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Beneficial effects of selective item repetition on the recall of other items

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ABSTRACT

Selective retrieval of some studied material can improve recall of the other material when access to study context at test is impaired, an effect that has been attributed to context reactivation processes (Bäuml and Samenieh, 2012). This study aimed at providing more direct evidence for this proposal by examining the influence of mental reinstatement of study context for the effects of selective retrieval. In addition, it was examined whether the induced beneficial effect generalizes from selective retrieval to selective restudy, and varies with retrieval difficulty, thus providing evidence on whether format of selective item repetition can influence context reactivation processes. In four experiments, prolonged retention intervals between study and selective item repetition were employed to impair study context access. Two main results emerged. First, mental reinstatement of the study context can eliminate, and even reverse, the beneficial effect of selective retrieval. Second, the size of the beneficial effect varies with repetition format, and is larger after selective retrieval than selective restudy, and larger when selective retrieval is demanding. These findings strengthen the view that context reactivation processes mediate the beneficial effects of selective item repetition. In particular, they indicate that the degree of repetition-induced context reactivation can vary with repetition format.

Introduction

Selective memory retrieval can impair the recall of other items. Such retrieval-induced forgetting has been observed in numerous studies using both the output-interference and the retrieval-practice task. Research employing the older output-interference task has demonstrated that recall performance at test can decline as a function of the items' testing position, indicating that prior recall of other list items can impair recall of target information (e.g., Roediger, 1974; Smith, 1971). Research employing the more recent retrieval-practice task has shown that intermittent retrieval practice on a subset of previously studied items can cause forgetting of related unpracticed items on a later memory test (e.g., Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995). Detrimental effects of selective retrieval were reported over a wide range of materials and settings and a variety of testing formats (for reviews, see Bäuml & Kliegl, in press; Storm & Levy, 2012; for a recent meta analysis, see Murayama, Miyatsu, Buchli, & Storm, 2014).

Beneficial effects of selective retrieval

However, selective memory retrieval can also improve the recall of other items. First corresponding evidence has come from studies examining the effects of selective retrieval in listwise directed forgetting and context-dependent forgetting. In the studies on listwise directed forgetting, subjects studied an item list and after study received a cue to either remember or forget the list (e.g., Bjork, 1972). After study of a second list, they recalled some predefined first list target items, either first or after prior selective retrieval of the list's remaining items. As expected from the literature on retrieval-induced forgetting, selective retrieval impaired recall of the target items in the remember condition. In the forget condition, however, selective retrieval improved target recall (Bäuml & Samenieh, 2010, 2012). The same pattern of results arose in context-dependent forgetting, when between study of two item lists, subjects either participated in a neutral counting task or engaged in an imagination task to change their internal context (e.g., Sahakyan & Kelley, 2002). Again, at test, subjects selectively retrieved some of the first list items before they recalled the list's target items, or recalled the target items first. Selective retrieval impaired recall of the target items after the counting task, but improved target recall after the imagination task (Bäuml & Samenieh, 2012; Schlichting, Aslan, Holterman, & Bäuml, 2015).

Two faces of selective retrieval have also been found in studies on time-dependent forgetting. In these studies, participants

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studied a list of items and, after a short retention interval of few minutes or a prolonged retention interval of 48 h, were again asked to recall predefined target items of the list. These target items were recalled first or after prior selective retrieval of the list's remaining items. Consistent with the literature on retrieval-induced forgetting, selective retrieval impaired recall of the target items after the short retention interval. In contrast, in the prolonged retention interval conditions, selective retrieval improved recall of the target items (Bäuml & Dobler, 2015; Bäuml & Schlichting, 2014). These findings fit with the results from the studies on context-dependent forgetting mentioned above, because prolonged retention intervals typically include a considerable amount of contextual change between study and test (e.g., Bower, 1972; Estes, 1955; Mensink & Raaijmakers, 1988). Together, all of these results demonstrate that retrieval dynamics can depend critically on situation and selective retrieval can both impair and improve recall of other items (for a recent review on these findings, see Bäuml, Aslan, & Abel, 2017).

Bäuml and Samenieh (2012) suggested a two-factor account to explain why selective retrieval is sometimes beneficial and sometimes detrimental for other memories. According to this account, selective retrieval generally triggers two types of processes, inhibition or blocking of interfering memories (e. g., Anderson, 2003; Roediger & Neely, 1982) and context reactivation (e. g., Howard & Kahana, 2002; Raaijmakers and Shiffrin, 1981). Critically, the relative contribution of the two types of processes in an experimental situation is supposed to depend on access to study context at test. When access to the study context is (largely) maintained – as may occur after a remember cue or a short retention interval filled with a neutral distractor task – then interference between items may be high enough to trigger inhibition or blocking processes, whereas there is little or no need to reactivate study context during retrieval. As a net result, selective retrieval may reduce recall of the remaining items. In contrast, when access to the study context is impaired and the interference level of the items is low – as may occur after a forget cue, an imagination task, or a prolonged retention interval – then access to the study context may benefit from retrieval-induced context reactivation processes, with inhibition or blocking processes hardly operating. The reactivated study context may then serve as a retrieval cue for recall of the remaining items and thus improve recall performance. The two-factor account is consistent with the finding of two faces of selective retrieval in listwise directed forgetting, context-dependent forgetting, and time-dependent forgetting.

The empirical support in favor of the view that the detrimental effect of selective retrieval is mediated by inhibition and blocking processes is currently much stronger than is the evidence for the view that the beneficial effect is mediated by context reactivation. Indeed, findings on retrieval-induced forgetting strongly indicate that the detrimental effect is mediated by inhibition and blocking processes. While neither inhibition nor blocking seem to be able to explain the whole range of findings on the detrimental effect in its own, the assumption that inhibition and blocking conjointly contribute to the effect may explain the main findings (e.g., Bäuml & Kliegl, in press; Storm & Levy, 2012; but see Jonker, Seli, & MacLeod, 2013). The proposal that context reactivation processes mediate the beneficial effect of selective retrieval is less well supported by data. Rather, current evidence for the proposal is fairly indirect, for instance, revealing a developmental trajectory of the beneficial effect that fits with the suggested development of context reactivation processes in children and older adults (e.g., Aslan & Bäuml, 2014; Aslan, Schlichting, John, & Bäuml, 2015). It is the first goal of this study to fill this gap and come up with more direct evidence that context reactivation processes mediate the beneficial effect of selective retrieval (see below).

From selective retrieval to selective restudy

A core question about the beneficial effect of selective retrieval is whether it is retrieval specific, that is, whether it is restricted to selective retrieval trials or alternatively generalizes to selective restudy trials. Results from numerous studies on retrieval-induced forgetting indicate that the detrimental effect of selective retrieval is largely retrieval specific. Comparing the effects of selective retrieval and selective restudy on later recall of related unpracticed items, these studies typically found retrieval practice, but not restudy, to impair recall of the unpracticed items (e.g., Bäuml, 2002; Ciranni & Shimamura, 1999; Hulbert, Shivde, & Anderson, 2012; for exceptions, see Raaijmakers & Jakab, 2012; Verde, 2013). Retrieval specificity of the detrimental effect of selective retrieval is consistent with the view that inhibition critically contributes to the effect. According to this view, the not-to-be practiced items interfere during selective retrieval, but not during selective restudy, and are inhibited to reduce the interference (Anderson, 2003; for a more detailed discussion of retrieval specificity of the detrimental effect, see Rupprecht & Bäuml, 2016; Rupprecht & Bäuml, 2017).

The question of whether the beneficial effect of selective retrieval is also retrieval specific has hardly been investigated yet. Bäuml and Dobler (2015) addressed the issue in two experiments, in which they compared the effects of selective retrieval and selective restudy on the recall of other items when access to study context was (largely) maintained and when access to study context was impaired. Experiment 1 employed listwise directed forgetting to manipulate study context access and asked subjects to either remember or forget a previously studied list; Experiment 2 employed time-dependent forgetting to manipulate context access and varied the retention interval after study (4 min vs. 48 h). In both experiments, subjects selectively retrieved or selectively restudied some of the studied items before they recalled the list's target items, or they recalled the target items in the absence of any prior selective item repetition. Consistent with the previous studies on retrieval specificity of retrieval-induced forgetting, the results of both experiments showed that selective retrieval, but not selective restudy, impaired recall of the other items when access to study context at test was maintained. In contrast, when context access was impaired, both selective retrieval and selective restudy enhanced the recall of the other items, indicating that, unlike the detrimental effect, the beneficial effect of selective retrieval is not retrieval specific.

