Forgetting: Inhibition or Interference?

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Cover Design

Printer
Print Partners IPSKAMP, Enschede

Lay-out
Legatron Electronic Publishing, Rotterdam

ISBN-10: 90-9021276-0
ISBN-13: 978-90-9021276-0

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Vergeten: inhibitie of interferentie?

PROEFSCHRIFT

Proefschrift ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag van de rector magnificus, Prof.dr. S.W.J. Lamberts
en volgens besluit van het College voor Promoties.
De openbare verdediging zal plaatsvinden op
donderdag 21 december 2006 om 16.00 uur door

Gino Camp

geboren te Maastricht

Promotiecommissie

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Chapter 1

Introduction

One of the most intriguing aspects of human memory is undoubtedly forgetting. Experiences that were once salient and vivid in memory can become impossible to retrieve over time. For more than a century, researchers have been trying to answer the question of what causes forgetting. Early theories of forgetting have argued that forgetting occurs because memory traces are not firmly stored in the first place (Müller & Pilzecker, 1900) or that memory traces fade spontaneously over time (Peterson & Peterson, 1959). Although these consolidation and trace decay theories have been largely disconfirmed as mechanisms of forgetting, they have played an important role in the development of the most dominant account of forgetting to this day: interference.

Interference theory

According to classical interference theory (McGeoch, 1932; 1942), forgetting is caused by the addition of new information to memory. These additions make it difficult to retrieve older, related information at a later time. A central mechanism in interference theory is response competition, which occurs when two or more items are responses to the same memory cue. For example, in a typical paired-associate experiment, participants study unrelated word pairs, such as *glass* – *mouse*. Then, in a subsequent task they study a second list of word pairs. In some cases, these new word pairs contain items from the original list (e.g., *glass* – *flag*). When memory for the items in the first list (e.g., *mouse*) is later tested with the original cue (e.g., *glass*), items from the first and the second list compete as potential responses. This reduces the probability that the item from the first list is produced as a response. Thus, addition or strengthening of a competing item reduces the probability of retrieving the original item. There are several ways in which interference can lead to reduced recall (see Anderson & Bjork, 1994; Anderson & Spellman, 1995). Some of these are based on the assumption that forgetting is caused by dynamics in cue-target associations.

In occlusion or blocking models for instance, strengthening of a competing trace leads to blocking of the retrieval of the target trace. When the cue is given after strengthening the cue-competitor association, failure to retrieve the target occurs because the strengthened competitor persistently intrudes and blocks retrieval of the target. Alternatively, in resource diffusion models, forgetting occurs because of an altered distribution of a limited amount of resources. When only a limited amount of activation can be divided among the associates of a cue, strengthening of the competitor-cue association can increase the relative amount of activation of the competitor and thereby decrease the amount of activation of the target. Finally, in associative decrement models, the associative strength between cue and target is weakened when the target is retrieved mistakenly. Retrieval of the target when the competitor is cued can decrease the association between target and cue, leading to reduced recall of the target to the same cue on a later memory test.

Mathematical models such as SAM (Raaijmakers & Shiffrin, 1981; Mensink & Raaijmakers, 1988) provide a formal description of interference processes. These models, using only a limited number of parameters, are successful at explaining memory performance in a wide variety of situations using different paradigms.

Inhibition theory

However, a different mechanism of forgetting has gained considerable empirical support over the last decade. According to inhibition theory, people have executive control over the activation of memory traces and can recruit inhibitory processes to suppress an activated memory trace when it is not an appropriate response (e.g., Anderson, 2003; Anderson & Spellman, 1995; Levy & Anderson, 2002). Thus, forgetting is caused by the active suppression of the activation of memory traces. Different paradigms have been developed to demonstrate inhibitory processes in memory retrieval.

One such paradigm is the retrieval-practice paradigm. This paradigm is set up to invoke retrieval competition between memory traces, which presumably leads to inhibition of the incorrect trace. In this paradigm, participants first study a number of category exemplar pairs (e.g., GREEN – *dollar*, GREEN – *lawn*, GREEN – *lettuce* and GREEN – *pepper*) and then receive a memory test for a subset of the exemplars in the form of a word-stem completion task (e.g., GREEN – *do*_____ and GREEN – *la*_____). According to inhibition theory, the retrieval competition between cued and noncued items invokes executive control processes that lead to the inhibition of noncued items (*lettuce* and *pepper*) in order to make cued items (*dollar* and *lawn*) more available. At a later memory test, recall for the inhibited items is reduced compared to recall for items from categories that did not appear in the intervening task (e.g., Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995). This retrieval-induced forgetting effect has not only been demonstrated with taxonomic categories, but it has been applied and replicated in a wide variety of domains including propositions (e.g., Anderson & Bell, 2001), visual material (Ciranni & Shimamura, 1999), eyewitness memory (e.g., Saunders & MacLeod, 2002; Shaw, Bjork, & Handal, 1995), autobiographical memory (e.g., Barnier, Hung, & Conway, 2004; Wessel & Hauer, 2006), and personality traits (e.g., Dunn & Spellman, 2003; Macrae & MacLeod, 1999).

A second paradigm that has demonstrated inhibitory processes in memory retrieval is the think/no-think paradigm. Participants first study unrelated cue target pairs, such as *tattoo* – *uncle*. Then, they are shown the cues of a subset of the cue-target pairs (e.g., *tattoo*) in a think/no-think task. For some of the cues, they are asked to recall the target (think condition). For other cues, however, they are instructed to prevent the target from entering consciousness (no-think condition). Reduced recall has been found on a later memory test for items in the no-think condition compared with control items for which the cue did not appear in the think/no-think task (Anderson & Green, 2001; Anderson et al., 2004). Thus, in this paradigm, forgetting occurs because participants are instructed not to think about certain previously studied information when it is cued. Participants are required to actively suppress certain information, which then leads to forgetting of that information. This provides further evidence for inhibitory processes.

Interference vs. inhibition

Inhibition theory differs from interference theory in a number of ways. First, inhibition is an active process, which is recruited when it is needed. It is an adaptive mechanism that involves executive control over the activation of memory traces. In contrast, interference is a passive process that does not involve control over the activation of memory traces. Changes in relative associative strengths between memory traces are sufficient to decrease the likelihood that a certain memory trace is retrieved. This brings us to a second crucial difference between inhibition and interference theories. In inhibition theory, the memory trace itself is inhibited. It follows that reduced recall should be found with any cue that tests the activation of the inhibited item. In interference accounts such as blocking, however, forgetting is caused by the strengthening of the association between the cue and a competitor, making the target less accessible with that cue. In this case, forgetting is only observed when memory for the target is tested with the original cue. This difference has been used to differentiate between interference and inhibitory accounts of forgetting.

The independent probe technique

The independent probe technique was designed to differentiate between the contributions of interference and inhibitory processes to the forgetting effects found in the retrieval-practice paradigm and the think/no-think paradigm (Anderson & Green, 2001; Anderson & Spellman, 1995). In the independent probe technique, memory for inhibited items is tested with cues that have not appeared in the experiment until the final memory test. These cues are used to provide an independent test of memory, because they do not depend on the changes in associative strength between cue and target and test the activation of experimental items directly. In the retrieval-practice paradigm, for example, the category VEGETABLE is used to test memory for the inhibited items *lettuce* and *pepper*. In the think/no-think paradigm, the category RELATIVE is used to test memory for the inhibited item *uncle*. Both VEGETABLE and RELATIVE have not appeared earlier in the experiment and their effectiveness does not depend on changes in associative strength between cue and target in previous phases of the experiment. By using independent probes, the contribution of inhibitory processes to the forgetting effect can be isolated, because interference accounts do not predict forgetting if memory for experimental items is not tested with the study cues. Forgetting has been found with independent cues in both the retrieval-practice paradigm (Anderson & Bell, 2001; Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995) and the think/no-think paradigm (Anderson & Green, 2001; Anderson et al., 2004), providing evidence for inhibitory processes.

A limit to inhibition

Although research using the independent probe technique seems to provide evidence for the existence of inhibitory processes, there is also evidence of limitations on the scope of inhibitory processes. Williams and Zacks (2001), for instance, did not replicate the retrieval-induced forgetting effect using independent cues. Moreover, although a number of studies have demonstrated retrieval-induced forgetting using independent cues, many studies using the retrieval-practice paradigm have not used independent cues to test memory for inhibited items (e.g., Anderson, Bjork, & Bjork, 1994, 2000; Anderson & McCulloch, 1999; Barnier, Hung, & Conway, 2004; Bauml, 2002; Bauml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; Shaw et al., 1995; Smith & Hunt, 2000; Wessel & Hauer, 2006). Therefore, it is not possible to determine whether interference or inhibitory processes caused the forgetting effect in these studies.

Other studies have also demonstrated boundary conditions of inhibition as an explanation of forgetting. MacLeod and Macrae (2001) have demonstrated that the duration of the retrieval-induced forgetting effect is limited. When the retrieval-practice phase and the test phase are separated by a 24-hour period, the retrieval-induced forgetting effect disappears. Moreover, the retrieval-induced forgetting effect seems to appear only under specific circumstances.

A number of studies have demonstrated that the forgetting effect disappears when category exemplars are integrated (Anderson & Bell, 2001; Anderson & McCulloch, 1999). This means that when there are many interconnections between items from a studied category, retrieval-induced forgetting is eliminated. Integration can be generated experimentally by instructing participants to find interrelationships between items from the same category, but it can also occur spontaneously.

Anderson, Green, & McCulloch (2000) showed that retrieval-induced forgetting is reduced when the similarity between practiced (e.g., *dollar* and *lawn* in the previous example) and unpracticed items (e.g., *lettuce* and *pepper*) is high. When practiced and unpracticed items share many features, practice of these common features in the retrieval-practice phase not only leads to a recall advantage for practiced items, but also for unpracticed items, thereby reducing the forgetting effect. Also, when the similarity within the set of unpracticed items from a category (e.g., *lettuce* and *pepper*) is low, this can also reduce the forgetting effect. According to Anderson et al., when unpracticed items share many features, the proportion of features of each item that is inhibited is larger than when unpracticed items do not share many features. Thus, when unpracticed items do not share many features, the proportion of inhibited features for each item is lower, leading to a reduced forgetting effect.

Finally, a number of studies have demonstrated that retrieval-induced forgetting is only found when competitors are retrieved in an intervening task, and not when they are restudied (Anderson, Bjork, & Bjork, 2000; Ciranni & Shimamura, 1999).* Anderson (2003) describes additional representational factors and test factors that can moderate or mask the retrieval-induced forgetting effect.

Outline of the thesis

The empirical studies described in this thesis aim to investigate the boundary conditions of inhibition processes in memory retrieval. Chapter 2, 3, and 4 focus on the generality of the retrieval-induced forgetting effect. More specifically, the studies described in these Chapters assess whether the retrieval-induced forgetting effect generalizes to different types of tests: implicit memory tests in Chapter 2 and perceptual memory tests in Chapter 3. The study in Chapter 4 assesses the scope of inhibitory processes by investigating if inhibition is context-specific or if it applies to more general properties of a memory trace. Another issue that is addressed in Chapters 2, 3, and 4 is the question if the independent probe technique can distinguish effectively between interference and inhibitory accounts of forgetting. A direct test of the independence of independent probes is presented in Chapter 5. Finally, the results of the studies described in the thesis are summarized in Chapter 6 and their implications for the role of inhibition in forgetting are discussed.

* Although this can be seen as a limitation of inhibition, it can also be seen as a limitation of the interference account, because interference accounts expect forgetting when competitors are restudied with the original cue. Inhibition accounts do not, because there is no retrieval competition.

Chapter 2

The study described in Chapter 2 assesses whether retrieval-induced forgetting is found in implicit memory tests. This is an important question, because inhibitory accounts predict that the inhibition effect should generalize to any memory test that tests the activation of the inhibited item. Moreover, when participants are not aware that their memory for previously studied items is tested, they cannot engage in retrieval strategies involving the use of studied categories. If participants would use such strategies, interference processes such as blocking can also be used to explain forgetting effects.

Previous studies using implicit memory tests in the retrieval-practice paradigm showed mixed results. Butler, Williams, Zacks and Maki (2001) used a word-stem completion task to test memory for inhibited items and found no retrieval-induced forgetting. Moreover, most participants were aware of the connection between the test phase and the previous phases of the experiment, making the task not truly implicit. Perfect, Moulin, Conway and Perry (2002) did find retrieval-induced forgetting in two out of five experiments using implicit memory tasks. However, in the implicit tasks that demonstrated retrieval-induced forgetting, no independent cues were used. Thus, interference processes such as blocking could also have caused the forgetting effect. Finally, Veling and van Knippenberg (2004) used a lexical decision task to test memory for inhibited items and found longer response latencies for inhibited items. However, also in their study, it is possible that participants noticed that they were judging words that were previously presented, making the task not truly implicit.

The first experiment of the study described in Chapter 2 was aimed to replicate the retrieval-induced forgetting effect in an *explicit* task using independent cues. In the second experiment, an *implicit* category generation task was used in the final test phase of the retrieval-practice paradigm using independent cues. A post-experimental questionnaire tested whether participants had been aware of the relation between the test phase and the previous phases of the experiment in order to assess if the test task had been truly implicit. In this way, it was assessed whether the retrieval-induced forgetting effect generalizes to truly implicit memory tasks and the retrieval strategies underlying the effect were explored.

Chapter 3

The study in Chapter 3 investigated whether retrieval-induced forgetting is found in perceptual memory tests. The general question of this study was if retrieval-induced forgetting generalized to this test type. Again, inhibition theory predicts retrieval-induced forgetting to occur with any cue that tests the activation of the inhibited item. This study also tested a prediction made by Anderson (2003) regarding transfer-inappropriate testing effects. Transfer-inappropriate testing effects have been proposed as an explanation for the failure to find retrieval-induced forgetting in previous studies using perceptual memory tests. Anderson (2003) has argued that some studies using perceptual memory tests in the test phase of the retrieval-practice paradigm failed to replicate the retrieval-induced forgetting effect because of a lack of overlap in the type of processing between retrieval practice and memory test. For instance, when the retrieval practice task is a conceptual memory task and the final test phase consists of a perceptual memory task, the type of presentation that is inhibited at retrieval practice (a conceptual memory representation) is not the same as the one that is being tested in the final memory test (a perceptual memory representation). Thus, no forgetting is found. Anderson has used this argument to explain why retrieval-induced forgetting is not demonstrated with some implicit memory tasks (e.g., in Perfect et al., 2002). He argues that these tasks were not only implicit, but also perceptual in nature. Therefore, Perfect and colleagues did not adequately assess the activation of the inhibited items. It follows that forgetting should be found when there is match between the retrieval practice phase and the test phase in the type of processing that occurs. This has been repeatedly shown when both tasks involve conceptual processing, but not when they involve perceptual processing.

In three experiments, we tested whether forgetting effects could be found when both the retrieval practice task and the final memory test consisted of perceptual memory tasks. All three experiments used different variations of perceptual materials and memory tasks. Inhibitory accounts of forgetting would predict a forgetting effect. However, if no forgetting is found, this would imply that retrieval-induced forgetting does not generalize to perceptual memory tests, thereby limiting the scope of inhibitory processes in memory retrieval and rejecting transfer-inappropriate processing as an explanation for the failure to find forgetting with certain implicit memory tests.

Chapter 4

The study presented in Chapter 4 focuses on the scope of inhibitory processes and also on the effectiveness of different forms of the independent probe technique in distinguishing between interference and inhibitory accounts of retrieval-induced forgetting. Perfect et al. (2004) have argued that variants of the independent probe technique using categories as independent probes are likely to induce the use of studied categories as additional cues in the final test phase. If this is the case, interference processes could have occurred at test and these processes could have caused the forgetting effect. Therefore, Perfect et al. used independent cues in their experiments that were specific for only one experimental item. They failed to find a retrieval-induced forgetting effect with these cues and concluded that either inhibitory processes are context-specific and are only found with cues that are also present when retrieval competition occurs, or associative processes cause retrieval-induced forgetting.

In contrast, Johnson and Anderson (2004) did find retrieval-induced forgetting using item-specific independent cues. Moreover, they demonstrated a forgetting effect for items that were not studied before retrieval practice took place. They concluded that inhibitory processes were used to suppress general concept memory representations. This is at odds with the findings of Perfect et al., who concluded that, if inhibition occurs at all, it is context-specific. The experiments described in Chapter 4 were designed to resolve this empirical ambiguity.

The first two experiments used item-specific independent cues to test memory for both studied and unstudied items. Broad inhibitory theories that involve the suppression of general concept memory representations would expect forgetting for both studied and unstudied items using item-specific independent cues. Narrow inhibitory theories that assume inhibition to be context-specific would predict forgetting only to occur for studied items. Finally, interference theory would expect no forgetting for both studied and unstudied items. In a third experiment, studied categories were used as cues in the test phase. Both interference and inhibitory theories would predict forgetting in these cases. The results can provide further insight into the scope of inhibitory processes in memory retrieval.

Chapter 5

The study in Chapter 5 directly tested whether independent cues can provide a memory test that does not depend on changes in associations between the inhibited item and the study cue. Cue-independent forgetting is seen as an empirical criterion for the existence of inhibitory processes (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). This is because interference accounts do not predict forgetting if memory is tested with cues that do not depend on the changes in associative strength between the item and the study cue. Thus, if independent probes are really independent, performance on the final memory test using independent probes should not depend on the accessibility of the study cues. If performance on the final memory test does depend on the accessibility of the study cues, this would provide direct evidence that study cues are used as additional cues in the test phase of inhibition paradigms, even though independent cues are presented. The interpretation of evidence for these covert-cuing strategies is not unequivocal. Anderson and colleagues argue that covert cuing can mask inhibitory processes and reduce the forgetting effect (Anderson, 2003; Anderson, Green, & McCulloch, 2000). However, other researchers argue that covert cuing could have *caused* the forgetting effects in studies employing the independent probe technique, because covertly cuing study categories may lead to interference processes such as blocking (e.g., Perfect et al., 2004).

In two experiments, the independence of independent probes was tested. In the first experiment, participants studied cue-target pairs (e.g., *rope – sailing*) after which they did additional study of a subset of the cues alone (e.g., *rope*). Then, their memory was tested using item-specific independent probes (e.g., SPORT for the item *sailing*). If these probes were truly independent, no effect of additional cue study on target recall was expected. However, if the independent probes were not truly independent, the cues that received additional study may have been activated in the test phase. If the study cues were activated and used as additional cues in the test phase, facilitation of their targets was expected.

In the second experiment, the order of cue-target study and the additional cue study was reversed. In this way, any facilitation effects could not have been caused by activation of the target during cue study, but only by activation of the study cues at test. This is because the cue target pairs had not yet been studied at the time of additional cue study. Facilitation effects would provide further evidence that independent cues are not truly independent.

Chapter 6

In Chapter 6, a summary of the studies described in the thesis is provided, followed by a general discussion.

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Chapter 2

Retrieval-induced forgetting in implicit memory tests: The role of test awareness*

* This chapter is published as: Camp, G., Pecher, D., & Schmidt, H.G. (2005). Retrieval-induced forgetting in implicit memory tests: The role of test awareness. *Psychonomic Bulletin & Review*, *12,* 490-494.

