

Remembering Can Cause Inhibition: Retrieval-Induced Inhibition as Cue Independent Process

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Previous experiments have mostly relied on recall as a dependent measure to assess whether retrieval of information from memory causes inhibition of related information. This study aimed to measure this inhibition in a more direct way. In Experiment 1, it was shown that repeated retrieval of exemplars from a category resulted in longer recognition latencies to nonretrieved exemplars from that same category, compared with recognition latencies to control exemplars. Experiment 2 obtained the same pattern of results using a lexical decision task. This was the 1st time that retrieval-induced forgetting was demonstrated on an implicit test of memory. To exclude noninhibitory explanations of the data, the exemplars were presented in both experiments without their categories as cues.

Remembering is a pervasive aspect of everyday life. Locating one's locker after a day in the swimming pool, doing grocery shopping for the weekend, or remembering the telephone number of an old friend all depend on our ability to retrieve specific information from memory. Paradoxically, recent research has shown that the act of remembering may cause forgetting (Anderson, Bjork, & Bjork, 1994). More specifically, retrieving information from a particular category (e.g., retrieving the phone number of an old friend) can induce forgetting of related information within that category (e.g., the phone number of a family member), compared with information about an independent category (e.g., one's groceries). This effect has been termed *retrieval-induced forgetting* (Anderson et al., 1994). Two experiments are reported that examine whether this forgetting (a) involves an inhibitory process and (b) is cue independent.

In the retrieval-induced forgetting paradigm, participants memorize category-exemplar pairs. After this study phase, participants perform retrieval practice on half of the exemplars of some of the studied categories. This procedure creates three types of exemplars: practiced exemplars (RP+ items), unpracticed exemplars from the practiced categories (RP- items), and unpracticed exemplars from the unpracticed categories (NRP items). After the retrieval practice, participants receive the categories as cues and are requested to recall as many exemplars as possible. An emerging literature on retrieval-induced forgetting has revealed that recall of RP- items is inferior to recall of NRP items. The explanation for this effect is that retrieving RP+ items in the retrieval practice phase inhibits access to competing exemplars from the same category (RP- items), thereby facilitating the search for the RP+ items. This inhibition of RP- items prevents these items from being retrieved in the cued-recall phase.

To exclude some noninhibitory explanations for this effect (see Anderson & Bjork, 1994), Anderson and Spellman (1995) adopted the same paradigm as previously described but used categories that had overlapping subcategories. They showed that retrieval practice of particular exemplars impaired recall of all competing exemplars even when these exemplars were cued in the recall phase under a different category. This cue independence excluded some noninhibitory accounts of retrieval-induced forgetting, and Anderson and Spellman concluded that retrieval-induced forgetting was an inhibitory process.

However, as Perfect, Moulin, Conway, and Perry (2002) have noted, recall may not be the most suitable measure to assess whether retrieval-induced forgetting is an inhibitory process. The most unambiguous definition of inhibition would describe it as a reduction in the level of activation of a memory representation (Perfect et al., 2002). On the basis of this definition, one cannot directly demonstrate inhibition by means of recall data. For instance, it is conceivable that the impaired recall of RP- items results from a specific retrieval process, independent of a possible reduction of the activation level of RP- items.¹

One way to measure inhibition directly may be achieved by using a reaction time paradigm in which participants are instructed to react as quickly as possible to the presented items. Presenting participants with the items themselves would preempt the active retrieval process, and the resulting response latencies would be more directly indicative of the activation level of the items. To our knowledge, there is only one published experiment that adopted such a procedure. In this experiment (Perfect et al., 2002; Experiment 5), participants verified as quickly as possible whether certain category-exemplar pairs were originally presented in the study phase. Their results showed that participants were reliably slower in reacting to RP- items than in reacting to either RP+ or NRP items (Perfect et al., 2002). However, the inclusion of the category in the recognition phase constitutes a problem here. It is conceivable that the presentation of a category automatically trig-

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¹ For a similar argument, see Bjork and Bjork (1996), who, in the context of directed forgetting, distinguished retrieval inhibition from a reduction in the strength of a memory representation.

gers the activation of RP+ items, because RP+ items were repeatedly activated in connection with their category during the retrieval practice phase. It is possible that whenever a category cue and RP- item are presented simultaneously, RP+ items are spontaneously activated and block RP- items from immediate recognition. A truly inhibitory account of retrieval-induced forgetting should be based on measures that tap inhibited access as directly as possible and without any category cues present. This is what we aimed to do in the experiments reported below.

Experiment 1

The aim of our first experiment was twofold. First, we aimed to replicate the findings of Perfect et al. (2002) by showing that retrieval-induced forgetting can be obtained using recognition latencies. Second, we aimed to extend the findings of Perfect et al. by not using the categories as cues in the recognition phase. This would exclude the alternative explanation for the Perfect et al. Experiment 5 results described above. We expected that participants would be slower to react to the RP- items than to either the RP+ or NRP items.

Method

Participants. Fifty-four undergraduate students at the University of Nijmegen participated in Experiment 1 in exchange for €1 (approximately U.S.\$1.15).