The findings by Bäuml and Dobler (2015) fit with the two-factor account and the comprised view that the beneficial effect is driven by reactivation of the retrieved items' study context. Indeed, context retrieval theory (Greene, 1989; Thios & D'Agostino, 1976) and more recent computational models that embody variants of the theory (Howard & Kahana, 2002; Polyn, Norman, & Kahana, 2009) assume that, when a previously studied item is repeated, be it by virtue of reexposure or its successful recall, it retrieves the context in which it was originally exposed. Such retrieval is then supposed to update the current state of context, which in turn is used to cue recall. Results on the contiguity effect, that is, the tendency to successively recall neighboring list items (e.g., Howard & Kahana, 1999, 2002), and the spacing effect, that is, the beneficial mnemonic effect of spaced over massed learning (e.g., Greene, 1989; Kahana, 1996), support such proposal.

Do different forms of selective item repetition differ in induced beneficial effects?

While the two-factor account together with context retrieval theory can thus explain the finding that both selective retrieval and selective restudy can improve recall of other findings, the question arises of whether selective repetition by virtue of retrieval and selective repetition by virtue of restudy are really equivalent. While context retrieval theory claims that both retrieval and restudy can trigger context reactivation, the theory is largely silent on whether the two forms of item repetition differ in degree of the induced reactivation. In their episodic-context account of the testing effect – the finding that retrieval practice on previously studied material can increase its long-term retention more than restudy of the information does (e.g., Karpicke & Roediger, 2008; Roediger & Karpicke, 2006) – Karpicke, Lehman, and Aue (2014) suggested a variant of context retrieval theory, which assumes that different forms of item repetition can differ in context reactivation.

In this variant of the theory, Karpicke et al. (2014) made two core assumptions. The one assumption is that retrieval can be more effective than restudy to reactivate the study context. This may be the case because with intentional recall instructions, i.e., during retrieval trials, context retrieval may be obligatory, whereas in the absence of such instructions, i.e., during restudy trials, it may not. Also, the degree of context updating supposed to occur during restudy may be reduced relative to retrieval, during which people deliberately search memory information about the prior occurrence of studied items. The second assumption is that retrieval difficulty can influence context reactivation, with more difficult retrieval (i.e., retrieval in the presence of weak item-specific cues) creating more context reactivation than easy retrieval (i.e., retrieval in the presence of strong item-specific cues). In fact, difficult retrieval may require subjects to reinstate a prior context with minimal cues, and such effortful reconstruction of the study context may drive the gains in learning compared to easy retrieval. The suggested difference in context retrieval between retrieval and restudy conditions can explain the basic testing effect, attributing the effect to a difference in the creation of unique context cues between the two repetition formats. In a similar way can the suggested difference in context retrieval between difficult and easy retrieval explain the finding that difficult retrieval often creates a larger testing effect than easy retrieval (Carpenter & DeLosh, 2006; Halamish & Bjork, 2011; Pyc & Rawson, 2009; for alternative explanations of the finding, see also Halamish & Bjork, 2011).

If context reactivation processes also mediate the beneficial effects of selective retrieval and selective restudy on recall of nonrepeated items (e.g., Bäuml & Dobler, 2015), then, following Karpicke et al.'s variant of context retrieval theory, repetition format may influence this beneficial effect as well. Whether this is the case is unclear to date. To the best of our knowledge, there is no study yet that examined whether the beneficial effect of selective retrieval depends on how demanding retrieval is. In fact, all previous studies employed word stems as retrieval cues in the selective retrieval trials, examining how this affects recall of the nonrepeated items (see Bäuml et al., 2017). Also, there is only a single study in the literature that compared the size of the beneficial effects of selective retrieval and selective restudy on nonrepeated items (Bäuml & Dobler, 2015). Employing listwise directed forgetting and time-dependent forgetting to impair study context access at test (see above), this study reported equivalent beneficial effects of selective retrieval and selective restudy after a forget cue, but a larger beneficial effect of selective retrieval than selective restudy after a prolonged retention interval. These results leave it open whether, in general, the beneficial effect of selective item repetition on nonrepeated items varies with repetition format, and whether Karpicke et al.'s (2014) variant of context retrieval theory can be applied to explain the beneficial effects of selective item repetition. It is the second goal of this study to provide an answer on this issue.

The present study

As emphasized above, it is the *first goal* of the present study to examine the proposal included in Bäuml and Samenieh's (2012) two-factor account of selective retrieval that context reactivation processes mediate the beneficial effect of selective retrieval more directly. Although the proposal has proven consistency with several lines of findings on the two faces of selective retrieval (e.g., Aslan & Bäuml, 2014; Bäuml & Dobler, 2015; Bäuml & Samenieh, 2012; Bäuml & Schlichting, 2014), to date there is no direct evidence yet for this theoretical position. More direct evidence for the proposal would arise from an experiment, in which, after inducing impaired study context access – for instance, by increasing the retention interval between study and selective retrieval – participants' study context was mentally reinstated immediately before selective retrieval starts. (Partial) reinstatement of the study context should reduce the need for further retrieval-induced context reactivation processes and, following the two-factor account, should thus reduce or eliminate the beneficial effect of selective retrieval. Moreover, if reinstatement of the study context was complete, even detrimental effects of selective retrieval should arise. In fact, a complete reinstatement of the study context should also reinstate the items' interference level and thus trigger inhibition and blocking, leading to retrieval-induced forgetting. The issue was addressed in Experiment 1.

To anticipate the results of Experiment 1, Experiment 1 will provide clear evidence that context reactivation processes mediate the beneficial effect of selective retrieval. On the basis of this result and the view that context reactivation processes mediate the beneficial effects of both selective retrieval and selective restudy (Bäuml & Dobler, 2015), it is the *second goal* of this study to examine the proposal that format of selective item repetition – difficult retrieval versus easy retrieval versus restudy – can influence repetition-induced context reactivation processes, and thus can influence the beneficial effects of selective item repetition on recall of the nonrepeated items. Following the two-factor account and Karpicke et al.'s (2014) variant of context retrieval theory, selective retrieval should induce stronger beneficial effects than selective restudy, and more difficult selective retrieval should induce stronger beneficial effects than easy selective retrieval. The issue was examined in three experiments (Experiments 2–4) that employed different study material and prolonged retention intervals of different length to vary the degree of study context access. The results of the experiments will provide important information on the role of repetition format for the beneficial effect of selective item repetition. In particular, together with the results of Experiment 1, they will offer a more conclusive picture of the role of context reactivation processes for the effects of selective item repetition.

Experiment 1

Experiment 1 aimed to come up with a rather direct test of the proposal that context reactivation processes mediate the beneficial effect of selective retrieval on recall of the nonretrieved items. In this experiment, subjects studied a list of unrelated items and, after a retention interval of 10 min, which included an imagination task to enhance contextual drift and the impairment in study context access (e.g., Bower, 1972; Estes, 1955), were asked to recall predefined target items of the list, either first or after prior selective retrieval of the list's remaining (nontarget) items. Immediately before recall started, two different testing conditions were induced. In the one testing condition, subjects' study context was (partially) reinstated by employing a mental context reinstatement technique. Subjects were asked to mentally reinstate their original list learning environment, and to recall and write down in brief

Table 1
Overview of Experiments 1–4: methods, predictions, and results.

	Methods	Predictions	Results
Exp. 1	(Easy) SR Study context reinstatement before test or no such context reinstatement 10 min delay Unrelated words	Reduced, if not reversed, beneficial effect of SR after study context reinstatement	Prediction confirmed
Exp. 2	Easy or difficult SR or SS 10 min or 30 min delay Unrelated words	Equivalent beneficial effects after 10 min Larger beneficial effect after SR than SS, and after difficult than easy SR after 30 min	Most predictions confirmed But: equivalent beneficial effects of difficult and easy SR after 30 min
Exp. 3	Easy or difficult SR or SS Control of number of successfully repeated items 24 h delay Unrelated words	Larger beneficial effect after SR than SS, and after difficult than easy SR	Predictions confirmed
Exp. 4	Easy or difficult SR Control of number of successfully repeated items 30 min delay Text passage	Larger beneficial effect after difficult than easy SR	Predictions confirmed

Note. SR = selective retrieval; SS = selective restudy.

phrases what they were doing prior to the study phase (e.g., Jonker et al., 2013; Sahakyan & Kelley, 2002). In the other testing condition, no such context reinstatement took place. On the basis of the two-factor account and the view that context reactivation mediates the beneficial effect of selective retrieval, we expected selective retrieval to improve recall of the other items when there was no preceding mental reinstatement of the study context. In contrast, when study context was mentally reinstated before recall started, there should be little or no need for further retrieval-induced context reactivation, and we therefore expected the beneficial effect of selective retrieval to be reduced, if not reversed (see also Table 1).

