Reminders can enhance or impair episodic memory updating: a memory-for-change perspective

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Abstract:

The *Memory-for-Change* framework proposes that retrieving episodic memories can facilitate new learning when changes between existing memories and new information are integrated during encoding and later recollected. Four experiments examined whether reminders could improve memory updating and enhance new learning. Participants studied two study lists of word pairs and were given a cued recall test on responses from both lists. Reminders of List 1 words pairs (A-B) appeared immediately before List 2 words pairs that included repeated cues and changed responses (A-D). Across experiments, we varied the types of reminders to determine whether differences in their effectiveness as retrieval cues would influence memory for the list membership of responses. We found that presenting intact reminders (cue-response) enhanced the memory benefits associated with recollection-based retrieval of changes relative to when no reminders appeared and when partial reminders (cue-only) appeared with and without feedback. Importantly, cue-response reminders benefitted memory when they were recognised in List 2 and when changes were later recollected. This suggests that integrative encoding can be facilitated when substantial environmental support is available to cue retrieval of existing memories. These findings have practical implications for understanding which reminders best aid the correction of memories for inaccurate information.

Keywords: Change recollection | interference | reminding | retrieval | updating

Article:

Change is a given in life. People change their appearance, organisations change their policies, and apparent facts sometimes become fiction. Successfully adapting to these everyday changes requires first *detecting* them to update episodic memory, and later *recollecting* them to distinguish older from more recent states of the environment. If change detection and recollection play critical roles in memory updating, then providing effective retrieval cues prior to changed events, such as *reminders* of past events, could facilitate these processes. This issue has theoretical import for understanding mechanisms of memory updating. This issue also has practical import as reminders appear often in everyday life, such as when one is reminded of fake news before a correction is provided. Here, we inform theories of reminder effects on memory updating by examining them from a *Memory-for-Change* (MFC) perspective (Jacoby, Wahlheim, & Kelley, 2015; Wahlheim & Jacoby, 2013). The present study provides a novel contribution to the MFC literature by examining how variations in explicit retrieval cues (i.e., reminders) affect the process of updating episodic memory to incorporate changes.

Memory-for-change framework

MFC proposes that when change is detected, people are reminded of existing memories. Remindings enable the formation of configural representations that include existing memories, new information, and information about temporal context. This framework is consistent with earlier accounts of memory for relative order that posit a critical role for remindings (e.g., Hintzman, 2010; Tzeng & Cotton, 1980; Winograd & Soloway, 1985). However, MFC adds a dual-process perspective (e.g., Jacoby, 1991) by proposing roles for controlled and automatic retrieval processes. According to MFC, change detection proactively facilitates order memory when configural representations are accessed using recollection-based retrieval. However, reminding also increases the accessibility of existing memories through retrieval practice. When recollection fails, the accessibility of existing memories becomes a stronger source of proactive interference. This mixture of effects determines levels of overall memory performance, which varies with the extent to which changes are detected and recollected.

The roles of detecting and recollecting change in memory updating were shown clearly by Jacoby et al. (2015; Experiments 2 and 3). In an A-B, A-D paradigm, participants studied two lists of word pairs including common cues (A) and changed responses (B to D). For one set of pairs, responses changed between lists, and for another set, responses changed within List 2. The retrieval instructions for List 2 were manipulated between groups to demonstrate the causal effects of reminding. One group identified pairs that changed from earlier in either list, whereas another group identified pairs that changed from earlier in List 2. This tested whether List 2 recall for changes that originated in List 1 was greater when List 1 was in the retrieval set. List 2 recall and recollection of between-list changes were higher when List 1 was in the retrieval set than when it was not. The effect of retrieval instructions of List 2 recall depended on differences in change recollection, as detecting and recollecting changes from List 1 was associated with proactive facilitation, whereas detecting but not recollecting changes was associated with proactive interference. Consistent with MFC, these results suggest that integrative encoding and recollection of configural representations facilitated order memory and counteracted interference. Similar conclusions have also been reached in other research examining the mechanisms of proactive facilitation effects in cued recall (e.g., Aue, Criss, & Novak, 2017).

More generally, the pattern showing that List 2 recall depends on change detection and recollection has been shown across a variety of paradigms and materials in both younger and older adults (e.g., Jacoby & Wahlheim, 2013; Jacoby, Wahlheim, & Yonelinas, 2013; Putnam, Sungkhasettee, & Roediger, 2017; Putnam, Wahlheim, & Jacoby, 2014; Wahlheim, 2014, 2015; Wahlheim & Zacks, 2019). A common feature across studies is that for change detection to occur, new information must cue retrieval of existing memories. Change detection varies with the accessibility of earlier information resulting from experimental manipulations, stimulus characteristics, and population differences. For example, increasing the accessibility of List 1 items through retrieval practice prior to List 2 increased change recollection, which benefitted List 2 recall (Wahlheim, 2015). In addition, older adults recollected fewer detected changes than younger adults, and these differences were associated with age-related episodic memory deficits (Wahlheim, 2014; Wahlheim & Zacks, 2019). Although these studies clearly show that variations in the accessibility of existing memories can influence change detection and its downstream effects, no studies have examined how reminders may alter these effects.

Hypotheses regarding the effects of reminders on proactive effects of memory can be informed by a recent study examining the role of remindings in retroactive effects of memory. Using variations of the A-B, A-D paradigm, Negley, Kelley, and Jacoby (2018) examined whether providing more time to study List 2 pairs would reduce retroactive interference on recall of List 1 pairs by promoting remindings. The outcome of this manipulation has foundational implications as interference theories predict that more exposure to sources of interference (in this case, List 2) should impair memory for information from an earlier source (e.g., Delprato, 2005; Melton & Irwin, 1940; Postman & Underwood, 1973). In contrast, MFC predicts that more exposure to List 2 items should provide more opportunity for List 1 remindings, which should facilitate List 1 memory through retrieval practice. Consistent with MFC, Negley et al. (2018) found retroactive facilitation for longer study times that was associated with an increase in remindings. Of relevance to the present study, these findings suggest that manipulations of List 2 stimulus characteristics may affect remindings.

The present study

The specific variable that we examined here was the type of reminder of List 1 pairs presented before List 2 pairs. We interpret MFC as predicting that reminders should enhance memory for recent information by cueing retrieval of List 1 pairs (cf. Wahlheim, Maddox, & Jacoby, 2014). Reminders should then facilitate detection and recollection of change. However, reminders should also become a source of interference when change is detected but not recollected (cf. Swire, Ecker, & Lewandowsky, 2017), due to the increased accessibility of List 1 pairs. Critically, these effects should depend on the extent to which reminders cue retrieval of existing memories. Although we interpret MFC as making these predictions, the model does not formally articulate predictions about reminder effects. The present study therefore served to refine MFC assumptions.

To understand the effects of reminders, we used variants of the A-B, A-D paradigm. Our variations included reminders of List 1 pairs immediately before corresponding List 2 pairs. Cue-response reminders (A-B) appeared immediately before some changed pairs (A-D) in all experiments. We compared the effects of cue-response reminders with either no reminders, or cue-only reminders (A-_). During cued recall, the left member of study pairs (A) appeared, and participants attempted to recall the right member from List 2 (D). After responding, participants indicated whether they remembered a different response appearing with the test cue in List 1 (i.e., that responses had changed). When participants indicated change, they were asked to recall the List 1 response. Based on earlier MFC studies, we assumed that classification of changed pairs along with recall of List 1 responses reflected instances of *change recollection*. This measure allowed us to assess reminder effects on List 2 recall, change recollection probabilities, and associated effects on order memory. We did not include a measure of change *detection* in List 2 to avoid overcomplicating the procedure, and because variables that affect change detection have parallel effects on change recollection (e.g., Wahlheim, 2014, 2015).

Based on earlier findings showing that increased access to List 1 responses during List 2 increases change recollection (e.g., Jacoby et al., 2015; Negley et al., 2018; Wahlheim, 2015), we expected reminders to increase change recollection to the extent that they effectively cue retrieval of List 1 episodes. Given what we know about memory performance associated with change recollection, effective reminders should then improve recall of responses from both lists and their sources. To foreshadow, the present results aligned with our assumptions that updating episodic memory to incorporate changes depended on reminder effectiveness. We found that the tradeoff of proactive facilitation and interference depended on the extent to which reminders cued List 1 retrieval. We leave descriptions of the rationale and specific hypotheses for reminder effects on List 2 recall and change recollection for each experiment below.

We also performed more fine-grained conditional analyses of List 2 recall than have been typically reported in MFC studies. As described above, we defined *recollected* changes as instances when A-B, A-D items were classified as changed and List 1 responses were recalled. We also defined *remembered* (*but not recollected*) changes as instances of correct change classification without List 1 recall. According to MFC, the memorial benefits associated with remembering changed items will be specific to instances of change recollection. However, MFC does not currently predict levels of List 2 recall when change is remembered (but not recollected). Nor does it articulate how variations in List 1 accessibility should influence List 2 recall. Wahlheim and Zacks (2019) found similar proactive interference when changes were remembered (but not recollected) and when changes were not remembered. This pattern suggests that the representations accessed when changes are remembered (but not recollected) lack the qualities necessary to facilitate order memory. It is possible that we will obtain the same patterns, but the materials from Wahlheim and Zacks (i.e., movies of everyday actions) differ from the paired-associates used here. Consequently, we did not have firm *a priori* hypotheses about patterns of List 2 recall when changes were remembered but not recollected. We report exploratory analyses of those effects in each experiment and briefly consider their implications for MFC in the General Discussion.

Experiment 1

In Experiment 1, we examined cue-response reminder effects on List 2 recall and change recollection. The materials included sets of cue-response pairs for which cues and responses were associated, but responses were not associated with each other (e.g., pearl-*harbour*, pearl-*jewellery*; see Wahlheim, 2014, 2015). We selected these materials to minimise the concern that reminding effects reflected spreading activation from List 1 to List 2 responses. Participants studied two lists containing word pairs that repeated across lists (A-B, A-B), only appeared in List 2 (C-D control pairs), or included shared cues with changed responses in each list (A-B, A-D). Participants then attempted to recall the List 2 response, indicated whether different responses appeared in List 1, and if so, attempted to recall the List 1 response. We examined reminder effects by presenting List 1 pairs (A-B) prior to half of the changed List 2 pairs (A-D). Based on MFC, we predicted that cue-response reminders would improve recall of responses from both lists by increasing change detection and recollection.

Method

In the experiments below, we report how we determined our sample size, all data exclusions, all manipulations, and all measures (Simmons, Nelson, & Simonsohn, 2012). The materials, data, and analysis scripts can be found on the Open Science Framework (OSF) website here: https://osf.io/vceba/. The research reported here was approved by the Institutional Review Board at The University of North Carolina at Greensboro (UNCG).

