Journal of Experimental Psychology:
Learning, Memory, and Cognition
2007, Vol. 33, No. 5, 950–958

0278-7393/07/$12.00 DOI: 10.1037/0278-7393.33.5.950

No Retrieval-Induced Forgetting Using Item-Specific Independent Cues: Evidence Against a General Inhibitory Account

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Retrieval practice with particular items from memory can impair the recall of related items on a later memory test. This retrieval-induced forgetting effect has been ascribed to inhibitory processes (M. C. Anderson & B. A. Spellman, 1995). A critical finding that distinguishes inhibitory from interference explanations is that forgetting is found with independent (or extralist) cues. In 4 experiments, the authors tested whether the forgetting effect is cue-independent. Forgetting was investigated for both studied and unstudied semantically related items. Retrieval-induced forgetting was not found using item-specific independent cues for either studied or unstudied items. However, forgetting was found for both item types when studied categories were used as cues. These results are not in line with a general inhibitory account, because this account predicts retrieval-induced forgetting with independent cues. Interference and context-specific inhibition are discussed as possible explanations for the data.

Keywords: memory retrieval, interference, retrieval-induced forgetting, inhibition, independent cues

Forgetting can be described as the inability to retrieve information from memory. For example, people may have difficulty remembering the name of their old soccer coach, after having played in different soccer clubs with other coaches. But what causes this forgetting? A widely accepted account of forgetting is that it is a result of interference effects during retrieval, caused by the addition or modification of associations between items in memory (e.g., Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981). In the case of the old soccer coach, the association of new names and faces to the cue *soccer coach* can cause interference when trying to recall the name of the old coach. However, this view has been challenged by an account of forgetting that involves inhibitory processes. Inhibitory control theory states that forgetting is not a passive process and that people can exert inhibitory control over the activation of memory traces (Anderson, 2003; Levy & Anderson, 2002). According to this theory, when an attempt is made to retrieve particular information from memory, other memory traces that compete for activation can be actively inhibited, causing forgetting of these inhibited items. For example, when someone retrieves the names of more recent soccer coaches, the name of the old soccer coach may have been activated and given rise to retrieval competition. To access the right name in these situations, the name of the old soccer coach may have been inhibited. This inhibition can lead to problems in retrieving the name of the old soccer coach at a later time.

Studies using the retrieval-practice paradigm have demonstrated that retrieval of particular items from memory may impair the retrieval of different, related items on a subsequent memory test (e.g., Anderson, Bjork, & Bjork, 1994; Anderson & McCulloch, 1999; Bäuml, 2002; Bäuml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; Perfect, Moulin, Conway, & Perry, 2002; Shaw, Bjork, & Handal, 1995; Smith & Hunt, 2000). In this paradigm, participants first study a number of category–exemplar pairs (e.g., RED – *brick*, RED – *tomato*). Next, participants perform retrieval practice on a category–cued word stem completion test with half of the items from half of the categories (e.g., RED – *b*_____). In this retrieval-practice phase, the exemplars from the studied category are expected to compete for activation. Inhibitory control processes then suppress the activation of unpracticed items of the practiced category (here *tomato*) in order to make the correct response (*brick*) more available. After a distractor phase, the activation of studied items is tested by means of a category–cued recall test with the studied categories as cues. Retrieval practice of RED – *brick* results in impaired recall of RED – *tomato* compared with items from unpracticed categories.

The finding that strengthening some items impairs memory for other items can easily be explained by interference mechanisms. Interference mechanisms cause forgetting because the cue (e.g., RED) has become a stronger cue for the practiced item (e.g., *brick*). As a result, the association between the cue and the nonpracticed item (e.g., *tomato*) has become relatively weaker. Thus, interference mechanisms explain forgetting as a result of changes in the effectiveness of the cue to retrieve a specific item. However, Anderson (e.g., Anderson, 2003; Anderson & Spellman, 1995; Levy & Anderson, 2002) proposes that at least part of the effect is due to active inhibition of the competitor (e.g., *tomato*) because of competition during retrieval attempts of another item (e.g., *brick*).

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We thank Michael Anderson, Karl-Heinz Bäuml, Anique de Bruin, Reed Hunt, Carol Madden, and Timothy Perfect for their constructive comments on a previous version of the manuscript. We also thank Jeroen Raaijmakers and Emoke Jakab for a fruitful discussion about this study and Marijn Knulst and Vera Duijnhouwer for their assistance in gathering the data.

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Thus, inhibitory theories explain forgetting as a result of changes in the availability of the item itself rather than the effectiveness of the cue. To distinguish between interference and inhibition, the final memory test should use independent cues. Independent cues are cues for studied items in the final memory test that are not associated with the practiced item and can thus provide an independent test of memory. For example, the unpracticed item *tomato* also belongs to the unstudied category FOOD. When memory for *tomato* is tested with the unstudied category FOOD, a forgetting effect should also be found, according to inhibition theory. Cue-independent forgetting is seen as an empirical criterion for inhibition, because inhibitory theories state that the item itself is suppressed and not the relation between the item and its category. This means that forgetting should be found with any cue that tests the activation of the suppressed item (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). Indeed, the retrieval-induced forgetting effect has been demonstrated with independent cues (e.g., Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995; Johnson & Anderson, 2004; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006; but see Perfect et al., 2004; Williams & Zacks, 2001) and tests of item recognition (Gómez-Ariza, Lechuga, Pelegrina, & Bajo, 2005; Hicks & Starns, 2004; Veling & van Knippenberg, 2004; but see Koutstaal, Schacter, Johnson, & Galluccio, 1999).