Method

Participants

48 students of Regensburg University participated in the experiment (M = 22.60 years, range = 19–29 years, 70.8% female). They were equally distributed across the two between-subjects conditions, resulting in n = 24 participants in each condition. Sample size was based on prior work examining beneficial effects of selective memory retrieval (e.g., Bäuml & Samenieh, 2012; Bäuml & Schlichting, 2014). All subjects spoke German as native language and received monetary reward or course credit for their participation.

Materials

Two study lists (A, B) were constructed, each containing 15 unrelated concrete German nouns. The items were drawn from the larger set of items used in Bäuml and Dobler (2015). Half of the participants studied List A, the other half List B. Each of the two lists consisted of 5 predefined target and 10 predefined non-target items. Among all items within a list, each target and each nontarget item had a unique initial letter.

Design

The experiment had a 2 × 2 design with the within-subjects factor of SELECTIVE RETRIEVAL (present, absent) and the between-subjects factor of CONTEXT REINSTATEMENT (present, absent). In the condition with context reinstatement, participants were instructed immediately before the test started to recall and write down details of what they were doing immediately prior to the study phase, whereas participants in the condition without context reinstatement were engaged in neutral filler tasks. Selective retrieval conditions differed in whether participants were asked to retrieve the target items first or after prior retrieval of the list's nontarget items (see Fig. 1A).

Procedure

Each participant completed two experimental blocks. To provide a distinctive initial experimental context at the beginning of each experimental block, in all experimental conditions participants initially rated a list of pictures (nice places, food). Each participant evaluated in the one block how attractive the provided places were to them for traveling in future, and indicated in the other how much they liked the presented food's taste. Each of the two ratings tasks lasted for 3 min. Subsequently, the study phase started and in each block the items of one study list were exposed individually in the center of a computer screen and in random order for 5 s each. A retention interval of 10 min followed, in which participants were engaged in several distractor tasks, which included counting backward from a three-digit number, resolving decision tasks, and doing one of two imagination tasks. The imagination tasks lasted 3 min each. Subjects were either asked to imagine their parents' house and mentally walk through it, or they were asked to imagine being back on their last vacation and to remember and re-feel the most beautiful moments as intensively as possible (e.g., Delaney, Sahakyan, Kelley, & Zimmerman, 2010; Sahakyan & Kelley, 2002). They were also asked to write down their imaginations. After the retention interval, subjects who participated in the mental context reinstatement conditions were told to take 1 min to recall and write down as detailed as possible their thoughts, feelings, or emotions while rating the pictures from the initial phase. Subjects who did not participate in the context reinstatement condition solved arithmetic problems for the same time period.

At test, recall order of target items was controlled through the presentation of the items' unique initial letters, which were presented successively and in random order, for 6 s each. Responses were given orally. Target items were either tested first or after selective retrieval of the nontarget items. Nontargets were retrieved successively, for 6 s each, and in two successive cycles, each with its own random order. The nontargets' word stems were provided as retrieval cues. Subjects who recalled the target items first in the first experimental block recalled the target items after

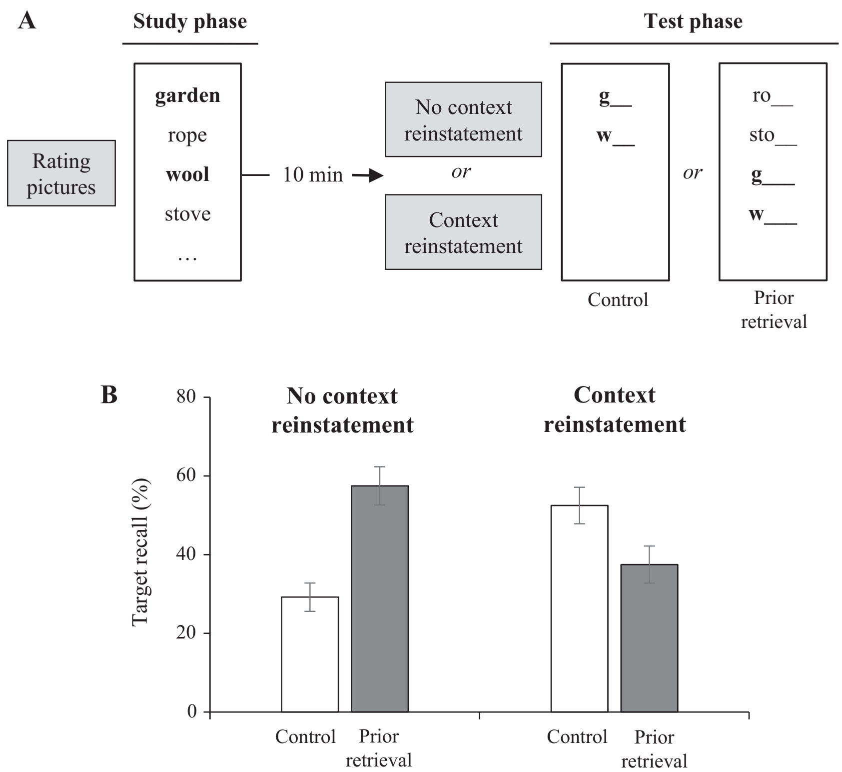

Fig. 1. (A) Procedure and conditions employed in Experiment 1. Participants rated a list of pictures (food/nice places) and then studied a list of words. After a delay of 10 min, half of the participants engaged in mental reinstatement of the study context (context reinstatement), while the other half solved arithmetic problems as a control (*no context reinstatement*). At test, participants were asked to recall predefined target items from the list (e.g., garden, wool). The targets were tested first (*control*) or after prior recall of the list's remaining items (e.g., robe, stove; *prior retrieval*). Predefined target items are depicted in bold letters. (B) Results of Experiment 1. Percentage of recalled target items is shown for the control and prior retrieval conditions, in the presence and absence of mental context reinstatement. Error bars represent standard errors.

prior recall of the nontarget items in the second block, and vice versa.

Results

Fig. 1B shows mean recall rates for the target items. A 2×2 analysis of variance with the within-subjects factor of SELECTIVE RETRIEVAL (present, absent) and the between-subjects factor of CONTEXT REINSTATEMENT (present, absent) showed a significant interaction between the two factors, $F(1,46) = 47.69$, $MSE = 236.23$, $p < .001$, $\eta^2 = 0.51$. There was no main effect of CONTEXT REINSTATEMENT, $F(1,46) < 1$, but a main effect of SELECTIVE RETRIEVAL, $F(1,46) = 4.52$, $MSE = 236.23$, $p = .039$, $\eta^2 = 0.09$, indicating that target recall was influenced by whether the nontarget items were previously retrieved. Planned comparisons showed that, whereas preceding selective retrieval improved target recall in the absence of context reinstatement, $t(23) = 6.82$, $p < .001$, $d = 1.35$, it impaired target recall in the presence of context reinstatement, $t(23) = 3.19$, $p = .004$, $d = 0.66$. Access to study context at test thus modulated the effect of selective retrieval.

Half of the participants in this experiment started testing with target items being recalled first and the other half with target items being recalled last. Testing order did not affect results, however. There was no main effect of testing order, $F(1,44) = 1.85$, $MSE = 729.55$, $p = .181$, $\eta^2 = 0.04$, and no interaction of testing order with any of the other factors, all $Fs(1,44) < 1.76$, $MSEs > 237.12$, $ps > .192$, $\eta^2 s < 0.04$. Further analyses showed that, if no prior selective retrieval took place, target recall was higher when context reinstatement was present than when it was absent, $t(46) = 3.97$, $p < .001$, $d = 1.15$, thus showing the typical context reinstatement effect.[1] Nontarget recall was high (reinstatement: 73.75%; no reinstatement: 79.58%) and did not vary between reinstatement conditions, $t(46) = 1.35$, $p = .183$, $d = 0.15$.

Discussion

The results replicate prior work (Bäuml & Dobler, 2015; Bäuml & Schlichting, 2014) by demonstrating a beneficial effect of selective retrieval after a prolonged retention interval when there was no mental reinstatement of the study context before recall started. In contrast, for the same retention interval, the results showed a detrimental effect of selective retrieval when study context was mentally reinstated before recall started. These results underline the critical role of study context access for the beneficial effect of selective retrieval and indicate that, with constant study and selective retrieval conditions, selective retrieval can both improve and impair recall of other items, depending on whether study context access at test is impaired or not. The finding strongly supports the proposal that context reactivation processes mediate the ben-

[1] Among other things, the results of Experiment 2 reported below show that, after a 10-min delay and without preceding context reinstatement, selective retrieval eliminates time-dependent forgetting. If, under the same conditions, selective retrieval also eliminated time-dependent forgetting in Experiment 1, then the recall level in the prior retrieval-no context reinstatement condition of this experiment can serve as a baseline to determine how effective the context reinstatement was. The finding that, after context reinstatement, the recall level in the control condition was nearly indistinguishable from the recall level in the prior retrieval-no context reinstatement condition (see Fig. 1) then indicates that the context reinstatement was more or less complete in the present experiment.

eficial effect of selective retrieval and thus supports the two-factor account of selective retrieval.