Participants

Forty-eight UNCG students (29 women/19 men), 18–26 years of age ($M = 19.44$, $SD = 1.75$), participated for partial course credit. Participants were tested individually. We matched our sample size to the original experiment from which we derived the materials and many aspects of the procedure (Wahlheim, 2015; Experiment 1). The sample size in that experiment was sufficient to detect effects of an interpolated task manipulation that is similar to the reminder manipulation in the present experiment. According to G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009), when comparing two conditions, we would have 80% power to detect a medium effect size (Cohen's $d \sim .42$) with $\alpha = .05$ (two-tailed) with this sample size. Although we were unable to compute effect size estimates for the results from the mixed effect models here, we made the raw data available on OSF so that others could conduct additional analyses if interested.

Design

We used a 2 (Reminder: cue-response vs. none) × 3 (Item Type: A-B, A-B vs. C-D vs. A-B, A-D) within-subjects design.

Materials

The materials, taken from Wahlheim (2015), consisted of 90-word triplets that each included a cue word (e.g., *pearl*) and two responses that were associated with the cue but not with each other (e.g., *harbour*, *jewellery*). The average forward and backward associative strengths between cues and responses, as indexed by Nelson, McEvoy, and Schreiber (1998), were low (forward: $M = .04$, $SD = .02$, $range = .01\text{-}.09$; backward: $M = .02$, $SD = .03$, $range = .00\text{-}.18$). Six groups of 15 triplets were counterbalanced across conditions. This arrangement produced six experimental formats. Groups appeared equally often in each condition across participants. The stimuli were presented on computers using E-Prime 2 software (2018) (Psychology Software Tools, Pittsburgh, PA, USA).

The experiment included three phases: List 1, List 2, and Test (for a design schematic, see Table 1). List 1 included 60 pairs divided into two groups of 30 that later became A-B, A-B or A-B, A-D items. Those groups of 30 pairs were divided into two smaller subgroups of 15 pairs that were later were assigned to the Reminder conditions. List 2 included 90 pairs divided into three groups of 30 that corresponded to each Item Type (i.e., A-B, A-B; A-B, A-D; C-D). The two groups of 30 pairs assigned to the A-B, A-B, and A-B, A-D conditions were each divided into two subgroups of 15 and assigned to each Reminder condition. The remaining group of 30 pairs (which comprised two smaller subgroups of 15 pairs) was assigned to the C-D condition. Although we analyzed the smaller subgroups in the C-D condition separately based on arbitrary Reminder condition labels that resulted from rotating groups through conditions, we assumed that there would be no systematic difference in recall because those groups were not subjected to the Reminder manipulation. For A-B, A-D pairs, the response paired with each cue (e.g., *pearl*) differed between List 1 (e.g., *harbour*) and List 2 (e.g., *jewellery*). The assignment of responses to lists remained constant across formats. The test phase included 90 test cues (15 per condition), which were the left member of List 2 pairs.

Table 1. Design schematic for Experiment 1

Item type	Reminder	List 1	List 2	Test
A-B, A-B	Cue-response	a-b	a-b, a-B	a - ?
	None	a-b	a-B	a - ?
A-B, A-D	Cue-response	a-b	a-b, a-D	a - ?
	None	a-b	a-D	a - ?
C-D	—	—	c-D	c - ?

Procedure

In List 1, word pairs appeared individually in the centre of the screen in white lowercase font against a black background. Each pair appeared 3 times (180 total presentations); individual pairs repeated after all pairs had appeared in a cycle. Pairs appeared in random order in each cycle for 3 s each followed by a 500 ms interstimulus interval (ISI). Participants were told to read pairs aloud and study them for a memory test.

In List 2, word pairs (both reminders and study items) appeared for 5 s each followed by a 500 ms ISI. Pairs appeared in two forms that distinguished cue-response reminders from List 2 study items. Reminders appeared in the same font as in List 1 (i.e., white lowercase), whereas List 2 study items appeared in green font with the left word in lowercase and the right word in uppercase. Reminders appeared on trials immediately preceding corresponding List 2 pairs (e.g., n = pearl-harbour; $n + 1$ = pearl-JEWELLERY). Participants were told that reminders would appear in the same font as in List 1, and that their tasks would be to read the reminders aloud and think about when they saw those pairs in List 1. They were also told that they would be presented with List 2 study items that included pairs that were the same as in List 1 (A-B, A-B), pairs that had the same cue as in List 1 and a different response (A-B, A-D), and pairs that were completely new in List 2 (C-D). They were instructed to note the relationship between reminders and List 2 study pairs, to read the List 2 pairs aloud, and to study List 2 pairs for an upcoming memory test. Pairs appeared in a predetermined fixed random order with the constraint that pairs from the same condition did not appear consecutively. The average input position was equated across all within-subjects conditions to control for serial position effects on memory performance.

On the cued recall test, the left member from each List 2 pair appeared individually in green lowercase font next to a blank space (e.g., pearl - _____). The presentation order was random. Participants were instructed to first type the List 2 response that had earlier appeared in uppercase green font. Next, participants indicated whether the same cue was associated with a different List 1 response by pressing the “1” key for “yes” and the “2” key for “no”. If participants indicated that another response had appeared in List 1, they were asked to type the List 1 response. Cues appeared until responses were entered. Participants were allowed to omit responses when they could not recall from the target source.

Results and discussion

All statistical tests were performed using R software (R Development Core Team, 2008). We examined the effects of the experimental manipulations using generalised linear mixed effects models, fitted with the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). This analytic approach represents a substantive contribution to the MFC literature, because it allows examination of conditional effects associated with change recollection while simultaneously controlling for variability due to subjects and items in a verbal paired-associate learning task. Consequently, any differences in memory performance associated with our measure of change recollection could not be entirely explained by item-selection artefacts. After fitting the models, we performed hypothesis tests using the Anova function of the car package (Fox & Weisberg, 2011), and performed post-hoc comparisons using the emmeans package (Lenth, 2018) with the Tukey method to control for multiple comparisons. We set the level for significance at $\alpha = .05$.

The general analysis plan for the following experiments was to examine: (1) List 2 recall, (2) List 1 intrusions, (3) change classifications, and (4) List 2 recall of A-B, A-D items conditionalised on change classifications.[1] We also report analyses involving reminder-cued retrievals in experiments that included such measures. For all analyses, we fitted models with experimental factors as fixed effects, and subjects and items as random effects.

List 2 recall

We first examined whether cue-response reminders affected overall List 2 recall (Figure 1, black points) using a 2 (Reminder) × 3 (Item Type) model. There was no significant effect of Reminder, χ^2 (1) = 0.71, $p = .40$, a significant effect of Item Type, χ^2 (2) = 617.11, $p < .001$, and no significant Reminder × Item Type interaction, χ^2 (2) = 4.06, $p = .13$. List 2 recall was significantly higher for A-B, A-B than C-D items, z ratio = 18.38, $p < .001$, and significantly higher for C-D than A-B, A-D items, z ratio = 7.12, $p < .001$. These results showed that repeating pairs produced proactive facilitation, changing responses produced proactive interference, and cue-response reminders did not affect overall List 2 recall.

[1] Note that a reviewer also expressed interest in List 2 recall performance for A-B, A-B and C-D items conditionalised on change classification responses. Because reporting those observations would create excursions from our main interests in the present study, we instead provide the raw data and descriptive statistics on OSF (https://osf.io/vceba/).

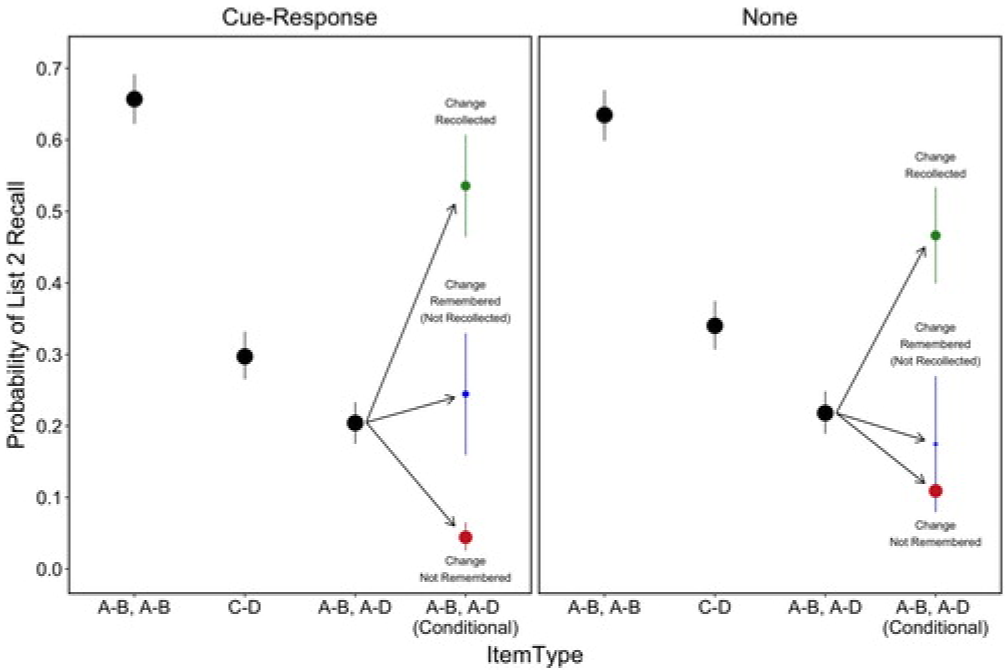

Figure 1. Probability of List 2 recall as a function of reminder and item type in Experiment 1. The left panel displays data from the "cue-response" reminder condition and the right panel displays data from the "none" reminder condition. Note that C-D items were not subjected to the Reminder manipulation. The last column of each panel displays List 2 recall conditionalised on combinations of change classifications and List 1 recall. The point areas reflect the proportion of observations included in each cell. Error bars are bootstrap 95% confidence intervals.

List 1 intrusions

Although cue-response reminders did not affect overall List 2 recall, they did lead to more List 1 intrusions. The model comparing List 1 intrusions for A-B, A-D items in each Reminder condition indicated significantly more intrusions in the cue-response ($M = .46$, $CI = [.42, .49]$) than none ($M = .31$, $CI = [.28, .34]$) condition, z ratio = 6.03, $p < .001$. Contrary to our MFC-based prediction, reminders impaired this aspect of order memory.