Abstract

Retrieval practice with particular items in memory may result in decreased recall of different, semantically related, items. This retrieval-induced forgetting effect has been demonstrated in studies using explicit memory tests. Anderson and Spellman (1995) have attributed retrieval-induced forgetting to inhibitory mechanisms. This hypothesis predicts similar effects in implicit memory tasks. In our first experiment, using Anderson and Spellman's original paradigm, retrieval-induced forgetting was found using an explicit memory test with independent extralist retrieval cues. In our second experiment, using the same materials, retrieval-induced forgetting was also found using an implicit memory test with independent extralist retrieval cues, but only for those participants, who were aware of the relationship between the study and practice phase on the one hand, and the test phase of the experiment on the other. Thus, test awareness seems to mediate retrieval-induced forgetting in implicit memory tasks.

A number of studies using the retrieval-practice paradigm have shown that inhibition can play a role in retrieval from memory (for a review, see Anderson, 2003). In the retrieval-practice paradigm, participants first study a number of category-exemplar pairs, followed by retrieval practice with half of the studied exemplars from half of the studied categories. Retrieval practice is carried out using a category-plus-word-stem cued recall task. Memory is then tested for both practiced and unpracticed exemplars. Typically, results show an increase in recall for practiced items (RP+ items) and a decrease in recall for unpracticed items that belong to the same category as the practiced items (RP- items), when compared to exemplars from categories that received no retrieval practice (NRP items). In this final recall test, the names of the studied categories are used as cues.

Anderson and Spellman (1995) adapted the retrieval-practice paradigm and found retrieval-induced forgetting using independent extralist retrieval cues. These results led Anderson and Spellman to conclude that retrieval-induced forgetting is an inhibitory effect and that the relation between the category and the exemplar or between the practiced and unpracticed items within the category is not inhibited, but rather the unpracticed item itself. They considered cue-independent forgetting to be an empirical criterion for inhibition.

However, if retrieval-induced forgetting is due to item inhibition, it should also be found using different types of tests. In principle, the retrieval-induced forgetting effect should be found with any type of test assessing the activation of the inhibited item. A number of studies have investigated the validity of this claim using implicit memory tasks rather than the category-cued recall task used traditionally in the test phase of the retrieval-practice paradigm. Unlike what is done in explicit memory tasks such as category-cued recall, no reference is made to the study phase in implicit memory tasks.

Butler, Williams, Zacks and Maki (2001) used a word-fragment completion task to test implicit memory in the retrieval-practice paradigm. They did not obtain retrieval-induced forgetting. Nor did they obtain retrieval-induced forgetting in several experiments with explicit tests of memory such as word-fragment-cued recall, category-plus-word-fragment cued recall and category-plus-stem-cued recall. They found retrieval-induced forgetting only in the standard category-cued recall condition. Therefore, retrieval-induced forgetting seems to depend more on visually presenting a part of the target item than on whether the final memory test is implicit or explicit. In addition, Butler et al. note that most participants detected the connection between the test phase and the study and practice phases. Therefore, the word-fragment completion task could not be regarded as truly implicit.

Perfect, Moulin, Conway and Perry (2002) used five different tests of implicit memory in the retrieval-practice paradigm: category generation, category verification, perceptual identification, category-cued perceptual identification and word-stem completion. The retrieval-induced forgetting effect was found only with the category generation task and the category verification task. Perfect and colleagues argue that the reason for this could be that these two tasks are *conceptual* implicit memory tasks and that other tasks not showing the effect are *perceptual* implicit memory tasks. Performance in perceptual memory tasks relies mostly on the processing of the physical attributes of the items, whereas conceptual memory tasks rely on semantic processing of the items (e.g., Blaxton, 1989). If retrieval-induced forgetting is restricted to conceptual tests of memory, this could explain why Butler et al. (2001) did not find retrieval-induced forgetting using explicit perceptual memory tests. However, Perfect et al. did not use independent cues in the category generation task and the category verification task. Therefore, as Perfect and colleagues indicate in their conclusion, their data cannot rule out a noninhibitory account of the reported retrieval-induced forgetting effects.

Moreover, Veling and van Knippenberg (2004) did find retrieval-induced forgetting with perceptual memory tests, using independent cues. They used a recognition test and a lexical decision task with the category exemplars from the study phase as cues. Longer response latencies were found for RP- items than for NRP items in both tests, indicating retrieval-induced forgetting. Thus, Veling and van Knippenberg showed that retrieval-induced forgetting can be found with perceptual memory tests using an independent cue. Longer response latencies for the RP- items in the lexical decision task also seem to indicate that retrieval-induced forgetting can be found with an implicit test of memory. However, it is unclear whether this test was truly implicit. It is conceivable that participants noticed the fact that they were making lexical decisions about words that were presented earlier in the experiment. The possibility of explicit contamination is always a concern in research using implicit memory tests (e.g., Mulligan, 2002; Mulligan & Hartman, 1996). The fact that participants in the Butler et al. (2001) study noticed the relation between the test phase and the study and practice phases indicates that this is indeed possible. Noticing this connection could have triggered explicit retrieval of the category, RP+ items and NRP items, which could have influenced the response latencies for the RP- items in Veling and van Knippenberg's experiment. For their lexical decision task to have been truly implicit, it would have been crucial that the participants not notice the connection between the test phase and the previous phases of the experiment. Veling and van Knippenberg do not report data on this subject, leaving open the possibility that the lexical decision task was not truly implicit.

The experiments reported in the present article were conducted to determine whether inhibition can be found in an implicit test of memory using independent cues, without participants being aware of the connection between the previous phases of the experiment and the test phase.

Experiment 1

The aim of our first experiment was to replicate the retrieval-induced forgetting effect found by Anderson and Spellman (1995) using new materials. This experiment served as a baseline for experiment 2, in which we used an implicit memory test for the same materials. Participants studied category-exemplar pairs much like those used by Anderson and Spellman in their Experiments 2–4. Half of the exemplars from each category within these pairs belonged to a hidden category not shown to the participants in the study phase or the retrieval-practice phase. Using the retrieval-practice paradigm, memory for exemplars from these hidden categories was tested using a category-cued recall test.

It should be noted here that Anderson and Spellman (1995) did not measure category-cued recall for the hidden categories independently in their experiments. They first administered a category-cued recall test for the categories used explicitly in the study phase and the retrieval-practice phase, directly *followed* by a category-cued recall test for the hidden categories. Anderson and Spellman then analyzed the data with and without including the additional items recalled in the hidden category test and found retrieval-induced forgetting in both situations. However, it cannot be ruled out that administering the category-cued recall test for the studied categories influenced the recall on the category-cued recall test for the hidden categories administered subsequently. All items that could be generated in the hidden category-cued recall test were also targets in the studied category-cued recall test administered previously. Therefore, performance on these two tests cannot be considered to be independent. It is unclear if retrieval-induced forgetting would have been found if the category-cued recall test for the hidden categories had been administered independently with the names of the hidden categories as cues. A number of studies have used independent cues (e.g., Anderson & Bell, 2001; Anderson & Green, 2001), but always with a different paradigm and/or different types of materials. Anderson, Green & McCulloch (2000) did administer an independent category-cued recall test with the names of the hidden categories as cues and found retrieval-induced forgetting. However, their study phase was quite different from Anderson and Spellman's original.

In the present experiment, the study phase was identical to that of Anderson and Spellman (1995) and only the hidden categories were used as cues in the category-cued recall task. In accordance with the inhibitory account of retrieval-induced forgetting, we hypothesized that the retrieval-induced forgetting effect should also be found for the hidden categories when tested independently.

Method

Participants

The participants were 48 psychology students. Most of them fulfilled a course requirement by participating in the experiment. Others received €10 (about $11.50 U.S.) for their participation. All participants were proficient speakers of Dutch.

Materials and design

Twelve categories, consisting of six related pairs were selected. Each category contained six exemplars. None of the exemplars was a member of any of the other 11 categories. However, within each related pair of categories, three exemplars of each category were also members of a hidden category that was not presented explicitly in the study phase or the retrieval-practice phase of the experiment. Only the six items from the two related categories were exemplars of these hidden categories. See Table 1 for examples. All hidden categories were selected on the basis of category norms (Hudson, 1984). The exemplars of the hidden categories were not among the five most typical category exemplars to prevent a ceiling effect in the implicit memory task used in Experiment 2. Their mean position on a frequency-sorted list for each hidden category was 20.5 (*SD* = 15.5). In selecting the exemplars, items were avoided that had strong associations with other items in order to prevent the use of retrieval strategies based on this association in the test phase. No exemplars shared the first two letters with another exemplar in the same category or with highly typical nonselected exemplars to ensure that the cue in the retrieval-practice phase matched only one exemplar. Categories were counterbalanced across conditions.

The design used in this experiment was identical to the design used by Anderson and Spellman (1995) in Experiment 2. There were three experimental category pairs and three control category pairs. Table 1 shows one experimental and one control category pair. Experimental category pairs consisted of one category that received retrieval practice (CIRCUS) and one category that did not (RIVER). Of the practiced category, three exemplars received retrieval practice (RP+ items) and three did not (RP- items). The RP- items were always the three exemplars from the hidden category. For example, some participants practiced the items CIRCUS-*clown*, CIRCUS-*audience* and CIRCUS-*trapeze* from the practiced experimental category CIRCUS (these were the RP+ items) and did not practice the items CIRCUS-*panther*, CIRCUS-*elephant* and CIRCUS-*bear* (these were the RP- items and members of the hidden category ANIMAL). In the unpracticed experimental category (RIVER) none of the exemplars received retrieval practice, but three of the six items also belonged to the hidden category: RIVER-*crocodile*, RIVER-*hippo* and RIVER-*rat* all belong to the hidden category ANIMAL. These items are called similar items, because they belong to the same hidden category as the RP- items.

Neither of the categories in the control category pairs received retrieval practice. These categories served as controls for the critical items in the experimental categories. To determine if the RP- items were truly inhibited, the percentage of correctly recalled RP- items on the hidden category cued recall test were compared to the percentage of correctly recalled items in the control category pairs that corresponded with the RP- items.

Table 1: *Example of an Experimental and a Control Category Pair Used in Experiment 1 and 2*

Experimental Category Pair		**Control Category Pair**	
CIRCUS	RIVER	LOUD	SHARP
RP+ items			
clown	bank	siren	needle
audience	pebbles	alarm clock	toothpick
trapeze	waterfall	scream	dart*
RP- items	**Similar items**	**Controls for RP- items**	**Controls for similar items**
panther	*crocodile*	*revolver*	*dagger*
elephant	*hippo*	*grenade*	*spear*
bear	*rat*	*bomb*	*lance*

Note – RP+ items are items from practiced categories that received retrieval practice; RP- items are items from practiced categories that did not receive retrieval practice; Similar items are items from unpracticed categories that are a member of the same hidden category as the RP- items. No items in the control category pair received retrieval practice. Therefore, certain items in the control category pair served as controls for the corresponding items in the experimental category pair. Items in italics were also a member of a hidden category. For items in the experimental category pair, the hidden category was ANIMAL. For items in the control category pair, the hidden category was WEAPON.

*In Dutch, this word is only used as an object used in games, not as a weapon.

Procedure

Participants were tested individually or in groups of up to 5 and they were told that they were participating in an experiment on memory and reasoning that consisted of performing several tasks on the computer. In accordance with the retrieval-practice paradigm (Anderson & Spellman, 1995), the experiment consisted of four phases: a study phase, a retrieval-practice phase, a distracter phase and a hidden-category cued recall test.

In the study phase, participants were told they would be presented with category-exemplar pairs on the computer screen and that they would see multiple examples from multiple categories. Each pair was shown for 5 s and participants were instructed to remember as many pairs as they could and to use the allotted 5 s to relate the exemplar to its category. Category-exemplar pairs were presented in random order with the restriction that two items from the same or from related categories were not shown successively. In addition to the 12 experimental categories, 6 filler categories with six exemplars each were also presented in the study phase. These filler categories were also selected on the basis of category norms (Hudson, 1984) and exemplars were also not among the five most typical examples of their category. The filler categories were unrelated to the experimental categories, and exemplars from filler categories satisfied the same constraints as the experimental exemplars. The first and the last three items on the study list were filler category exemplars to control for recency and primacy effects.

In the retrieval-practice phase, participants performed retrieval practice with three items of three experimental and all six filler categories. The name of the category was presented on the screen, followed by the first two letters of an exemplar and a blank line (e.g., CIRCUS-*cl*______). The length of the blank line was held constant to avoid giving cues for word length. Participants were told they would be shown the names of categories from the previous task and the first two letters of a studied category exemplar. They were given 10 s to complete the word. Items were presented to the participants in random order. This procedure was repeated twice, so that all items received retrieval practice three times. The first and last three pairs were always exemplars from the filler categories. After the retrieval-practice phase, participants were given a distracter task in which they were asked to solve a number of puzzles. The content of the puzzles was in no way related to any of the categories or exemplars in the experiment. The distracter task took 20 minutes.

Finally, in the test phase, participants were given a category-cued recall test for the hidden categories. They were shown the names of all hidden categories on the screen consecutively and in random order. For each category, they were asked to type six exemplars within 30 s, after which the next category name appeared. It was made explicit that participants had not seen these categories before in the experiment, but they were instructed to use exemplars they had seen previously in the experiment. Thus, the test was an explicit category-cued recall test using independent cues.

Results and discussion

Retrieval-practice success rate was measured for the experimental categories. Each participant had to retrieve a total of 9 exemplars: 3 exemplars from 3 experimental categories. Each exemplar was retrieved 3 times, resulting in 27 retrieval-practice trials. The average success rate was 79% (*SD* = 11.1), which is similar to the success rates reported by Anderson and Spellman (1995).

The cued recall data for the final memory test are shown in Table 2. The data from two participants were removed because their recall rates were more than 2 standard deviations from the mean. Data from another two participants were removed to leave the counterbalancing design intact. A paired-samples t-test showed that fewer RP- items were recalled in the experimental condition than their corresponding items in the control condition, $t(43) = -2.0$, $p < .05$, showing retrieval-induced forgetting.** These results show that retrieval-induced forgetting can also be found in a category-cued recall test using only the hidden category names as cues.

Table 2: *Mean and Standard Deviation of the Recall and Generation Percentages of RP- items and their controls in Experiment 1 and 2*

Variable	*M*	*SD*
Experiment 1		
RP- items	35.4	19.4
Controls for RP- items	41.7	18.9
Difference	-6.30*	
Experiment 2		
RP- items aware participants	21.8	14.6
Controls for RP- items aware participants	28.6	17.8
Difference	-6.83*	
RP- items unaware participants	20.3	12.0
Controls for RP- items unaware participants	18.9	12.4
Difference	1.39	

* $p < .05$

** We also examined the recall percentages of similar items and their controls for evidence of cross-category inhibition. In Experiment 1, we found no reliable difference between the recall percentages of similar items (M = 38.9%) and their controls (M = 38.6%), $t(43) = .08$, n.s. However, in Experiment 2, cross-category inhibition was found, but only for the aware participants. The mean difference in generation percentages between similar items (M = 18.4%) and their controls (M = 23.5%) was significant, $t(51) = -1.69$, $p < .05$, one-tailed. For unaware participants, the difference between similar items (M = 18.1%) and their controls (M = 20%) was not significant, $t(39) = -.52$, n.s.

Experiment 2

We obtained retrieval-induced forgetting in Experiment 1 using category-cued recall as an explicit memory task. The aim of the second experiment was to determine if this effect could also be found with an implicit memory task using the same materials and independent cues as in Experiment 1. Test awareness was measured to determine if the memory task was truly implicit. Inhibitory accounts of retrieval-induced forgetting would predict the same results when an implicit memory task is used.

Method

Participants

The participants were 112 psychology students. Most of them fulfilled a course requirement by participating in the experiment. Others received €10 (about $11.50 U.S.) for their participation. All participants were proficient speakers of Dutch. None had participated in Experiment 1.

Materials and Procedure

The materials and procedure were identical to those of Experiment 1, except that an implicit category generation task was used in the test phase. Participants were asked to produce six exemplars of each of the given hidden categories. No reference was made to the study phase, making it an implicit test of memory, again using independent cues. 14 filler categories were added to the 6 hidden categories to further obscure the relation between the test phase and the previous phases of the experiment. Thus, the test phase included 20 trials. The participants were first given 4 filler categories. Then, they were given one hidden category followed by two filler categories. This last procedure was repeated until all hidden categories had been presented. Hidden categories and filler categories were randomly selected.

After the category generation task, we assessed if the test had been truly implicit by administering an awareness questionnaire (e.g., Mulligan, 2002; Mulligan & Hartman, 1996), which assessed whether the participants had been aware of the relation between the two parts of the experiment and whether they had consciously tried to remember the words from the earlier part of the experiment during the test phase.

Results and Discussion

Retrieval-practice success rate for the 27 relevant retrieval-practice trials was measured for the experimental categories. The average success rate was 78% (SD = 15.4), which is similar to the success rates in Experiment 1 and those reported by Anderson and Spellman (1995).

Generation percentages are shown in Table 2. Data from 16 participants who indicated that they had consciously tried to remember the words from the earlier part of the experiment during the test phase or who had deliberately not reported items from the earlier part of the experiment during the test phase were removed and replaced, because for these participants it was clear that their awareness of the connection between the two parts of the experiment had affected their responses in the test phase. Removal of participants in such cases is a common approach (see Mulligan, 2002). Our main focus was on the difference between participants who indicated that they had noticed the connection between the two phases of the experiment, but indicated that they had not used explicit retrieval strategies (aware participants) and those who had not noticed any connection between the two phases of the experiment at all (unaware participants). Fifty-two participants were aware, 44 were unaware. To retain complete counterbalancing of retrieval practice categories, we randomly removed data from 4 unaware participants. This did not influence the reliability of our effects.

A paired-samples t-test showed that aware participants generated reliably fewer RP- items than control items, $t(51) = -2.1$, $p < .05$. By contrast, there was no difference in generation of RP- items and control items for the unaware participants, $t(39) = .48$, n.s.** Thus, the results indicate that the retrieval-induced forgetting effect was only found for participants who noticed the connection between the previous phases of the experiment and the test phase and not for participants that were unaware of this relation.

General Discussion

In Experiment 1, we found retrieval-induced forgetting using an explicit memory test and the names of the hidden categories as independent cues. Thus, retrieval-induced forgetting can be found with Anderson and Spellman's (1995) original paradigm, even when memory for inhibited items is tested independently, using cues that were not presented in the study or retrieval-practice phase of the experiment.

Previous studies have shown retrieval-induced forgetting in implicit memory tasks. Perfect et al. (2002) found retrieval-induced forgetting with two implicit memory tests, but these tests did not employ independent cues. Instead, studied category cues were used. Moreover, Perfect and colleagues did not find retrieval-induced forgetting for a number of different implicit memory tests. Veling and van Knippenberg (2004) found retrieval-induced inhibition using a lexical decision task, but we argue that is unclear if this test was truly implicit, since it is conceivable that participants noticed the connection between the two phases of their experiment. The present study used independent cues to test memory for the inhibited items and an awareness questionnaire to control for explicit contamination. Retrieval-induced forgetting was found using an implicit memory test and the same set of independent cues as in Experiment 1, but only for participants who were aware of the connection between the two phases of the experiment. Retrieval-induced forgetting was not found when participants were unaware of this relation.