Episodic and Semantic Effects of Retrieval Practice

Retrieval practice may have an effect on items that were studied in the experiment (episodic effects), but it may also have an effect on items that were not studied in the experiment (semantic effects). Studies involving the retrieval-practice paradigm have typically demonstrated the episodic effects of retrieval practice (e.g., Anderson et al., 1994; Anderson & McCulloch, 1999; Bäuml, 2002; Bäuml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; Perfect et al., 2002; Shaw et al., 1995; Smith & Hunt, 2000). These studies show that retrieval practice with particular items can lead to forgetting of related items that were studied in the same episodic context. However, does retrieval practice also have a semantic effect beyond the episodic context of the study phase? In other words, can retrieval practice also lead to forgetting of related items that were not studied in the same episodic context? This is an important question, because it addresses the scope of inhibitory processes in memory retrieval. In principle, according to inhibition theory, any item that competes for activation with the target item during retrieval practice can be inhibited. Category exemplars that have not been presented in the study phase (e.g., *rose*) may also be activated by the retrieval-practice cue (RED) and compete for activation, which can lead to inhibition. This can cause forgetting of the unstudied item (*rose*) when it is tested in the final memory test. Alternatively, inhibition may be limited to the episodic context of the experiment and affect only items that were activated in the study phase.

A number of studies have addressed this issue, with mixed results. Perfect et al. (2002, Experiment 5) used a category-verification task in the test phase of the retrieval-practice paradigm to test whether unstudied items from practiced categories (e.g., *rose*) showed longer response latencies than unstudied items for unpracticed categories. Although they did find a standard retrieval-induced forgetting effect for studied items (e.g., *tomato*), no effect was found for unstudied items (e.g., *rose*). However, other studies did demonstrate retrieval-induced forgetting for unstudied items after retrieval of studied category exemplars (Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004). These studies show that retrieval practice with a subset of items from a Deese–Roediger–McDermott (DRM; Roediger & McDermott, 1995) list impaired recall for other items on the DRM list but also reduced the amount of false recall of unstudied critical items on a free recall test (Bäuml & Kuhbandner, 2003) and on a cued recall test (Starns & Hicks, 2004). Moreover, Johnson and Anderson (2004, Experiment 2) demonstrated that retrieval practice with items that were not previously studied (e.g., SEASONING – *nu_____* for *nutmeg*) can impair generation of related items that also did not appear earlier in the experiment (e.g., *salt*), even when these items were tested with independent cues (e.g., *popcorn – s_____*). Johnson and Anderson did not include a study phase in their experiment, demonstrating that retrieval practice with items that were not previously studied (semantic retrieval practice) can induce forgetting of other unstudied items.

This leaves open the question of whether retrieval practice with studied items (episodic retrieval practice) can induce forgetting of unstudied items. Perfect et al. (2004) did not find retrieval-induced forgetting for unstudied items after episodic retrieval practice, whereas two other studies did demonstrate forgetting after episodic retrieval practice (Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004). A problem of all three studies is that they did not employ independent cues (e.g., the cue FOOD for *tomato*, when RED – *tomato* was studied). Thus, interference processes may also have caused the obtained forgetting effects for unstudied items in these studies. To rule out noninhibitory accounts of the forgetting effect, independent cues should be used in the test phase of the retrieval-practice paradigm. The aim of our study was to examine whether retrieval practice with studied (episodic) items leads to forgetting of unstudied (semantic) items when independent cues are used at test.

Cue Independence

The use of independent cues is crucial in determining if inhibitory processes caused the forgetting effect, because other accounts, such as interference, do not predict forgetting when this type of cue is used. There is, however, some discussion in the literature about the preferred form of independent cues and whether certain types of independent cues can provide a truly independent test of memory.

There are two problems associated with the use of independent cues as support for the inhibitory explanation. First, the forgetting effect found by Anderson and Spellman (1995) with independent cues may not have been caused by inhibitory processes. In their study, retrieval practice with items from one category (e.g., GREEN – *emerald*) led to forgetting of unpracticed items from the same category (e.g., GREEN – *lettuce*) but also led to forgetting of similar items that were studied and tested under a different category (e.g., SOUPS – *mushroom*). The fact that these items were tested under a different category than the category that was practiced (GREEN) made the final memory test cue-independent. Perfect et al. (2004) argue convincingly that this (cross-category) retrieval-induced forgetting effect found by Anderson and Spellman in Experiments 2 and 4 with independent cues seems to be caused by an increase in the level of recall of control items (52% and 54%, respectively, compared with 48% in Experiment 3a, where there was no retrieval-practice phase) rather than a decrease in the level of recall of experimental items. Moreover, they maintain that the results are surprising given findings by Anderson et al. (1994), who demonstrated that retrieval-induced forgetting is not found for weak category exemplars (see also Bäuml, 1998). Perfect et al. considered the suppressed category exemplars in the Anderson and Spellman studies also to be weak category exemplars (e.g., *artichoke*, *lettuce,* and *pepper* for the category GREEN). Thus, it seems questionable whether the forgetting effects in these experiments were caused by inhibitory processes.[1]