Change classifications

To verify that participants understood the instructions to classify pairs that had the same cue (A) and different responses (B, D) as changed, we compared correct change classifications for A-B, A-D items with false alarms to A-B, A-B items (Table 2, top rows). If participants did not understand the instructions, and instead made change classifications based on cue-familiarity (the repeated A term), then rates would be comparable for both of these item types. A 2 (Reminder) × 2 (Item Type) model indicated no significant effect of Reminder, $\chi^2(1) = 0.17$, $p = .68$, a significant effect of Item Type, $\chi^2(1) = 191.98$, $p < .001$, and no significant Reminder × Item Type interaction, $\chi^2(1) = 1.67$, $p = .20$. Participants classified more A-B, A-D than A-B, A-B items as changed, indicating that they followed the task instructions.

Table 2. Change classification probabilities as a function of item type and reminder: Experiments 1–4

		Item type		
Experiment	**Reminder**	**A-B, A-B**	**C-D**	**A-B, A-D**
Experiment 1	Cue-response	.16 [.13, .19]	.10 [.08, .13]	.40 [.37, .44]
	None	.17 [.15, .20]	.08 [.06, .10]	.38 [.34, .41]
Experiment 2	Cue-response	.10 [.08, .12]	.08 [.06, .10]	.41 [.38, .44]
	Cue-only	.13 [.11, .15]	.07 [.06, .09]	.41 [.38, .44]
Experiment 3	Cue-response	.09 [.07, .11]	.10 [.08, .12]	.34 [.30, .37]
	Foil	.12 [.09, .14]	.09 [.07, .11]	.28 [.25, .32]
		A-B, A-B	A-B, A-D (List 1 × 1)	A-B, A-D (List 1 × 6)
Experiment 4	Cue-response	—	.45 [.43, .48]	.56 [.53, .59]
	Cue-only (feedback)	—	.58 [.55, .60]	.67 [.64, .70]
	None	.20 [.17, .22]	.32 [.29, .34]	—

Note: Note that the C-D items were not subjected to any of the Reminder manipulations. Bootstrap 95% confidence intervals are displayed in brackets

Next, we examined reminder effects on each combination of change classification and List 1 recall for A-B, A-D items (Table 3, top rows). Here, and in the following experiments, we defined these combinations as follows: *Change Recollected* refers to instances when items were classified as changed and List 1 responses were recalled; *Change Remembered* (*Not Recollected*) refers to instances when items were classified as changed but List 1 responses were not recalled; *Change Not Remembered* refers to instances when items were not classified as changed. Contrary to our predictions, cue-response reminders did not affect change recollection, χ^2 (1) = 0.61, p = .43. However, more changes were remembered but not recollected in the cue-response than none condition, χ^2 (1) = 7.12, p = .008. Finally, reminders did not affect how often changes were not remembered, χ^2 (1) = 1.25, p = .26. These results suggest that cue-response reminders did not increase remindings during List 2 relative to providing List 2 study pairs alone.

Table 3. Combinations of Change Classification and List 1 Recall Probabilities for A-B, A-D Items: Experiments 1-4

		Change classification		
Experiment	**Reminder**	**Change recollected**	**Change remembered (not recollected)**	**Change not remembered**
Experiment 1	Cue-response	.27 [.24, .30]	.13 [.11, .16]	.60 [.56, .63]
	None	.29 [.26, .32]	.09 [.07, .11]	.62 [.59, .66]
Experiment 2	Cue-response	.30 [.27, .33]	.11 [.09, .13]	.59 [.56, .62]
	Cue-only	.25 [.22, .28]	.16 [.14, .18]	.59 [.56, .62]
Experiment 3	Cue-response	.14 [.11, .17]	.20 [.17, .23]	.66 [.63, .70]
	Foil	.06 [.05, .08]	.22 [.19, .25]	.72 [.68, .75]
Experiment 4	Cue-response (List 1 × 1)	.28 [.25, .30]	.18 [.15, .20]	.54 [.52, .58]
	Cue-only (feedback; List 1 × 1)	.46 [.43, .49]	.11 [.09, .13]	.43 [.40, .45]
	Cue-response (List 1 × 6)	.45 [.42, .48]	.11 [.09, .13]	.44 [.41, .47]
	Cue-only (feedback; List 1 × 6)	.59 [.56, .62]	.08 [.06, .10]	.33 [.30, .36]
	None	.12 [.11, .15]	.18 [.16, .20]	.68 [.66, .71]

Note: Change Recollection indexes instances of correct change classification and List 1 recall. Change Remembered (Not Recollected) indexes instances of correct change classification and no List 1 recall. Change Not Remembered indexes instances when changed items were incorrectly classified. Bootstrap 95% confidence intervals are displayed in brackets.

Conditionalised List 2 recall

The results thus far indicate that cue-response reminders did not affect overall correct recall of responses from either list. However, there may have been compensating costs and benefits to providing reminders that depended on whether change was recollected. Further, these effects may have interacted with reminder condition, as the additional elements present for cue-response reminders could improve response integration or create additional interference, which should depend in part on later change recollection. We examined these possibilities by comparing List 2 recall of A-B, A-D items conditionalised on combinations of change classifications and List 1 recall (see Figure 1, green, blue, and red points).

MFC predicts facilitation when change is recollected and interference when change is not remembered. However, MFC does not make clear predictions about the direction and magnitude of proactive effects when changes are remembered but not recollected. A 2 (Reminder) × 3 (Classification) model indicated no significant effect of Reminder, χ^2 (1) = 0.26, $p = .61$, a significant effect of Classification, χ^2 (2) = 182.13, $p < .001$, and a significant Reminder × Classification interaction, χ^2 (2) = 16.32, $p < .001$. The effect of Classification indicated the following significant differences: Change Recollected > Change Remembered (Not Recollected) > Change Not Remembered, *smallest z* ratio = 5.01, $p < .001$. To explain the interaction, we compared performance for each level of Classification between Reminder conditions. When change was recollected, there was a non-significant trend showing numerically higher recall in the cue-response than none condition, *z* ratio = 1.66, $p = .097$. When change was remembered (but not recollected), there was no difference between Reminder conditions, *z* ratio = 1.02, $p = .31$. When change was not remembered, recall was significantly lower in the cue-response than none condition, *z* ratio = 3.63, $p < .001$.

These results provisionally show two offsetting effects of cue-response reminders. The benefits associated with change recollection tended to be greater when cue-response reminders appeared in List 2. To foreshadow, we replicated this pattern in Experiments 2 and 4, finding significant differences in both experiments. In contrast, the interference associated with the absence of change recollection was greater when cue-response reminders appeared. These results suggest that while reminders seemingly enhanced integrative encoding, these benefits were offset by enhanced proactive interference experienced when change was not recollected. We do not have a clear interpretation of the intermediate recall performance when change was remembered (but not recollected), but we discuss some possibilities in the General Discussion.

Summary

Contrary to our initial expectations based on MFC, Experiment 1 showed that cue-response reminders did not affect change recollection. However, cue-response reminders tended to enhance proactive facilitation effects in List 2 recall when change was recollected. This suggests that bringing competitors into the same context can enhance response integration. However, doing so can also have deleterious effects as shown by increased interference when change was not recollected. We explore this tradeoff further in the following experiments.

Experiment 2

Experiment 1 was the first to show that cue-response reminders can moderate the magnitude of proactive facilitation when change is recollected. In Experiment 2, we sought to replicate this in a larger sample. We hypothesised that cue-response reminder benefits depend on how effectively they cue retrieval of List 1 pairs. We examined this by including both cue-response reminders, and cue-only reminders that required overt recall of List 1 responses. Based on Experiment 1, we predicted that cue-response reminders would amplify proactive effects of memory in conditional analyses. Further, if List 1 retrieval plays a role in reminder effects, then correct recall of List 1 responses during List 2 for cue-only reminders should be necessary for change recollection. Finding that change recollection for cue-only reminders depends on List 1 recall and that change recollection is associated with proactive facilitation of List 2 recall would implicate a role for List 1 retrieval in cue-response reminder effects on List 2 recall.

Method

Participants

Seventy-three individually-tested UNCG students participated for partial course credit. One participant was excluded for not following instructions, resulting in a final sample of 72 participants (50 women/22 men), 18–45 years of age ($M = 19.57$, $SD = 4.12$). Participants were tested individually. We selected a larger sample size than in Experiment 1 to increase the power to detect cue-response reminder effects in conditional analyses of List 2 recall performance. According to G*Power 3.1 (Faul et al., 2009), we would have 80% power to detect a small-medium effect size (Cohen's $d \sim .34$) with $\alpha = .05$ (two-tailed).

Design, materials, and procedure

We used a 2 (Reminder: cue-response vs. cue-only) × 3 (Item Type: A-B, A-B vs. C-D vs. A-B, A-D) within-subjects design. The materials and procedure were mostly the same as in Experiment 1, but there were slight variations (for a design schematic, see Table 4). Instead of comparing cue-response reminders to a condition without reminders, we included a cue-only condition for which the left member of List 1 pairs appeared next to a blank space (e.g., pearl - _____). Participants attempted to recall the List 1 response when these cues appeared. Feedback was not provided about response accuracy, but the List 2 study item appeared immediately after. Cue-only reminders appeared in white lowercase font, before List 2 study items that appeared in green font as in Experiment 1. Participants read cue-response reminders and recalled responses for cue-only reminders aloud. An experimenter recorded responses for the cue-only reminders.

Table 4. Design schematic for Experiment 2

Item type	Reminder	List 1	List 2	Test
A-B, A-B	Cue-response	a-b	a-b, a-B	a - ?
	Cue-only	a-b	a-_, a-B	a - ?
A-B, A-D	Cue-response	a-b	a-b, a-D	a - ?
	Cue-only	a-b	a-_, a-D	a - ?
C-D	—	—	c-D	c - ?

Results and discussion

List 1 recall during List 2 study (cue-only condition)

We first examined List 1 recall accuracy for cue-only recall reminders in each Item Type condition. List 1 recall did not differ between items that were assigned to the A-B, A-B ($M = .53$, $CI = [.50, .56]$) and A-B, A-D ($M = .52$, $CI = [.49, .55]$) conditions, χ^2 (1) = 0.40, $p = .53$. These probabilities are ideal for conditional analyses because successful and unsuccessful List 1 recall were approximately evenly divided.

List 2 recall

We then examined reminder effects on overall List 2 recall using a 2 (Reminder) × 3 (Item Type) model (Figure 2, black points). There were significant effects of Reminder, χ^2 (1) = 10.21, $p = .001$, and Item Type, χ^2 (2) = 847.47, $p < .001$, and a near-significant Reminder × Item Type interaction, χ^2 (2) = 5.79, $p = .055$. List 2 recall was significantly greater for A-B, A-B than C-D items, and for C-D than A-B, A-D items, *smallest z* ratio = 5.71, $p < .001$, replicating the general pattern from Experiment 1. List 2 recall for A-B, A-B items was also significantly higher in the cue-only than cue-response condition, *z* ratio = 3.61, $p < .001$, presumably due to retrieval practice benefits (for a review, see Roediger & Butler, 2011). There was a non-significant trend showing numerically greater List 2 recall for A-B, A-D items in the cue-only than cue-response condition, *z* ratio = 1.66, $p = .096$, which may indicate a benefit of retrieval practice for counteracting proactive interference (cf. Szpunar, McDermott, & Roediger, 2008). Finally, List 2 recall for C-D items did not differ between Reminder conditions, *z* ratio = 0.42, $p = .68$.