A possible explanation of these findings is interference. In the retrieval-practice phase, retrieval from memory is not only guided by semantic features, but also by contextual features of the study phase. As a result, these contextual features might become stronger cues for RP+ items. In the test phase, at least for aware participants, these contextual features might again be used as cues. Because these are strong cues for RP+ items, these items have a higher probability of being retrieved and might interfere with the retrieval of items that are similar to RP+ items. This interference results in a lower probability of retrieval of RP- items. For unaware participants, no such interference occurs, since the contextual features from the study phase are not used as cues in the test phase. This could also explain why generation of studied items is lower for unaware participants than for aware participants (see Table 2). Not only might contextual features have caused this interference effect, but aware participants might also have retrieved the categories from the study and retrieval-practice phase when they noticed the connection between the two parts of the experiment. Because of the strong link between RP+ items and the category due to the retrieval-practice phase, it is possible that RP+ items were activated in the test phase and this might have caused interference with the activation of RP- items. These explanations would argue against an inhibitory account of the results in both Experiment 1 and 2.

Alternatively, Anderson (2003) argues that the lack of inhibition in implicit tests may be explained by the assumption that only episodic representations are inhibited. Implicit tests might not tap the activation of episodic representations, thereby masking inhibitory effects. However, Anderson also indicates that it is impossible to distinguish between semantic and episodic representations.

We believe these experiments help to define the scope of inhibitory effects in memory retrieval. Awareness may be a crucial factor in finding retrieval-induced forgetting. Therefore, experiments on retrieval-induced forgetting should include some measure of participant awareness.

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Chapter 3

Retrieval-induced forgetting in perceptual memory tests*

* This Chapter is submitted for publication as: Camp, G., Pecher, D., & Schmidt, H.G. (2005). *Retrieval-induced forgetting in perceptual memory tests.* Manuscript submitted for publication.

Abstract

Retrieval of certain items from memory may result in memory impairment of related items. Studies using the retrieval-practice paradigm introduced by Anderson, Bjork and Bjork (1994) have demonstrated this retrieval-induced forgetting effect using conceptual memory tests. However, previous studies have failed to produce the retrieval-induced forgetting effect using perceptual memory tests. Anderson (2003) suggests that transfer-inappropriate testing effects masked the retrieval-induced forgetting effect in these studies. In three experiments, we used different variations of perceptual memory tasks in both the retrieval-practice phase and the test phase of the retrieval-practice paradigm. Thereby, we controlled for transfer-inappropriate testing effects. We did not find retrieval-induced forgetting in any of the experiments. We conclude that retrieval-induced forgetting is not found using perceptual memory tests and we discuss the implications for the scope of the retrieval-induced forgetting effect in memory retrieval.

Why do people forget? Most theories of memory assume that forgetting is due to interference effects during retrieval (e.g, Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981). Recently however, Anderson (e.g., Anderson & Spellman, 1995; Anderson, 2003) has proposed that another mechanism, inhibition, can explain forgetting in certain cases. This is a challenge for traditional accounts, because, in this view, forgetting is caused by executive control processes that involve active suppression of activation of memory traces. A considerable number of studies using the retrieval-practice paradigm introduced by Anderson, Bjork, and Bjork (1994) have demonstrated the role of inhibition as a mechanism for retrieval interference (for a review, see Anderson, 2003). The retrieval-practice paradigm consists of three phases. First, in the study phase, participants study a number of category-exemplar pairs (e.g., RED – *blood*, RED – *tomato*, LOUD – *thunder*). Second, participants retrieve half of the exemplars from half of the categories from memory in a category-plus-word-stem-cued recall task (e.g., RED – *bl*_____). Finally, participants' memory is tested for both practiced and unpracticed exemplars. Results typically show increased recall for practiced exemplars (RP+ items, *blood*) and decreased recall for unpracticed exemplars from practiced categories (RP- items, *tomato*), when compared with unpracticed exemplars from unpracticed categories (control items, *thunder*). The decrease of recall of RP- items compared to control items is called retrieval-induced forgetting. An important prerequisite for demonstrating inhibitory processes in the retrieval-practice paradigm is the use of independent retrieval cues in the test phase of the experiment. The use of independent cues can rule out non-inhibitory explanations for the retrieval-induced forgetting effect (Anderson, 2003; Anderson & Spellman, 1995; but see Camp, Pecher, & Schmidt, 2005; Williams & Zacks, 2001 for alternative views).

Most studies that use the retrieval-practice paradigm used materials from semantic categories and conceptual memory tests to demonstrate retrieval-induced forgetting. Thus, in these experiments the stimuli were processed in tasks that focused on the conceptual aspects of the stimuli in all parts of the experiment. In the present paper, we examined if retrieval-induced forgetting is also found for perceptual memory tests. Only a few studies have used perceptually oriented memory tests in the retrieval-practice paradigm. Ciranni and Shimamura (1999) applied the retrieval-practice paradigm to objects that varied in color, shape and location. Objects in their Experiment 1 were grouped based on the shape of the object (4 circles, 4 crosses and 4 triangles). In the study phase, participants were given the shape and the color of an object and had to guess its location. They then received feedback about the object's location. The objects were repeatedly presented to the participants until they had learned the location of each of the 12 objects. In the retrieval-practice phase, participants engaged in retrieval practice with 2 of the items from 2 of the shape categories. They were given the shape and location of the object, and had to retrieve its color from memory. They then received feedback about the correct color of the object. Each item received retrieval practice three times. The test phase was identical to the retrieval-practice phase, with the exception that no feedback was given and each item was presented only once. The color of the unpracticed items from practiced shape categories (RP- items) were recalled significantly worse than unpracticed items from unpracticed shape categories (control items). Thus, Ciranni and Shimamura found retrieval-induced forgetting in this experiment. They also found retrieval-induced forgetting in four similar experiments, which varied the grouping variable, the variables that were presented in the retrieval-practice phase and the variables that were presented in the test phase. This might indicate that inhibition can play a role in the retrieval of perceptual memory representations. However, Ciranni and Shimamura did not use independent cues in their experiments. In all their experiments, the grouping variable was presented in the study phase, the retrieval-practice phase and the test phase. Presenting the grouping variable in the test phase makes it possible that noninhibitory processes, such as blocking (e.g., Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981; Roediger, 1974; Rundus, 1973), caused the retrieval-induced forgetting effect. Thus, their results do not provide sufficient evidence for inhibitory processes in the retrieval of perceptually oriented materials.

Other studies have investigated retrieval induced forgetting for word stimuli using perceptual memory tests in the test phase. Butler, Williams, Zacks and Maki (2001) asked participants to study 9 exemplars of each of 12 semantic categories in the study phase of their experiments (e.g., BIRD – *Sparrow*). In the retrieval-practice phase, participants practiced with three exemplars from 4 of the studied categories. Participants were given the category name, followed by a word stem (BIRD – *Sp*_____). Each items was practiced three times. Butler et al. administered a number of different tasks in the test phase of their experiments. These included variations of a word-fragment completion task. In one variant, they presented word fragments of studied items and filler items, but made no reference to the study phase of the experiment (*_p_r_ow* for *Sparrow*, implicit instruction). In another variant, they told participants explicitly that they would see fragments of words that they had studied (*_p_r_ow* for *Sparrow*, explicit instruction). In a third variant, they added the category name to the word fragment (BIRD – *_p_r_ow*) and in a fourth variant they replaced the word fragments with word stems (BIRD – *Sp*_____). Butler et al. did not find retrieval-induced forgetting in any of these experiments. A problem of the last two experiments is that they did not use independent cues, because the category names from the study phase were provided in the test phase. This does not rule out an effect of noninhibitory processes, such as blocking. The first two experiments seem to indicate that retrieval-induced forgetting cannot be demonstrated with perceptual memory tests. Similar results were obtained by Perfect, Moulin, Conway and Perry (2002). They used a similar design as Butler et al. in the study and retrieval-practice phase of their experiments. They did not find retrieval-induced forgetting in a perceptual identification task (Experiments 2 and 3) nor in a word-stem completion task (Experiment 4).

These results, combined with the results of Butler et al., could lead to the conclusion that retrieval-induced forgetting is limited to conceptual representations. However, there is another explanation for the failure to find retrieval-induced forgetting in these experiments. As Anderson (2003) indicates, the retrieval-induced forgetting effect in these experiments could have been masked through transfer-inappropriate testing effects (e.g., Blaxton, 1989; Morris, Bransford, & Franks, 1977; Roediger, 1990; Roediger & McDermott, 1993). According to the transfer-appropriate processing framework, memory performance depends on the overlap in processing between study and test. A distinction is made between conceptual processing and perceptual processing of materials. Conceptual processing focuses on semantic properties of stimuli, whereas perceptual processing focuses on the physical properties of stimuli. Thus, memory performance in conceptual test tasks is better for materials that were studied in conceptual study tasks than for materials that were studied in perceptual study tasks. Memory performance in perceptual test tasks, however, is better for materials that were studied in perceptual study tasks than for materials that were studied in conceptual study tasks.

Anderson (2003) has proposed that retrieval-induced forgetting may also depend on the overlap in type of processing between retrieval practice and memory tests. When there is no overlap, the retrieval-induced forgetting effect may not be found. Since Butler et al. (2001) and Perfect et al. (2002) used a conceptual memory test in the retrieval-practice phase of their experiments, and a perceptual memory test in the test phases of their experiments, transfer-inappropriate testing effects could have masked the retrieval-induced forgetting effect.

In our experiments, we used perceptual memory tasks in both the retrieval-practice phase and the test phase. If the retrieval-induced forgetting effect is indeed sensitive to transfer-appropriate processing, we expected to obtain a retrieval-induced forgetting effect with tasks that relied on processing of the perceptual features of the stimuli in all phases of the experiment. If, however, retrieval-induced forgetting is restricted to conceptual aspects of the stimuli, no effect was expected even if all tasks in the experiment relied on perceptual processing.

Experiment 1

In our first experiment, we assessed if retrieval-induced forgetting can be found using word-fragment completion as a perceptual memory task in both the retrieval-practice phase and the test phase of the experiment. We opted for the word-fragment completion task, because both Butler et al. (2001) and Perfect et al. (2002) used word-fragment or word-stem completion in the test phase of one or more of their experiments. Word-fragment completion is often used in studies that investigate transfer appropriate processing (e.g., Blaxton, 1989). If the failure to find retrieval-induced forgetting in previous experiments was due to transfer-inappropriate testing effects, we would expect to find retrieval-induced forgetting when both the retrieval-practice phase and the test phase employed perceptual memory tasks. Apart from the use of perceptual tasks, the procedure used in the present experiment was a standard retrieval-induced forgetting paradigm, with a study phase, retrieval-practice phase, distractor task, and final test phase.

Method

Participants

Thirty psychology students at Erasmus University Rotterdam participated in the experiment. All were proficient speakers of Dutch and received course credit for their participation.

Materials and design

Ten categories were constructed in Dutch, each containing four words. Words in a category shared the first three letters (e.g., *diamant*, *diameter*, *dialect*, *dialoog*). Thereby, we constructed categories based on a perceptual feature of the words. We ensured that none of the words were semantically related to other words in the same or in different categories to prevent retrieval based on semantic association in the test phase. A study by Anderson, Green and McCulloch (2000) showed that the retrieval-induced forgetting effect is more likely to occur when feature overlap between practiced and nonpracticed items from a category (target-competitor similarity) is low and feature overlap between unpracticed items (competitor-competitor similarity) is high. To induce lower target-competitor similarity and higher competitor-competitor similarity on a perceptual level, we constructed two word pairs within each category that also shared the fourth letter (*diamant*, *diameter* and *dialect*, *dialoog*), thereby decreasing orthographic similarity between the pairs and increasing orthographic similarity within the pairs. Three filler categories, each containing two items, were also constructed to serve as fillers in the experiment.

Participants engaged in retrieval practice with half of the categories. The remaining categories served as controls. One pair from each practiced category received retrieval practice (RP+ items), the other pair did not (RP- items). Thus, 10 items were practiced, 10 items were unpracticed that came from practiced categories and 20 items were unpracticed that came from unpracticed categories. Categories were counterbalanced across conditions. The retrieval-practice phase entailed a word-fragment completion task. Items in the retrieval-practice phase consisted of the first three letters of the word and a subset of the remaining letters. The number of remaining letters that was presented was proportional to the total number of remaining letters (e.g., *dia..t.r* for *diameter* and *dia.o..* for *dialoog*). The fourth letter was never presented during retrieval practice. The test phase also consisted of a word-fragment completion task. Items in the test phase did not include the first three letters of the word and consisted of a subset of the remaining letters. For every item, we constructed two different word fragments: one for the retrieval-practice phase and one for the test phase (e.g., *dia.o..* in the retrieval-practice phase and *...l.og* in the test phase). There was no overlap in letters presented in the retrieval-practice phase and the test phase for any item.

Procedure

Participants were tested individually or in small groups of up to five 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, the words were presented individually for 5 s on a computer screen. Participants were asked to study the word and the first three letters and to quietly pronounce the word for a later memory test. After the presentation of each word, participants were given 10 s to type the presented word using the keyboard. Their response was presented on the computer screen. We used this procedure to stimulate processing of the perceptual features of the word. To control for primacy and recency effects, the first and the last three words on the study list were fillers. The 40 experimental words were presented randomly in blocks of 10 items, containing one item from each category. The study list was repeated, so that every word was presented twice.

In the retrieval-practice phase, participants were told that they were going to see word fragments of studied words from the previous task. Each word fragment (e.g., *dia..c.* for *dialect*) was presented individually for 10 s, during which time participants were asked to type the whole word with the keyboard. Their response was presented on the computer screen. Participants performed retrieval practice with 5 pairs from different categories. The items were presented randomly in blocks of 5 items, containing one item from each category. The retrieval-practice phase consisted of three cycles, so every word was practiced three times. To control for primacy and recency effects, the first and the last three fragments that were presented in the retrieval-practice phase were fillers. Categories were counterbalanced across conditions. After the retrieval practice, participants were given a distractor phase, which consisted of an unrelated mathematical task in which participants did number puzzles. This task took 5 minutes.

In the final test phase, participants were told that they would see word fragments of words that they had seen previously in the experiment. Each word fragment (e.g., *...le.t* for *dialect*) was presented individually for 20 s, during which time participants were asked to type the whole word onto the screen. Participants were given 10 s more to type in the word than in the retrieval-practice phase, because it was more difficult to complete the fragment without displaying the first three letters. The 40 fragments were presented randomly in blocks of 10 items, containing one item from each category. The first three fragments that were presented in the test phase were fillers to control for recency effects.

Results and discussion

The average retrieval-practice success rate for the 10 items that received retrieval-practice was 69% (SD = 19.6). Recall percentages in the test phase can be found in Table 1. A significance level of .05 was adopted for all analyses in our experiments. The mean difference in recall percentage between practiced items (RP+ items) and their control items was 23.3% (SD = 22.8). A paired-samples t-test showed that this difference was significant, $t(29) = 5.61$, $p < .001$. This indicates that retrieval practice helped participants to remember practiced items better than control items in the test phase. The mean difference in recall percentage between unpracticed items from practiced categories (RP- items) and their control items was 1.67% (SD = 28.3). A paired-samples t-test showed that this difference was not significant, $t(29) = .32$, *ns*. Thus, there was no impairment of recall for RP- items in the test phase.

Thus, we did not find retrieval-induced forgetting using perceptual memory tasks. Transfer-inappropriate testing effects cannot explain these results, because the memory tasks in the retrieval-practice phase and the test phase both relied on perceptual processing of the stimuli. These results could indicate that retrieval-induced forgetting is found only using materials that are semantically related. There is, however, an alternative explanation. It is possible that participants did not use their memory of the study phase to complete the word fragments in the retrieval-practice phase. In contrast, they could have tried to complete the fragment with any word that might fit, without retrieving the perceptual features of words from the study phase. Thereby, they could have circumvented interference caused by shared perceptual features within the category (for a similar argumentation, see Anderson, 2003). In standard retrieval-induced forgetting experiments, a category name is given in the retrieval-practice phase, followed by a word stem. The category name that is given may play an important role in triggering retrieval of words from the study phase, inducing competition between words that were studied under the same category. Experiment 2 was designed to provide these category cues, while still using perceptual word features as the basis for interference.

Table 1: *Recall and Identification Percentages of Experiment 1–3*

	Item type							
	RP+		Controls for RP+		RP-		Controls for RP-	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiment 1	58.3	22.1	35.0	14.1	34.7	21.1	33.0	20.7
Experiment 2	50.6	17.5	20.7	10.4	32.2	13.2	29.6	13.9
Experiment 3	69.4	21.9	58.5	23.3	53.7	24.5	50.7	23.7

Note - RP+ items are items from practiced categories that received retrieval practice; RP- items are items from practiced categories that did not receive retrieval practice; Control items for RP+ and RP- items are items from unpracticed categories that correspond with the RP+ and RP- items.

Experiment 2

The aim of our second experiment was to determine whether the absence of category names in the retrieval-practice phase of Experiment 1 might have prevented interference from occurring between words within a practiced category. For this purpose, we presented category names in both the study phase and retrieval-practice phase of the experiment. Since the relation between the category and its items needed to be perceptual in nature, we constructed categories based on rhyme, with one rhyming word serving as the category name.

Method

Participants

Thirty psychology students at Erasmus University Rotterdam participated in this experiment. All were proficient speakers of Dutch and received course credit for their participation.

Materials and design

Twelve categories were constructed in Dutch, each containing six words. The category names were nouns and the members of each category were words that rhymed with this noun. For example, there was a category noun OLIFANT and six category members that rhymed with OLIFANT: *diamant*, *ovenwant*, *bloedverwant*, *informant*, *bajesklant*, *bovenkant*. We ensured that none of the words were semantically related to other words in the same or in different categories to prevent retrieval based on semantic association in the test phase. Three filler categories, each containing two items, were also constructed to serve as fillers in the experiment.

Participants engaged in retrieval practice with half of the categories, the other categories served as controls. Three words within each practiced category received retrieval practice (RP+ items), the other three did not (RP- items). Thus, 18 items were practiced, 18 items were unpracticed that came from practiced categories and 36 items were unpracticed that came from unpracticed categories. Categories were counterbalanced across conditions. The retrieval-practice phase entailed a category-cued word-fragment completion task. Items in the retrieval-practice phase consisted of the category name, followed by a word fragment that did not include the first three letters of the word or the last few letters of the word that rhymed with the category name (e.g., OLIFANT – *...orm...* for *informant*). The first three letters were not presented, because they served as cues in the test phase of the experiment. The number of letters that was presented of the remainder of the word was proportional to its total number of letters (e.g., *...orm...* for *informant* and *...ed.erw...* for *bloedverwant*). The test phase consisted of a word-stem completion task. Items in the test phase consisted of the first three letters of the word followed by a blank line (e.g., *inf*_____ for *informant*). The length of the blank line was held constant to prevent giving cues for word length.