A second problem is that the use of unstudied category names as cues (e.g., Anderson, Green, & McCulloch, 2000) may not guarantee that the final memory test is cue-independent. Perfect et al. (2004) and Camp, Pecher, and Schmidt (2005) have argued that it is possible that participants use the studied category (e.g., RED for the item *tomato*) as a retrieval cue in the test phase of these studies, although they are only cued with an unstudied category (e.g., FOOD). Perfect et al. argue that FOOD may be associated with RED in the study phase, because half of the RED items are also FOOD items. The cue FOOD may be a poor cue relative to the cue with which the item is originally studied (Tulving & Thomson, 1973), and participants may try to use a more effective cue. The category RED has been made highly accessible because of the retrieval-practice phase. Thus, it is likely that participants use the studied categories at test even though they are not presented. If this is the case, unstudied categories may not be able to provide an independent test of memory and forgetting may not be cue-independent.

Thus, it seems questionable whether this type of independent cue can provide a truly independent test of memory for items that are supposedly inhibited. The use of unstudied category cues may not be sufficient to ensure an independent test of memory for the suppressed items. Item-specific independent cues (e.g., *salad* – *t*_____ for *tomato*) may provide a solution for this problem. There are two reasons why item-specific cues may be better as independent cues. First, there is no association between the item-specific cues and the studied category. Second, the cues are specific for only one item. This reduces the chance that studied categories will be used as additional cues in the test phase. Only a few studies have used item-specific independent cues in the test phase of the retrieval-practice paradigm, and the results of these studies are mixed. Perfect et al. (2004) associated each exemplar with a specific, unrelated, and independent item before retrieval practice took place (e.g., *apple* was associated with the unrelated item *zinc* before participants studied FRUIT – *apple*). Later, this item-specific cue was used in the test phase of the retrieval-practice paradigm to test memory for the suppressed item. Perfect et al. found retrieval-induced forgetting by using studied categories as cues (e.g., FRUIT) but not the unrelated words as cues (e.g., *zinc*). They interpreted these findings as a form of transfer-appropriate forgetting, in which forgetting is seen only when there is a close match between the conditions when competition arises (the retrieval-practice phase) and when the items are retrieved (the test phase). This means that forgetting occurs only when memory for studied items is tested with the original study cue. Their results provide evidence that retrieval-induced forgetting is a context-specific and cue-dependent effect.

To our knowledge, only two studies have demonstrated retrieval-induced forgetting with item-specific independent cues (Aslan, Bäuml, & Pastötter, 2007, Experiment 2; Saunders & MacLeod, 2006, Experiment 1). The test phases of those studies differed from Perfect et al.'s (2004) because in those studies, item-specific cues were used that were semantically related to the target items (e.g., *pie* for *apple*), whereas Perfect et al. used item-specific cues that were episodically related to the target items (e.g., *zinc* for *apple*).

Because item-specific cues can provide a better independent test of memory than unstudied categories can, we used item-specific independent cues to test memory for both studied and unstudied items in our experiments. In this manner, we could assess whether inhibitory processes caused the forgetting effect for studied and unstudied items. Inhibition theory predicts a forgetting effect for studied items involving this type of cue. If episodic retrieval practice also leads to inhibition of unstudied items, then retrieval-induced forgetting is also expected for unstudied items involving this type of cue.

Experiments

Our studies were set up to measure the effects of retrieval practice on both studied and unstudied items. We used a paradigm in which participants studied category–exemplar pairs (ANIMAL – *rat*, ANIMAL – *horse*), followed by retrieval practice with half of the exemplars from half of the categories (ANIMAL – *h*_____). This part of the design follows the standard retrieval-induced forgetting paradigm. In the test phase, however, we tested the activation of both studied (*rat*) and unstudied (*elephant*) exemplars belonging to the studied categories.

We used both item-specific independent cues (*poison* – *r*_____, *zoo* – *e*_____) and studied category cues (ANIMAL – *r*_____, ANIMAL – *e*_____) to test memory for items in the test phase in different experiments. The item-specific cues were independent because they were not presented previously in the experiment.

Experiment 1

In our first experiment, we used the studied categories as cues in the test phase. This study was conducted to replicate the standard retrieval-induced forgetting effect for studied items found with studied categories as cues. We also tested whether retrieval practice can lead to forgetting of unstudied items when studied category cues are used at the time of testing. Some studies have demonstrated this forgetting effect for unstudied items (Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004). However, in those experiments, the unstudied items were the critical items from a DRM list, and retrieval-induced forgetting was found in measures of false recall for these critical items. This method involving DRM lists and false recall measures is somewhat different from the standard method of the retrieval-practice paradigm. Other studies that involve the standard retrieval-practice paradigm did not find forgetting of unstudied items with a category verification task

[1] Also, Williams and Zacks (2001) failed to replicate the forgetting effect found by Anderson and Spellman (1995), even though they used more participants and more items per category (but see Anderson & Bell, 2001; MacLeod & Saunders, 2005).

(Perfect et al., 2002). Our experiment served as a baseline for Experiments 2–4, in which item-specific independent cues were used.

Method

Participants. The participants in the experiment were 36 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for participation.