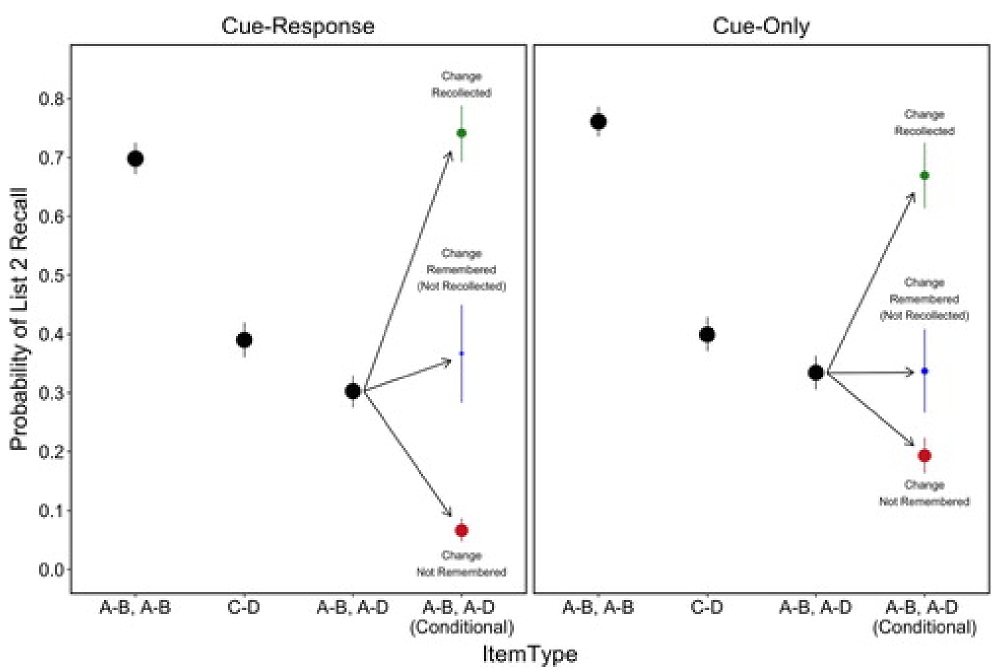

Figure 2. Probability of List 2 recall as a function of reminder and item type in Experiment 2. The left panel displays data from the "cue-response" reminder condition, and the right panel displays data from the "cue-only" reminder condition. Note that C-D items were not subjected to the Reminder manipulation. The last column of each panel displays List 2 recall conditionalised on combinations of change classifications and List 1 recall. The point areas reflect the proportion of observations included in each cell. Error bars are bootstrap 95% confidence intervals.

List 1 intrusions

Replicating the cost of reminders on order memory from Experiment 1, List 1 intrusions for A-B, A-D items were significantly higher for cue-response ($M = .38$, $CI = [.35, .41]$) than cue-only ($M = .26$, $CI = [.23, .29]$) reminders, χ^2 (1) = 39.57, $p < .001$.

Change classification

We verified that participants understood the change classification instructions by comparing correct change classifications of A-B, A-D items with false alarms to A-B, A-B items (Table 2, second rows) using a 2 (Reminder) × 2 (Item Type) model. There was no significant effect of Reminder, χ^2 (1) = 1.41, $p = .24$, a significant effect of Item Type, χ^2 (1) = 453.65, $p < .001$, and a significant Reminder × Item Type interaction, χ^2 (1) = 5.71, $p = .02$. Participants classified more A-B, A-D than A-B, A-B items as changed. False alarms to A-B, A-B items were higher in the cue-only than cue-response condition, z ratio = 2.65, $p = .008$, but correct classifications did not differ between reminder conditions, z ratio = 0.34, $p = .74$. These results show slightly better discriminability in change classifications in the cue-response condition.

Recall that in Experiment 1, cue-response reminders produced similar change recollection to no reminders (see Table 3, top rows). In contrast, Table 3 (second rows) shows that cue-response reminders produced higher change recollection than cue-only reminders, χ^2 (1) = 9.86, $p = .002$. In addition, change recollection in the cue-only condition was significantly higher when List 1 responses were recalled during List 2 ($M = .45$, $CI = [.41, .49]$) than when they were not ($M = .03$, $CI = [.02, .05]$), χ^2 (1) = 138.53, $p < .001$. Accordingly, this suggests that change recollection may have been greater for cue-response than cue-only reminders because cue-response reminders cued List 1 retrieval more effectively than cues alone. (To foreshadow, Experiments 3 and 4 showed direct evidence for the role of reminder-cued retrieval of List 1 pairs in cue-response reminder effects on change recollection.)

The models fit to A-B, A-D items for the other two categories of change classification indicated that changes were remembered but not recollected significantly more often for cue-only than cue-response reminders, χ^2 (1) = 10.47, $p = .001$, and there was no difference in changes not being remembered between conditions, χ^2 (1) = 0.13, $p = .72$.

Conditionalised List 2 recall

We verified the general pattern of conditionalised List 2 recall (see Figure 2, green, blue, and red points) using a 2 (Reminder) × 3 (Classification) model. There were significant effects of Reminder, χ^2 (1) = 8.29, $p = .004$, and Classification, χ^2 (2) = 367.73, $p < .001$, and a significant Reminder × Classification interaction, χ^2 (2) = 40.70, $p < .001$. The Classification effect indicated the following significant differences: Change Recollected > Change Remembered (Not Recollected) > Change Not Remembered, *smallest* z ratio = 8.59, $p < .001$. The interaction showed that when change was recollected, recall was significantly higher for cue-response than cue-only reminders, z ratio = 2.22, $p = .03$. In addition, when change was remembered (but not recollected), recall did not differ between reminder conditions, z ratio = 0.15, $p = .88$. Finally, when change was not remembered, recall was significantly lower in the cue-response than cue-only condition, z ratio = 6.68, $p < .001$. Like Experiment 1, these results showed that cue-response reminders amplified proactive effects of memory on conditionalised List 2 recall.

Summary

Experiment 2 showed that cue-response reminders increased change recollection relative to cue-only reminders. This finding is different from Experiment 1, which showed no effects of cue-response reminders on change recollection. Speculatively, the procedure in Experiment 2 may have encouraged participants to use cue-response reminders as retrieval cues to a greater extent. Including cue-only reminders in Experiment 2 required participants to attempt retrieval for some trials, which may have established a task set of attempting retrieval when all reminders appeared. Consistent with this, change recollection for cue-only reminders depended heavily on correct List 1 recall during List 2. Taken with the finding that proactive effects of memory depended on change recollection, these results suggest that reminder effects on List 2 recall depended on how effectively they cued List 1 retrieval. Finally, we replicated the finding that cue-response reminders amplified the magnitude of proactive effects of memory in conditional analyses. These effects suggest that retrieval cued by complete reminders may facilitate integrative encoding better than reminders including partial information.

Experiment 3

The results from Experiment 1 and 2 suggest that cue-response reminder effects depend on how effectively they cue List 1 retrieval. In Experiment 3, we examined the role of List 1 retrieval in cue-response reminder effects directly by assessing how recognition of reminders influenced List 2 recall and change classification. Cue-response reminders appeared before all List 2 pairs, but only half of the reminders were List 1 repetitions (the other half were foils). Participants rated the likelihood that each reminder appeared in List 1. We examined subsequent memory effects based on those ratings. Based on the finding in Experiment 2 that change recollection in the cue-only condition depended on List 1 recall during List 2, we hypothesised that change recollection and its associated effects on recall would depend on recognition of cue-response reminders as List 1 repetitions.

Method

Participants

Forty-eight individually-tested UNCG students (33 women/15 men), 18–26 years of age ($M = 19.10$, $SD = 1.52$), participated for partial course credit or \$10. We determined that the minimum acceptable sample size would be the same as in Experiment 1, for the reasons that we chose that sample size earlier. We used a smaller sample than in Experiment 2 because 48 participants were the most that we could reasonably test during the semester when we collected the data. The power analysis results were the same as in Experiment 1.

Design, materials, and procedure

We used a 2 (Reminder: cue-response vs. foil) × 3 (Item Type: A-B, A-B vs. C-D vs. A-B, A-D) within-subjects design. We modified our earlier paradigms to incorporate the recognition test of cue-response reminders (for a design schematic, see Table 5).

Table 5. Design schematic for Experiment 3

Item type	Reminder	List 1	Math problems	List 2	Test
A-B, A-B	Cue-response	a-b		a-b, a-B	a - ?
	Foil	—		a-b, a-B	a - ?
A-B, A-D	Cue-response	a-b	10 min	a-b, a-D	a - ?
	Foil	—		a-b, a-D	a - ?
C-D	—	—		c-D	c - ?

List 1 included 30 pairs (15 A-B, A-B, and 15 A-B, A-D) that each appeared once for 3 s followed by a 500 ms ISI. Following List 1, participants completed individually-presented math problems for 10 min by typing each solution onto the screen. Pilot results indicated that these design features were necessary to keep recognition accuracy below the ceiling.

The List 2 structure paralleled the earlier experiments, except that a cue-response pair appeared in lowercase white font before every green A-B and A-D pair. Half of the white pairs were List 1 repetitions (cue-response reminders) and half were new pairs (foil reminders). For each reminder, participants decided whether it appeared in List 1 (i.e., the pair was "old") using a four-point scale ranging from 1 (Certain New) to 4 (Certain Old). We used this scale to encourage participants to think carefully about their responses, and so that we could examine the highest-confidence responses separately. We were interested in high confidence responses, assuming that they would best distinguish between reminders that cued List 1 retrieval and those that did not. The values 1 and 2 corresponded to "new" ratings, and the values 3 and 4 corresponded to "old" ratings. Participants were instructed to use the full range of the scale and to make their ratings by pressing a key. Rarely (fewer than 3% of items), participants failed to respond before 5 s had elapsed; the program automatically advanced to the next item when this occurred.

On the cued recall test, participants first attempted to recall the uppercase green List 2 response when given the cue item. To measure change recollection, participants were then asked to indicate whether the test cue appeared with a different response at any earlier point in the experiment by pressing the "1" key for "yes" and the "2" key for "no". When participants responded "yes", they were prompted to recall the other response by typing it onto the screen. They were then asked to indicate whether the other response appeared "in both List 1 and List 2" by pressing the "1" key, or "in List 2 only" by pressing the "2" key. This measure assessed whether participants remembered the source of changes. We did not have *a priori* hypotheses about whether participants would better remember List 1 or List 2 pairs as sources of change, so we report exploratory analyses of this measure and interpret the results cautiously.