Procedure

Participants were tested individually or in small groups of up to five 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, participants studied the category-exemplar pairs. They were told that they would see multiple rhyme words for each word in capital letters. The word pairs were presented individually for 5 s on a computer screen. On each trial, the category word was presented, followed by an exemplar (e.g., OLIFANT – *informant*). Participants were asked to study the pair and to quietly pronounce the words for a later memory test. The 72 experimental word pairs were randomly presented with the restriction that exemplars from the same category were always separated by at least two intervening pairs. To control for primacy and recency effects, the first and the last three words that were presented in the study phase were fillers.

In the retrieval-practice phase, participants saw the category words from the previous task, followed by a word fragment of one of the studied rhyme words. Each category-fragment pair (e.g., OLIFANT – *...orm...*) was presented individually for 10 s, during which time participants were asked to type the whole word using the keyboard. Their response was presented on the computer screen. Participants performed retrieval practice with 18 items from 6 different categories. The items were presented randomly with the restriction that exemplars from the same category were always separated by at least two intervening pairs. This procedure was repeated three times, so that every item was practiced three times. To control for primacy and recency effects, the first and the last three items that were presented in the retrieval-practice phase were fillers. After the retrieval practice, participants were given a distractor task, which consisted of the same task as in Experiment 1, but contained more items. This task took 10 minutes.

In the final test phase, participants saw the first three letters of words that they had seen previously in the experiment. They were instructed to try to complete the word stems with words from the previous phases of the experiment. Each word stem (e.g., *inf_____* for *informant*) was presented individually for 10 s, during which time participants typed the completed word with the keyboard. The 72 word stems were presented in random order. The first three fragments that were presented in the test phase were fillers to control for recency effects.

Results and discussion

The average retrieval-practice success rate for the 18 items that received retrieval-practice was 57% (SD = 16.9). Recall percentages for the final test phase can be found in Table 1. The mean difference in recall percentage between practiced items (RP+ items) and their controls was 29.8% (SD = 16.1). A paired-samples t-test showed that this difference was significant, $t(29) = 10.1$, $p < .001$. This indicates that retrieval practice helped participants to remember practiced items better than control items in the test phase. The mean difference in recall percentage between unpracticed items from practiced categories (RP- items) and their controls was 2.59% (SD = 15.1). A paired-samples t-test showed that this difference was not significant, $t(29) = .94$, *ns*. Thus, there was no impairment of recall for RP- items in the test phase.

The results of Experiment 2 indicate that the absence of the category names during retrieval practice in Experiment 1 did not cause participants to circumvent interference. The retrieval-induced forgetting effect was found neither with (Experiment 2) nor without (Experiment 1) category names being presented at retrieval practice.

Experiment 3

In our third experiment, we assessed whether the failure to find retrieval-induced forgetting with perceptually oriented materials would generalize to other tasks that are also based on perceptual features of the stimuli. Therefore, we used a perceptual identification task in the test phase of Experiment 3.

Method

Participants

Thirty psychology students at Erasmus University Rotterdam participated in this experiment. All were proficient speakers of Dutch and received course credit for participation.

Materials and design

We used the same materials and design as in Experiment 2, with the following exceptions. Only words that were no longer than 11 letters were used. During normal reading, word identification is usually based on 3–4 characters on the left and 5–7 characters on the right of fixation (Rayner & Sereno, 1994). Thus, words that are longer than 11 letters might be hard to identify in one fixation. Due to the short presentation times in perceptual identification, it was important that all stimuli would be identifiable in one fixation. Therefore, 8 rhyme words from the stimulus set of Experiment 2 that contained more than 11 letters were replaced. A set of 72 additional items was constructed that served as nonstudied words in the test phase. An additional set of 31 items was constructed for filler and practice trials. It was made sure that none of the nonstudied items were associated to experimental items. We matched the nonstudied and studied items on word frequency per million (M = 99.4, SD = 45.7 and M = 98.3, SD = 193.2) and on word length (M = 9.1, SD = 1.0 and M = 9.1, SD = 1.0). All stimuli were presented on a Dell CRT monitor, model P793. This display allowed variation of presentation duration in steps of 10 ms.

Procedure

The procedure was identical to the procedure of Experiment 2, with the exception of the final test phase. In the test phase we used a perceptual identification task (e.g., Jacoby & Dallas, 1981; Pecher, Zeelenberg, & Raaijmakers, 2002). A trial in the test phase consisted of the presentation of a fixation point (700 ms), a stimulus (40 ms) and a mask (700 ms), all presented in the center of the screen. The mask consisted of 12 characters (§§£§££§§§£§§). Mask characters occupied the remaining positions on the screen for shorter stimuli, so that no cues for word length were given. A pilot study had shown that this procedure resulted in an average identification rate of 49% (*SD* = 22) for nonstudied words.

In the test phase of Experiment 3, participants were told that a list of words that they had seen previously in the experiment and new words would be presented very briefly each. They were asked to identify the word by typing it with the keyboard after each trial. They were given 10 s to type in the word for each trial. Participants first received 26 practice trials, to familiarize them with the procedure. They received feedback on the practice trials by presenting the stimulus for 2 s. They did not receive feedback on the experimental trials. Participants did 144 experimental trials (72 familiar words and 72 new), preceded by 5 filler trials. Experimental stimuli were presented in random order.

Results and discussion

The average retrieval-practice success rate for the 18 items that received retrieval-practice was 60% (*SD* = 17.5) across the 54 trials. Identification percentages for the test phase can be found in Table 1. The mean difference in identification percentage between practiced items (RP+ items) and their controls was 10.9% (*SD* = 15.4). A paired-samples t-test showed that this difference was significant, $t(29) = 3.89$, $p < .01$. This indicates that retrieval practice helped participants to identify practiced items better than control items in the test phase. The mean difference in identification percentage between unpracticed items from practiced categories (RP- items) and their controls was 2.96% (*SD* = 12.6). A paired-samples t-test showed that this difference was not significant, $t(29) = 1.29$, *ns*. Thus, there was no impairment of identification for RP- items in the test phase. These results are similar to the results of Experiment 1 and 2, showing no retrieval-induced forgetting effect. Thus, it seems that the failure to find the retrieval-induced forgetting effect in Experiment 1 and 2 generalizes to other perceptual memory tasks.

General Discussion

Previous studies have shown that retrieval-induced forgetting can be demonstrated when both the retrieval-practice task and the final memory test require the processing of semantic aspects of a memory representation (e.g., Anderson & Bell, 2001; Anderson, Bjork, and Bjork, 1994, 2000; Anderson, Green, & McCulloch, 2000; Anderson & McCulloch, 1999; Anderson & Spellman, 1995; Bauml, 2002; Bauml & Hartinger, 2002; Camp, Pecher, & Schmidt, 2005; Johnson & Anderson, 2004; M.D. MacLeod & Macrae, 2001; Williams & Zacks, 2001). However, studies using a conceptual retrieval-practice task and a perceptual final memory task failed to obtain retrieval-induced forgetting (Butler et al., 2001; Perfect et al., 2002). The aim of our experiments was to examine whether the failure to find retrieval-induced forgetting in these studies was caused by transfer-inappropriate testing effects as was proposed by Anderson (2003). An alternative explanation could be that retrieval-induced forgetting is limited to conceptual memory tasks and cannot be found for perceptual memory tasks. In our experiments, we used perceptual memory tasks in the retrieval-practice phase and the test phase.

In Experiment 1, we used word-fragment completion as a perceptual task in the retrieval-practice phase and the test phase of the experiment. In Experiment 2, we added the names of perceptual categories as cues in the retrieval-practice phase, since providing the category name may be crucial for inducing retrieval competition. In Experiment 3, we used perceptual identification in the final test phase to assess whether our findings generalized to other perceptual memory tasks. We did not find retrieval-induced forgetting in any of the experiments, even though in all three experiments perceptual memory tests were used in both the retrieval-practice phase and the test phase, which prevented transfer-inappropriate processing. The fact that we did obtain significant effects of retrieval practice for the RP+ items shows that our procedure was adequate to obtain effects.

These results imply that retrieval-induced forgetting is limited to conceptual memory tasks and cannot be found in tasks that focus on the perceptual features of the stimuli. One might argue that the retrieval practice tasks did not force participants to retrieve items from the study list. It is possible that the inclusion of the categories from the study phase as cues in the retrieval-practice phase of Experiment 2 and 3 was still not sufficient to induce the activation of the perceptual features of words from the study phase. In theory, participants could have ignored the category cue and completed the word fragments with any word that fit (Anderson, 2003). However, a number of researchers (Graf & Mandler, 1984; Reingold & Goshen-Gottstein, 1996; Zeelenberg & Pecher, 2002) have argued that even in an implicit word-fragment completion task, participants attempt to retrieve words they have already seen when they are unable to complete the word fragment immediately. Thus, word-fragment completion is a difficult task, in which participants are prone to use information from previous phases of the experiment. This makes it unlikely that participants did not use their memory of the study phase to complete the word fragments.

As C.M. MacLeod et al. (2003) indicate, a number of boundary conditions exist on the retrieval-induced forgetting effect. Anderson and McCulloch (1999) have demonstrated that integration of category exemplars eliminates the retrieval-induced forgetting effect. Anderson, Bjork, and Bjork (2000) found evidence that retrieval-induced forgetting is a recall-specific mechanism. M.D. MacLeod and Macrae (2001) have demonstrated a limitation on the duration of the retrieval-induced forgetting effect. Other studies (Butler et al., 2001; Camp et al., 2005; Perfect et al., 2002; but see Veling & van Knippenberg, 2004) have shown that the retrieval-induced forgetting effect is not found using implicit memory tests. The results of our experiments indicate a new boundary condition on the retrieval-induced forgetting effect. We conclude that retrieval-induced forgetting is not found using perceptual memory tasks. Thus, it seems that retrieval-induced forgetting can only be demonstrated using conceptual explicit memory tests. This indicates a limitation to the scope of inhibitory processes in memory retrieval.

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Chapter 4

No retrieval-induced forgetting using item-specific independent cues: Evidence against a general inhibitory account

[*] This Chapter is submitted for publication as: Camp, G., Pecher, D., & Schmidt, H.G. (2006). *No retrieval-induced forgetting using item-specific cues: Evidence against a general inhibitory account.* Manuscript submitted for publication.

Abstract

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 (Anderson & Spellman, 1995). In three Experiments, we tested whether the forgetting effect generalizes to items that are not studied in the context of the experiment (i.e., semantic forgetting) and whether the forgetting effect is cue-independent. We did not find retrieval-induced forgetting using item-specific independent cues for either studied or unstudied items. However, we did find forgetting for both item types when studied categories were used as cues. These results indicate that retrieval-induced forgetting is a cue-dependent effect. They indicate that, if inhibition occurs, it is a context-specific process.

Forgetting can be described as the inability to retrieve information from memory. For example, people may have difficulties 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 your 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 retrieving the names of more recent soccer coaches, the name of your old soccer coach may have been activated and may have given rise to retrieval competition. To access the right name in these situations, the name of your old soccer coach may have been inhibited. This inhibition can lead to problems in retrieving the name of your 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, Green, & McCulloch, 2001; Anderson & McCulloch, 1999; Anderson & Spellman, 1995; Bauml, 2002; Bauml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; MacLeod & Saunders, 2005; Perfect, Moulin, Conway, & Perry, 2002; Shaw, Bjork, & Handal, 1995; Smith & Hunt, 2000; Saunders & MacLeod, 2006). In this paradigm, participants first study a number of category-exemplar pairs (e.g., RED – *brick*, RED – *tomato*). Next, participants perform retrieval practice with half of the items from half of the categories using a category-cued word-stem completion test (e.g., RED – *b*_____). In this retrieval-practice phase, it is expected that the exemplars from the studied category 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 using 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. This retrieval-induced forgetting effect has also been demonstrated with extralist cues (Anderson et al., 2000; Johnson & Anderson, 2004; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006, but see Perfect et al., 2004; Williams & Zacks, 2001). In these experiments, memory for studied items was tested with cues that did not appear in earlier phases of the experiment and could thus provide an independent test of memory for studied items. 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 is also found. 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 cue. 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).

Although a number of studies seem to provide evidence for cue-independent forgetting, some researchers have questioned whether retrieval-induced forgetting is truly cue-independent. First, Perfect et al. (2004) argue convincingly that the retrieval-induced forgetting effect found by Anderson and Spellman in Experiments 2 and 4 with independent probes seems to be caused by a high level of recall of control items and not by impaired recall of experimental items. Moreover, they maintain that the results are surprising given findings by Anderson, Bjork and Bjork (1994), who demonstrated that retrieval-induced forgetting is not found for weak category exemplars. 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). Also, Williams and Zacks (2001) failed to replicate the forgetting effect found by Anderson and Spellman, even though they used more participants and more items per category.

Second, the use of unstudied categories as independent cues (Anderson et al., 2000) may pose problems for the cue-independence of the final memory test. Perfect et al. (2004) and Camp, Pecher and Schmidt (2005) have argued that it is possible that participants use the studied category (RED) as a retrieval cue in the test phase of these studies, although they are only cued with an unstudied category (FOOD). Perfect et al. argue that FOOD may be associated to 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 the studied category as cue. 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.

Evidence for the occurrence of this covert cuing process has been found by Anderson et al. (2000). In their study, participants were asked to indicate on a post-experimental questionnaire to what extent they mentally scanned through the earlier category names to help them find category exemplars. They reported an average rating of 2.68 on a five-point scale. Thus, covert cuing does indeed occur when participants are tested with unstudied categories. This indicates that unstudied categories cannot provide a truly independent memory test for suppressed items. However, the effect of covert cuing on forgetting has not been interpreted unequivocally.

Anderson and colleagues argue that covert cuing can mask the forgetting effect (Anderson, 2003; Anderson et al. 2000). They argue that practiced categories are more available at test to participants that engage in covert cuing than are unpracticed categories, because the practiced categories appeared in the retrieval-practice phase and unpracticed categories did not. This leads to a retrieval advantage for suppressed items relative to control items, because the suppressed items are cued by both the extralist category and the studied category when covert cuing occurs, whereas the control items are only cued by the extralist cue. Thus, Anderson and colleagues conclude that covert cuing may mask the forgetting effect.

However, this conclusion is based on numerical and not statistical differences in forgetting. Although participants that gave low covert cuing ratings did show numerically more forgetting, there were no statistical differences in the amount of forgetting between participants when they were divided into three groups based on their covert cuing ratings. Moreover, participants' self-reports may have been biased by their performance on the recall task. Participants who performed poorly and thus showed forgetting may have denied the use of covert cuing strategies and participants that performed well and thus did not show forgetting could have done the opposite (see Perfect et al., 2004, for a further discussion).

A different interpretation of covert cuing proposed by Perfect et al. (2004) and Camp et al. (2005) is that it leads to associative blocking (e.g., Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981; Roediger, 1974; Rundus, 1973). According to blocking theory, retrieval-practice with RED – *brick* strengthens the association between RED and *brick*. When the category RED is later used as a cue in the test phase of the experiment, the heightened availability of *brick* can block the retrieval of *tomato*. In this view, covert cuing does not mask the forgetting effect, but increases it. Some evidence for this effect has been reported by Camp et al., who used an implicit memory test in the retrieval-practice paradigm with unstudied categories as cues. They demonstrated that participants who were aware that their memory for studied items was being tested demonstrated forgetting, whereas participants that were unaware did not. Camp et al. argue that forgetting was found when covert cuing strategies were plausible (i.e., for the aware participants), but not when covert cuing strategies were not plausible (i.e., for the unaware participants). This indicates that covert cuing may play a role in causing the forgetting effect.

Thus, although the interpretation of covert cuing effects is still subject of discussion, it does seem questionable whether the independent probe technique can provide a truly independent test of memory for items that are thought to be inhibited. The use of unstudied category-cues may not be sufficient to ensure an independent test of memory for the suppressed items. Perfect et al. (2004) have tried to resolve this issue by associating each exemplar to a specific, unrelated and independent item before retrieval-practice took place. Later, this item-specific cue was used in the test phase of the retrieval-practice paradigm to test memory for the suppressed item. This procedure using item-specific independent cues is less susceptible to the problem of retrieval strategies involving the activation of practiced categories than the procedures using unstudied categories as cues in the test phase. This is because there was no association between the item-specific cues and the category and the cues were specific for only one item. In their third experiment, they added a pre-study phase to the retrieval-practice paradigm, in which all category exemplars were presented together with unrelated words (e.g., *zinc-apple*, *nylon-orange* for the category FRUIT). This phase preceded the regular study phase in which participants studied all 24 category-exemplar pairs from 6 different categories. In this way, the unrelated word was only associated to the exemplar, not to the category. In the test phase of the experiment, the studied category or the unrelated word was used as cue. Retrieval-induced forgetting was found using the category cues, but not using the unrelated words as cues. Perfect et al. interpreted these findings as a form of transfer appropriate forgetting, in which forgetting is only seen 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 is only found 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.

However, a number of studies contradict this conclusion. In Anderson & Bell (2001), participants studied the object *violin* in two propositions that had different topics and relations (e.g, 'The actor is looking at the *violin*' and 'The teacher is lifting the *violin*'). Retrieval-practice of different objects studied under one of these topics and relations (e.g., 'The actor is looking at the *tulip*') resulted in forgetting of *violin*, even when it was tested with the other topic and relation that did not receive retrieval practice (e.g., 'The teacher is lifting the *v*_____'). This provides evidence for forgetting with episodic independent cues. MacLeod and Saunders (2005) and Saunders and MacLeod (2006) demonstrated retrieval-induced forgetting with unstudied categories as cues. They not only found forgetting for unpracticed items from practiced categories, but also for items that were related to the items from practiced categories, but that were studied under a different category. Moreover, Johnson and Anderson (2004, Experiment 2) found retrieval-induced forgetting for unstudied items using item-specific independent cues in the test phase of the retrieval-practice paradigm. Their experiment did not include a study phase. In the retrieval-practice phase, participants engaged in retrieval-practice with 0, 1, 4 or 8 members of 24 categories (e.g., SEASONING – *nu*_____ for *nutmeg*). The test phase consisted of a free association test, in which participants were given an independent probe that was related to a high-frequency unpracticed member of one of the categories (e.g., *popcorn – s_____* for *salt*). Results showed that participants generated reliably fewer items from categories that were practiced 4 or 8 times in the retrieval-practice phase than items from categories that received no retrieval practice. Thus, Johnson and Anderson found retrieval-induced forgetting for unstudied items using item-specific independent cues. These studies indicate that retrieval-induced forgetting is a cue-independent effect and that semantic retrieval can induce inhibition of general concept memory representations.

The aim of the experiments reported in this article was to shed light on this empirical ambiguity. First, Perfect et al. (2004) tested memory of items in the test phase that had been presented earlier in a study phase, whereas Johnson and Anderson (2004) did not include a study phase and therefore tested memory of unstudied items. Put differently, Perfect et al. tested forgetting of episodic information, whereas Johnson and Anderson tested forgetting of semantic information. Our studies were set up to measure the effects of retrieval practice on both studied and unstudied items. To accomplish this, we used a paradigm in which participants studied category-exemplar pairs (ANIMAL – *rat*, ANIMAL – *horse*), followed by retrieval practice with half of the examples 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 items (*elephant*) belonging to the studied categories.