Materials and design. Ten categories were constructed in Dutch, each category containing six items: three experimental exemplars (e.g., ANIMAL – *horse*, ANIMAL – *rat*, ANIMAL – *elephant*) and three filler items (e.g., ANIMAL – *donkey*, ANIMAL – *hamster,* and ANIMAL – *rhinoceros*). The filler items were not tested in the final test phase but served to prevent integration between items from the same category (Anderson & McCulloch, 1999). When only a limited number of items per category are used, participants may spontaneously create interconnections between the to-be-practiced and the unpracticed items from a category (integration), which makes the unpracticed items immune to retrieval-induced forgetting. Adding filler items also helps to increase the number of retrieval-practice trials per category. Also, retrieval-induced forgetting is more likely to occur when feature overlap between practiced and unpracticed items from a category (target–competitor similarity) is low (Anderson, Green, & McCulloch, 2000; see also Bäuml & Hartinger, 2002). Therefore, experimental items that were not very similar were selected for each category. Anderson, Green, and McCulloch also found that retrieval-induced forgetting is more likely to occur when feature overlap between unpracticed items (competitor–competitor similarity) is high. Therefore, the filler items were similar to one of the three experimental items (e.g., filler item *donkey* was similar to *horse*, *hamster* to *rat,* and *rhinoceros* to *elephant*). Categories and their exemplars were taken from Dutch category norms (Hudson, 1982). Their mean position on a frequency-sorted list was 7.1 (SD = 7.3). Two filler categories, each containing two items, were also constructed to serve as fillers in the experiment.

Four exemplars from each category were presented in the study phase (e.g., *horse*, *donkey*, *rat*, *hamster*), and two were not (e.g., *elephant*, *rhinoceros*). Participants engaged in retrieval practice with half of the categories. For practiced categories, one experimental item and its similar filler item received retrieval practice three times in the retrieval-practice phase (e.g., *horse*, *donkey*). Therefore, for each practiced category, there were three types of experimental items: one studied item that received retrieval practice (*horse*, RP+), one studied item that did not receive retrieval practice (*rat*, RP–), and one unstudied item (*elephant*, U). The remaining categories served as controls. Practiced categories and item type were counterbalanced across conditions. This meant that experimental items served as an RP+, RP–, or U item when their category received retrieval practice and as control for the same type of item when their category did not receive retrieval practice. Also, each experimental item served as an RP+, RP–, and U item and as a control item for RP+, RP–, and U an equal number of times across participants. The retrieval-practice phase consisted of a category–cued word stem completion task. Items in the retrieval-practice phase consisted of the category name, followed by a word stem (ANIMAL – *h*_____). The length of the blank line was held constant to avoid giving cues for word length.

The final test phase was identical to the retrieval-practice task. We used a category–cued word stem completion task, with the studied categories as cues (e.g., ANIMAL – *h*_____).

Procedure. Participants were tested individually or in small groups of up to 5 people. They were informed that they were going to participate in an experiment on language and arithmetic that consisted of a number of tasks on the computer. The experiment, following the retrieval-practice paradigm (Anderson & Spellman, 1995), consisted of four phases: a study phase, a retrieval-practice phase, a distractor phase, and a test phase.

In the study phase, category–exemplar pairs were presented for 2.5 s on a computer screen. Participants were asked to study the word and to relate the word to its category. The first and the last two words on the study list were fillers to control for primacy and recency effects. Four pairs were presented from each of 10 experimental categories. The 40 pairs were presented randomly in blocks of 10 items, each block containing one item from each category.

In the retrieval-practice phase, participants were told that they were going to see a category from the previous task, followed by the first letter of a studied word from that category (e.g., ANIMAL – *h*_____). Each pair was presented individually for 10 s, during which time participants were asked to type the word with the keyboard. Their response was presented on the computer screen. Participants performed retrieval practice with two exemplars (e.g., *horse*, *donkey*) from half of the categories. The retrieval-practice phase consisted of three cycles, so each exemplar was practiced three times. In each cycle, items were presented in random order. The first and the last two pairs that were presented in the retrieval-practice phase were fillers to control for primacy and recency effects. After the retrieval practice, participants were given a distractor task, which consisted of number puzzles. This task took 5 min.

In the final test phase, participants were presented with the studied category, followed by the first letter of an experimental example from that category. They were made aware that some of these category exemplars were studied in the experiment, and others were not. In the first case, they could fill in the studied word, and in the second case, they could fill in the first word that came to mind. This instruction is a variant of the inclusion test condition of the widely used process dissociation procedure (Jacoby, 1991). Participants were given 10 s to type their response. The first two items were from filler categories. To control for output order effects, RP– and U items and their control items were tested first. Two sets of 10 items each contained all RP–, U, and their control items from five categories. Participants were presented with a randomly selected item from one set followed by a randomly selected item from the second set to make sure that consecutive items were never from the same category. This procedure was repeated until all items had been presented. Finally, participants were presented with the RP+ items and their controls in random order.

Results and Discussion

The average retrieval-practice success rate was 76% (SD = 16.5). Recall and generation percentages in the test phase can be found in Figure 1. There was a significant difference in recall between RP+ items and control items: 21.7% (*SD* = 32.2), *t*(35) = 4.0, $p < .001$, *d* = 0.67. This indicates that retrieval practice facilitated recall of the practiced items. Also, a significant difference was found between the recall of RP– items and their control items: –9.4% (*SD* = 24.1), *t*(35) = 2.3, $p < .05$, *d* = 0.39, indicating retrieval-induced forgetting with studied categories as cues in the test phase. Finally, a significant difference was also found between U items and their unstudied control items: –10.6% (*SD* = 28.1), *t*(35) = 2.3, $p < .05$, *d* = 0.38. Thus, forgetting was found for both RP– and U items involving studied categories as cues. These results served as a baseline for Experiments 2–4, where item-specific independent cues were used in the test phase.