Experiment 2

Experiment 2 was aimed as a first step to investigate whether the context reactivation processes that supposedly underlie the beneficial effect of selective retrieval vary with repetition format. Following the two-factor account and Karpicke et al.'s (2014) variant of context retrieval theory, repetition format may influence the effects of selective item repetition on the recall of the nonrepeated items: selective retrieval may induce a higher degree of context reactivation and thus a stronger beneficial effect for nonrepeated items than selective restudy, and more difficult selective retrieval may induce a higher degree of context reactivation and thus a stronger beneficial effect for nonretrieved items than easy selective retrieval. In addition, Experiment 2 investigated whether such relationship would depend on the extent to which access to study context at test is impaired, so that the single repetition formats may create different beneficial effects when study context access is strongly impaired at test, but largely equivalent beneficial effects when the impairment is only moderate. Such finding could explain the discrepancy in results in the Bäuml and Dobler (2015) study, which reported equivalent beneficial effects of retrieval and restudy after moderate episodic forgetting (after a forget cue) but stronger beneficial effects of retrieval than restudy after strong episodic forgetting (after a 48-h retention interval; see also General Discussion).

Participants studied a list of unrelated words and after study were engaged in several distractor tasks. There were a shorter (10 min) and a longer (30 min) retention interval condition, with one (10-min condition) or three (30-min condition) imagination tasks included to enhance contextual drift. At test, participants in both delay conditions were asked to recall predefined target items of the list first or after prior selective repetition of the list's remaining (nontarget) items. There were three repetition conditions: in the restudy condition, subjects restudied the nontarget items; in the easy retrieval condition, they retrieved the nontarget items with the item's unique word stems as retrieval cues; in the difficult retrieval condition, they retrieved the nontarget items with the words' unique initial letters as retrieval cues (see Fig. 2A). On the basis of the two-factor account of selective retrieval and Karpicke et al.'s variant of context retrieval theory, we expected all three repetition formats to induce beneficial effects on the nonrepeated items, after both the shorter and the longer retention interval. In particular, we expected the three repetition formats to differ in amount of the beneficial effect, with selective retrieval inducing a larger beneficial effect than selective restudy, and more difficult retrieval inducing a larger beneficial effect than easier retrieval. On the basis of the findings of Bäuml and Dobler (2015), however, one may expect this pattern to arise mainly for the longer (30-min) retention interval (see also Table 1).

Method

Participants

Another 192 students of Regensburg University took part in the experiment (M = 23.00 years, range: 18–33 years, 87.0% female). They were equally distributed across the eight between-subjects conditions, resulting in n = 24 participants in each single condition. Sample size followed Experiment 1. All participants spoke German as native language and took part on a voluntary basis. They received monetary reward or course credits for their participation.

Materials

Materials were identical to Experiment 1.

Design

The experiment had a 2 $\times$ 4 factorial design with the between-subjects factors of REPETITION FORMAT (control, prior restudy, prior easy retrieval, prior difficult retrieval) and DELAY (10 min, 30 min). Between study of the list and the test phase participants took part in several distractor tasks that lasted either 10 min or 30 min. At test, subjects recalled the target items first (control) or after restudy the nontarget items (prior restudy) or after retrieval of the nontarget items, with either the items' unique initial letters serving as retrieval cues (prior difficult retrieval) or their word stems serving as retrieval cues (prior easy retrieval). Assignment of conditions and lists was counterbalanced.

Procedure

List items were exposed on a screen individually and in random order for 5 s each. In the 10-min retention interval condition, participants were engaged in one block of distractor tasks; in the 30-min retention interval condition, they were engaged in three successive 10-min blocks of distractor tasks. In each block, subjects were first asked to participate in a number of tasks, like counting backward from a three-digit number, solving arithmetic problems, resolving some decision tasks, playing tetris, doing the Ravens Progressive Matrices, or rating pictures of food or nice places, for a total of 7 min. Afterwards, subjects were engaged in an imagination task of 3 min duration. In this task, participants were either asked to imagine their parents' house and to mentally walk through it, or to imagine the things they would like to do if they were invisible and did not have to take responsibility for their actions, or to imagine being back on their last vacation and to remember and re-feel the most beautiful moments as intensively as possible (e.g., Delaney et al., 2010; Sahakyan & Kelley, 2002). They were also asked to write down their imaginations. For the 30-min delay condition, all three imagination tasks were employed in random order; for the 10-min delay condition, one of the tasks was randomly selected.

At test, in all four repetition conditions, recall order of the target items was controlled through the presentation of the items' unique initial letters, which were presented successively and in random order, for 6 s each. Responses were given orally. In the prior restudy condition, participants were asked to study the list's nontarget items a second time, for 6 s each and in random order, before being tested on the list's target items. In the prior easy retrieval condition, nontargets were tested before target items, providing the nontargets' word stems as retrieval cues; the stems were presented successively and in random order, for 6 s each. In the prior difficult retrieval condition, nontargets were also tested before target items, but the nontargets' initial letters only were provided as retrieval cues; the initial letters were presented successively and in random order, for 6 s each. In the control condition, targets were tested immediately at the beginning of the test phase. All nontargets were repeated in two successive cycles, with two different random orders, prior to target recall.

Additional baseline condition

Another 24 students (M = 21.69 years, range: 19–28 years, 66.7% female) took part in an additional, ninth experimental condition, in which they studied a list of items and recalled the list's target items after a 30-s distractor task, in which they counted backward from a three-digit number. Material and procedure were identical to the four repetition conditions above with the only exceptions that target items were tested only and there was a 30-s retention interval between study and test. This condition was included to serve as a baseline, in both Experiment 2 and

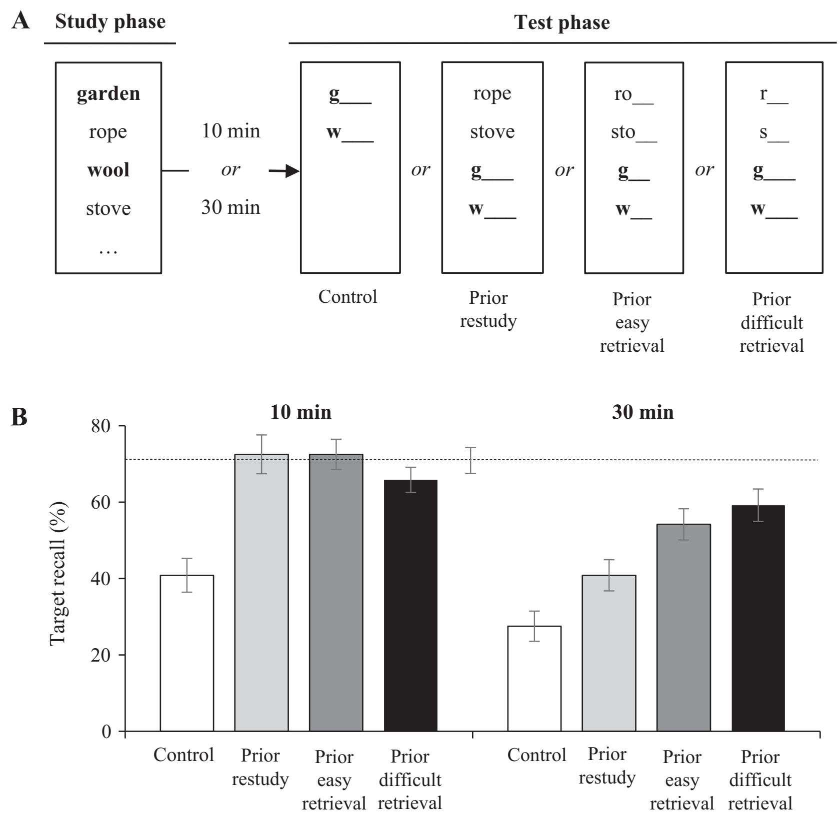

Fig. 2. (A) Procedure and conditions employed in Experiment 2. Participants studied a list of words and, after a 10-min or a 30-min delay, were asked to recall predefined target items from the list. The targets were tested first (*control*) or after prior restudy the list's remaining items (*prior restudy*) or after prior retrieval of the list's remaining items, with either the items' word stems serving as retrieval cues (*prior easy retrieval*) or their unique initial letters serving as retrieval cues (*prior difficult retrieval*). Predefined target items are depicted in bold letters. (B) Results of Experiment 2. Percentage of recalled target items is shown as a function of delay (10 min, 30 min) and repetition format (control, prior restudy, prior easy retrieval, prior difficult retrieval). Error bars represent standard errors. The dashed line represents a 30-s delay baseline condition, in which target items were recalled first.