Second, some studies provide evidence that retrieval-induced forgetting is a cue-independent effect (Anderson & Bell, 2001; Anderson et al., 2000; Anderson & Spellman, 1995; Johnson & Anderson, 2004; MacLeod & Saunders, 2005; Saunders & MacLeod 2006), whereas other studies indicate problems of the independent probe technique and demonstrate that retrieval-induced forgetting is cue-dependent (Camp et al., 2005; Perfect et al., 2004; Williams & Zacks, 2001). For example, Perfect et al. only found forgetting when memory was tested with studied categories as cues and not with item-specific independent cues. Johnson and Anderson, however, did find forgetting using item-specific independent cues. In different experiments, we used both item-specific independent cues (*poison – r*_____, *zoo – e*_____) and studied category cues (ANIMAL – *r*_____, ANIMAL – *e*_____) to test memory of items in the test phase. The item-specific cues were independent, because they were not presented in the retrieval-practice phase, and thus had no association to the practiced item or the practice context.

Experiment 1

In our first 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.

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 and design

Sixteen categories were constructed in Dutch, each containing three exemplars (e.g., ANIMAL – *horse*, ANIMAL – *rat*, ANIMAL – *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. Anderson et al. (2000) have demonstrated that the retrieval-induced forgetting effect is more likely to occur when feature overlap between practiced and nonpracticed items from a category (target-competitor similarity) is low. Therefore, items were selected for each category that were not very similar. Two of the exemplars from each category were presented in the study phase, one was not.

Participants engaged in retrieval practice with half of the categories. Therefore, for each practiced category, there were three types of items. One studied item that received retrieval practice (RP+), one studied item that did not (RP-) and one unstudied item (U). The remaining categories served as controls. Practiced categories and item type were counterbalanced across conditions. This meant that items served as 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 item served as RP+, RP- and U item and as control item for RP+, RP- and U an equal amount 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.

For the test phase, a specific independent cue was created for each exemplar (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 .17 (*SD* = 1.3), according to Dutch association norms (van Loon-Vervoorn & Bekkum, 1991).

Procedure

Participants were tested individually. 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. The 32 pairs were presented randomly in blocks of 16 items, containing one item from each category.

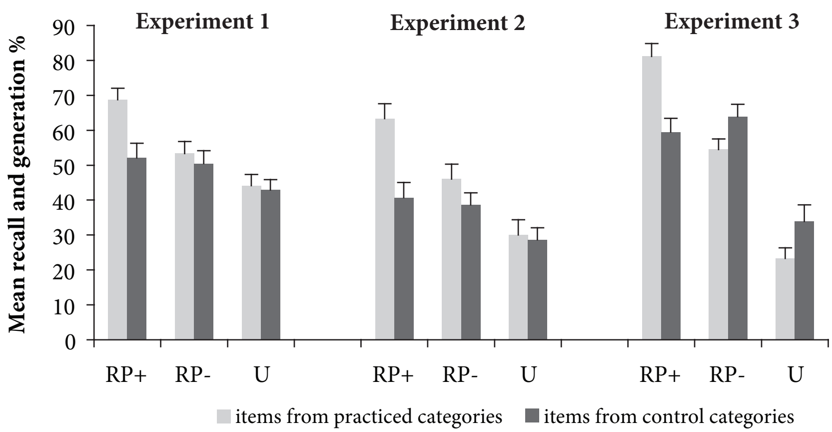
In the retrieval-practice phase, participants were told that they were going to see a category from the previous task, followed by the first letter of a studied word from that category (e.g., ANIMAL – *h*_____). Each pair was presented individually for 10 s, during which time participants were asked to type the word using the keyboard. Their response was presented on the computer screen. Participants performed retrieval practice with 8 exemplars from different categories. The retrieval-practice phase consisted of three cycles, so every 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 minutes.

In the final test phase, participants were presented with an independent cue for each item (e.g., *cowboy* – *h*_____, *poison* – *r*_____, *zoo* – *e*_____). They were made aware that some of these words 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, 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 48 pairs were presented randomly in blocks of 16 items. Each block contained 1 item from each category. The first two pairs that were presented in the test phase were fillers.

Results and discussion

The average retrieval-practice success rate was 85% (*SD* = 14,6). 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 their control items: 16.7% (*SD* = 27.3), $t(29) = 3.3$, $p < .01$. This indicates that retrieval-practice facilitated recall of the practiced items. Surprisingly, RP- items were recalled slightly better than their control items, but this difference was not significant: 2.9% (*SD* = 24.9), $t(29) < 1$. No difference was found between U items and their unstudied control items: 1.3% (*SD* = 21.6), $t(29) < 1$. Thus, contrary to the results of Johnson and Anderson (2004), retrieval-induced forgetting was not found for items that were not studied. This seems to indicate that semantic memories were not inhibited. Moreover, the lack of forgetting for RP- items using item-specific cues seems to indicate that forgetting is not cue-independent.

Figure 1: *Recall and Generation Percentages of Experiment 1–3*



Note - 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.

However, it is possible that integration effects masked inhibitory effects for the RP- items in this study (Anderson & Bell, 2001; Anderson & McCulloch, 1999). For example, Anderson and McCulloch showed that instructing participants to interrelate items from the same category reduced retrieval-induced forgetting and that spontaneous integration could also reduce retrieval-induced forgetting. Although the studied category exemplars were deliberately chosen not to be similar (i.e., *horse*, *rat* and *elephant* for the category ANIMAL), participants could have spontaneously interrelated the two studied items from each category, because only two exemplars were presented for each category in the study phase. Second, the number of retrieval-practice trials per category was 3, which is lower than the number of trials in Johnson and Anderson with which retrieval-induced forgetting was found (4 or 8). Although Perfect and colleagues (2002, Experiment 1) found retrieval-induced forgetting with only 2 studied items and 3 retrieval practice trials per category, it could still be the case that the smaller number of retrieval-practice trials per category was insufficient to invoke enough inhibition to demonstrate retrieval-induced forgetting. We addressed these issues in Experiment 2.

Experiment 2

In Experiment 2, we tried to resolve the issue of integration and the low number of retrieval practice trials by doubling the amount of exemplars for each category. Because the amount of exemplars per category was doubled, we did not expect any integration effects that could have occurred in Experiment 1. Moreover, by adding three exemplars to each category, the number of retrieval-practice trials per category was increased to 6. Several studies have demonstrated retrieval-induced forgetting with comparable sets of materials (e.g., Bauml & Hartinger, 2002; Perfect et al., 2002; Perfect et al., 2004).

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 Experiment 1, except that 3 items were added to each category. The extra items were not tested in the final test phase but served to prevent integration between items from the same category (Anderson & McCulloch, 1999) and to increase the number of retrieval-practice trials per category. As indicated before, retrieval-induced forgetting is more likely to occur when feature overlap between practiced and nonpracticed items from a category (target-competitor similarity) is low (Anderson et al., 2000). Anderson and colleagues also found that retrieval-induced forgetting is more likely when feature overlap between unpracticed items (competitor-competitor similarity) is high. Therefore, we selected extra items that were similar to one of the three original items (e.g., extra item *donkey* was similar to *horse*, *hamster* to *rat* and *rhinoceros* to *elephant*). For practiced categories, one experimental item and its similar extra item received retrieval practice three times in the retrieval-practice phase. The number of categories was reduced from 16 in Experiment 1 to 10 in Experiment 2.

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), $t(29) = 4.0$, $p < .001$. This indicates that retrieval-practice facilitated recall of the practiced items. As in Experiment 1, 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 to 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 using item-specific cues, even with larger numbers of items and more retrieval-practice trials per category. The absence of forgetting for U items again argues against inhibition of semantic memories. The lack of forgetting for RP- items is not consistent with a cue-independent view of retrieval-induced forgetting. We will elaborate on this point in the general discussion. Although retrieval-induced forgetting has not been found for RP- and U items using item-specific cues, a cue-dependent view of retrieval-induced forgetting would expect the effect to occur when studied categories are used as cues. This was tested in Experiment 3.

Experiment 3

In our third experiment, we used the studied categories as cues in the test phase of the Experiment. Cue-dependent views of retrieval-induced forgetting predict retrieval-induced forgetting when studied categories are used as cues.

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, design and procedure

The materials, design and procedure were identical to the procedure of Experiment 2, with the exception of the final test phase. 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*_____). The first 2 items were filler items. To control for output interference effects (see Anderson, 2003), we tested the RP- and U items and their controls first. Two blocks of 10 items each contained all RP-, U and their control items from 5 categories. Participants were presented with a randomly selected item from one block, followed by a randomly selected item from the second block. 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), $t(35) = 4.0$, $p < .001$. 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), $t(35) = -2.3$, $p < .05$, indicating retrieval-induced forgetting using 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), $t(35) = -2.3$, $p < .05$. Thus, forgetting was found for both RP- and U items using studied categories as cues.

General Discussion

In Experiment 1 and 2, we found no retrieval-induced forgetting for both studied items and unstudied items using item-specific independent cues. However, in experiment 3, we demonstrated retrieval-induced forgetting for both studied and unstudied items using studied categories as cues. We will discuss the implications of these findings for inhibitory theories of forgetting.

A broad view of inhibitory processes in memory retrieval proposes 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. Evidence for inhibition of semantic memories comes from Johnson and Anderson (2004), who demonstrated that retrieval-practice with particular category-exemplar pairs resulted in less generation of different, unstudied category exemplars in a memory test using item-specific independent cues. If semantic inhibition occurred in our experiments, we would have expected forgetting for unstudied items using item-specific independent cues. However, in both Experiment 1 and 2, retrieval-induced forgetting was not found for unstudied items.

Moreover, we also failed to find retrieval-induced forgetting for studied items with item-specific independent cues. This seems to indicate that retrieval-induced forgetting is a cue-dependent effect, which is only found when studied categories are used as cues. There are two explanations for this cue-dependent forgetting effect. One is a context-specific inhibitory account (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.

However, it is unclear if a context-specific view of inhibition can account for forgetting of unstudied items in Experiment 3. 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. It is, however, somewhat contradictory that inhibitory effects are context-specific (that is, tied to a context-specific retrieval cue), but that they do occur for items that were not studied in the experimental context. In other words, the type of cue with which forgetting is demonstrated is thought to be context-sensitive, while the type of memory item that is sensitive to inhibition is not.

Another problem is that inhibition theory maintains that it is the item itself that is inhibited, and not the relation between an 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.

A second explanation of cue-dependent forgetting is interference. As argued before, the use of studied category cues in the test phase of the retrieval practice paradigm can induce the activation of practiced items, which can in turn block the retrieval of unstudied items without the occurrence of any inhibitory processes (e.g, Mensink & Raaijmakers, 1988; Perfect et al., 2004; Raaijmakers & Shiffrin, 1981; Roediger, 1974; Rundus, 1973). The probability of this type of interference is increased by the contextual similarity between the retrieval-practice phase and the test phase. The contextual features of the retrieval-practice phase have been associated with practiced items during retrieval practice. Thus, presenting participants with a similar context may also result in activation of these items and subsequently in blocking of unpracticed items from the same category. A blocking account also explains why forgetting of unstudied items occurs. Unstudied items from practiced categories are expected to be blocked in the same way and to the same degree as are studied items from practiced categories in the test phase, even though they were not studied. This is supported by the results of Experiment 3, in which the forgetting effect was comparable for studied and unstudied items (9.4% and 10.6% respectively). In contrast, it can be argued that the context-specific inhibition account would expect more forgetting for studied items than for unstudied items, because studied items are more available at retrieval practice than unstudied items, and would therefore lead to more retrieval competition.

However, a number of studies using the retrieval-practice paradigm argue against a blocking account of retrieval-induced forgetting. In blocking accounts, strengthening of the association between practiced items and their category should result in reduced recall for unpracticed items at test. Anderson et al. (1994) demonstrate that strengthening of practiced items in the retrieval-practice phase does not predict the amount of retrieval-induced forgetting. Other studies found that forgetting only occurs when the practiced item is retrieved and not when it is merely restudied (Anderson, Bjork, & Bjork, 2000; Ciranni & Shimamura, 1999). Moreover, two studies found retrieval-induced forgetting in tests of item recognition (Hicks & Starns, 2004; Veling & van Knippenberg, 2004). The fact that forgetting was found when the target was presented without its category in these studies is difficult to explain by interference processes such as blocking.

While blocking cannot fully explain all of the data in the literature, 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 is of context-specific retrieval-induced forgetting. In any case, our results provide evidence that retrieval-induced forgetting is a cue-dependent effect that is only found with episodic cues. This indicates that, if inhibition occurs, it is a context-specific process.

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Chapter 5

How independent are independent probes?

Abstract

Retrieval practice of a subset of previously studied category-exemplar pairs can cause forgetting of the unpracticed exemplars on a later memory test. Extralist cues, also called independent probes, have been used to provide an independent test of memory for unpracticed exemplars. This technique has been developed to differentiate between the contributions of inhibition and interference to the retrieval-induced forgetting effect. However, evidence from post-experimental questionnaires suggests that participants use covert cuing strategies involving the use of studied categories as additional cues, even though they are cued with extralist cues. The use of studied categories as additional cues challenges the value of the independent probe technique as an independent test of memory. In two experiments, we assessed directly whether performance on the final memory test using extralist cues depends on the accessibility of the study cues. The results provide direct evidence that study cues are used at test and thus challenge the independence of independent probes.

Forgetting of information in memory has been ascribed to interference processes by most memory models (e.g., Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981). In this view, a memory item becomes less accessible over time by the addition of interfering memory traces. However, researchers have argued that not only interference, but also inhibitory processes can play a role in forgetting (Anderson, 2003; Anderson, Bjork, & Bjork, 1994; Anderson & Green, 2001; Anderson & Spellman, 1995; Levy & Anderson, 2002). Inhibition theory states that people have executive control over the activation of items in memory and that they can actively inhibit the activation of certain memory items when they compete with other items for retrieval.

Two paradigms have been developed that provide evidence for inhibitory processes in memory retrieval. First, in the retrieval-practice paradigm, inhibitory processes are invoked by inducing retrieval competition between memory items. According to inhibition theory, this competition leads to a reduction of the activation of the nontarget items. For example, participants study category-exemplar pairs such as SOUPS – *chicken*, SOUPS – *turkey*, SOUPS – *tomato* and SOUPS – *onion*. Then, in the retrieval-practice phase, participants retrieve a subset of the studied items in a category-cued word-stem completion task (e.g., SOUPS – *ch*_____ and SOUPS – *tu*_ ____*)*. The retrieval competition between cued and non-cued items from a category in this task leads to reduced recall of the non-cued items (*onion* and *tomato*) on a later cued memory test using the studied category (SOUPS) as cue compared to control items from categories that did not receive retrieval practice (Anderson et al., 1994).

A second paradigm that has provided evidence for inhibitory processes is the think/no-think paradigm. In this paradigm, participants are actively instructed to forget certain information that was previously studied. For example, participants study a number of unrelated cue-target pairs such as *ordeal – roach*. Then, in a think/no-think task, they are presented with only the cue (*ordeal*) for a subset of the pairs and are instructed either to recall and think about the target (think condition) or to prevent the target from entering consciousness (no-think condition). Finally, in the test phase, all studied cues are presented and participants are asked to respond with the studied target. Reduced recall has been found for items in the no-think condition compared with control items for which the cue did not appear in the think/no-think task (Anderson & Green, 2001; Anderson et al., 2004).

Although forgetting effects have been demonstrated with both paradigms described above, it is unclear whether these effects were caused by inhibition or by interference processes. In inhibitory accounts, forgetting is caused by decreasing the activation of the item itself (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). In interference accounts however, forgetting is caused by changes in relative associative strength between cue and target. A number of interference accounts have been offered that can also explain the forgetting effects found with the retrieval-practice and think/no-think paradigms (Anderson & Bjork, 1994; Anderson & Spellman, 1995). In the retrieval-practice paradigm, for example, associative blocking may also have caused the forgetting effect (e.g., Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981; Roediger, 1974; Rundus, 1973). The association between SOUPS and *chicken* was strengthened in the word-stem completion task. When the category name SOUPS was later used as cue in the test phase, the heightened availability of *chicken* may have blocked recall of *onion*. As Anderson and Green (2001) indicate, interference may also have occurred in the think/no-think paradigm. Participants may have used certain strategies to avoid retrieval of the target in the no-think condition. For instance, participants may have tried to avoid stimuli associated to the target from reminding them of the target in the no-think task. They may have generated diversionary thoughts to these stimuli to avoid retrieval of the target. These new associations may then have caused interference when memory was tested with the cue.

However, a number of other studies have provided evidence for the role of inhibition in causing retrieval-induced forgetting. First, strengthening of practiced items by restudy does not lead to forgetting in the retrieval practice paradigm, whereas retrieval of practiced items does (Anderson, Bjork, & Bjork, 1994, 2000; Ciranni & Shimamura, 1999). Other evidence for the role of inhibition is the demonstration of retrieval-induced forgetting using extralist cues (also called independent probes). Extralist cues have been used to test memory for inhibited items in order to differentiate between the contributions of interference and inhibition. These are cues that are related to the inhibited item, but that were not presented earlier in the experiment. These cues are usually category names, sometimes followed by the first letter of the target. For example, in the retrieval-practice paradigm, memory for *onion* and *tomato* is tested with the cue VEGETABLE. In the think/no-think paradigm, memory for *roach* is tested with INSECT – *r*_____. Note that in both paradigms only the inhibited items are related to the extralist cues and these cues have not been presented in earlier phases of the experiment. Inhibitory accounts predict forgetting with extralist cues, interference accounts do not. Presenting the intralist cue used at test is crucial in interference accounts. In interference accounts, forgetting is caused by strengthening the association between the intralist cue and competing items, which lead to the failure of the cue to elicit the target in the test phase. Thus, no forgetting is predicted when that cue is not presented. In inhibitory accounts however, the target *itself* is inhibited and forgetting should be found with any cue that tests memory for the inhibited item (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Spellman, 1995; Levy & Anderson, 2002). In experiments using extralist cues in both the retrieval-practice paradigm and the think/no-think paradigm, forgetting has been found (e.g., Anderson & Bell, 2001; Anderson & Green, 2001; Anderson, Green, & McCulloch, 2000; Anderson et al., 2004; Anderson & Spellman, 1995). This indicates that inhibition can play a role in forgetting.

However, a number of studies have provided evidence that extralist cues may not be able to provide an independent test of memory for inhibited items. A potential problem of the independent probe technique is covert cuing (Anderson, 2003; Anderson, Green, & McCulloch, 2000). It is possible that participants used the studied category (e.g., SOUPS) as a retrieval cue in the test phase of these studies, even though they were cued with an extralist cue (e.g., VEGETABLE). Half of the SOUPS items from the study phase were also VEGETABLE items, thereby possibly creating an association between the two categories. Moreover, attempting to recall studied items with an extralist cue in the test phase may have proven difficult (Tulving & Thomson, 1973) and participants may have tried to use the category with which the items were originally studied as a more effective cue. Thus, it is likely that participants used the studied categories as cues in the test phase, because of the association between VEGETABLES and SOUPS and the higher effectiveness of SOUPS as retrieval cue. Moreover, the heightened accessibility of SOUPS due to the retrieval-practice phase may also have increased the likelihood that it was used as a cue in the test phase. The same process may occur in the think/no-think paradigm. There, the cues from the study phase and the think/no-think task (e.g., *ordeal* for *roach*) may have been used as cues in the test phase, even when cued with an unstudied category (INSECT – *r*_____).