Experiment 2

In our second experiment, we assessed whether the use of item-specific independent cues in the test phase of the retrieval-practice paradigm would yield retrieval-induced forgetting for studied and unstudied items. Inhibitory accounts of retrieval-induced forgetting predict forgetting for studied items when item-specific independent cues are used, because the memory item itself is suppressed in inhibitory accounts. Thus, forgetting should be found with any cue that tests the activation of the suppressed item (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). Two previous studies have also demonstrated forgetting of unstudied items after episodic retrieval practice (Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004). In those studies, the forgetting effect was attributed to inhibitory processes. However, those studies did not use independent cues in the test phase. If inhibition caused the forgetting effect in those studies, forgetting should also be found for unstudied items when item-specific independent cues are used in the test phase. This was also assessed in Experiment 2.

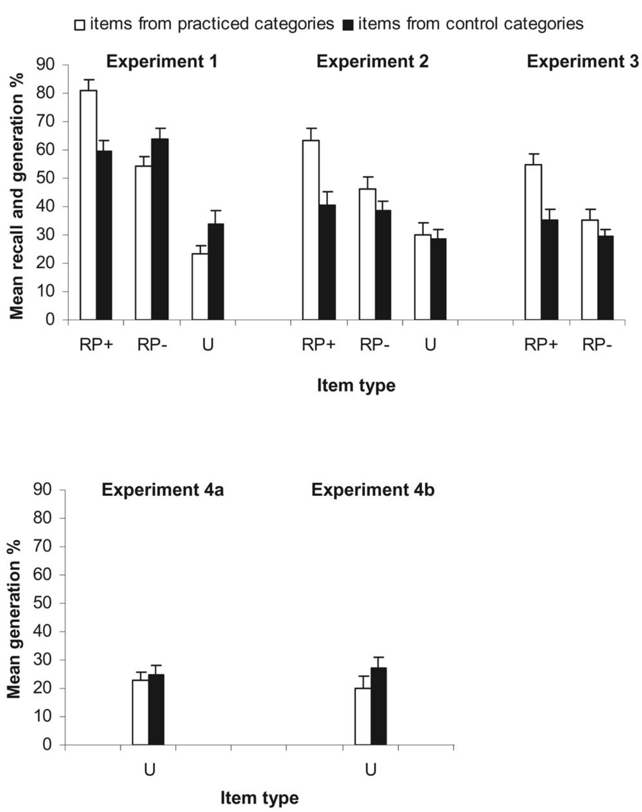

Figure 1. Recall and generation percentages of experiments 1–4. RP+ items are studied items from practiced categories that received retrieval practice; RP– items are studied items from practiced categories that did not receive retrieval practice; U items are unstudied items from practiced categories; control items for RP+, RP–, and U items are items from unpracticed categories that correspond with the RP+, RP–, and U items. Error bars represent standard errors of the mean.

Method

Participants. The participants in the experiment were 30 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for their participation.

Materials, design, and procedure. The materials, design, and procedure were identical to those in Experiment 1, except for the final test phase. For the test phase, a specific independent cue was created for each experimental item (e.g., *cowboy – h*_____, *poison – r*_____, *zoo – e*_____). These independent and item-specific cues were not related to any of the other words used in the experiment. The average cue-to-target strength was 0.17 (*SD* = 1.3), according to Dutch association norms (van Loon-Vervoorn & Bekkum, 1991).

During the test phase, participants were presented with an independent cue for each experimental item. The 30 cues were presented randomly in three blocks of 10 items. Each block contained 1 item from each category. The experimental cues were preceded by two filler cues. Participants were made aware that some of the cues were related to studied words and others to words that were not studied in the experiment. In the first case they could fill in the studied word, and in the second case they could fill in the first word that came to mind. Participants were given 10 s to type their response.

Results and Discussion

The average retrieval-practice success rate was 73% (*SD* = 14.8). Recall and generation percentages in the test phase can be found in Figure 1. There was a significant difference in recall between RP+ items and control items: 22.7% (*SD* = 31.0), *t*(29) = 4.0, $p < .001$, *d* = 0.73. This indicates that retrieval practice facilitated recall of the practiced items. RP– items were recalled better than their control items, although this difference was not significant: 7.3% (*SD* = 30.4), *t*(29) = 1.3, $p > .05$. This is surprising, given that inhibition theory would expect impaired recall for RP– items compared with control items. No difference was found between U items and their unstudied control items: 1.3% (*SD* = 29.2), $t(29) < 1$. This shows that no retrieval-induced forgetting was found for RP– items or U items through the use of item-specific cues. The lack of forgetting for RP– items is not consistent with a cue-independent view of retrieval-induced forgetting. The absence of forgetting for U items argues against inhibition of semantic memories by episodic retrieval practice.