Stimuli. Three categories (fruits, sports, and animals), each comprising six exemplars, were constructed for Experiment 1. These category-exemplar pairs were selected from a recent study on category norms in which Dutch category-exemplar pairs were generated (Storms, 2001).² The exemplars were selected from this sample so that the two most frequently occurring exemplars per category were excluded from the stimulus set. Furthermore each exemplar had a unique two-letter word stem. The fillers for the recognition task were selected in such a way that they could not be interpreted as belonging to one of the experimental categories.

Procedure. Participants were tested in individual cubicles. They read at their own pace through the instructions presented on a computer screen. In the first phase, participants were asked to study word pairs that belonged to one of three categories: fruits, sports, or animals. They were informed that they would have to retrieve those word pairs later in the experiment. The category-exemplar pairs were presented for 5 s in a rectangle that was displayed in the center of the computer screen. The categories were presented in capitals and were separated by a dash from the exemplars, which were presented in lowercase letters (e.g., FRUIT - strawberry). Between presentations, there was a 1-s interval. The category-exemplar pairs of each category were presented as a block. The order in which these blocks were presented, and the presentation of the exemplars within each block were randomized. Before each block, participants were informed about the category to be presented.

Immediately after the study phase, participants were informed that they would receive category cues followed by the first two letters of corresponding exemplars from the study phase. The categories were presented in capitals and were separated by a dash from the word stems, which were presented in lowercase letters (e.g., FRUIT- st—). Category-word stem combinations were displayed one at a time. The participants' task was simply to complete the word stems by typing in the corresponding exemplars below the category-word stem combinations. In this retrieval practice phase, each participant was presented with six different category-word stem combinations, which were presented three times in three blocks of six trials. Within each block, every combination was presented once in a random order. Participants always practiced six exemplars, three exemplars of two different categories. This way, the number of RP+, RP-, and NRP items was always six. To ensure that every exemplar would function as an

RP+, RP-, and NRP item, six sets were constructed counterbalancing exemplars across item types.

After the retrieval practice phase, participants were informed that words would be presented in the middle of the computer screen. These words would be either new or taken from the study phase. The presentation of the words on the screen was preceded by an asterisk. After a random interval of between 1.5 and 2 s, the asterisk was replaced by a word, and participants had to indicate as quickly and accurately as possible whether this word had been presented in the study phase. They could do so by pressing the left button (the *a*) when a new word was presented and the right button (the *o*) when a word from the study phase was presented, on a QWERTY keyboard. The stimulus words disappeared from the screen immediately after the participant's response. The intertrial interval was 1 s.

The recognition task included 36 trials, 18 new words and the 18 exemplars from the study phase. Two orders of stimulus presentation (new words, studied words) were constructed to prevent the same response from occurring more than two times in a row. Within these two orders, the stimuli were randomly selected. One of these orders was randomly selected between participants.

Results and Discussion

An average recall rate of 99.1% in the retrieval practice phase indicated that the participants were very successful in retrieving the exemplars.

The analyses of both Experiments 1 and 2 were computed on the participants' median reaction latencies with the exclusion of error trials.³ First, we performed a single-factor (item type: RP+, RP-, or NRP) within-subjects analysis of variance (ANOVA) to assess whether retrieval-induced forgetting on recognition times had occurred. The main effect of item type was reliable, $F(2, 106) = 22.13, p < .05$. Simple effects tests revealed that participants were reliably quicker at indicating that RP+ items had been presented ($M = 678$ ms, $SEM = 112$) than indicating that NRP items had been presented ($M = 759$ ms, $SEM = 118$), $F(1, 53) = 15.76, p < .05$. More important, however, RP- items had reliably longer recognition latencies ($M = 810$ ms, $SEM = 158$) than did NRP items, $F(1, 53) = 5.02, p < .05$. Finally, participants had longer reaction latencies on RP- items than on RP+ items, $F(1, 53) = 65.66, p < .05$.

We replicated the retrieval-induced forgetting effect in this experiment using a recognition test: Participants were slower in recognizing RP- items relative to recognizing NRP items. In addition, it was shown that this effect was obtained without presenting the categories as cues in the recognition phase, thus supporting a cue independent account of retrieval-induced forgetting.

However, there may still be one alternative interpretation. Theoretically it could well be that participants, when verifying whether they had seen a particular exemplar, retrieved the category to facilitate their response. The fact that we selected filler items that did not belong to the experimental categories might even have fostered the use of the categories as peripheral cues in the recognition process. Because the categories are strongly linked to the RP+ items in the retrieval practice phase, it could be that exposure to RP- items also activated RP+ items. This activation of RP+ items could have interfered with the recognition of RP- items,

² All stimuli can be obtained from Harm Veling.

³ Using means with a cut-off criterion of either 2 s or 3 s as data instead of medians led to similar results compared with the median reaction latencies in both Experiments 1 and 2.

resulting in slower responses to RP– items. Note that this interpretation would argue against an inhibitory explanation. We therefore conducted a second experiment in which interference from spontaneous category activation was extremely implausible.