Some evidence for covert cuing strategies has been found by Anderson, Green, and McCulloch (2001). Participants in their experiment were given a post-experimental questionnaire on which they were asked to rate the degree to which they scanned back through the study categories to help them think of responses to the independent probes. They reported an average rating of 2.68 on a five-point scale. When the participants were divided into three groups based on their covert cuing ratings, no statistical differences were found between these groups in the amount of forgetting. However, there was a numerically greater amount of forgetting for the low covert cuing group. According to Anderson (2003), this indicates that covert cuing can mask inhibitory effects by facilitating recall of inhibited items relative to control items. Participants who use covert cuing strategies are more likely to use practiced categories (e.g., SOUPS) as covert cues than unpracticed categories. This is because practiced categories have been made more accessible due to the retrieval-practice phase and unpracticed categories have not. Thus, for inhibited items, two cues could have been available at test: the extralist cue and the covertly generated intralist cue. For the control items, generation of the intralist cue was less likely. This could have lead to a retrieval advantage for inhibited items relative to control items, thereby masking the inhibitory effect. Although this explanation is plausible, it is based on numerical and not statistical differences in recall. Moreover, it is based on self-reports. Participants' self-reports may have been colored by their performance on the recall task. Participants who showed forgetting (poor performers) could have denied the use of covert cuing strategies and participants that did not show forgetting (high performers) could have done the opposite (Perfect et al., 2004).

Other evidence for covert cuing strategies in the independent probe technique is reported by Camp, Pecher and Schmidt (2005). Camp et al. (Experiment 2) used an implicit memory task with extralist cues in the final memory test of the retrieval-practice paradigm. After the experiment, participants were asked if they were aware of the relation between the test phase and the other phases of the experiment. Retrieval-induced forgetting was found when participants were aware that there memory for studied items was tested, but no forgetting was found when participants were unaware that their memory for studied items was tested. Thus, contrary to the results of Anderson et al. (2001), forgetting was found when covert cuing was plausible (i.e., for the aware participants), but did not occur when covert cuing was not plausible (i.e., for the unaware participants). Camp et al. argue that aware participants may have used a retrieval strategy involving activation of studied categories. Although Anderson (2003) argues that this leads to a recall advantage for inhibited items, Camp et al. argue that the use of the studied category as extra cue can lead to a recall disadvantage. The use of the studied category (e.g., SOUPS) as cue could have lead to blocking of the inhibited item (e.g., *onion*) because of the heightened availability of the practiced items from that category (e.g., *chicken*). Unaware participants were unlikely to use retrieval strategies involving the activation of studied categories, because they were not aware that they were generating previously studied items. Thus, blocking did not occur for unaware participants. Although other studies using implicit memory tests in the retrieval-practice paradigm have demonstrated forgetting (e.g., Veling & van Knippenberg, 2004; Johnson & Anderson, 2004), these studies did not measure participant awareness. Therefore, it is possible that participants in these studies noticed the connection between the test phase and the earlier phases of the experiment and therefore the test was not truly implicit. If covert cuing leads to blocking, this would indicate that the independent probe technique cannot adequately differentiate between interference and inhibitory accounts of forgetting.

Thus, the role of covert cuing in the independent probe technique is at least questionable. Therefore, it is important to investigate more directly if extralist cues are truly independent. Earlier studies only provide evidence for covert cuing using post-experimental questionnaires. The present experiments were set up to provide a more direct test of the independence of extralist cues. Because we were not interested in inhibition per se, but in the independence of extralist cues, we made an effort to keep the design as simple as possible. Thus, we focused on the effect of presenting the studied categories in an intervening second study task on the final memory test using extralist cues.

In Experiment 1, participants studied weakly related cue-target pairs such as *rope – sailing*. Then, in a second study phase, a subset of the cues was presented alone and participants were required to rate the cues on pleasantness and frequency. Finally, in the test phase, the effect of additional cue study was measured by testing memory for target items with extralist cues (e.g., SPORT). If the extralist cues were truly independent, we would expect no effect of additional cue study on target recall. However, if the extralist cues were not truly independent, the cues that received additional study may have been more available and used as additional cues in the test phase. In that case, we would expect facilitation of their targets.

Experiment 1

Method

Participants

The participants in the experiment were 40 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for their participation.

Materials and design

We constructed 24 cue-target pairs such as *rope – sailing* (note: all words were in Dutch). Cues and targets were weakly associated according to Dutch association norms (van Loon-Vervoorn & Bekkum, 1991). The mean cue-to-target strength and the mean target-to-cue strength were .023 (*SD* = .018) and .024 (*SD* = .016) respectively. Cues and targets within each pair were not related to any other cues or targets in the Experiment. Each target was a member of a different taxonomic category (e.g., SPORT – *sailing*). The category names were used in the test phase of the Experiment as extralist cues to test target recall. The mean position of the targets on a frequency-sorted list of their category was 7.0 (*SD* = 5.09) according to Dutch category production norms (Hudson, 1982). Apart from the target, no other item in the study list was a member of the category. The mean target-to-category strength was .022 (*SD* = .028). Category-to-cue and cue-to-category strengths were weak: 0.001 (*SD* = .003) in both cases, and they were always less than .011. Not all association strengths were available within each cue-target-category triple. In these cases, we selected items that we judged to be similar in association strength to items for which these association strengths were available.

Procedure

Participants were tested individually. The experiment consisted of two study phases and a test phase. In the first study phase, all cue-target pairs were presented for 4 s on a computer screen. After each presentation, participants were asked to give a similarity rating for the pair on a scale of 1–5. The 24 pairs were presented in random order.

In the second study phase, half of the cues were presented again for 2 s on the computer screen. After each presentation, participants were asked to give a pleasantness rating for each cue on a scale of 1–5. Cues were presented in random order. This procedure was repeated, but now participants were asked to give a frequency rating of the cue in Dutch language on a scale of 1–5. Studied cues were counterbalanced across conditions.

In the test phase, recall was tested for targets of which the cue was studied in the second study phase (cue study items) and targets of which the cue was not studied in the second study phase (control items). The 24 category names were presented individually and participants were asked to type a word that they had seen in the first study phase that was a member of the presented category. Categories were presented in random order and the task was self paced.

Results and discussion

Recall percentages in the test phase can be found in Table 1. There was a significant difference in recall between cue study items and control items: 8.54% (SD = 18.2), $t(39) = 2.96$, $p < .01$. Thus, additional study of a cue (e.g., *rope*) led to higher recall of its target (e.g., *sailing*). This indicates that cues that received additional study were activated during the test phase to aid target recall. This would demonstrate that even unrelated, extralist cues may activate studied cues and thus cannot provide an independent test of memory for target items.

However, there is an alternative explanation for the findings in Experiment 1. When a subset of the cues received additional study in the second study phase, their targets may also have been activated due to their association to the cue. Thus, for example, additional study of the cue *rope* may have led to activation of the target *sailing*. Target activation during the second study phase could have strengthened these items in memory and subsequently have facilitated target recall in the test phase. Thus, it is possible to explain the present results without the assumption that studied cues were used at retrieval. Rather, the target items themselves might have been strengthened.

To determine whether the facilitation effect might have been caused by activation and strengthening of the target items during study of the intralist cue, we reversed the order of the two study phases in Experiment 2. Thus, participants first rated a subset of the cues on pleasantness and frequency. After study of the cues they studied the cue-target pairs. Finally, the effect of additional cue study was tested with extralist cues. If target facilitation in Experiment 1 was caused by activation of the targets during cue study rather than by activation of the intralist cue during the test phase, no effect was expected in Experiment 2. This is because cue study occurred before study of the cue-target pairs. Activation of the targets during cue study is very unlikely, because the participants had not yet seen the targets. However, if target facilitation in Experiment 1 was caused by retrieval of the study cues during the test phase, these retrieved cues could in turn have activated the targets. Cues that received additional study were more accessible than cues that did not, leading to facilitation effects. If this was the case in Experiment 1, reversing the order of the two study phases would not moderate the facilitation effect. Thus, replication of the facilitation effect in Experiment 2 could provide direct evidence that study cues were activated in the test phase.

Table 1: *Recall Percentages of Experiment 1 and 2*

	Item type			
	Cue study items		**Control items**	
	M	*SD*	M	SD
Experiment 1	38.3	22.6	29.8	19.3
Experiment 2	55.0	21.3	44.8	21.2

Experiment 2

Method

Participants

The participants were 40 psychology students at Erasmus University Rotterdam. All were proficient speakers of Dutch and received course credit for their participation. None of the participants had participated in Experiment 1.

Materials, design and procedure

The materials, design and procedure were identical to Experiment 1, except that the order of the two study phases was reversed. In Experiment 2, participants first gave pleasantness and frequency ratings for a subset of the cues. Then, participants were presented with all cue-target pairs in the study phase. Finally, recall for the targets was tested in the test phase with extralist cues.

Results and discussion

Recall percentages in the test phase can be found in Table 1. Recall percentages for both item types were higher than in Experiment 1. This was expected, because the time lag between study of the cue-target pairs and the final memory test was shorter than in Experiment 1.

Again, there was a significant difference in recall between cue study items and control items: 10.2% (SD = 18.3), $t(39) = 3.52$, $p < .01$. Thus, providing pleasantness and frequency ratings of a cue *before* the cue-target pair was studied also facilitated recall of the target. This indicates that the facilitation effect must have been due to retrieval of the intralist cue during the test phase and not to strengthening of the target during study of the intralist cues. Because the study of the cue occurred before study of the cue-target pairs, participants could not have activated the targets when rating the cues in the cue study phase. Thus, retrieval of the target when the cue received additional study cannot have been the cause of the facilitation effect. It follows that the effect was caused in the test phase. When the extralist cues were presented, participants used the study cues as extra cues for the targets. Because the cues that received additional study were more accessible, recall of their targets was facilitated compared to targets of which the cue did not receive additional study.

General Discussion

Extralist cues have been used to differentiate between interference and inhibitory accounts of forgetting effects in the retrieval-practice paradigm and the think/no-think paradigm (e.g., Anderson et al., 2000; Anderson & Spellman, 1995). Because interference accounts do not predict forgetting for cues that have not been presented earlier in the experiment, forgetting effects found using extralist cues have been attributed to inhibitory processes. However, a number of studies have demonstrated that participants report covert cuing strategies involving the activation of intralist cues, even though they are cued with extralist items. Although the consequences of covert cuing have not been interpreted unequivocally, covert cuing can pose a problem for the independence of extralist cues. The present experiments explored more directly whether extralist cues can provide an independent test of memory for inhibited items.

In Experiment 1, additional study of cues from previously studied cue-target pairs resulted in facilitation of the targets on a later test using extralist cues. This demonstrates that target recall depends on the accessibility of the study cue at test, even though extralist cues are used that are expected to test the activation of the targets directly. Experiment 2 demonstrated that the facilitation effect was not caused by activation of the targets during cue study. Thus, the effect was caused in the test phase when the extralist cues were presented, providing further evidence that study cues were used at test to aid target recall.

The observed facilitation effect in both Experiments indicates that covert cuing can provide a recall advantage for those items of which the cue received additional study. At first sight, this may be seen as evidence that covert cuing in the retrieval practice paradigm leads to a recall advantage for non-cued items from practiced categories (e.g., SOUPS – *tomato* and SOUPS – *onion*) compared with control items in the test phase. When memory for these non-cued items is tested with extralist cues in the retrieval-practice paradigm (e.g., VEGETABLES), the studied categories may have been used as extra cue. Because the categories of non-cued items from practiced categories were more accessible due to the retrieval-practice phase, this advantage was greater for these items than for control items, thereby masking the forgetting effect.

However, it is unclear if this is the case. The current experiments did not employ an inhibition or interference paradigm, but merely focused on the effects of restudy of the cue. In the retrieval practice paradigm, however, the study cue is not just restudied in the retrieval-practice phase, but it is used primarily as a cue for a competitor. The strengthening of the association between the study cue and a competitor may lead to blocking of the target when the study cue is covertly cued in the test phase.

Thus, although the consequences of covert cuing are still unclear, covert cuing does provide a problem for the independence of extralist cues. The current experiments provide direct evidence for the occurrence of covert cuing when extralist cues are used at test. Although additional study is needed to specify the effects of covert cuing on the forgetting effect in inhibition paradigms, covert cuing can potentially weaken the effectiveness of the independent probe technique in differentiating between interference and inhibitory accounts of forgetting.

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Chapter 6

Summary and discussion

Let's suppose you are trying to remember the name of the professor that gave you a cognitive psychology class in your first year at university. This may turn out to be quite difficult, because you have had many other classes since then with different professors. There are different accounts of why this forgetting occurs. One explanation is that forgetting occurs because of interference when you are trying to retrieve the professor's name. Because you have had classes by many other professors, the cue *professor* has been associated to many other names and faces. These names and faces can interfere when you are trying to remember the name of your cognitive psychology professor. Thus, according to interference accounts, forgetting is caused by the addition or strengthening of competing items in memory (e.g., McGeoch, 1932, 1942; Raaijmakers & Shiffrin, 1981; Mensink & Raaijmakers, 1988).

A second account of why you are unable to remember the name of your old professor is inhibition. Over the years, there have probably been many occasions on which you retrieved the names of professors of more recent classes. During these retrieval attempts, the name of your old professor may have been activated and this may have given rise to retrieval competition. Because your old professor was not the name you were looking for, the name of your old professor may have been inhibited to make the correct name more available. Because of this inhibition, the name of your old professor may have become more difficult to retrieve at a later time. Thus, according to inhibitory accounts, forgetting is caused by the active suppression of memory items when these memory items compete with the appropriate response (e.g., Anderson, 2003; Anderson & Spellman, 1995; Levy & Anderson, 2002). In this view, forgetting is not a passive consequence of adding new information to memory, but it is an active process. People can exert inhibitory control over the activation of memory traces.

This is different from interference theories of forgetting, because in interference theories, no such control processes are hypothesized. In interference accounts, the addition or strengthening of competing memory traces is sufficient to decrease the likelihood that a particular memory trace is retrieved. A second difference between the two accounts is that in interference theories, forgetting critically depends on changes in relative strengths of associations to a specific cue (e.g., *professor*). Thus, forgetting is only predicted when memory is tested with this cue. In inhibitory accounts, however, the memory item itself is inhibited and forgetting is thus thought to be cue-independent. That is, forgetting should be found with any cue that tests the activation of the inhibited item.

A number of paradigms have been developed that investigate inhibitory processes in memory retrieval. One example is the retrieval practice paradigm. In this paradigm, participants study category exemplar pairs (e.g., FRUIT – *orange* and FRUIT – *banana*), followed by retrieval of a subset of the exemplars in a category cued word-stem completion task (e.g., FRUIT – *or*_____ for *orange*). Finally, memory is tested for all items. Memory impairment is found for unpracticed items from practiced categories (*banana*), compared with control items from categories that were studied but not practiced. This effect has been termed the retrieval-induced forgetting effect. The effect occurs when studied categories are used as cues to test memory for inhibited items (e.g., FRUIT), but also when extralist cues are used (e.g., YELLOW). The latter finding is seen as crucial evidence that inhibitory processes cause the effect, because interference accounts of retrieval-induced forgetting only predict forgetting when items are tested with the original study cue and not when extralist cues are used.

As outlined in the introduction of this thesis, a number of boundary conditions exist for inhibition as an explanation for forgetting. These boundary conditions are often related to specific properties of the to-be-forgotten experimental materials (e.g., similarity between items, integration of items) or procedures (e.g., transfer inappropriate testing effects, covert cuing). The present thesis investigated under specific circumstances whether the retrieval-induced forgetting effect occurred. The studies presented in the thesis attempted to clarify the scope of inhibitory processes in memory retrieval.

Summary of the main results

An important aspect of inhibitory accounts of forgetting is that the memory item itself is inhibited, rather than its relation to a cue. It follows that, in principle, forgetting should be found with any cue that tests the activation of the inhibited item. A particularly interesting type of memory test in this respect is the implicit memory test. Because participants do not know that their memory for studied items is being tested in truly implicit memory tests, these tests are not contaminated by retrieval strategies that participants may use when they know that they are being tested. In previous studies using implicit memory tests in the retrieval-practice paradigm, retrieval-induced forgetting was either not found, or no extralist cues were used (Butler, Williams, Zacks, & Maki, 2001; Perfect, Moulin, Conway, & Perry, 2002). Also, none of these studies measured if participants were aware that their memory for previously studied items was being tested (e.g., Veling & van Knippenberg, 2004). In the study in Chapter 2, a comparison was made between implicit and explicit memory tests. We investigated if retrieval-induced forgetting is found in implicit and explicit memory tests using extralist cues. Moreover, after the experiment using an implicit memory test, a questionnaire was administered that measured participants' test awareness. In Experiment 1, the retrieval-induced forgetting effect was replicated using extralist cues in an explicit memory test. In Experiment 2, an implicit memory test was used. Results showed that participants who were aware that their memory for studied items was being tested demonstrated retrieval-induced forgetting, but participants who were unaware did not. One explanation for these findings may be that aware participants engaged in retrieval strategies involving the use of studied categories as cues, thereby causing the forgetting effect through associative interference. Unaware participants could not have used these strategies, and thus showed no forgetting effect.

Interestingly, Anderson (2003) proposed a different explanation of why no retrieval-induced forgetting is found in some studies using implicit memory tests. Anderson argues that no forgetting is found with some implicit memory tests because they are perceptual in nature. That is, they provide a memory test for perceptual aspects of the memory items and not for semantic aspects. However, the type of representation that is typically inhibited by retrieval practice (e.g., FRUIT – *or*_____) is not *perceptual* but *conceptual* in nature. Thus, the conceptual representation of *banana* is inhibited after retrieval practice with *orange*, and not its perceptual representation. Thus, if the final memory test focuses on perceptual aspects of the memory item, no forgetting is found because of a mismatch between the representation that is inhibited and the representation that is tested. Most studies demonstrating retrieval-induced forgetting use conceptual memory tasks in all phases of the experiment. However, there is only one study demonstrating retrieval-induced forgetting using perceptual tasks in all phases of the experiment, and this study did not use independent cues (Ciranni & Shimamura, 1999). The study described in Chapter 3 tested whether retrieval-induced forgetting is found using perceptual memory tests with item-specific cues. In three experiments using different variations of perceptual memory tests, no retrieval-induced forgetting was found. These results limit the scope of inhibitory processes and indicate that transfer-inappropriate processing may not explain why forgetting is not found in implicit memory tests.