However, a number of factors may have moderated or masked the forgetting effect in Experiment 2. First, participants were given

10 s to generate a response in the final test phase. Although a considerable number of studies that demonstrated retrieval-induced forgetting have also used a response time of 10 s (Anderson, Bjork, & Bjork, 1994; Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995; Bäuml & Hartinger, 2002; Perfect et al., 2002; Williams & Zacks, 2001), it is possible that participants used this time to augment their performance by recalling studied categories. This covert cuing strategy may have masked the retrieval-induced forgetting effect (Anderson, 2003; Anderson, Green, & McCulloch, 2000). Therefore, in Experiment 3, we reduced the response time to 5 s.

Second, output order was controlled in Experiment 1 but not in Experiment 2. Output-interference effects have been demonstrated to augment impairment (see Anderson, 2003). Because output interference was controlled in Experiment 1 and not in Experiment 2, we would have expected augmentation of impairment in Experiment 2 and not in Experiment 1. However, the opposite pattern was found: impairment in Experiment 1 and no impairment in Experiment 2. Thus, if any output-interference effects occurred, these were overshadowed by the effect of cue type. Even so, in Experiment 3, we controlled for output-interference effects to isolate the contribution of the retrieval-practice phase to the impairment and to prevent the occurrence of any differences between Experiment 1 and Experiment 2 based on output-interference effects.

Third, in the test phase of Experiment 2, memory for both studied and unstudied items was tested. This test format may have had different effects on recall and generation when participants were cued with studied categories (Experiment 1) and when participants were cued with item-specific independent cues (Experiment 2). This may have caused the absence of retrieval-induced forgetting in Experiment 2. To control for this effect, we did not test unstudied items in Experiment 3. Instead, we added the unstudied items to the study list. In this way, we could assess the effect of using item-specific independent probes in the absence of the possible effect of testing both studied and unstudied items.

This change has an additional benefit, namely that the number of items per category is increased to six, as opposed to four in Experiment 2. Although several studies have demonstrated retrieval-induced forgetting with sets of materials that are comparable to those in Experiment 2 (e.g., Bäuml & Hartinger, 2002; Perfect et al., 2002, 2004), it is possible that integration effects masked inhibitory effects for the RP– items in this study (Anderson & Bell, 2001; Anderson & McCulloch, 1999). By increasing the number of studied items per category, the likelihood of occurrence of integration effects is reduced.

Experiment 3

In Experiment 3, we introduced a number of changes to the materials and design of Experiment 2 to control for covert cuing effects, output order effects, effects of testing both studied and unstudied items, and integration effects. In this way, we sought to isolate the effect of using item-specific independent probes in the retrieval-practice paradigm.

Method

Participants. The participants in the experiment were 30 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for participation.

Materials, design, and procedure. The materials, design, and procedure were identical to those in Experiment 2, with the following exceptions: All unstudied items were added to the study phase so that six items per category were studied. To control for output-interference effects in the final test phase, we tested the RP– and U items and their controls first. As in Experiment 1, two sets of 10 items each contained all RP–, U, and their control items from five categories. Participants were presented with a randomly selected item from one set, followed by a randomly selected item from the second set. This procedure was repeated until all items had been presented. Participants were given 5 s to type their response. Finally, participants were presented with the RP+ items and their controls in random order.

Results and Discussion

The average retrieval-practice success rate was 65% (SD $=$19.2). Recall and generation percentages in the test phase can be found in Figure 1. There was a significant difference in recall between RP+ items and control items: 19.3% ($SD = 26.5$), $t(29) = 4.0$, $p < .001$, $d = 0.73$. This indicates that retrieval practice facilitated recall of the practiced items. As in Experiment 2, RP– items were recalled better than their control items, although this difference was not significant: 6.0% ($SD = 25.1$), $t(29) = 1.3$, $p > .05$. These results are consistent with the results of Experiment 2, in which we also found numerically higher recall for RP– items than for control items. This pattern of results is not in line with inhibition theory, because inhibitory accounts predict impaired recall for RP– items compared with control items.

However, it is still unclear what caused the absence of retrieval-induced forgetting for unstudied items in Experiment 2. The results of Experiment 3 indicate that the simultaneous testing of studied and unstudied items in Experiment 2 cannot explain the absence of retrieval-induced forgetting for studied items when item-specific independent cues are used. Still, it is unclear if the same is true for unstudied items. Perhaps the mixed test format of Experiment 2 did not affect memory for studied items but did affect memory for unstudied items. To control for this effect, we tested only unstudied items in Experiments 4A and 4B. In Experiment 4A, we tested unstudied items with item-specific independent probes. In Experiment 4B, we tested unstudied items with studied categories as cues.

Experiment 4A

Experiment 4A aimed to test whether the lack of retrieval-induced forgetting for unstudied items in Experiment 2 was caused by the mixed test format, in which both studied and unstudied items were tested simultaneously with item-specific independent cues. Therefore, we tested only unstudied items in the test phase of Experiment 4A, using item-specific independent probes.

Method

Participants. The participants in the experiment were 30 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for participation.

Materials, design, and procedure. The materials, design, and procedure were identical to those of Experiment 3, with the following exceptions: In Experiment 3, all unstudied items were added to the study list. These items were removed from the study list in Experiment 4A so that they could serve again as unstudied items in the final test phase. In the final test phase, only unstudied items were tested with item-specific independent probes. The first two items were items from filler categories. A set of 10 items each contained all U items and their control items. The items were presented in random order. Participants were given 5 s to type their response.