Results and discussion

Reminder recognition

We first assessed reminder recognition accuracy by computing probabilities of “old” ratings for each Reminder condition. To verify that participants could discriminate between cue-response and foil reminders and that discrimination did not differ between item types, we submitted “old” ratings (collapsed across 3 and 4) to a 2 (Reminder) × 2 (Item Type) model. There was a significant effect of Reminder, χ^2 (1) = 886.90, p < .001, no significant effect of Item Type, χ^2 (1) = 2.04, p = .15, and no significant Reminder × Item Type interaction, χ^2 (1) = 0.69, p = .40. Participants made more “old” ratings for cue-response (M = .81, CI = [.78, .83]) than foil (M = .13, CI = [.12, .15]) reminders, showing that they could discriminate between reminder types. Given that we were interested in the highest-confidence responses for conditional analyses (for reasons that we describe below), we display those probabilities in Table 6.

Table 6. High confidence recognition response probabilities as a function of item type, reminder, and recognition response: Experiment 3

	Item type			
	A-B, A-B		**A-B, A-D**	
Response	**Cue-response**	**Foil**	**Cue-response**	**Foil**
Old (4)	.48 [.65, .72]	.06 [.04, .08]	.70 [.66, .73]	.04 [.03, .06]
New (1)	.10 [.08, .12]	.63 [.59, .67]	.11 [.09, .14]	.69 [.66, .73]

Note: Bootstrap 95% confidence intervals are displayed in brackets.

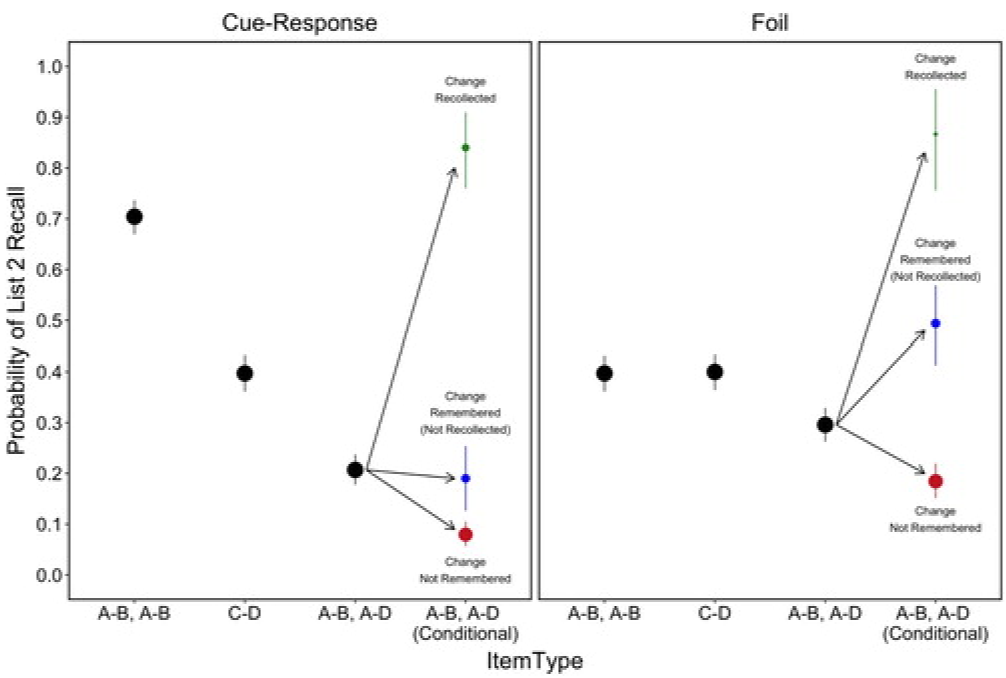

Figure 3. Probability of List 2 recall as a function of reminder and item type in Experiment 3. The left panel displays data from the “cue-response” reminder condition and the right panel displays data from the “foil” reminder condition. Note that C-D items were not subjected to the Reminder manipulation. The last column of each panel displays List 2 recall conditionalised on combinations of change classifications and List 1 recall. The point areas reflect the proportion of observations included in each cell. Error bars are bootstrap 95% confidence intervals.

List 2 recall

We then assessed reminder effects on List 2 recall (see Figure 3) using a 2 (Reminder) × 3 (Item Type) model. There were significant effects of Reminder, χ^2 (1) = 23.24, $p < .001$, and Item Type, χ^2 (2) = 249.57, $p < .001$, and a significant Reminder × Item Type interaction, χ^2 (2) = 145.58, $p < .001$. Recall was significantly higher for A-B, A-B than C-D items for cue-response reminders, *z* ratio = 12.38, $p < .001$, whereas recall did not differ between those items for foil reminders, *z* ratio = 0.15, $p = .99$. In addition, recall was significantly lower for A-B, A-D than C-D items in both conditions, *smallest z* ratio = 4.43, $p < .001$, and recall of A-B, A-D items was significantly lower in the cue-response than foil condition, *z* ratio = 4.16, $p < .001$. Overall, these results show that A-B pairs in List 1 had proactive effects on memory for List 2 pairs that were consistent with the earlier experiments. Also, including foil reminders in List 2 led to smaller proactive interference effects than when competing responses appeared in List 1.

List 1 intrusions

Intrusion rates for responses alternative to List 2 targets were significantly higher in the cue-response (*M* = .48, *CI* = [.45, .52]) than in the foil (*M* = .23, *CI* = [.20, .26]) condition, χ^2 (1) = 108.78, $p < .001$, indicating that the costs on memory accuracy incurred from cue-response reminders in Experiments 1 and 2 partly depended on alternative responses appearing in List 1.

Change classification

We examined reminder effects on change classification (Table 2, third rows) using 2 (Reminder) × 2 (Item Type) model. There was no significant effect of Reminder, χ^2 (1) = 0.85, $p = .36$, a significant effect of Item Type, χ^2 (1) = 182.50, $p < .001$, and a significant Reminder × Item Type interaction, χ^2 (1) = 7.07, $p = .008$. There was a non-significant trend showing that false alarms to A-B, A-B items were numerically greater for foils than cue-response reminders, *z* ratio = 1.69, $p = .09$; and correct classification of A-B, A-D items was significantly greater for cue-response than foil reminders, *z* ratio = 2.25, $p = .02$. Consistent with this, Table 3 (third rows) shows that change recollection was significantly higher for cue-response than foil reminders, χ^2 (1) = 24.13, $p < .001$. Note that change recollection was lower than in the earlier experiments because here, List 1 items appeared only once (versus three times) and there was a distractor task between lists. These results provided preliminary evidence for the role of List 1 retrieval during List 2 in change recollection and associated recall performance.

To verify the role of List 1 retrieval in cue-response reminder effects, we conditionalised change recollection on whether or not cue-response reminders were recognised. We restricted our examination to high-confidence responses to minimise the impact of any other processes that could occur when participants compared reminders to earlier-learned items. Results showed that change recollection was significantly higher when cue-response reminders were recognised (*M* = .19, *CI* = [.16, .23]) than when they were rejected (*M* = .06, *CI* = [.01, .12]), χ^2 (1) = 6.49, $p = .01$, suggesting that change recollection partly depended on cue-response reminders effectively cueing List 1 retrieval.

The models for the other types of change classification for A-B, A-D items (Table 3, third rows) indicated that for changes remembered (but not recollected), there was no significant difference between reminder conditions, χ^2 (1) = 1.47, p = .23. However, changes were not remembered significantly more often for foil than cue-response reminders, χ^2 (1) = 5.25, p = .02.

Finally, we performed exploratory analyses of memory for the source of changed responses. Change source accuracy was significantly higher for foil reminders (M = .72, CI = [.67, .79]) than cue-response reminders (M = .33, CI = [.27, .39]), χ^2 (1) = 57.09, p < .001, suggesting that the more remote source of change was more susceptible to forgetting than the more local source. We also examined whether change recollection was associated with change source accuracy. A positive association between change recollection and change source accuracy would be consistent with MFC, which proposes that change recollection allows access to the temporal context of earlier representations that facilitate source discrimination for competing responses. We examined change recollection rates conditionalised on source change accuracy for each reminder condition using a 2 (Source Accuracy) × 2 (Reminder) model. There were significant effects of Source Accuracy, χ^2 (1) = 99.76, p < .001, and Reminder, χ^2 (1) = 40.28, p < .001. The effect of Source Accuracy showed that change recollection was greater when the source of change was remembered than when it was not for both cue-response reminders (Remembered: M = .54, CI = [.43, .66] vs. Not Remembered: M = .09, CI = [.07, .11]) and foil reminders (Remembered: M = .20, CI = [.14, .27] vs. Not Remembered: M = .03, CI = [.01, .04]). The Reminder × Source Accuracy interaction was not significant, χ^2 (1) = 0.30, p = .59. These results suggest that change recollection provides information about the source of changes.

Conditionalised List 2 recall

Finally, we examined List 2 recall conditionalised on change recollection (see Figure 3, green, blue, and red points) using a 2 (Reminder) × 3 (Classification) model. There were significant effects of Reminder, χ^2 (1) = 47.25, p < .001, and Classification, χ^2 (2) = 214.56, p < .001, and a near-significant Reminder × Classification interaction, χ^2 (2) = 5.59, p = .06. The effect of Classification indicated the following significant differences: Change Recollected > Change Remembered (Not Recollected) > Change Not Remembered, *smallest* z ratio = 7.19, p < .001. The interaction showed that when change was recollected, recall did not differ between Reminder conditions, z ratio = 0.41, p = .68; when change was remembered (but not recollected) recall was significantly lower in the cue-response than foil condition, z ratio = 5.46, p < .001; and when change was not remembered, recall was significantly lower in the cue-response than foil condition, z ratio = 4.75, p < .001.

These results showed that change recollection was associated with facilitation, and the absence of change recollection was associated with interference that was greater when reminders were List 1 repetitions. This replicates earlier findings showing that greater List 1 accessibility leads to more proactive interference when change is not recollected. We do not have a clear explanation for the difference in recall performance when changes were remembered (but not recollected). One possibility is that those were instances when participants were metacognitively aware that there were competing responses, but they could not use recollection for source discrimination. Consequently, the greater List 1 accessibility in the cue-response condition led to more proactive interference than in the foil condition, despite participants' awareness of change.