Experiment 3, to (i) measure amount of time-dependent forgetting after the single prolonged retention intervals, and (ii) measure the extent to which possible beneficial effects of selective item repetition eliminate time-dependent forgetting.

Results

Fig. 2B shows mean recall rates for the target items in both the eight experimental conditions and the baseline condition. A 2×4 analysis of variance with the between-subjects factors of REPETITION FORMAT (control, prior restudy, prior easy retrieval, prior difficult retrieval) and DELAY (10 min, 30 min) showed a main effect of DELAY, $F(1,184) = 35.28$, $MSE = 416.67$, $p < .001$, $\eta^2 = 0.16$, and a main effect of REPETITION FORMAT, $F(3,184) = 21.49$, $MSE = 416.67$, $p < .001$, $\eta^2 = 0.26$. There was also a significant interaction between the two factors, $F(3,\ 184) = 3.23$, $MSE = 416.67$, $p = .024$, $\eta^2 = 0.05$, suggesting that repetition format affected target recall in the two delay conditions differently.

Planned comparisons for the 10-min delay condition showed that all three repetition formats facilitated recall of the target items relative to the (no-repetition) control condition, all $ts(46) > 4.70$, $ps < .001$, $ds > 1.31$. The three repetition formats did not differ in recall rates, $F(2,69) < 1$, indicating that they induced about the same beneficial effects on target recall. In the 30-min delay condition, again all three repetition formats facilitated target recall relative to the control condition, all $ts(46) > 2.35$, $ps < .023$, $ds > 0.67$. In contrast to the 10-min retention interval condition, however, the three repetition formats differed in recall rates in this condition, $F(2,69) = 5.25$, $MSE = 410.87$, $p = .008$, $\eta^2 = 0.13$. In fact, both easy retrieval and difficult retrieval induced larger beneficial effects than restudy, $t(46) = 2.31$, $p = .025$, $d = 0.67$, and $t(46) = 3.11$, $p = .003$, $d = 0.90$, whereas the two retrieval formats did not create different recall rates, $t(46) < 1$.

Additional analyses showed that target recall in the 30-s baseline condition was higher than in the 10-min control condition (70.83% vs. 40.83%), $t(46) = 5.38$, $p < .001$, $d = 1.55$, and was higher in the 10-min control condition than in the 30-min control condition (40.83% vs. 27.50%), $t(46) = 2.25$, $p = .029$, $d = 0.65$, thus showing the typical pattern of time-dependent forgetting. Interestingly, in the 10-min delay condition, recall rates in the three repetition conditions were statistically indistinguishable from recall in the (30-s) baseline condition, all $ts(46) < 1.06$, $ps > .296$, $ds < 0.31$, indicating that selective item repetition did not only induce beneficial effects but eliminated all time-dependent forgetting. In contrast, in the 30-min delay condition, recall rates in all three repetition conditions were below baseline, all $ts(46) > 2.14$, $ps < .037$, $ds > 0.62$, indicating that selective item repetition induced only partial elimination of the time-dependent forgetting. Nontarget recall rates in the easy and difficult retrieval conditions differed in the 10-min delay condition (94.17% vs. 55.00%), $t(46) = 11.17$, $p < .001$, $d = 3.23$, as well as in the 30-min delay condition (87.50% vs. 55.00%), $t(46) = 7.20$, $p < .001$, $d = 2.08$. They did not depend on delay (74.58% vs. 71.25%), $F(1,\ 92) = 1.36$, $MSE = 196.01$, $p = .246$, $\eta^2 = 0.02$.

Discussion

For both delay conditions and all three repetition formats, the results show beneficial effects of selective item repetition on recall of the nonrepeated items. However, whereas after the shorter 10-min retention interval, the three repetition formats induced about the same beneficial effects and completely eliminated time-dependent forgetting, after the longer 30-min retention interval, there was only partial elimination of time-dependent forgetting and selective retrieval improved recall of the other items more than selective restudy did. The findings for selective retrieval and selective restudy thus simulate the results reported in Bäuml and Dobler (2015), which found selective retrieval and selective restudy to induce largely equivalent beneficial effects after presentation of a forget cue, i.e., after moderate episodic forgetting, but larger beneficial effects of selective retrieval than selective restudy after a retention interval of 48 h, i.e., after stronger episodic forgetting. Together, the results thus indicate that the degree to which access to study context at test is impaired can influence whether selective retrieval induces stronger beneficial effects than restudy (see also General Discussion).

The finding that, after a longer retention interval, selective retrieval can improve recall of other items more than selective restudy is consistent with the two-factor account of selective retrieval and Karpicke et al.'s (2014) variant of context retrieval theory, according to which retrieval may trigger more context reactivation than restudy. However, the finding that, after the same retention interval, difficult retrieval did not improve target recall more than easy retrieval does not agree with the theory, indicating that context reactivation processes may not vary with retrieval difficulty and the beneficial effect of selective retrieval may not depend on how demanding retrieval is.

However, the procedure employed in Experiment 2 may have underestimated the beneficial effect of difficult retrieval. In fact, while in the selective restudy condition of the experiment participants should have repeated more or less all of the nontarget items and in the selective easy retrieval condition nearly all of the items (91% success rate for nontarget recall), in the difficult retrieval condition only about half of the nontarget items were repeated (55% success rate for nontarget recall). Because the beneficial effect of selective retrieval has been shown to increase with number of successfully retrieved nontarget items (Bäuml & Samenieh, 2010), this finding indicates that the beneficial effect of difficult selective retrieval may have been underestimated in this experiment. If so, an effect of retrieval difficulty on the beneficial effect of selective retrieval may emerge if number of successfully retrieved nontargets was controlled across retrieval conditions. Experiment 3 addresses the issue.

Experiment 3

Experiment 3 repeated Experiment 2 with two changes. The first change was that Experiment 3 was aimed at roughly equating number of successfully repeated nontarget items across the three repetition conditions to no longer underestimate the beneficial effect of difficult retrieval. This was achieved by reducing number of to-be-repeated nontarget items in the restudy and easy retrieval conditions. In fact, while in the difficult retrieval condition, subjects should repeat all 10 nontarget items, only 6 of the 10 nontargets should be repeated in the restudy and easy retrieval conditions. On the basis of the results of Experiment 2, we expected that this adjustment created similar numbers of successful repetitions in the three repetition conditions. As the second change, we employed a single retention interval condition only but increased the retention interval between study and test to 24 h. If differences in repetition format are more easily detected after longer than after shorter retention interval (see Experiment 2), then the increase in retention interval to 24 h may enhance chances to find pairwise differences between the three repetition formats. On the basis of the results of the 30-min condition of Experiment 2, we again expected all three repetition formats to show beneficial effects of selective item repetition and to find selective retrieval to create larger beneficial effects than selective restudy. By holding number of successfully repeated items roughly constant across repetition conditions, we additionally expected that difficult selective retrieval created a larger beneficial effect for the nonretrieved items than easy selective retrieval. Such pattern of results would indicate that the beneficial effect of selective item repetition indeed depends on difficulty of selective item repetition (see also Table 1).

Method

Participants

Another 128 students of Regensburg University took part in the experiment (M = 22.89 years, range = 19–35 years, 74.2% female). They were equally distributed across the four between-subjects conditions, resulting in $n = 32$ participants in each single condition. Bäuml and Dobler Exp. 2 (2015) reported an effect size of $d = .62$ for the difference in recall levels between easy retrieval and restudy for a prolonged retention interval of several hours. To ensure that such difference would be detected in the present experiment, in which we also employed a prolonged retention interval, an analysis of test power with the G*Power program (version 3, Faul, Erdfelder, Lang, & Buchner, 2007) was conducted. Setting alpha = .05 and beta = .20, this analysis suggested a sample size of $n = 33$ subjects per condition, which is close to the sample size of $n = 32$ employed in Bäuml and Dobler (2015). We followed the prior work. All subjects spoke German as native language and received monetary reward or course credit for their participation.

Materials

Materials were identical to Experiments 1 and 2.