The study in Chapter 4 also concerned the generality of the retrieval-induced forgetting effect. A study by Johnson and Anderson (2004) demonstrated that retrieval practice with particular items (e.g., SEASONING – *nutmeg*) resulted in forgetting of unstudied items that belonged to the same category (e.g., *salt*) when tested with extralist cues (e.g., POPCORN – *s*_____). They concluded that inhibition also occurs for semantic knowledge. However, Perfect et al. (2004) showed that the retrieval-induced forgetting effect is context-specific and that it only occurs with episodic material when tested with episodic cues. The study in Chapter 4 tried to resolve this empirical ambiguity by using a design in which both episodic and semantic effects of retrieval practice could be assessed with item-specific extralist cues. Forgetting did not depend on whether items were studied or not. It did depend on whether memory was tested with extralist cues or studied cues: forgetting only occurred when memory was tested with studied cues, not with item-specific extralist cues. The results can be explained by inhibitory processes, but only if inhibition is seen as a context-specific process, limited to the direct context of the experiment. Moreover, interference accounts can also explain the data pattern, making it unclear if forgetting was caused by inhibition or interference.

Finally, in Chapter 5, we tested whether extralist cues are effective in differentiating between the contributions of inhibition and interference to the retrieval-induced forgetting effect. Forgetting with extralist cues is seen as evidence for inhibitory processes, because interference accounts only predict forgetting when memory is tested with studied categories. However, if extralist cues cannot provide an independent test of memory, this evidence may be less reliable. The study in Chapter 2 provides some evidence that participants may have used studied categories as extra cues in the test phase. Participants in Anderson, Green and McCulloch (2000) also report this covert cuing strategy. Although the effects of covert cuing have not been interpreted unequivocally, one possibility is that use of studied categories leads to associative blocking of unpracticed items from that category, thereby causing the forgetting effect (Camp, Pecher, & Schmidt, 2005; Perfect et al., 2004). The study in Chapter 5 tested the independence of extralist cues directly. In the first experiment, participants studied cue-target pairs (e.g., *rope* – *sailing*), followed by additional study of a subset of the cues (e.g., *rope*). Then, target memory was tested using item-specific extralist cues (e.g., SPORT for the item *sailing*). Presentation of a subset of the cues in the intervening task led to facilitation of their targets on the final memory test. This indicates that the cues that received additional study were activated in the test phase. A second experiment provided additional evidence for this claim. In the second experiment, the order of the study phase and additional cue study phase was reversed. Thus, any effects could only be caused by activation of the studied cues in the test phase, and not by activation of targets during the additional cue study. Again, a facilitation effect was found. These results indicate that extralist cues cannot provide an independent test of memory.

Discussion and conclusion

The results of the studies described in this thesis demonstrate a number of boundary conditions for inhibitory processes in memory retrieval. We were unable to replicate the retrieval-induced forgetting effect using implicit memory tasks in the study in Chapter 2, unless participants were aware of the fact that their memory for studied items was being tested. These results suggest that explicit retrieval strategies involving the use of studied categories as additional cues (covert cuing) play a role in causing the retrieval-induced forgetting effect. Additional support for this hypothesis was found in the study in Chapter 5, where it was shown that study cues are activated at test, even when memory is tested with extralist cues. Moreover, in the study in

Chapter 4, no forgetting was found when item-specific extralist cues were used. The use of extralist item-specific cues as opposed to extralist category cues may help to prevent covert cuing to a certain extent. Item-specific cues cue only one studied item, whereas extralist category cues cue more than one studied item. Thus, covert cuing strategies are more effective for extralist category cues than for extralist item-specific cues. This can explain why no forgetting was found with item-specific extralist cues in the study in Chapter 4, but forgetting *was* found in the study in Chapter 2 with extralist category cues (in Experiment 1 and for the aware participants in Experiment 2). Although Anderson interpreted covert cuing as a masking factor for inhibitory effects (Anderson, 2003; Anderson, Green, & McCulloch, 2000), the results of the studies presented in this thesis suggest that activation of studied categories may not mask the forgetting effect, but play a role in causing the forgetting effect.

It follows that the experimental technique that is used to differentiate between the contributions of interference and inhibition to the retrieval-induced forgetting effect may not be reliable. If covert cuing occurs when memory is tested with extralist cues, these cues cannot provide an independent memory test. The study in Chapter 5 provides direct evidence that this is the case. Thus, even in studies that use extralist cues in the test phase of the retrieval-practice paradigm, it is unclear what the contribution of inhibition and interference is to the forgetting effect. Moreover, it is important to mention that many studies using the retrieval-practice paradigm did not use extralist cues in the test phase in the first place (e.g., Anderson, Bjork, & Bjork, 1994, 2000; Anderson & McCulloch, 1999; Barnier, Hung, & Conway, 2004; Bauml, 2002; Bauml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; Shaw, Bjork, & Handal, 1995; Smith & Hunt, 2000; Wessel & Hauer, 2006).

The results also suggest that interference processes may play a greater role in retrieval-induced forgetting than is generally assumed. Interference processes may even, at least in part, be the cause of the retrieval-induced forgetting effect. As indicated above, the studies in Chapter 2, 4, and 5 provide evidence that covert cuing of studied categories occurs when extralist cues are used. This means that when the extralist cues appeared not to be very good cues for studied items (Tulving & Thomson, 1973), participants activated studied categories to help them find the appropriate response. When participants then used the studied categories as cues, the strengthening of practiced items (e.g., *orange*) in the previous task may have resulted in blocking of the recall of unpracticed items from the same category (e.g., *banana*), thereby causing the forgetting effect.

However, a number of other findings suggest that inhibition also plays a role in retrieval-induced forgetting. Anderson et al. (1994) found that strengthening of practiced items did not predict the magnitude of the retrieval-induced forgetting effect. Other studies demonstrated that the effect only occurs when the practiced item is retrieved and not when it is merely restudied (Anderson, Bjork, & Bjork, 2000; Ciranni & Shimamura, 1999). In both cases, strengthening of the association between cue and competitor should lead to reduced recall of the target, according to interference theories. Moreover, a number of studies have demonstrated retrieval-induced forgetting in item recognition tests (Hicks & Starns, 2004; Veling & van Knippenberg, 2004). Presenting the target without the category in these studies makes it difficult for interference processes to explain the forgetting effect.

Even so, the study in Chapter 4 demonstrates that, if inhibition occurs, it is limited to the episodic context of the experiment. It should be noted, however, that interference accounts such as blocking make the same predictions as context-specific inhibition and can also explain the data in Chapter 4. In fact, interference accounts can provide a better explanation for the occurrence of retrieval-induced forgetting for unstudied items when studied categories are used as cues.

An additional problem that complicates the theoretical interpretation of forgetting in the retrieval-practice paradigm is the sensitivity of the effect. Anderson (2003) describes a large number of factors that can moderate or mask the forgetting effect, many of which are addressed in this thesis. These include representational factors, such as integration and similarity, and test factors, such as output interference, transfer-inappropriate testing and covert cuing. These factors do not only indicate that the effect is found only under rather specific circumstances, they also make interpretation of null results very difficult. A failure to replicate the retrieval-induced forgetting effect in any experiment can easily be interpreted as a failure to take one or more of these moderating and masking factors into account, without having any theoretical implications.

In sum, the studies reported in this thesis indicate important boundary conditions for the role of inhibition in memory retrieval. They suggest that inhibition is limited to semantic, explicit memory tests and that it is a context-specific phenomenon. They also suggest that interference processes play a role in the retrieval-induced forgetting effect. This challenges the dominant view in the literature that retrieval-induced forgetting is a demonstration of retrieval inhibition. However, it appears to be quite difficult (if not impossible) to determine definitively what the role of interference and inhibition is in causing the retrieval-induced forgetting effect.

Suggestions for future research

Although the present thesis provides new insights into the scope of inhibition in forgetting and the processes underlying the retrieval-induced forgetting effect, a number of issues remain unresolved and require further investigation.

An important question future research should answer is what the role is of covert cuing in retrieval-induced forgetting. Anderson and colleagues (Anderson, 2003; Anderson, Green, & McCulloch, 2001) believe that covert cuing can mask inhibitory effects. They argue that the use of studied categories as additional cues in the test phase of the retrieval-practice paradigm can only help participants to remember studied items. Because practiced categories are more available than unpracticed categories, this would lead to a retrieval advantage for putatively inhibited items compared to control items, thereby masking the forgetting effect. This masking hypothesis is supported only by numerical differences in post hoc analyses in the amount of forgetting of participants that indicate high or low covert cuing on a post-experimental questionnaire. Our studies provide evidence for the contrary. The use of studied categories as additional cues may lead to associative blocking of unstudied items, which increases and may even cause the forgetting effect. Future research in which covert cuing is experimentally manipulated may provide more insight in the effect of covert cuing on the amount of forgetting.

A second question that future research should address is what the effect of retrieval-induced forgetting is in our daily lives, more specifically in education. Retrieval-induced forgetting has been successfully applied to a number of domains, including eyewitness memory (e.g., Saunders & MacLeod, 2002; Shaw, Bjork, & Handal, 1995), autobiographical memory (e.g., Barnier, Hung, & Conway, 2004; Wessel & Hauer, 2006), and personality traits (e.g., Dunn & Spellman, 2003; Macrae & MacLeod, 1999). However, there is no published research on the effect of retrieval-induced forgetting in an educational setting. It may be argued that particular study strategies may involve the practice and retrieval of a subset of the material related to a topic. This may lead to forgetting of other information related to the same topic. Testing students' knowledge in an exam can involve selective retrieval of certain aspects of the subject that is being tested, which may also lead to forgetting of related aspects. Thus, testing or restudying of particular aspects of to-be-learned information may have a detrimental effect on the memory for related information. If retrieval-induced forgetting effects are as large in an educational setting as in research with taxonomic categories, student may forget 10-15% of their knowledge by practicing related knowledge. This would have important implications for the design of education. Future research should investigate if this is the case. If retrieval-induced forgetting occurs in educational settings, research on retrieval-induced forgetting may also provide ways to prevent the forgetting effect in educational settings.

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Samenvatting

Stel je voor dat je je de naam probeert te herinneren van de docent die in het eerste jaar van je studie het vak cognitieve psychologie heeft gegeven. Dit zou best wel eens lastig kunnen blijken te zijn, omdat je sinds die tijd vele andere vakken hebt gehad die werden gegeven door allerlei andere docenten. Er bestaan verschillende verklaringen voor deze vorm van vergeten. Eén verklaring is dat vergeten optreedt vanwege interferentie tijdens het ophalen van de naam van de docent. Omdat je ondertussen veel vakken van andere docenten hebt gehad, is de term *docent* geassocieerd met vele andere namen en gezichten. Deze namen en gezichten kunnen zorgen voor interferentie wanneer je de naam van de bewuste docent probeert op te halen uit je geheugen. Volgens interferentietheorieën wordt vergeten veroorzaakt door het toevoegen of versterken van concurrerende items in het geheugen (bv., McGeoch, 1932, 1942; Raaijmakers & Shiffrin, 1981; Mensink & Raaijmakers, 1988).

Een tweede verklaring voor het vergeten van de naam van je docent is onderdrukking of inhibitie. Over de jaren heen zijn er waarschijnlijk meerdere gelegenheden geweest waarbij je je de namen moest herinneren van docenten van meer recente vakken. Tijdens deze pogingen om informatie op te halen uit het geheugen zou de naam van de cognitieve psychologie docent ook geactiveerd kunnen zijn geweest. Dit zou kunnen hebben geleid tot competitie tussen de verschillende namen van docenten. Omdat de naam van de cognitieve psychologie docent niet de naam was waar je naar op zoek was, is hij wellicht onderdrukt om de correcte naam meer beschikbaar te maken. Deze inhibitie zou ertoe kunnen leiden dat de naam van de cognitieve psychologiedocent later moeilijker op te halen is. Volgens de inhibitieverklaring is vergeten dus een gevolg van de actieve onderdrukking van items in het geheugen wanneer deze concurreren met de geschikte respons (bv., Anderson, 2003; Anderson & Spellman, 1995; Levy & Anderson, 2002). Vergeten is dus niet een passief gevolg van het toevoegen van informatie aan het geheugen, maar het is een actief proces. Volgens de inhibitietheorie hebben mensen controle over de activatie van items in het geheugen.

De inhibitieverklaring verschilt van interferentieverklaringen van vergeten, omdat dit soort controleprocessen daarin niet worden verondersteld. Volgens interferentietheorieën is het toevoegen of versterken van concurrerende geheugenitems voldoende om de kans te verkleinen dat een bepaald geheugenitem wordt opgehaald. Een tweede verschil tussen de twee verklaringen is dat volgens interferentietheorieën vergeten afhankelijk is van veranderingen in de relatieve associatiesterkte tussen geheugenitems en een bepaalde cue (bv., *docent*). Dat wil zeggen dat vergeten alleen zou moeten optreden wanneer het geheugen wordt getest met behulp van deze cue. Echter, volgens inhibitieverklaringen wordt het geheugenitem zelf onderdrukt en zou vergeten niet moeten afhangen van welke cue er wordt gebruikt. Vergeten zou gevonden moeten worden met elke cue die de activatie van het onderdrukte item test.

Een aantal paradigmata is ontwikkeld dat de rol van inhibitieprocessen bij het ophalen van geheugenitems onderzoekt. Eén voorbeeld is het zogenaamde *retrieval-practice* paradigma. In dit paradigma bestuderen proefpersonen woordparen bestaande uit een categorie en een exemplaar van deze categorie (bv., FRUIT – *sinaasappel* en FRUIT – *banaan*). Hierna moeten proefpersonen een deel van de voorbeelden van de categorieën ophalen uit het geheugen in een geheugentaak (bv., FRUIT – *sin*_____ voor *sinaasappel*). Tenslotte wordt het geheugen voor alle bestudeerde items getoetst in een testfase. De typische uitkomst is dat ongeoefende woorden van geoefende categorieën (bv., *banaan*) slechter worden herinnerd dan ongeoefende woorden van ongeoefende categorieën. Dit effect wordt ook wel het *retrieval-induced forgetting* (RIF) effect genoemd. Dit effect wordt niet alleen gevonden wanneer bestudeerde categorieën als cue worden gebruikt in de testfase (bv., FRUIT), maar ook wanneer onbestudeerde categorieën worden gebruikt (bv., GEEL, dit wordt een onafhankelijke cue genoemd). Deze laatste bevinding wordt als cruciaal bewijs gezien dat onderdrukkingsprocessen ten grondslag liggen aan het RIF-effect, omdat interferentieverklaringen alleen een RIF-effect voorspellen wanneer het geheugen wordt getest met de cue waarmee het item werd bestudeerd en niet met een cue die niet eerder voorkwam in het experiment en dus onafhankelijk is.

Zoals beschreven in de introductie van dit proefschrift, bestaat er een aantal condities waarin het effect niet wordt gevonden en die dus beperkingen opleggen aan inhibitie als een verklaring voor vergeten. Deze condities hebben vaak te maken met specifieke eigenschappen van het materiaal dat moet worden vergeten (bv., semantische gelijkenis tussen items, integratie van items) of met de experimentele procedures die worden gebruikt (bv., *transfer-inappropriate testing effects*, *covert cuing*). In dit proefschrift is onderzocht of het RIF-effect onder bepaalde omstandigheden optreedt. Daarmee is getracht de reikwijdte van inhibitieprocessen bij het ophalen van items uit het geheugen te verduidelijken.

Samenvatting van de belangrijkste bevindingen

Een belangrijk aspect van de inhibitieverklaring van vergeten is dat het geheugenitem zelf onderdrukt is, en niet de relatie tussen het item en een cue. Hieruit volgt dat, in principe, met elke geheugentest waarin de activatie van het geheugenitem wordt getest een RIF-effect zou moeten worden gevonden. In dit kader is de impliciete geheugentest bijzonder interessant. In een impliciete geheugentest zijn proefpersonen zich er niet van bewust dat hun geheugen voor bestudeerde items wordt getest. Daarom is dit type geheugentest niet ontvankelijk voor beïnvloeding door expliciete ophaalstrategieën die proefpersonen kunnen gebruiken wanneer ze wel weten dat hun geheugen wordt getest. In eerdere studies met impliciete taken in het *retrieval-*

practice paradigma werd er ofwel geen RIF-effect gevonden, ofwel werden er geen onafhankelijke cues gebruikt in de testfase van het experiment (Butler, Williams, Zacks, & Maki, 2001; Perfect, Moulin, Conway, & Perry, 2002). Daarnaast werd er niet gemeten of proefpersonen zich ervan bewust waren dat hun geheugen voor bestudeerde items werd getest (bv., Veling & van Knippenberg, 2004).

In de studie in Hoofdstuk 2 werd een vergelijking gemaakt tussen impliciete en expliciete geheugentests. We onderzochten of het RIF-effect optrad bij zowel impliciete als expliciete taken wanneer we gebruik maakten van onafhankelijke cues. Bovendien namen we na afloop van het experiment een vragenlijst af om te bepalen of de proefpersonen die de impliciete taak hadden gekregen doorhadden dat hun geheugen voor eerder bestudeerde woorden werd getest. In Experiment 1 werd het RIF-effect gerepliceerd in een expliciete geheugentaak met onafhankelijke cues. In Experiment 2 werd een impliciete geheugentaak gebruikt met onafhankelijke cues. De resultaten lieten zien dat proefpersonen die zich bewust waren van de het feit dat hun geheugen voor bestudeerde items werd getest het RIF-effect vertoonden. Proefpersonen die niet doorhadden dat hun geheugen voor bestudeerde items werd getoetst vertoonden echter geen RIF-effect. Een mogelijke verklaring voor deze bevindingen is dat ‘bewuste’ proefpersonen bepaalde ophaalstrategieën gebruikten in de testfase, waarbij ze de bestudeerde categorieën als cue gebruikten. In dat geval zou het RIF-effect kunnen zijn veroorzaakt door interferentie. ‘Onbewuste’ proefpersonen konden deze strategieën niet gebruiken, en vertoonden daarom geen RIF-effect.

Anderson (2003) geeft een andere verklaring voor het ontbreken van een RIF-effect in sommige studies met impliciete geheugentests. Anderson beargumenteert dat het effect niet is gevonden met sommige impliciete tests omdat deze tests perceptueel van aard waren. Dit wil zeggen dat deze tests het geheugen toetsten voor perceptuele aspecten van een geheugenitem, maar niet voor semantische aspecten van een geheugenitem. Het type representatie dat typisch wordt onderdrukt in experimenten met het *retrieval-practice* paradigma is niet *perceptueel* maar *conceptueel* van aard. De conceptuele representatie van *banaan* is onderdrukt na het ophalen van *sinaasappel*, maar niet de perceptuele representatie van *banaan*. Als de geheugentest in de testfase zich dus richt op perceptuele aspecten van een geheugenitem wordt geen RIF-effect gevonden, omdat er een discrepantie is tussen het type representatie dat wordt onderdrukt (de conceptuele representatie) en het type representatie dat wordt getest (de perceptuele representatie). De meeste studies die het RIF-effect laten zien gebruiken conceptuele taken in alle fases van het experiment. Er is daarentegen maar één studie die perceptuele taken gebruikt in alles fases van het experiment, maar deze studie gebruikt geen onafhankelijke cues (Ciranni & Shimamura, 1999). De studie die wordt beschreven in Hoofdstuk 3 testte of het RIF-effect optreedt wanneer itemspecifieke onafhankelijke cues worden gebruikt in perceptuele geheugentaken. In drie experimenten, waarin verschillende varianten van perceptuele taken werden gebruikt, werd geen RIF-effect gevonden. Deze resultaten beperken de reikwijdte van onderdrukkingsprocessen en geven aan dat verschillen in de aard van de taken binnen het experiment (perceptueel of conceptueel) niet kunnen verklaren waarom er geen RIF-effect wordt gevonden met impliciete geheugentaken.