Taken together, several results implicate a role for List 1 retrieval in the facilitative effects of reminders when change is later recollected. Proactive facilitation was similar across reminder conditions when change was recollected, and change was recollected more frequently in the cue-response condition, suggesting that including alternative responses in List 1 produced more effective response integration in List 2. Also, the finding of similar magnitudes of proactive facilitation when change was recollected suggested that presenting an alternative response in close temporal proximity to changed pairs may facilitate integrative encoding.

Summary

Experiment 3 showed that change recollection was higher when cue-response reminders were recognised than when they were rejected in List 2 (with high confidence). In combination with change recollection being associated with proactive facilitation, these results supported the hypothesis that cue-response reminders facilitate memory integration to the extent that they cue retrieval of List 1 pairs. Given the importance of these findings in suggesting a role for reminder-cued retrieval in cue-response reminder effects, we examined this issue further in Experiment 4.

Experiment 4

Thus far, we have shown that when cue-response reminders effectively cue List 1 retrieval, they can increase change recollection and amplify proactive effects of memory in conditional analyses. In Experiment 4, we attempted to replicate the finding that reminder recognition is critical for change recollection and its associated benefits. Here, cue-response reminders appeared before some changed pairs, and participants made a recognition strength judgment for each reminder. If reminder recognition plays a role in change recollection and its associated effects, then higher recognition strength ratings should be associated with higher rates of change recollection, and change recollection should be associated with greater magnitudes of proactive facilitation relative to a contrast condition. For the contrast condition, cue-only reminders with feedback appeared before the other changed pairs. Importantly, the inclusion of feedback allowed us to examine whether the amplified proactive facilitation conferred by cue-response reminders when change is recollected depends on both members of a reminder pair appearing for the entire duration.

Based on the finding that retrieval practice with feedback enhances memory relative to restudying information (for a review, see Roediger & Butler, 2011), we hypothesised that change recollection would occur more often for cue-only (with feedback) than cue-response reminders. However, if the benefits of cue-response reminders associated with change recollection depend on reminders appearing for the entire duration, then the magnitude of proactive facilitation associated with change recollection should be greater for cue-response than cue-only reminders. This predicted dissociation of change recollection frequency and proactive facilitation magnitude would indicate that presenting all reminder features can enhance integrative encoding, even though it does not lead to superior memory for List 1 pairs. Finally, we included an exploratory manipulation of List 1 repetitions to determine whether the reminder effects on List 2 recall revealed by conditional analyses interacted with pre-existing differences in List 1 accessibility. This manipulation was intended to provide insight into whether variation in the strength and/or quality of existing memories would lead to differential effects on memory for updated information, as shown in earlier work (e.g., St. Jacques & Schacter, 2013).

Method

Participants

Seventy-two individually-tested UNCG students (54 women/18 men), 18–21 years of age ($M = 18.64$, $SD = 0.89$), participated for partial course credit. We chose this sample size to match Experiment 2, because that sample size was sufficient to detect conditional cue-only reminder effects on List 2 recall and change recollection. The power analysis results were the same as in Experiment 2.

Design, materials, and procedure

To compare the reminder and List 1 accessibility effects on memory performance, we crossed two variables for A-B, A-D items only. For those items, we used a 2 (Reminder: cue-response vs. cue-only [feedback]) × 2 (List 1 Presentations: 1 vs. 6) within-subjects design. The design also included A-B, A-B and A-B, A-D items without reminders. For those items, A-B appeared once in List 1 and either A-B or A-D appeared once in List 2 (for a design schematic, see Table 7).

Table 7. Design schematic for Experiment 4

Item type	Reminder	List 1 presentations	List 1	List 2	Test
A-B, A-B	None	1	a-b (×1)	a-B	a - ?
A-B, A-D	None	1	a-b (×1)	a-D	a - ?
A-B, A-D	Cue-only (feedback)	1	a-b (×1)	a-_b, a-D	a - ?
	Cue-response	1	a-b (×1)	a-b, a-D	a - ?
A-B, A-D	Cue-only (feedback)	6	a-b (×6)	a-_b, a-D	a - ?
	Cue-response	6	a-b (×6)	a-b, a-D	a - ?

The materials and procedure included aspects from Experiments 2 and 3, but there were several exceptions. The six within-subjects reminder conditions each included 15 word-triplets (90 total). Item groups were rotated through conditions and appeared equally often across participants. Six filler items were included in List 1 (one from each condition) and were used later in practice phases before List 2 and the cued recall test.

In List 1, items appeared either once or six times for 2 s each followed by a 500 ms ISI in random order. In List 2, reminders appeared for 6 s each followed by a 500 ms ISI. For cue-response reminders, participants read each pair aloud, and then indicated how strongly they remembered it from List 1 on a scale from 1 (weak memory) to 6 (strong memory) by pressing the corresponding number key. They were instructed to use the full range of the scale. A prompt with the response scale appeared below each word pair. When participants entered a rating, the prompt disappeared and the cue-response pair remained until the remainder of 6 s had elapsed. For cue-only (feedback) reminders, each cue appeared next to a blank space (e.g., pearl - ___) for 4 s each, and then feedback in the form of the List 1 response (e.g., harbour) appeared below the cue for 2 s (6 s total). Participants were instructed to recall List 1 responses aloud or to say "pass" if they could not remember. They were told to pay attention to the feedback for every item. An experimenter recorded responses to cue-only reminders. Reminders appeared in white lowercase font, which was different from the green font for study items. The green items were bordered by a green rectangle to further differentiate them from reminders.

The cued recall test was designed to further emphasise the list from which responses should be recalled. Participants were first asked to recall the uppercase green word from List 2. The prompt “Green List 2 response?” appeared in green below the cue word. Participants then rated how confident they were that their response was the uppercase green word from List 2 on a scale from 1 (Completely Unsure) – 6 (Completely Sure). This measure determined whether participants had different levels of confidence for correct List 2 recall and List 1 intrusions, which would indicate their understanding of the recall task instructions. Higher confidence in correct recalls than intrusions would suggest that participants understood when to report List 2 responses that appeared in green. When participants indicated that a different response appeared in List 1, the text turned white and the prompt “List 1 response?” appeared below.

Results

Reminder recognition responses (cue-response conditions)

We first examined the effects of List 1 repetitions on the perceived memorability of cue-response reminders by comparing recognition ratings between List 1 presentation conditions. Ratings were significantly higher when List 1 items appeared six times ($M = 5.10$, $CI = [5.01, 5.17]$) compared to once ($M = 3.54$, $CI = [3.43, 3.67]$), χ^2 (1) = 788.19, $p < .001$, showing that the perceived memorability of List 1 pairs was higher following more List 1 presentations.

List 1 recall during List 2 study [cue-only (feedback) conditions]

We then examined the effects of List 1 repetitions on List 1 response accessibility for cue-only reminders by comparing List 1 recall between List 1 presentation conditions. Correct List 1 recall was significantly higher when List 1 items were presented six times ($M = .82$, $CI = [.80, .84]$) compared to once ($M = .66$, $CI = [.64, .68]$), χ^2 (1) = 151.31, $p < .001$, again showing that List 1 accessibility was higher following more List 1 presentations.

List 2 recall

We assessed reminder effects on List 2 recall (see Figure 4, black points) using a model with the factor Item Type that included each within subject condition. The model indicated a significant effect, χ^2 (5) = 319.46, $p < .001$, showing that recall was significantly higher for A-B, A-B than all other item types, *smallest z* ratio = 11.82, $p < .001$, and for A-B, A-D items in the none condition than in the cue-only feedback (List 1 × 1 presentation) condition, z ratio = 3.17, $p = .02$. No other comparisons were significantly different, *largest z* ratio = 1.96, $p = .37$. Note that we did not obtain a benefit of cued recall with feedback relative to recognition memory for cue-response reminders on List 2 recall due to the balance of facilitation and interference effects in each condition (see conditional analyses below).

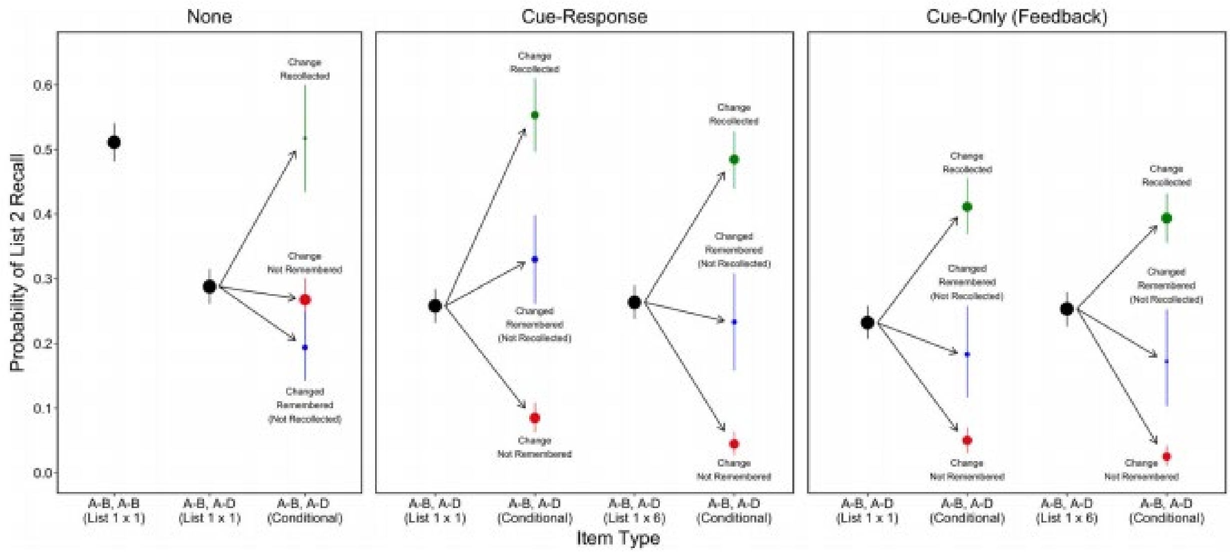

Figure 4. Probability of List 2 recall as a function of reminder, item type, and List 1 presentations in Experiment 4. The left panel displays data from the “none” reminder condition, the middle panel displays data from the “cue-response” reminder condition, and the right panel displays data from the “cue-only (feedback)” reminder condition. Note that A-B, A-B items were not subjected to the List 1 presentation manipulation. The last column of each panel displays List 2 recall conditionalised on combinations of change classifications and List 1 recall. The point areas reflect the proportion of observations included in each cell. Error bars are bootstrap 95% confidence intervals.