Design and Procedure

The experiment had a unifactorial design with the between-subjects factor of REPETITION FORMAT (control, prior restudy, prior easy retrieval, prior difficult retrieval). The procedure was largely identical to Experiment 2, with two exceptions only: First, we increased the retention interval between study and test to 24 h. Included in this interval was a 10-min distractor block conducted immediately after study and another 10-min distractor block conducted immediately before test. The two distractor blocks were identical in design to the distractor blocks employed in Experiment 2. Second, whereas at test, participants were asked to recall all 10 nontargets in the difficult retrieval condition, in the easy retrieval and restudy conditions, they recalled or restudied only 6 of the 10 nontarget items; for each subject, the 6 items were randomly selected from the set of 10 nontarget items. These items remained constant across the two repetition cycles, although retrieval or presentation order were randomized within each single repetition cycle. In all other aspects Experiment 3 was identical to Experiment 2.

Results

In the easy retrieval condition, 5.41 of the (6) nontarget items were successfully recalled, and in the difficult retrieval condition 5.66 of the (10) nontarget items were successfully recalled. The difference between the two conditions was not significant, $t(62) < 1$, and the number of successfully retrieved items was also close to the number of restudied items (6) in the selective restudy condi-

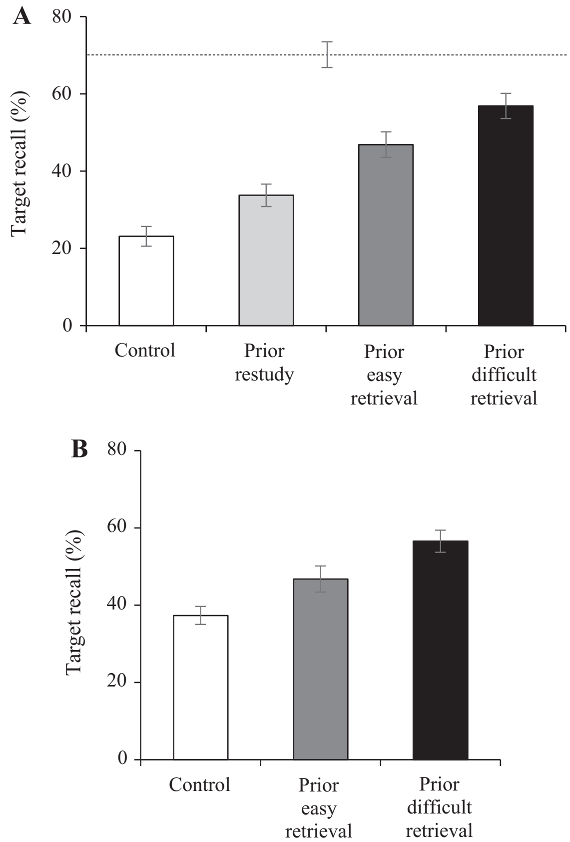

Fig. 3. Results of Experiments 3 and 4. (A) Results of Experiment 3. Percentage of recalled target items is shown as a function of repetition format (control, prior restudy, prior easy retrieval, prior difficult retrieval). Error bars represent standard errors. The dashed line represents the same baseline condition as shown in Fig. 2B. (B) Results of Experiment 4. Percentage of recalled target items is shown as a function of repetition format (control, prior restudy, prior easy retrieval, prior difficult retrieval). Error bars represent standard errors.

tion. All this indicates that control of number of successfully repeated items was quite effective in this experiment.

Fig. 3A shows mean recall rates for the target items. A unifactorial analysis of variance with the between-subjects factor of REPETITION FORMAT (control, prior restudy, prior easy retrieval, prior difficult retrieval) showed a main effect of REPETITION FORMAT, $F(3, 124) = 23.95$, $MSE = 292.04$, $p < .001$, $\eta^2 = 0.37$. Planned comparisons revealed beneficial effects for all three repetition formats relative to the (no-repetition) control condition, all $ts(62) > 2.75$, $ps < .008$, $ds > 0.69$. In particular, repetition formats differed pairwise in the size of the beneficial effect, with difficult retrieval inducing higher target recall than easy retrieval, $t(62) = 2.15$, $p = .035$, $d = 0.54$, and easy retrieval inducing higher target recall than restudy, $t(62) = 2.98$, $p = .004$, $d = 0.75$.

Including the 30-s baseline condition of Experiment 2 into the analysis also showed that, like in Experiment 2, time-dependent forgetting was present, $t(54) = 11.44$, $p < .001$, $d = 3.06$. In particular, like in the 30-min retention interval condition of Experiment 2, recall rates in all three repetition conditions were below the 30-s baseline condition, indicating that in all three repetition conditions only partial elimination of the time-dependent forgetting was present, all $ts(54) > 2.92$, $ps < .005$, $ds > 0.80$.

Discussion

Employing a longer retention interval than in Experiment 2 and controlling the number of successfully repeated items across repetition conditions, we replicated the results of the 30-min condition of Experiment 2 by showing that (i) all three repetition formats can improve recall of target information, (ii) none of the three repetition formats eliminates time-dependent forgetting completely, and (iii) both forms of selective retrieval induce stronger beneficial effects on target recall than selective restudy. Unlike in Experiment 2, however, the two retrieval conditions differed in amount of the beneficial effect, with difficult retrieval improving target recall more than easy retrieval. These findings are consistent with the view that context reactivation processes mediate the beneficial effects and Karpicke et al.'s (2014) variant of context retrieval theory, according to which difficulty of item repetition should influence the amount of context reactivation and thus should influence the size of the beneficial effect that arises for nonrepeated items in response to selective item repetition.

Experiment 4

By showing that selective retrieval can induce larger beneficial effects for recall of other items than selective restudy, the results of Experiment 3 confirmed the results of Experiment 2 as well as the results from prior work on selective item repetition (Bäuml & Dobler, 2015). Besides, Experiment 3 provided the first indication that difficult selective retrieval may improve recall of nonrepeated items more than easy selective retrieval. It was therefore the goal of Experiment 4 to replicate this latter finding. In contrast to Experiment 3, more coherent prose material was used as study material in this experiment. While prior work already demonstrated that, after prolonged retention interval, selective retrieval can induce beneficial effects on recall of other information also with coherent prose material (Bäuml & Schlichting, 2014), this prior work used easy retrieval for selective item repetition only and did not address the role of retrieval difficulty in selective memory retrieval.

Experiment 4 compared the beneficial effects of easy and difficult selective retrieval employing the text passage *The Big Bang*, which was already used in previous studies (Bäuml & Schlichting, 2014; Chan, McDermott, & Roediger, 2006). Subjects studied the text passage and after a retention interval of 30 min were tested on some target questions, either first or after prior selective answering of some nontarget questions. Analogous to Experiments 2 and 3, we employed two selective retrieval conditions: in the easy retrieval condition, subjects answered the nontarget questions with the word stems of the missing items serving as retrieval cues; in the difficult retrieval condition, nontarget questions were answered in the absence of any item-specific cues. Like Experiment 3, Experiment 4 aimed at equating number of successfully retrieved items in the two retrieval conditions, which was achieved by reducing the number of presented nontarget questions in the easy retrieval condition. On the basis of the results of Bäuml and Schlichting (2014) on the effects of selective retrieval with coherent prose material, we expected that selective retrieval can induce beneficial effects on recall of the target information. Following the results of Experiment 3 of this study, we expected that this beneficial effect may be larger after difficult than after easy selective retrieval (see also Table 1).

Method

Participants

Another 138 students of Regensburg University participated in the experiment ($M = 22.09$ years, range = 17–35 years, 88.4% female). They were equally distributed across the three between-subjects conditions, resulting in $n = 46$ participants in each condition. Number of subjects per condition was increased relative to Experiment 3 because, on the basis of the results of Bäuml and

Schlichting (2014), we expected effect sizes to be reduced by the order of $d = .10$ with prose material relative to lists of unrelated items. With alpha = .05 and beta = .20, analysis of test power suggested a sample size of $n = 47$ subjects per condition to detect an effect of $d = .52$ (relative to .62 in Experiment 3). We followed this suggestion closely. All subjects spoke German as native language. In exchange for participation, course credit or monetary reward was provided.

Materials

The text passage *The Big Bang*, which was already used in prior work (Bäuml & Schlichting, 2014; Chan et al., 2006), served as study material. We used the German translation of the text used in Bäuml and Schlichting. The text was approximately 1800 words long. We selected the same 6 target and the same 12 nontarget questions as were employed in the prior work (gapped sentences like "The Hubble telescope found the heavy element ____ in extremely ancient stars." [Answer: boron] or "Arthur Eddington said: 'We must allow ____ an infinite amount of time to get started.' " [Answer: evolution]).

Design

The experiment had a unifactorial design with the between-subjects factor of REPETITION FORMAT (control, prior easy retrieval, prior difficult retrieval). Participants answered the target questions first (control) or after prior selective answering of the nontarget questions. In the two retrieval conditions, subjects answered the nontarget questions first with the missing information's word stem provided as a retrieval cue (prior easy retrieval), or in the absence of any item-specific cues (prior difficult retrieval). Assignment of conditions was counterbalanced.

