 1 s interstimulus interval and participants were instructed to write down the scene and the English translation of the Swahili word just as they did during the acquisition trials. No feedback was provided during the retrieval practice trials.

Participants returned one week later for a final recall test. All 20 Swahili words were presented one at a time in a random order, without any accompanying scenes. For each trial, which lasted for 10 s with a 1 s interstimulus interval, participants were instructed to write down the English translation of the Swahili word on the screen. After completing the final recall test, participants were thanked for their participation and dismissed.

Results

Study session

We examined initial recall data from the acquisition trials in a 5 (retrieval practice conditions: acquisition-only, SCM, SCS, DCM, DCS) × 4 (acquisition block: 1, 2, 3, 4) mixed ANOVA. As shown in Figure 1, there was a main effect of acquisition block, $F(3, 237) = 276.60, p < .001$, $\eta^2_p = .78$, but there was no main effect of retrieval practice condition, $F(4, 79) = 1.09$, $p = .37$, and no interaction ($F < 1$). This suggests that significant learning occurred across the four blocks of acquisition trials, and that the performance and rate of learning was similar across participants in the five retrieval practice conditions.

A 3(retrieval practice block: 1, 2, 3) × 4(retrieval practice condition: SCM, SCS, DCM, DCS) mixed ANOVA indicated a main effect of retrieval practice condition, $F(3, 60) = 23.55$, $p < .001$, $\eta^2_p = .54$, but no significant main effect of retrieval practice block, $F(2, 120) = 1.87, p = .16$, or interaction, $F(6, 120) = 1.31, p = .26$. Since there was no effect of retrieval
practice block, we collapsed across the three retrieval practice blocks and further examined the effect of retrieval practice conditions in a 2(context: same vs. different) × 2 (spacing: massed vs. spaced) between-subjects ANOVA. As shown on the far right of Figure 1, there was a main effect of context, $F(1, 60) = 70.31, p < .001, \eta^2_p = .54$, but no significant effect of spacing or interaction ($F_s < 1$). Thus, despite the near ceiling recall performance achieved by the last acquisition block, there was a significant decline in recall performance in the different context conditions. This is consistent with the context-dependent memory effects discussed earlier (Smith & Vela, 2001).

**Final recall session**

First, we examined recall performance in the retrieval practice conditions compared to the acquisition-only condition. As shown in Figure 2, a one-way ANOVA revealed a significant overall effect of condition, $F(4, 79) = 5.70, p < .001, \eta^2_p = .22$. Subsequent comparisons demonstrated significantly better recall in all of the retrieval practice conditions compared to the acquisition-only condition (SCS $F(1, 34) = 5.05, p < .04, \eta^2_p = .13$; DCS $F(1, 36) = 15.11, p < .001, \eta^2_p = .30$; DCM $F(1, 33) = 5.49, p < .03, \eta^2_p = .14$), except for the SCM condition, which resulted in no advantage over the acquisition-only condition ($F < 1$).

Most importantly, we examined the effects of spacing and environmental context on long-term retention. A 2 (spacing: massed vs. spaced) × 2 (context: same vs. different) between-subjects ANOVA indicated a significant main effect of spacing, $F(1, 60) = 6.00, p < .02, \eta^2_p = .09$, and a main effect of context, $F(1, 60) = 7.67, p < .008, \eta^2_p = .11$, but no interaction ($F < 1$). This replicates previous findings (Karpicke & Bauernschmidt, 2011) that long-term retention is enhanced when retrieval practice occurs in different contexts rather than the same context. This context effect occurred even though recall performance during the retrieval practice blocks in the study session was significantly lower in the different context conditions than in the same context conditions.

To examine final recall performance compared to study session recall, we calculated forgetting scores by subtracting final recall from the mean retrieval practice percentage or, in the case of the acquisition-only condition, the last acquisition block percentage. As shown in Figure 3, there was a significant main effect of spacing, $F(1, 60) = 5.14, p < .03, \eta^2_p = .08$, and a main effect of context, $F(1, 60) = 158.84, p < .001, \eta^2_p = .73$, but no interaction, $F(1, 60) = 1.50, p = .23, \eta^2_p = .02$, which is consistent with the pattern of performance observed with the recall data. Very little forgetting occurred in the different context conditions ($M = 12.25\%$) relative to the same context conditions ($M = 62.68\%$).