List 1 intrusions

We assessed the effects of reminders on List 1 intrusions (Table 8) using a model with the factor Item Type including all within subject conditions, except for the A-B, A-B items. We excluded A-B, A-B items because that condition measured the baseline intrusions rate, which was <.01. The model indicated a significant effect, χ^2 (4) = 141.17, $p < .001$, showing that intrusion rates were higher when reminders appeared than when they did not, *smallest z* ratio = 8.82, $p < .001$. The intrusion rate for cue-response reminders was higher when List 1 items appeared six times rather than once, *z* ratio = 2.74, $p = .049$, and there was a non-significant trend showing numerically higher intrusions for cue-only (feedback) reminders when List 1 items appeared six times rather than once, *z* ratio = 2.58, $p = .08$. No other differences among A-B, A-D conditions were significant, *largest z* ratio = 1.41, $p = .62$. As in the earlier experiments, these results showed that reminders conferred a cost to source memory in the form of more intrusions; these results also showed that the costs were greater when List 1 pairs appeared more often.

Table 8. List 1 intrusions as a function of item type and reminder: Experiment 4

	Item type		
Reminder	**A-B, A-B**	**A-B, A-D (List 1 × 1)**	**A-B, A-D (List 1 × 6)**
Cue-response	—	.27 [.25, .30]	.32 [.30, .35]
Cue-only (feedback)	—	.28 [.25, .30]	.30 [.27, .32]
None	<.01	.13 [.11, .15]	—

Note: Note intrusions for A-B, A-B items are baseline rates of outputting responses that were presented in List 1 when those items were in the A-B, A-D conditions. Bootstrap 95% confidence intervals are displayed in brackets

Recall confidence

We examined participants' understanding of the recall task instructions by comparing the magnitudes of confidence ratings for recall attempts to A-B, A-D item types across correct List 2 recalls, List 1 intrusions, and other errors that included omissions (see Table 9). If participants understood that they were supposed to recall the uppercase green response that appeared in List 2, then confidence in those responses should be higher than confidence in List 1 intrusions that corresponded to responses that appeared as reminders or were retrieved in response to reminder cues in List 2. A 5 (Reminder) × 3 (Response) model indicated a significant effect of Response, χ^2 (2) = 6487.76, $p < .001$, showing that confidence ratings were significantly higher for List 2 recalls than List 1 intrusions, and for List 1 intrusions than other errors for all Item Types, *smallest t* ratio = 21.38, $p < .001$. These results suggested that participants understood the task.

Table 9. Confidence ratings as a function of reminder and cued recall response: Experiment 4

	Reminder				
	Cue-response		**Cue-only (feedback)**		**None**
Response	**List 1 × 1**	**List 1 × 6**	**List 1 × 1**	**List 1 × 6**	**List 1 × 1**
List 2 recall	4.25 [4.40, 4.75]	4.91 [4.75, 5.06]	4.81 [4.63, 4.98]	5.02 [4.88, 5.16]	4.38 [4.21, 4.55]
List 1 intrusions	4.02 [3.85, 4.20]	3.97 [3.80, 4.13]	3.80 [3.62, 3.99]	3.95 [3.76, 4.13]	3.54 [3.29, 3.80]
Other	1.54 [1.44, 1.64]	1.56 [1.45, 1.67]	1.40 [1.32, 1.49]	1.43 [1.35, 1.52]	1.43 [1.35, 1.50]

Note: Bootstrap 95% confidence intervals are displayed in brackets.

Change classification

To remind the reader, the primary purpose of Experiment 4 was to look for more evidence of reminder-cued List 1 retrieval on change recollection and associated memory performance. Here, we first assessed the effects of reminders on overall change classification responses (Table 2) using a model with the Item Type factor that included all conditions. There was a significant effect, χ^2 (5) = 694.10, $p < .001$, showing that all conditions differed from each other, *smallest z* ratio = 4.80, $p < .001$, except for the cue-response (List 1 × 6) and cue-only (feedback; List 1 × 1) conditions, z ratio = 0.68, $p = .98$. Change classifications of A-B, A-D items were greatest for cue-only (feedback), moderate for cue-response reminders, and lowest for when no reminders appeared. Change classification rates were also greater when List 1 pairs appeared six times compared to once. These results indicated that both retrieval practice with feedback and additional List 1 repetitions increased classification accuracy for A-B, A-D items.

Next, we examined reminder effects on change recollection (Table 3, bottom rows) using a model with the factor Item Type including all conditions (except A-B, A-B; baseline intrusion <.01). The model indicated a significant effect, χ^2 (4) = 600.36, $p < .001$, showing that all conditions were significantly different from each other, *smallest z* ratio = 6.40, $p < .001$, except for the cue-response (List 1 × 6) and cue-only (feedback; List 1 × 1) conditions, z ratio = 0.88, $p = .91$. Change recollection was higher for cue-only (feedback) than cue-response conditions, for List 1 × 6 compared to List 1 × 1 conditions, and when reminders were present versus absent.

To examine the effects of reminder-cued List 1 retrieval on change recollection, we first examined change recollection for cue-response reminders conditionalised on reminder recognition ratings (Figure 5). A 2 (List 1 Presentations) × 6 (Reminder Recognition) model indicated significant effects of List 1 Presentations, χ^2 (1) = 9.57, *p* = .002, and Reminder Recognition, χ^2 (5) = 88.90, *p* < .001, and no significant interaction, χ^2 (5) = 8.05, *p* = .15. These results showed that change recollection increased with recognition ratings, and although the interaction was not significant, change recollection tended to be higher when List 1 pairs appeared six times rather than once, mostly at the highest rating.

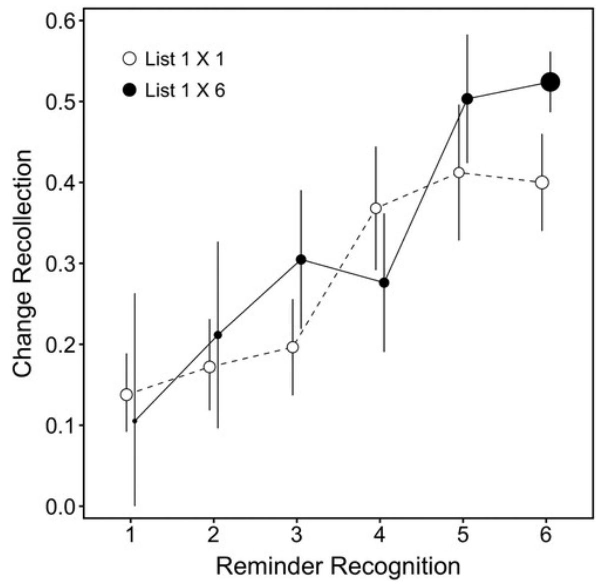

Figure 5. Change recollection as a function of cue-response recognition strength ratings in List 2. Point areas indicate the proportion of all observations in each cell within a condition. Error bars are bootstrap 95% confidence intervals.

To further examine the effect of reminder-cued List 1 retrieval, we next examined change recollection for cue-only (feedback) reminders conditionalised on List 1 recall accuracy during List 2 in each List 1 presentation condition. A 2 (List 1 Recall) × 2 (List 1 Presentations) model indicated significant effects of List 1 Recall, χ^2 (1) = 92.99, *p* < .001, and List 1 Presentations, χ^2(1) = 7.63, *p* = .006, showing higher change recollection when List 1 responses were recalled during List 2 (*M* = .68, *CI* = [.65, .71]) than when they were not recalled (*M* = .38, *CI* = [.36, .41]), and higher change recollection when List 1 pairs appeared six times (*M* = .59, *CI* = [.56, .62]) as compared to once (*M* = .46, *CI* = [.43, .49]). The interaction was not significant, χ^2 (1) = 0.57, *p* = .45. Note that change recollection when List 1 responses were not recalled was substantially higher here (*M* = .38) than in Experiment 2 (*M* = .03), showing that feedback following incorrect recall improved change recollection, but correct List 1 recall during List 2 still led to the best performance. Together with the results from the cue-response condition, these findings suggest that reminder effects on change recollection depended on List 1 retrievals.

Finally, we fit models including only A-B, A-D item types to the other two categories of change classification (Table 3, bottom rows). For changes remembered (but not recollected), a significant effect of Item Type, χ^2 (4) = 83.19, *p* < .001, indicated that response rates did not differ between the none and cue-response (List 1 × 1) conditions, *z* ratio = 0.24, *p* = .99, but rates in those conditions were significantly higher than in the other conditions, *smallest z* ratio = 4.65, $p < .001$. For changes not remembered, a significant effect of Item Type, χ^2 (4) = 345.39, $p < .001$, indicated significant differences among all conditions, *smallest z* ratio = 4.84, $p < .001$, except between the cue-only (feedback; List 1 × 1) and cue-response (List 1 × 6) conditions, *z* ratio = 0.69, $p = .96$. The relative differences in the pattern for changes not remembered were the inverse of the pattern for recollected changes described above.

List 2 recall conditionalised on change classifications

In the final series of analyses, we conditionalised List 2 recall on all three levels of change classification (Figure 4, green, blue, and red points). A 5 (Item Type) × 3 (Classification) model including only A-B, A-D items indicated significant effects of Item Type, χ^2 (4) = 116.69, $p < .001$, and Classification, χ^2 (2) = 390.58, $p < .001$, and a significant Item Type × Classification interaction, χ^2 (8) = 120.29, $p < .001$. List 2 recall was significantly higher when change was recollected than when it was remembered (but not recollected) in all conditions, *smallest z*ratio = 2.70, $p = .02$, except for the cue-only (feedback; List 1 × 6) condition, which showed a numerical trend in the same direction, *z* ratio = 2.17, $p = .08$. List 2 recall was also higher when change was remembered (but not recollected) than when it was not remembered in all conditions, *smallest z* ratio = 5.52, $p < .001$, except for the none condition, *z* ratio = 1.15, $p = .48$. These results largely replicate the differences across conditional analyses shown in Experiments 1–3. However, it is noteworthy that recall in the two cells that were not instances of change recollection did not differ in the none condition. This could reflect weak interference effects when changes were not remembered resulting from the absence of reminders and only a single List 1 presentation.

To determine whether cue-response and cue-only (with feedback) reminders had differential effects on levels of List 2 recall performance associated with change classifications, we compared List 2 recall performance across Item Type conditions within each level of change classification. When change was recollected, List 2 recall was significantly higher in both cue-response than both cue-only (feedback) conditions, *smallest z* ratio = 2.77, $p = .045$; no other comparisons were significantly different, *largest z* ratio = 1.79, $p = .38$. When change was remembered (but not recollected), List 2 recall was significantly higher in the cue-response (List 1 × 1) than cue-response (none) condition, *z* ratio = 3.18, $p = .01$; no other comparisons were significantly different, *largest z* ratio = 2.54, $p = .08$. When change was not remembered, List 2 recall was higher in the cue-response (none) condition than all other conditions, *smallest z* ratio = 7.85, $p < .001$; and in the cue-response (List 1 × 1) than cue-only (feedback; List 1 × 6) condition, *z* ratio = 3.35, $p = .007$; no other comparisons differed, *largest z* ratio = 2.49, $p = .09$. Taken with the findings above, these results show that although cue-only (feedback) reminders led to higher change recollection than cue-response reminders, the magnitude of proactive facilitation associated with change recollection was greater for cue-response than cue-only reminders.