De studie in Hoofdstuk 4 onderzocht eveneens de reikwijdte van het RIF-effect. Johnson en Anderson (2004) hebben laten zien dat het ophalen van bepaalde geheugenitems (bv., KRUIDEN – *nootmuskaat*) leidt tot het vergeten van onbestudeerde items van dezelfde categorie (bv., *zout*), wanneer deze worden getest met onafhankelijke cues (bv., POPCORN – *z*_____). Zij concludeerden dat inhibitie ook optreedt voor kennis die ligt buiten de directe context van het experiment (semantische kennis). Echter, Perfect en collega's (2004) lieten zien dat het RIF-effect juist contextspecifiek is en alleen optreedt voor materiaal dat is bestudeerd in de experimentele context (episodisch materiaal) wanneer het getest wordt met episodische cues.

In de studie in Hoofdstuk 4 is getracht deze empirische tegenstelling op te helderen door een design te gebruiken waarbij zowel episodische als semantische effecten konden worden onderzocht met onafhankelijke cues. De grootte van het RIF-effect bleek niet af te hangen van de studiestatus van het geteste item (bestudeerd binnen het experiment of onbestudeerd). Het RIF-effect hing wel af van het type cue dat werd gebruikt in de testfase (onafhankelijke cues of bestudeerde cues). Het effect trad namelijk alleen op als er getest werd met bestudeerde cues. Deze resultaten kunnen wel verklaard worden door inhibitieprocessen, maar alleen als inhibitie gezien wordt als een contextspecifiek proces dat beperkt is tot de directe context van het experiment. Bovendien kunnen interferentietheorieën ook het datapatroon verklaren, waardoor het onduidelijk blijft of het RIF-effect is veroorzaakt door interferentie of inhibitie.

Tenslotte hebben we in Hoofdstuk 5 onderzocht of onafhankelijke cues effectief kunnen differentiëren tussen de bijdragen van inhibitie en interferentie aan het RIF-effect. Als het RIF-effect wordt gevonden met onafhankelijke cues kan dat worden gezien als bewijs voor inhibitieprocessen, omdat interferentietheorieën het effect alleen voorspellen wanneer er bestudeerde (en dus afhankelijke) cues worden gebruikt. Echter, als onafhankelijke cues niet daadwerkelijk onafhankelijk zouden blijken te zijn, zou een dergelijke gevolgtrekking minder betrouwbaar zijn. De studie in Hoofdstuk 2 laat zien dat proefpersonen in de testfase wellicht gebruik maken van bestudeerde categorieën als extra cue, zelfs als ze worden getest met onafhankelijke cues. Proefpersonen in een studie van Anderson, Green en McCulloch (2000) rapporteren ook een dergelijke *covert cuing* strategie. De effecten van *covert cuing* worden door onderzoekers verschillend geïnterpreteerd. Eén mogelijkheid is dat het gebruik van bestudeerde categorieën leidt tot het blokkeren van het ophalen van ongeoefende items van de categorie (*associative blocking*), omdat de geoefende items zorgen voor interferentie (Camp, Pecher, & Schmidt, 2005; Perfect et al., 2004).

De studie in Hoofdstuk 5 testte de mate van onafhankelijkheid van onafhankelijke cues. In het eerste experiment bestudeerden proefpersonen *cue-target* paren (bv., *touw – zeilen*), gevolgd door extra studie van een deel van de cues (bv., *touw*). Daarna werd het geheugen getest voor de targets met itemspecifieke onafhankelijke cues (bv., SPORT voor het item *zeilen*). Het presenteren van een deel van de cues in de tussenliggende taak leidde tot betere herinnering van de bijbehorende targets in de geheugentaak. Dit geeft aan dat de cues die extra bestudeerd waren tijdens de tussenliggende taak werden geactiveerd in de testfase. Een tweede experiment gaf hiervoor aanvullend bewijs. In dit experiment werd de volgorde van de studiefase en de tussenliggende taak omgedraaid. Hierdoor kon elk effect in de testfase alleen gewijd worden aan de activatie van extra bestudeerde cues in de testfase en niet aan activatie van targets tijdens voorafgaande extra studie van de cues. Opnieuw werden meer targets herinnerd van cues die extra studie hadden gekregen. Deze resultaten geven aan dat het gebruik van onafhankelijke cues geen garantie is voor een onafhankelijke geheugentest.

Discussie en conclusie

De resultaten van de studies in dit proefschrift tonen een aantal beperkingen aan in de reikwijdte van inhibitieprocessen bij het ophalen van herinneringen uit het geheugen. We vonden geen RIF-effect met een impliciete geheugentest in Hoofdstuk 2, tenzij proefpersonen zich ervan bewust waren dat hun geheugen voor bestudeerde items werd getest. Dit suggereert dat expliciete ophaalstrategieën, waarbij gebruik wordt gemaakt van bestudeerde categorieën als extra cue (*covert cuing*), een rol spelen bij het veroorzaken van het RIF-effect. De studie in Hoofdstuk 5 biedt additionele ondersteuning voor deze hypothese. In deze studie werd aangetoond dat cues uit de studiefase ook in de testfase geactiveerd kunnen worden, zelfs wanneer er getest wordt met onafhankelijke cues. Bovendien werd in de studie in Hoofdstuk 4 geen RIF-effect gevonden met itemspecifieke onafhankelijke cues in de testfase van het experiment. Het gebruik van itemspecifieke onafhankelijke cues in plaats van onafhankelijke categoriecues kan helpen om *covert cuing* effecten tot op zekere hoogte te voorkomen. Itemspecifieke cues hebben namelijk op slechts één item betrekking, terwijl categoriecues vaak op meerdere items betrekking hebben. Daarom zijn *covert cuing* strategieën meer effectief bij categoriecues dan bij itemspecifieke cues. Deze redenering kan verklaren waarom geen RIF-effect werd gevonden met itemspecifieke cues in de studie in Hoofdstuk 4, en wel een RIF-effect werd gevonden met categoriecues in de studie in Hoofdstuk 2 (in Experiment 1 en voor de bewuste proefpersonen in Experiment 2). Hoewel Anderson *covert cuing* ziet als een strategie die het RIF-effect kan maskeren en doen verdwijnen (Anderson, 2003; Anderson, Green, & McCulloch, 2000), suggereren de resultaten van de studies in dit proefschrift dat activatie van bestudeerde categorieën het effect niet maskeert, maar juist zou kunnen veroorzaken.

Hieruit volgt dat de techniek die wordt gebruikt om te differentiëren tussen de bijdrages van interferentie en inhibitie aan het RIF-effect wellicht niet betrouwbaar is. Als *covert cuing* optreedt wanneer het geheugen wordt getest met onafhankelijke cues, kunnen deze cues geen onafhankelijke geheugentest bieden. De studie in Hoofdstuk 5 geeft direct bewijs dat dit inderdaad het geval is. Dit wil zeggen dat zelfs in studies die onafhankelijke cues gebruiken in het *retrieval-practice* paradigma het onduidelijk is wat de bijdrage is van inhibitie en interferentie aan het RIF-effect. Bovendien is het de moeite waard om te vermelden dat veel studies die gebruik maken van het *retrieval-practice* paradigma überhaupt geen onafhankelijke cues gebruiken in de testfase (bv., Anderson, Bjork, & Bjork, 1994, 2000; Anderson & McCulloch, 1999; Barnier, Hung, & Conway, 2004; Bauml, 2002; Bauml & Hartinger, 2002; Ciranni & Shimamura, 1999; MacLeod & Macrae, 2001; Shaw, Bjork, & Handal, 1995; Smith & Hunt, 2000; Wessel & Hauer, 2006).

De resultaten suggereren ook dat interferentieprocessen een grotere rol spelen in het veroorzaken van het RIF-effect dan algemeen wordt aangenomen. Zoals eerder aangegeven suggereren de studies in Hoofdstuk 2, 4 en 5 dat bestudeerde categorieën worden opgehaald in de testfase, zelfs als er onafhankelijke cues worden gebruikt. Voor proefpersonen bleken de onafhankelijke cues geen goede cues te zijn voor bestudeerde items (Tulving & Thomson, 1973) en daarom activeerden ze bestudeerde categorieën om hen te helpen de geschikte respons te vinden. Toen de proefpersonen de bestudeerde categorieën gebruikten, kan het versterken van geoefende items (bv., *sinaasappel*) in de vorige taak hebben geleid tot het blokkeren van de herinnering van ongeoefende items van dezelfde categorie (bv., *banaan*). Dit proces kan het RIF-effect hebben veroorzaakt.

Een aantal andere bevindingen in de literatuur suggereert echter dat inhibitieprocessen ook een rol spelen bij het RIF-effect. Anderson et al. (1994) vonden dat het versterken van geoefende items geen goede voorspeller was van de grootte van het effect. Andere studies hebben laten zien dat het effect alleen optreedt als het geoefende item opgehaald dient te worden uit het geheugen en niet als het item simpelweg nogmaals wordt aangeboden ter bestudering (Anderson, Bjork, & Bjork, 2000; Ciranni & Shimamura, 1999). In beide gevallen zou het versterken van de relatie tussen de categorie en het geoefende item moeten leiden tot verminderde herinnering van ongeoefende items volgens interferentietheorieën. Daarnaast heeft een aantal studies het RIF-effect aangetoond bij herkenningstests (Hicks & Starns, 2004; Veling & van Knippenberg, 2004). Interferentietheorieën kunnen deze resultaten moeilijk verklaren omdat de bestudeerde items zonder de categorie in de testfase van deze studies werden aangeboden.

Desalniettemin liet de studie in Hoofdstuk 4 zien dat, als er al inhibitie optreedt, het effect hiervan beperkt is tot de episodische context van het experiment. Bovendien doen interferentieverklaringen dezelfde voorspellingen als contextspecifieke inhibitieverklaringen en kunnen zij dus ook de data in Hoofdstuk 4 verklaren. Het is zelfs zo dat interferentietheorieën het gerapporteerde RIF-effect voor onbestudeerde items (wanneer er bestudeerde categorieën als cue worden gebruikt) beter kunnen verklaren.

Een additioneel probleem dat de theoretische interpretatie van RIF-effecten in het *retrieval-practice* paradigma bemoeilijkt, is de gevoeligheid van het effect. Anderson (2003) beschrijft een groot aantal factoren dat het effect kan modereren of maskeren, waarvan een aantal in dit proefschrift aan de orde komt. Hiertoe behoren factoren die te maken hebben met de manier waarop items gerepresenteerd zijn in het geheugen, zoals integratie en semantische gelijkenis tussen items. Hiertoe behoren ook testfactoren, zoals *output interference*, *transfer-inappropriate testing* en *covert cuing*. Het bestaan van deze factoren geeft niet alleen aan dat het effect alleen onder nogal specifieke omstandigheden wordt gevonden, maar het maakt ook de interpretatie van nuleffecten erg lastig. Het niet kunnen repliceren van het RIF-effect in een willekeurig experiment kan eenvoudigweg worden gezien als een gevolg van het niet controleren voor een van deze vele factoren, zonder dat het nuleffect enige theoretische implicaties heeft.

Kort samengevat geven de resultaten van de studies in dit proefschrift een aantal beperkingen aan in de reikwijdte van inhibitieprocessen bij het ophalen van herinneringen uit het geheugen. Ze suggereren dat inhibitieprocessen beperkt zijn tot semantische, expliciete geheugentests en dat inhibitie een contextspecifiek fenomeen is. De resultaten suggereren ook dat interferentieprocessen een rol spelen bij het RIF-effect. Dit is niet in overeenstemming met de dominante zienswijze in de literatuur, waarin het effect een demonstratie is van inhibitie. Toch lijkt het erg moeilijk (zoniet onmogelijk) om definitief vast te stellen wat de rol van interferentie en inhibitie is in het veroorzaken van het RIF-effect.

Suggesties voor toekomstig onderzoek

Hoewel dit proefschrift nieuwe inzichten biedt in de reikwijdte van inhibitie in vergeten en in de processen die ten grondslag liggen aan het RIF-effect, blijft een aantal vragen onbeantwoord.

Een belangrijke vraag die toekomstig onderzoek zou moeten beantwoorden is wat de rol is van *covert cuing* bij het RIF-effect. Anderson en collega's (Anderson, 2003; Anderson, Green, & McCulloch, 2000) menen dat *covert cuing* het effect van inhibitie kan maskeren. Zij argumenteren dat het gebruik van bestudeerde categorieën als additionele cues in de testfase van het *retrieval-practice* paradigma proefpersonen alleen maar kan helpen bij het zich herinneren van bestudeerde items. Omdat geoefende categorieën meer beschikbaar zijn dan ongeoefende categorieën, zou dit kunnen leiden tot een 'herinnervoordeel' voor items die mogelijk onderdrukt zijn vergeleken met controle items van ongeoefende categorieën. Hierdoor wordt het RIF-effect gemaskeerd. Deze maskeringhypothese wordt echter alleen ondersteund door numerieke verschillen in de grootte van het effect in post hoc analyses. Proefpersonen die aangeven op een postexperimentele vragenlijst dat ze veel *covert cuing* strategieën gebruiken vertonen een numeriek kleiner effect dan proefpersonen die aangeven dat ze weinig *covert cuing* strategieën gebruiken. Onze studies laten een tegengesteld patroon zien. Het gebruik van bestudeerde categorieën als extra cues kan leiden tot het blokkeren van de herinnering van ongeoefende items. Dit zou het RIF-effect kunnen vergroten of zelfs veroorzaken. Toekomstig onderzoek waarin *covert cuing* experimenteel wordt gemanipuleerd zou meer inzicht kunnen geven in het effect van *covert cuing* op de mate van vergeten.

Een tweede vraag die toekomstig onderzoek zou moeten beantwoorden is wat het RIF-effect voor gevolgen heeft in ons dagelijks leven, meer specifiek in het onderwijs. Het *retrieval-practice* paradigma is reeds succesvol toegepast op een aantal domeinen, waaronder het geheugen van ooggetuigen (bv., Saunders & MacLeod, 2002; Shaw, Bjork, & Handal, 1995), het autobiografisch geheugen (bv., Barnier, Hung, & Conway, 2004; Wessel & Hauer, 2006) en persoonlijkheidskenmerken (bv., Dunn & Spellman, 2003; Macrae & MacLeod, 1999). Er is echter nog geen gepubliceerd onderzoek dat de rol van *retrieval practice* onderzoekt in een onderwijssetting. Bepaalde studiestrategieën kunnen wellicht bestaan uit het ophalen van een deel van de recentelijk opgedane kennis op een bepaald gebied. Dit zou kunnen leiden tot het vergeten van de ongeoefende kennis op datzelfde gebied. Het toetsen van een bepaald onderwerp in een examen kan op zijn beurt leiden tot het selectief ophalen van bepaalde aspecten van dat onderwerp, wat ook zou kunnen leiden tot het vergeten van andere aspecten van het onderwerp die niet worden getoetst. Kort gezegd, het testen of herbestuderen van bepaalde aspecten van leerstof kan negatieve effecten hebben op het geheugen voor gerelateerde informatie. Als het RIF-effect in een onderwijssetting even groot zou zijn als het effect dat wordt gevonden met taxonomische categorieën, dan zouden studenten 10–15% van kun kennis kunnen vergeten door het oefenen met gerelateerde kennis. Dat zou grote gevolgen hebben voor de manier waarop onderwijs vorm zou moeten worden gegeven. Toekomstig onderzoek zal moeten uitwijzen of dit inderdaad het geval is. Als het RIF-effect optreedt in het onderwijs, dan zou onderzoek naar het effect ook methodes kunnen voortbrengen die het RIF-effect in het onderwijs zouden kunnen tegengaan.

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Dankwoord

Als eerste wil ik graag Henk Schmidt, mijn promotor, bedanken. Ik was pas een paar weken aio in Maastricht toen jij plots op mijn kamer stond met de mededeling “Ik heb goed nieuws en slecht nieuws”. Het slechte nieuws was dat je naar Rotterdam vertrok om een nieuwe psychologieopleiding op te zetten, het goede nieuws was dat ik daar ook een rol in mocht vervullen. Het werd een intensieve periode waar ik erg van heb genoten en ook veel van heb geleerd. Henk, bedankt voor je vertrouwen. Ik ben erg blij dat je me deze kans hebt geboden.

Ten tweede wil ik graag Diane Pecher, mijn co-promotor, bedanken. Onze onderzoeksbesprekingen heb ik als heel waardevol en inspirerend ervaren en ik heb veel geleerd van je kritische blik op onderzoek en je ervaring met experimenteren.

Ten derde wil ik graag alle collega’s bedanken die de pioniersjaren in Rotterdam tot een speciale tijd hebben gemaakt. Ik kan helaas niet iedereen persoonlijk bedanken, want dan zou de lijst met namen wel erg lang worden. Toch wil ik Eveline, Marja, Pascal (en Anne), Peter V., Remy, Wilco en de beide Henken speciaal bedanken voor de gezelligheid en *team spirit* in het M, J en T-gebouw. Ook wil ik graag de student-assistenten en stagiaires bedanken voor het draaien van een enorm aantal proefpersonen: Manon, Marijn, Nelly, Sander, Suzanne en Vera bedankt! Daarnaast wil ik Jeroen Raaijmakers en Emoke Jakab bedanken voor vruchtbare discussies over het *retrieval-practice* paradigma.

Tenslotte wil ik graag mijn familie en vrienden bedanken. *Vettige herders*, familie de Bruin, opa en oma’s bedankt voor de gezelligheid en vriendschap die het leven naast het proefschrift tot zo’n leuke tijd hebben gemaakt. Rico en Gertjan, ik vind het heel fijn dat jullie mijn paranimfen willen zijn. Lieve ouders, ik wil jullie speciaal bedanken voor de mogelijkheden en ruimte die jullie me hebben geboden. Als laatste wil ik Anique bedanken. We hebben deze prachtige tijd samen beleefd en afgesloten en onderweg vele hoogtepunten meegemaakt in Rotterdam en (ver) daarbuiten. Bedankt voor je steun en liefde. Ik weet zeker dat er nog veel meer hoogtepunten gaan volgen.

Curriculum Vitae

Gino Camp was born in Maastricht on September 28th, 1977. He completed secondary education in 1995 at the Stedelijke Scholengemeenschap Maastricht. In October 2000 he received a Master's degree in cognitive psychology at Maastricht University (cum laude). After a brief period as Ph. D. student at the Faculty of Psychology at Maastricht University, he accepted a position as assistant professor in psychology at the Erasmus University Rotterdam in 2001, where a new psychology curriculum was being constructed. There, he was involved in a number of educational tasks, including the development of training programs for staff and students in problem-based learning and a first year course on social psychology. These activities were combined with research on retrieval-induced forgetting, which resulted in the present dissertation.

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