Procedure

The procedure largely followed the one used in Bäuml and Schlichting (2014, Experiment 2), differing only in the length of the retention interval and format of selective retrieval. Participants had 16 min to read the study text with the instruction that all information can be relevant for the later test and without knowing what type of test would be conducted. After study, a 30-min retention interval followed that included three blocks of 10 min, with each block consisting of several distractor tasks including one imagination task (see Method of Experiment 2 above). At test, subjects had 25 s to answer a single target or nontarget question. Responses were given orally. Target questions were either tested first or after selective answering of the nontarget questions. In the prior easy retrieval condition, nontarget questions were answered providing the word stems of the missing items as retrieval cues; in the prior difficult retrieval condition, no such retrieval cues were provided. No item-specific cues were provided for the answers of the target questions. Both target and nontarget questions were presented successively and in random order. Like Experiment 3 above, the experiment was aimed at roughly equating number of successfully retrieved nontarget items between retrieval conditions, which was achieved by reducing the number of to-be-repeated nontarget questions in the easy retrieval condition. Accordingly, participants were asked to answer all 12 nontarget questions in the difficult retrieval condition, but were asked to answer only 8 of the 12 questions in the easy retrieval condition. For each subject, the 8 questions were randomly selected from the set of 12 nontarget questions. The selection of the nontarget questions remained constant across two repetition cycles, but order of questions was randomized within each of the two cycles.

Results

In the easy retrieval condition 5.79 of the (8) nontarget questions and in the difficult retrieval condition 5.65 of the (12) nontarget questions were correctly answered. Nontarget recall thus did not differ between retrieval conditions, $t(90) = 1.24$, $p = .217$, $d = 0.26$, indicating that control of number of successfully retrieved nontargets was effective.

Fig. 3B shows mean recall rates for the target questions. A unifactorial analysis of variance with the between-subjects factor of REPETITION FORMAT (control, prior easy retrieval, prior difficult retrieval) showed a main effect of REPETITION FORMAT, $F(2, 135) = 11.08$, $MSE = 383.89$, $p < .001$, $\eta^2 = 0.14$. Planned comparisons revealed beneficial effects in both retrieval formats relative to the (no-repetition) control condition, both $ts(90) > 2.30$, $ps < .024$, $ds > 0.48$. In particular, the two retrieval formats affected target recall differently, with higher recall in the difficult than the easy retrieval condition, $t(90) = 2.21$, $p = .030$, $d = 0.46$.

Discussion

The results of Experiment 4 mimic recent findings of Bäuml and Schlichting (2014) by showing that, after a prolonged retention interval, selective retrieval can induce beneficial effects on other items also with coherent prose material. They go beyond the prior work by demonstrating that the beneficial effect can be modulated by retrieval difficulty, with difficult selective retrieval inducing a stronger beneficial effect than easy selective retrieval. Doing so, the results replicate the findings of Experiment 3 that employed unrelated word lists as study material with coherent prose material. Together with Experiment 3, the results thus indicate that retrieval format can influence the size of the beneficial effect of selective retrieval and that the effect increases with difficulty of retrieval task.[2]

General discussion

The first goal of this study was to examine the proposal included in Bäuml and Samenieh's (2010) two-factor account of selective retrieval that the beneficial effect of selective retrieval is mediated by context reactivation processes more directly. Impairing study context access through a prolonged retention interval, the results of Experiment 1 first of all showed that, in the absence of preceding mental reinstatement of the study context, selective retrieval of some studied information can in fact improve recall of the other information, thus replicating results from previous studies (e.g., Bäuml & Dobler, 2015; Bäuml & Schlichting, 2014). However, when immediately before selective retrieval started, study context was mentally reinstated, no such beneficial effect arose and selective retrieval rather impaired recall of the other items. These findings provide direct evidence for the

[2] Experiment 4 had a focus on the role of retrieval format and did not include a restudy condition. If a restudy condition had been included, we would have expected that the beneficial effect is larger after easy retrieval than restudy (see Experiments 2 and 3). Inspection of Fig. 3B suggests that, in such case, recall in the restudy condition would not have been much different from recall in the (no-repetition) control condition, indicating that, with prose material, selective restudy may not induce any beneficial effects. However, whether a repetition format creates beneficial effects for some study material may depend on number of repeated nontarget items (see Bäuml & Samenieh, 2010). The results of Experiment 4 may thus suggest that, with prose material, a larger number of nontarget items must be repeated than with lists of unrelated items to improve recall of other information. Future work may address the issue directly.

critical role of impaired study context access for the beneficial effect of selective retrieval and thus support the proposal that context reactivation processes mediate the beneficial effect.

The second goal of this study was to examine whether the size of the beneficial effect of selective retrieval on recall of the nonrepeated items is the same for easy and difficult selective retrieval, and can even generalize to selective restudy trials. On the basis of the view that context reactivation processes mediate the beneficial effect and Karpicke et al.'s (2014) variant of context retrieval theory, repetition format may influence the effect, with more difficult selective item repetition inducing a stronger beneficial effect on nonrepeated items than more easy item repetition. The results of Experiments 2–4 show such pattern. Employing retention intervals of 30 min and 24 h, Experiments 2 and 3 showed that selective retrieval improves recall of other items more than selective restudy. In addition, for the same retention intervals, Experiments 3 and 4 showed that, when number of successfully selectively retrieved items is controlled, difficult selective retrieval improves recall of other items more than easy selective retrieval. These results converge on the view that difficulty of selective item repetition can influence the beneficial effect on nonrepeated items, which, together with the results of Experiment 1, supports the proposal that context reactivation processes mediate the effect and are modulated by repetition format. For the shorter retention interval of 10 min, such effect of repetition format was absent and the single repetition formats created equivalent beneficial effects (but see below).

Implications for the two-factor account of selective retrieval

The present results strengthen and extend the two-factor account of selective memory retrieval. This account claims that, in general, selective retrieval triggers inhibition and blocking as well as context reactivation processes. Critically, the contribution of the two types of processes is assumed to depend on access to study context at test, with a larger relative contribution of inhibition and blocking when study context access is (largely) maintained, and a larger relative contribution of context reactivation processes when access to study context at test is impaired. As a result, detrimental effects of selective retrieval on other items may be observed when access to study context is maintained at test, but beneficial effects when access to study context is impaired.

This account is supported by the present demonstration that, after a prolonged retention interval, mental reinstatement of the study context immediately before recall starts can eliminate and even reverse the beneficial effect. Indeed, in the absence of a mental context reinstatement, the delay-induced impairment in study context access should trigger retrieval-induced context reactivation and thus induce beneficial effects on the recall of the other items. In contrast, in the presence of such reinstatement, the impairment in context access should be reduced, reducing the need for (further) retrieval-induced reactivation and thus attenuating possible beneficial effects of selective retrieval. Rather, the induced context reinstatement may revive item interference, leading to inhibition and blocking and detrimental effects of selective retrieval. By showing the two faces of selective retrieval in the presence versus absence of mental context reinstatement, the present findings are consistent with this proposal.

The present results also extend the two-factor account. Empirically, they extend the account by showing that beneficial effects on nonrepeated items do not only arise in response to (easy) selective retrieval trials, as has been shown in the prior work (see Bäuml et al., 2017), but do also arise in response to difficult selective retrieval and selective restudy trials. This holds while repetition format can modulate the size of the beneficial effect, with more difficult repetition formats creating larger beneficial effects than more easy repetition formats. Theoretically, the results extend the account by imposing a restriction on the proposed context reactivation processes, suggesting that amount of context reactivation varies with repetition format. This view on the underlying context reactivation processes fits with Karpicke et al.'s (2014) variant of context retrieval theory. In this variant, it was argued that degree of context reactivation may be higher after retrieval than restudy, because context retrieval may not be obligatory during restudy cycles, and because, with retrieval, people deliberately search memory information about the prior occurrence of studied information. Similarly, difficult and easy retrieval conditions may also induce a difference in context reactivation, because mostly difficult retrieval and less easy retrieval requires reactivation of the study context.

Including this variant of context retrieval theory into the two-factor account leads to a more general two-factor account, which is able to explain the beneficial effects of selective item repetition on nonrepeated items, as they are reported in this study, but is also able to explain the detrimental effects of selective item repetition, as they were reported in prior work on retrieval-induced forgetting (e.g., Bäuml & Kliegl, in press; Storm & Levy, 2012). These results showed mostly retrieval-specific detrimental effects of selective item repetition, a pattern well explained by inhibition and blocking processes (see above). Whether the size of the detrimental effect of selective retrieval also varies with difficulty of selective retrieval has not been examined yet. Because more difficult selective retrieval (e.g., providing weak item-specific cues) may create more interference from other items than easy selective retrieval (e.g., providing strong item-specific cues), on the basis of the inhibition view there would be reason to expect larger detrimental effects after difficult than easy retrieval.[3] Future work may address the issue and fill this empirical gap.