Summary

Experiment 4 showed that overall List 2 recall was comparable across A-B, A-D items. Importantly, this invariance reflected reminders creating a tradeoff between change recollection frequency and proactive facilitation magnitudes. Change recollection was greater for cue-only (feedback) than cue-response reminders, and change recollection was higher to the extent that both reminder types cued List 1 retrieval. However, the magnitude of proactive facilitation when change was recollected was greater for cue-response than cue-only (feedback) reminders. When change was not remembered, proactive interference was comparable across cue-response and cue-only (feedback) reminder conditions. This pattern is inconsistent with results observed in Experiment 2 showing that proactive interference was greater in the cue-response than cue-only (no feedback) reminding condition. The comparable magnitude of interference effects in Experiment 4 is easily explained as the List 1 responses that appeared as feedback were an additional source of interference that exerted its influence when change was not recollected.

The pattern of conditional results was consistent with the original predictions of MFC: overall List 2 recall performance depended on the balance of proactive facilitation and interference, which in turn depended on change recollection. These results also extended MFC by replicating the differential effects of reminder types on the magnitude of proactive facilitation when change was recollected. Finally, the exploratory manipulation of List 1 accessibility did not appear to interact with the magnitude of proactive facilitation in List 2 recall associated with change recollection. Collectively, the results from Experiment 4 suggested that: (1) effective reminders increased change recollection, (2) including more elements of existing memories in reminders amplified the benefits change recollection associated with memory updating, and (3) the efficacy of reminders as retrieval cues were more influential than the accessibility of existing memories on memory updating.

General discussion

The primary purpose of the present study was to examine the effects of reminders on memory updating from an MFC perspective. We focused primarily on whether the effects of complete reminders differed from the effects of partial reminders. Based on MFC, we hypothesised that cue-response reminders would facilitate integrative encoding by promoting effective retrieval of existing memories. Accordingly, we expected List 2 recall and change recollection to be greatest when cue-response reminders were provided.

We did not find initial support for this hypothesis in Experiment 1, as correct List 2 recall and change recollection were comparable when cue-response reminders appeared and when there were no reminders. However, Experiment 2 showed greater change recollection when cue-response than cue-only reminders appeared, and the extent to which change recollection occurred for cue-only reminders depended on correct recall of List 1 responses in List 2. This suggested that cue-response reminders facilitated integrative encoding to the extent that they cued List 1 retrieval more effectively than the cues included in changed pairs that were not preceded by reminders. One reason why cue-response reminders may not have increased change recollection in Experiment 1 is that participants may not have consistently treated those reminders as retrieval cues because overt memory judgments were not required. This could result in cue-response reminders and the cues in changed pairs behaving similarly as cues for retrieving List 1 pairs. This possibility suggests that the extent to which participants use reminders as retrieval cues may depend on task demands that are partly influenced by the type of contrast condition.

Related to reminder effectiveness, in Experiment 2, one may have expected different effects of cue-only and cue-response reminders, because cue-only reminders provide an obvious cued recall testing opportunity. Testing can improve memory and source discrimination (e.g., Szpunar et al., 2008), and this could lead to benefits for order memory. Consistent with this, in the cue-only condition, we found that change recollection depended on List 1 retrieval during List 2. Taken together with the association between change recollection and proactive facilitation, these results indicate that correctly recalled responses to reminder cues improved order memory. However, a critical point to note is that correct List 1 recall for cue-only reminders was around 50%, which means that testing benefits should only be obtained for about half of the items (because there was no feedback). To understand why cue-only reminders were less effective that cue-response reminders at promoting change recollection, one should consider that cue-response reminders act as recognition test probes. Cue-response reminders therefore provided more environmental support for List 1 retrieval than cues alone, and this may have enhanced List 1 retrieval during List 2 study. Thus, cue-only reminders should be a *less* powerful tool for improving order memory to the extent that they are less effective cues than cue-response reminders.

Consistent with the idea that cue-response reminders can act as recognition test probes, Experiment 3 showed that change recollection was higher when cue-response reminders were recognised. Experiment 4 replicated this by showing a positive association between the perceived memorability of cue-response reminders and change recollection. These results show that cue-response reminders promoted change recollection to the extent that they were effective retrieval cues for List 1 pairs. This fits well with the MFC framework as a primary assumption is that reminding of existing memories is necessary to encode those memories together with new information. These findings extend on earlier studies showing that increasing List 1 accessibility (e.g., Wahlheim, 2014, 2015) and the effectiveness of List 2 items as retrieval cues (e.g., Jacoby et al., 2015; Negley et al., 2018) improve detection and recollection of change. These findings also contribute uniquely to the MFC literature in showing that variations in reminder type affected the magnitude of both proactive facilitation and interference in conditional analyses. The present study was the first to show that cue-response reminders produced greater proactive facilitation when change was recollected. Importantly, this occurred even when cue-only reminders (feedback) led to higher rates of change recollection than cue-response reminders.

The dissociation between reminder effects on the frequency and benefits of change recollection has important theoretical implications for MFC. Prior to the present study, MFC did not articulate how different methods of inducing response integration during encoding could impact the memory benefits associated with change recollection. MFC proposes that remindings of existing memories allow them to be encoded together with new information, presumably through an associative mechanism that binds together discrete elements. It is possible that the efficacy of this mechanism is enhanced when all perceptual elements from existing memories appear in the same context as new information. The strong overlap in shared features between cue-response reminders and existing memories could lead to more qualitatively distinct representations for existing memories and new information within configural representations. In addition, the presence of cues and responses in reminders could lead to a more equitable distribution of attention across retrieved and presented pairs during List 2 encoding than when reminders do not include responses. This could lead to both stronger item-to-item (within-pair) and pair-to-context associations, such that each pair would be strongly associated with their original temporal context and with the recent episode during which they were both accessible in working memory. These representational consequences of cue-response reminders would then lead incorporated pairs to become better associated with the recent list context, and also better distinguished from each other within a configural representation. This proposal could be explored by considering whether computational models of three-way bindings in associative memory (e.g., Yim, Osth, Sloutsky, & Dennis, 2018) could account for such reminder effects.

Although this potential explanation for cue-response reminder benefits points the way for future research, it does not explain how cue-response and cue-only (with feedback) reminders produced different magnitudes of proactive facilitation in Experiment 4. The mechanism underlying this dissociation is worth considering because the feedback provided for cue-only reminders transformed cue-only into cue-response reminders late in each trial. One possibility is that the different time courses in the appearance of responses for each reminder type are responsible for differences in proactive facilitation magnitudes associated with change recollection. It could be that integrative encoding of multiple responses is more effective when more time is available to encode retrieved List 1 responses before a changed response enters the focus of attention. This could facilitate more effective maintenance of both responses in working memory, thus facilitating the binding of responses together with the common cue and the associated cognitive state. In contrast, engaging in cued recall prior to the appearance of a changed response might result in lingering attention to the previous retrieval attempt when the changed response appears, thus impairing integrative encoding. More research is required to determine how response presentation timing affects the structure of configural representations.

Regarding the theoretical structure of memory representations, we assumed based on MFC that configural representations were formed when existing memories were encoded with new information. However, a critic could argue that these results do not provide evidence for configural representations, and that better-remembered items were simply better remembered. Against this, we propose that variations in List 2 recall resulting from interactions between reminder type and change recollection provided evidence of integrative encoding during List 2. Specifically, the finding that the magnitude of List 2 recall when change was recollected was greater when cue-response than other reminder types appeared suggested differences in how three-way bindings among cues and responses were formed. We also assumed that these differences influenced how effectively List 1 response served as additional retrieval cues for List 2 responses at test. These considerations suggest to us that the proposal that better-remembered items were better remembered is insufficient to explain the present results.

Another theoretical challenge for MFC is that there is currently no explanation for variation in the levels of List 2 recall when changes are remembered (but not recollected). For parsimony, MFC has focused on predictions related to the memorial consequences of change detection and recollection on order memory. This approach has worked well thus far, as MFC has consistently predicted recall performance conditionalised on change classification responses across variations in measurement and stimuli (e.g., Jacoby et al., 2015; Jacoby & Wahlheim, 2013; Putnam et al., 2014, 2017; Wahlheim, 2015; Wahlheim & Jacoby, 2013; Wahlheim & Zacks, 2019). However, as mentioned in the Introduction, MFC does not formally articulate the processing involved in remembering but not recollecting change, nor does it predict levels of associated recall performance. One possibility is that the subjective experience associated with those instances includes awareness that multiple responses were associated with a cue, but without recollection-based retrieval of responses, their source, or some combination of both. This could occur when changes are detected but List 1 responses are either not retrieved or are retrieved but are ineffectively integrated into configural representations. The downstream consequences would be diminished potential for List 1 responses to serve as retrieval cues for List 2 responses at test. Therefore, the prediction would be that analyses aggregated across these instances would not reveal the type of strong proactive facilitation obtained when changes are recollected, but it is unclear whether this would lead to interference.

Further development of this aspect of MFC stands to benefit from data-driven inferences. Here, we found that when change was remembered but not recollected, List 2 recall was intermediate to the other categories of change classification in all but one instance. However, the levels of intermediate recall varied across reminder conditions and experiments in ways that were not obvious, as performance trended towards both proactive facilitation and interference across conditions. In contrast, when changes were remembered but not recollected, Wahlheim and Zacks (2019) consistently found proactive interference effects for recall of features from recent everyday activities that were comparable to those obtained when changes were not remembered. One possibility is that the degree of response competition accrued from existing memories through variables such as presentation frequency of material saliency could determine the direction and magnitude of proactive effects. For example, greater response competition could lead to greater proactive interference if the competitor is more accessible than the target and recollection is not available to oppose this misleading basis for retrieval. However, experiments designed to examine this issue directly are needed to refine this aspect of MFC.

In summary, the present experiments are the first to document the effects of various reminder types on memory updating and their interactions with change recollection. Our findings have theoretical implications for MFC in suggesting that representational qualities may vary depending on the features available for cueing retrieval of existing memories immediately prior to encoding new information. Providing additional features led to better memory integration, but those benefits were only realised when recollection was the basis for retrieval. More generally, our findings are also relevant to naturalistic situations, such as updating memory to incorporate corrections of misinformation (e.g., Ecker, Hogan, & Lewandowsky, 2017). We believe that extensions of our approach could further inform mechanistic theories of memory updating and applications to real-world situations that involve the same underlying memory processes.

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