Results and Discussion

The average retrieval-practice success rate was 74% (SD =11.1). Recall and generation percentages in the test phase can be found in Figure 1. There was no difference between generation percentages of U items and their controls: –2.0% (SD = 20.6), $t(29) = 0.53$, $p > .05$. This indicates that the lack of retrieval-induced forgetting for unstudied items in Experiment 2 was not caused by the mixed test format. These results are not in line with the idea of semantic inhibition.

Experiment 4B

In Experiment 4B, we tested only unstudied items in the test phase, using studied categories as cues. In Experiment 1, we found a forgetting effect for unstudied items by using studied categories as cues when both studied and unstudied items were tested in the test phase. In Experiment 4B, we assessed whether the results of Experiment 1 could be replicated when only unstudied items were tested with studied categories as cues.

Method

Participants. The participants in the experiment were 30 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for participation.

Materials, design, and procedure. The materials, design, and procedure were identical to those of Experiment 4A, with the exception of the final test phase. In the test phase, studied categories were used as cues (e.g., ANIMAL – *h*_____) to test unstudied items.

Results and Discussion

The average retrieval-practice success rate was 77% (SD = 15.5). Recall and generation percentages in the test phase can be found in Figure 1. There was a significant difference between generation percentages of U items and their controls: –7.3% (SD = 23.2), $t(29) = 1.73$, $p < .05$, one-tailed, $d = 0.32$. These results are consistent with the findings of Experiment 1, in which we also found retrieval-induced forgetting for unstudied items, using studied categories as cues.

General Discussion

In Experiment 1, we demonstrated retrieval-induced forgetting for both studied and unstudied items, using studied categories as cues. However, in Experiment 2, we did not find retrieval-induced forgetting for either studied or unstudied items when using item-specific independent cues in the test phase of the retrieval-practice paradigm. In Experiments 3 and 4A, we also did not find retrieval-induced forgetting for studied or unstudied items when using independent cues after improving our design to control for covert cuing effects, output-order effects, integration effects, and effects of testing studied and unstudied items simultaneously. We did replicate the forgetting effect for unstudied items, using studied categories as cues in Experiment 4B when only unstudied items were tested. We will discuss the implications of these findings for the scope of inhibitory theories of forgetting.

First, we found evidence in Experiments 1 and 4B that retrieval of items from memory may have a detrimental effect on the activation of related memory items, even though these related items were not studied in the same episodic context. These results are in line with previous studies in which retrieval practice with items from a DRM list impaired recall for unstudied critical items (Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004). However, none of these studies used independent cues. In order to determine whether inhibitory processes caused these forgetting effects, we used item-specific independent cues in Experiments 2 and 4A to isolate the contribution of inhibitory processes (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). No retrieval-induced forgetting was found for unstudied items in Experiments 2 and 4A, which indicates that inhibition did not cause forgetting of unstudied items. An alternative explanation for the forgetting of unstudied items is interference. Interference will cause forgetting if the test cue activates competing items (e.g., Mensink & Raaijmakers, 1988; Perfect et al., 2004; Raaijmakers & Shiffrin, 1981; Roediger, 1974; Rundus, 1973). In Experiments 1 and 4B the test cues were studied category cues. Because of retrieval practice, the RP+ items were strongly related to the category cues and were very likely activated during the final test even when the cues for unstudied items were presented. Because the practiced items were much stronger, they blocked retrieval of the unstudied items. In Experiments 2 and 4A, however, the practiced items were not related to the cues for unstudied items. Therefore, practiced items could not block retrieval of unstudied items, and therefore no forgetting occurred. Thus, the interference account can explain why we found retrieval-induced forgetting for unstudied items in Experiment 1 and 4B. It can also explain why we did not find forgetting of unstudied items in Experiments 2 and 4A, where independent cues were used, because interference theory does not predict forgetting with independent cues.

Second, we found retrieval-induced forgetting for studied items in Experiment 1 by using studied categories as cues in the test phase. In contrast, we did not find retrieval-induced forgetting for studied items when we employed item-specific independent cues in Experiments 2 and 3. The absence of the forgetting effect cannot be explained by covert cuing effects, output-order effects, integration effects, or the effects of testing studied and unstudied items simultaneously, because we controlled for these factors in Experiment 3. These results are not in line with inhibition theory, which predicts a forgetting effect no matter whether dependent or independent cues are used at test. Just as for the unstudied items, this pattern of results can be explained by interference theory. The use of studied category cues in the test phase of the retrieval-practice paradigm may have induced the activation of practiced items, which can in turn block the retrieval of unpracticed items.

Our findings thus provide evidence for an interference account of forgetting in the retrieval-induced forgetting paradigm and are problematic for the inhibition account. This adds to a mixed body of results, some of which show cue-independent forgetting (Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995; Aslan et al., 2007; Johnson & Anderson, 2004; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006), whereas others did not find evidence for cue-independent forgetting (Williams & Zacks, 2001; Perfect et al., 2004). In the introduction we argued, however, that particular types of independent cues may not be able to discriminate effectively between inhibitory and interference accounts of retrieval-induced forgetting. The retrieval-induced forgetting effect found by Anderson and Spellman (1995) with independent cues may have been caused by a high level of recall of control items and not by impaired recall of experimental items. Second, unstudied category names as cues (e.g., Anderson, Green, & McCulloch, 2000) may not guarantee that the final memory test is truly cue-independent, because this type of cue may also lead to the activation of studied categories at test. If studied categories are activated in the test phase, even though they are not explicitly presented as cues, then the memory test is not truly independent and interference accounts can also explain retrieval-induced forgetting (Camp et al., 2005; Perfect et al., 2004). Thus, even though independent cues were used, interference might still be able to explain some of the forgetting effects reported in the literature.