Finally, we examined the joint probabilities associated with recall performance during the last block of retrieval practice (or last acquisition block for the acquisition-only condition) and final recall performance, following Tulving’s (1964) conventions for examining item recall across two tests (also see Karpicke & Zaromb, 2010; Whiffin & Karpicke, 2017). The probability of correctly recalling items during final recall after correctly recalling them during retrieval practice (see C1C2 in Table 1) was significantly greater in the spaced and different context conditions than in the massed and same context conditions, as indicated by a main effect of spacing, $F(1, 76) = 9.15, p < .004, \eta^2_p = .11$, and context, $F(1, 76) = 7.63, p < .008, \eta^2_p = .09$. There was no interaction ($F < 1$). Critically, the probability of not-recalling items during final recall after correctly recalling them during retrieval practice (C1N2) was
significantly lower in the spaced and different context conditions, as indicated by a main effect of spacing, \( F(1, 76) = 6.41, p < .01, \eta^2_p = .08 \), a large context effect, \( F(1, 76) = 202.18, p < .001, \eta^2_p = .73 \), and an interaction that approached significance, \( F(1, 76) = 3.03, p = .09, \eta^2_p = .04 \). Consistent with the analysis of the forgetting rates reported above, this finding indicates that participants were unlikely to forget items that were successfully retrieved during retrieval practice when retrieval practice occurred in different contexts.

**Discussion**

The current findings replicate the well-documented effects of spaced retrieval practice (e.g., Karpicke & Bauernschmidt, 2011) and provide new evidence for the role of environmental context in retrieval-based learning. Indeed, forgetting items during final recall after successfully retrieving them in the study session (see \( C_1C_2 \) in Table 1) was 371% more likely in the same context conditions (\( M = .63 \)) than in the different context conditions (\( M = .17 \)). This clarifies previous findings (Smith & Handy, 2014) by eliminating re-exposure to stimuli during retrieval practice and manipulating both temporal and environmental contexts, thus demonstrating the unique contributions of temporal and environmental contexts to retrieval-based learning. Interestingly, there was a trend toward a significant interaction between the temporal and environmental context conditions in the forgetting and joint probability analyses, suggesting that the effect of temporal spacing was enhanced when retrieval practice occurred in different contexts. Our failure to observe a significant interaction effect may be attributable to a lack of power and this possibility should be examined in future research. We also note that participants were instructed to write down a brief description of each scene in order to ensure that they attended to the environmental context associated with each word. It will be important to examine whether the environmental context effect observed under these conditions will be replicated when participants are not explicitly instructed to attend to and make note of the environmental contexts associated with items to be remembered.

The present findings support modifying the episodic context account (Karpicke et al., 2014) to accommodate the observed environmental context effect. Specifically, the observed effect suggests that updated, distinct environmental context representations formed during successful retrieval practice may help to restrict the search set during future retrieval attempts and thus enhance recall. Further, the present findings may have important implications for recent models of the spacing effect (i.e., enhanced memory following spaced rather than massed restudying; e.g., Delaney, Verkoeijen, & Spirgel, 2010; Raaijmakers, 2003), since these models also emphasise changes in context that occur over time and study-phase retrieval to account for the spacing effect. Thus, it will be important for future research to examine the role of environmental context in accounts of both the spacing effect and retrieval-based learning.

**Table 1.** Mean joint probabilities between item recall during study and test sessions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>C1C2</th>
<th>C1N2</th>
<th>N1C2</th>
<th>N1N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition Only</td>
<td>.28(.04)</td>
<td>.66(.04)</td>
<td>.00(.00)</td>
<td>.06(.01)</td>
</tr>
<tr>
<td>Same Context Massed</td>
<td>.28(.03)</td>
<td>.70(.04)</td>
<td>.00(.00)</td>
<td>.02(.01)</td>
</tr>
<tr>
<td>Different Context Massed</td>
<td>.42(.04)</td>
<td>.18(.02)</td>
<td>.03(.01)</td>
<td>.37(.04)</td>
</tr>
<tr>
<td>Same Context Spaced</td>
<td>.43(.04)</td>
<td>.56(.04)</td>
<td>.00(.00)</td>
<td>.01(.00)</td>
</tr>
<tr>
<td>Different Context Spaced</td>
<td>.51(.04)</td>
<td>.15(.02)</td>
<td>.03(.01)</td>
<td>.31(.04)</td>
</tr>
</tbody>
</table>

Note: \( C_1C_2 \) = items correctly recalled during retrieval practice and final recall; \( C_1N_2 \) = items correctly recalled during retrieval practice, but not during final recall; \( N_1C_2 \) = items not correctly recalled during retrieval practice, but correctly recalled during final recall; \( N_1N_2 \) = items not recalled during retrieval practice or final recall. Standard errors are in parentheses.

**Figure 3.** Mean forgetting after one week. Error bars represent 95% confidence intervals.
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Disclosure statement

No potential conflict of interest was reported by the authors.

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