Relation to prior work on effects of selective item repetition in listwise directed forgetting

In a previous study, Bäuml and Dobler (2015) compared the effects of selective retrieval with the effects of selective restudy, both when a forget cue was provided after study and when a prolonged 48-h retention interval occurred between study and selective item repetition. Equivalent effects of selective retrieval and selective restudy were found after the forget cue (which created moderate episodic forgetting), whereas stronger beneficial effects of retrieval than restudy were found after the prolonged retention interval (which created strong episodic forgetting). Moreover, while both forms of selective item repetition eliminated the episodic forgetting induced by the forget cue completely, selective item repetition eliminated only about half of the episodic forgetting that was induced by the prolonged retention interval. Interestingly, the results of the present Experiments 2 and 3 mimic these findings using shorter (10 min) and longer (30 min, 24 h) retention intervals. They show equivalent effects of selective retrieval and selective restudy after the shorter (10-min) delay, with a complete elimination of the time-dependent forgetting. In contrast, they show larger beneficial effects of selective retrieval than selective restudy after the longer (30-min and 24-h) delays, with elimination of only about half of the time-dependent forgetting.

These parallels indicate that the effects of selective item repetition in listwise directed forgetting can be simulated using time-dependent forgetting with a moderate length of retention

[3] If difficult selective retrieval strengthened practiced items more than easy selective retrieval (e.g., Bjork & Kroll, 2015), then the same prediction would arise on the basis of the blocking account, arguing that stronger practiced items may block recall of unpracticed items more than weaker practiced items.

interval, thus supporting the view that, in both forms of forgetting, inaccess to study context plays a critical role for the induced forgetting (e.g., Estes, 1955; Geiselman, Bjork, & Fishman, 1983; Sahakyan and Kelley, 2002). Moreover, on the basis of the parallels, the prediction arises that, if a forget cue created stronger episodic forgetting than the forget cue is doing in the standard listwise directed forgetting task (for an example, see Bäuml & Kliegl, 2013, Experiments 1A und 1B), then also in listwise directed forgetting selective retrieval may create larger beneficial effects than selective restudy. Why selective retrieval and selective restudy induced equivalent beneficial effects in Bäuml and Dobler's (2015) directed forgetting experiment and the moderate retention interval condition of the present Experiment 2, but different beneficial effects in the other conditions of the present study is less clear. A possible reason, however, may be the presence of a ceiling effect. Indeed, both in Bäuml and Dobler's directed forgetting experiment and the moderate retention interval condition of the present Experiment 2, selective restudy already eliminated all episodic forgetting, so that no further room may have been left for an enhanced beneficial effect of selective retrieval. If so, the present results would indicate that selective retrieval improves recall of other items more than selective restudy whenever room is left for retrieval to create more context reactivation than restudy.

Relation to prior work on effects of selective retrieval in social recall

Abel and Bäuml (2015) recently suggested that the finding of beneficial effects of selective retrieval in individuals may generalize to social recall. Using the speaker-listener task – a task, in which two individuals study a list of items and one of the two persons (the "speaker") selectively retrieves a subset of the information before the other person (the "listener") recalls the remaining information (Cuc, Koppel, & Hirst, 2007) – these researchers found that, when access to study context at test was impaired for the two persons – by providing a forget cue after study, being engaged in an imagination task, or a prolonged retention interval between study and selective retrieval – the selective retrieval by the speaker improved the subsequent recall of the listener, similar to how selective retrieval had been shown to improve the recall of other items in individuals. In contrast, Hirst and colleagues reported that the selective retrieval of a speaker reduced the recall of a listener when recalling autobiographical or flashbulb memories, that is, memories that were encoded a long time before selective retrieval started and whose encoding context may therefore not have been easy to access (e.g., Coman, Manier, & Hirst, 2009; Stone, Barnier, Sutton, & Hirst, 2013).

The results of the present Experiment 1, which showed that mental reinstatement of the study context before test can eliminate and even reverse the beneficial effect, may bridge the gap between the two lines of studies. Indeed, while in the Abel and Bäuml (2015) study, nothing was done to reinstate participants' study context after access to study context was experimentally impaired, in the studies by Hirst and colleagues target memories were reactivated before selective retrieval started. In Coman et al. (2009) a questionnaire probed participants' flashbulb memories before subjects engaged in selective retrieval; in Stone et al. (2013) participants first underwent an elicitation phase and generated the autobiographical memories, before, a day later, they studied each generated memory again right before selective retrieval began. Thus, in both studies, access to the encoding context may no longer have been impaired when selective retrieval started, providing little or no need for further context reactivation and any beneficial effects of selective retrieval. The findings by Hirst and colleagues thus are not in direct conflict with Abel and Bäuml's proposal that retrieval dynamics in individuals may generalize to social groups.

Relation to prior work on the testing effect

The present results together with the two-factor account of selective retrieval suggest that repetition formats can differ in the degree to which they cause context reactivation and thus differ in the degree to which they induce beneficial effects on the recall of other items. This proposal parallels Karpicke et al.'s (2014) view on the testing effect. These authors argued that repetition formats can differ in the degree to which they cause context reactivation and thus differ in the degree to which they cause recall improvements for the repeated information itself. Indeed, the difference in context reactivation may induce a difference in the creation of unique context cues for the repeated items, and the larger number of unique context cues after retrieval may enhance retention of retrieved items more than of restudied items. Results from numerous studies in fact showed that (nonselective) retrieval practice can induce better recall of practiced items than restudy, and difficult (nonselective) retrieval can induce better recall of practiced items than easy retrieval (e.g., Carpenter & DeLosh, 2006; Halamish & Bjork, 2011; Karpicke & Roediger, 2008; Roediger & Karpicke, 2006).

While the results from the testing effect studies and the results from the present selective item repetition study thus suggest a similar role of repetition format for context reactivation processes in the two lines of studies, there is also an important difference in circumstances that surround the effects of repetition format in the two types of situations. Indeed, while the present results on beneficial effects of selective item repetition for nonrepeated items are tied to an impairment in study context access, with a reversal of effects when the impairment is absent (see present Experiment 1), the testing effect does not show such restriction. In fact, testing effects can easily be observed without inducing any major change in context between study and practice (see Roediger & Butler, 2011).

The apparent inconsistency between the two lines of findings is not in conflict with the view that item repetition triggers context reactivation processes already in the absence of major context change. Indeed, according to the two-factor account, possible beneficial effects of context reactivation in the absence of major context change can be masked by the simultaneous action of inhibition and blocking processes, thus inducing detrimental, rather than beneficial effects on nonrepeated items (e.g., Bäuml & Samenieh, 2012). The view that the role of context reactivation processes is increased in the presence of context change, as it is included in both the two-factor account and the episodic-context account, is supported by the finding of two faces of selective retrieval as well as results from testing effect studies. Indeed, at least the results of two such studies suggest that larger testing effects can arise when context between study and retrieval practice is changed than when it is left largely unaffected (Pyc, Balota, McDermott, Tully, & Roediger, 2014; Smith & Handy, 2014). Future work may examine the issue in more depth and investigate the effects of (selective) item repetition simultaneously on repeated and nonrepeated items. Such work should provide more detailed insights into the role of repetition-induced context reactivation.

Finally, there may also be relation between the present study and studies on test-potentiated learning. Test-potentiated learning refers to the finding that retrieval practice on previously studied material can enhance the ability of a learner to benefit from a subsequent restudy opportunity (Arnold & McDermott, 2013a, 2013b; Izawa, 1966). If this retrieval-practice effect was also (partly) mediated by retrieval-induced context reactivation processes, then the effect may also increase if context between study and retrieval practice is changed, and it may be larger after difficult than easy retrieval practice. Future work may address the issue, thus providing information on whether context reactivation processes can contribute to test-potentiated learning as well.

Conclusions

In this series of experiments we showed that context reactivation processes mediate the beneficial effects of selective item repetition on recall of other items. In addition, we demonstrated that repetition format can influence such context reactivation processes, with the beneficial effect of item repetition being larger after selective retrieval than selective restudy, and being larger when selective retrieval is demanding. These findings strengthen and extend the two-factor account of selective retrieval. They impose restrictions on context retrieval theory and suggest interesting parallels between the effects of selective item repetition and the testing effect.

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