However, retrieval-induced forgetting has been found with other types of independent cues that do not suffer from these problems. For example, three studies found retrieval-induced forgetting in tests of item recognition (Gómez-Ariza et al., 2005; Hicks & Starns, 2004; Veling & van Knippenberg, 2004, but see Koutstaal et al., 1999). The fact that forgetting was found in these studies when the target was presented without its category at test is difficult to explain by interference processes such as blocking. Also, in two experiments retrieval-induced forgetting was found through the use of item-specific independent cues in the test phase (Aslan et al., 2007, Experiment 2; Saunders & MacLeod, 2006, Experiment 1), which can only be explained by inhibition theory.

Moreover, in interference accounts, strengthening of the association between practiced items and their category should result in greater interference and thus reduced recall for unpracticed items at test. However, Anderson et al. (1994) demonstrated that strengthening of practiced items in the retrieval-practice phase does not predict the amount of retrieval-induced forgetting. Other studies found that forgetting occurs only when the practiced item is retrieved and not when it is merely restudied (Anderson, Bjork, & Bjork, 2000; Ciranni & Shimamura, 1999). However, interference theory predicts forgetting for unpracticed items when the association between the practiced items and the category is strengthened, regardless of whether the practiced item is retrieved or restudied. Finally, Bäuml, Zellner, & Vilimek (2005) found that response latencies for unpracticed items were not affected by retrieval practice, indicating that practiced items may not be sampled at testing, as is predicted by interference accounts.

Thus, although interference theory can provide a good explanation of our findings, it cannot fully explain all of the data in the literature. However, it is also unclear how inhibition theory can account for the results of our experiments. One possibility is that inhibition is context-specific (Perfect et al., 2004). In this view, a context-specific representation is inhibited by retrieval practice with related items. Alternatively, a general concept representation is inhibited but only within a specific retrieval context. In both views, there needs to be a match between the context in which the inhibition took place (the retrieval-practice phase) and the context in which the activation of the inhibited item is tested. Testing with item-specific independent cues does not satisfy this criterion, and thus no retrieval-induced forgetting is expected. Testing with studied category cues, which are the same cues that are used in the retrieval-practice phase, should result in retrieval-induced forgetting, according to this modified inhibitory view. Thus, the context-specific inhibitory account can explain Perfect et al.'s results as well as the results of our experiments.

However, the scope of the context-specific inhibitory account is limited. First, it makes the same predictions regarding cue-independent forgetting as the interference account. Thus, it cannot explain cue-independent forgetting effects found with recognition tests (Gómez-Ariza et al., 2005; Hicks & Starns, 2004; Veling & van Knippenberg, 2004) or item-specific independent cues (Aslan et al., 2007; Saunders & MacLeod, 2006). Second, if inhibition is context-specific, one might expect that inhibition is limited to items that have been presented in the context of the experiment and that unstudied items would not be affected. In this case, context-specific inhibition cannot explain why we found retrieval-induced forgetting for unstudied items in Experiment 1. However, in principle, forgetting effects may also occur for unstudied items in a context-specific inhibitory view, because unstudied items may also have been activated in the retrieval-practice phase and may have competed for activation. Thus, a context-specific representation of unstudied items may also have been inhibited. Still, if context-specific inhibition did occur for unstudied items, one would expect a smaller inhibitory effect for unstudied items than for studied items. Studied items are more available at retrieval practice than unstudied items and would therefore lead to more retrieval competition. Thus, inhibitory accounts would predict a larger forgetting effect for studied items than for unstudied items. However, in Experiment 1, the forgetting effect was comparable for studied and unstudied items (9.4% and 10.6%, respectively). These results are more in line with interference accounts, because interference theory does not predict any differences in forgetting between studied and unstudied items. Finally, a central problem of even a modified inhibitory account is that inhibition theory maintains that the item itself is inhibited and not the relation between the item and its category (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). If this is the case, it is difficult for inhibitory theories to explain why forgetting in our experiments was only found with studied categories as cues and not with items that were independent of the relation between the item and its category.

In summary, our Experiments 1 and 4B demonstrate retrieval-induced forgetting for both studied and unstudied items when studied categories are used as cues. However, Experiments 2, 3, and 4A show no retrieval-induced forgetting for either studied or unstudied items when item-specific independent cues are used. These results are in line with interference accounts of retrieval-induced forgetting. However, interference accounts such as blocking cannot fully explain all of the data in the literature. Even so, it is also unclear how inhibition theory can account for the results of our experiments. Further research is needed to determine what the underlying process of context-specific retrieval-induced forgetting is. In any case, our results provide evidence that retrieval-induced forgetting is a cue-dependent effect that can be demonstrated for both studied and unstudied items, but only with studied category cues.

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Received March 22, 2006
Revision received June 6, 2007
Accepted June 7, 2007 ■