Experiment 2

The main goal of Experiment 2 was to examine whether retrieval-induced forgetting could be found in an implicit test of memory. This would be important for two reasons. First, it would rule out the alternative interpretation of the results of Experiment 1 and show that retrieval-induced forgetting is really cue independent. Second, by ruling out competitive RP+ retrieval as a potential causal factor, we would have a strong case for arguing that retrieval-induced forgetting is indeed an inhibitory process. The first two phases of Experiment 2 were similar to Experiment 1. The third phase in Experiment 2, the implicit memory test, was a lexical decision task. We expected that participants would be slower to indicate that exemplars of RP– items were words than exemplars of either RP+ or NRP items. The lexical decision task seemed suitable for our present purpose, because it did not require any activation of the categories of the previously studied categories, nor did it involve an active retrieval process of the RP+, RP–, and NRP items.

Method

Participants. Thirty-nine undergraduate students at the University of Nijmegen participated in Experiment 2 in exchange for €1.

Stimuli. In Experiment 2, we used 12 categories, each containing two exemplars. Nine of these categories were selected as experimental categories, and 3 of them were selected as filler categories. These category-exemplar pairs were again selected from the sample of Storms (2001). Within each category, exemplars were matched for word frequency and word length. In addition, each exemplar had a unique two-letter word stem.

There were two types of fillers used in the lexical decision task. First, there were 18 words that did not belong to any of the categories. These were included to separate the experimental exemplars by at least three trials. Second, we used 36 pronounceable letter strings, which were not part of the Dutch vocabulary (i.e., nonwords). Word length of those letter strings was matched to the length of the experimental exemplar words.

Procedure. The procedure of the first two phases of Experiment 2 was virtually identical to the procedure of the first two phases of Experiment 1. Only deviations from this procedure are mentioned. First, the category names were not presented on the instruction screen of the study phase. Second, the experimental category-exemplar pairs were presented in two blocks of nine presentations. The allocation of category-exemplar pairs to the blocks was randomized, with the restriction that each category appeared only once within a block. Before, between, and after these two experimental blocks, two category-exemplar pairs were presented as fillers to prevent the occurrence of primacy and recency effects and to separate the presentation of exemplars of the same category by at least three trials. This last measure was taken to reduce opportunities for association among exemplars. In the retrieval practice phase, participants practiced six exemplars of six different categories. This way, the number of RP+, RP–, and NRP items was always six. Six sets were constructed, counterbalancing exemplars among item types.

Following the retrieval practice, participants were presented with a lexical decision task. They were instructed to indicate as quickly and as accurately as possible whether a letter string, presented in the middle of the computer screen, was a word. Participants were instructed to press the left button (the *a*) when a nonword was presented and the right button (the *o*) when a word was presented, on a QWERTY keyboard. An asterisk that indicated the spot where the letter string would appear preceded the presentation of the letter strings. After a random interval of between 1.5 and 2 s, a letter string replaced this

asterisk. After a participant's response, the letter string disappeared from the screen immediately. The intertrial interval was 1.5 s.

Before the actual test block, a practice block of six filler trials was presented, in which three words and three nonwords were presented in a random order. This practice block was followed by the lexical decision task, which consisted of 72 trials, including 18 exemplars from the first phase, 18 new filler words, and 36 nonwords. Two orders of stimulus presentation (exemplars, fillers, and nonwords) were constructed on the basis of two criteria. First, the same response (word or nonword) was not allowed to occur more than three times in a row. Second, when the same response occurred three times in a row, it was never followed by an exemplar from the first phase of the experiment. Within these two orders, the stimuli were randomly selected. One of these orders was randomly selected between participants.

Results and Discussion

An average recall rate of 96.0% in the retrieval practice phase indicated that the participants were very successful in retrieving the exemplars. First, we performed a single-factor (item type: RP+, RP–, or NRP) within-subjects ANOVA on the participants' median reaction times to assess whether retrieval-induced forgetting on lexical decision times had occurred. The main effect of item type was reliable, $F(2, 76) = 4.28, p < .05$. Simple effects tests revealed that this effect was due to longer reaction times to the RP– items ($M = 574$ ms, $SEM = 61$) compared with both NRP items ($M = 542$ ms, $SEM = 48$) and RP+ items ($M = 542$ ms, $SEM = 48$), respective comparisons $F(1, 38) = 6.42, p < .05$, and $F(1, 38) = 5.90, p < .05$.

The results of Experiment 2 show that participants were slower in deciding that RP– items are words compared with both RP+ items and NRP items, thereby showing retrieval-induced forgetting on an implicit test of memory. Actually, *forgetting* is not an appropriate term to describe the results of Experiment 2. Our dependent measure, the lexical decision latencies, taps into word accessibility rather than explicit retrieval and may therefore be argued to be more directly indicative of inhibition effects. A more appropriate label for the effect obtained in Experiment 2 would therefore be *retrieval-induced inhibition*.

A second important finding of Experiment 2 is that this retrieval-induced inhibition is cue independent. We presented the exemplars of the RP+, RP–, and NRP items in the lexical decision task without their categories and obtained slowest responses to the RP– items. Theoretically, one could still argue that the participants might have spontaneously retrieved the categories when presented with these exemplars, but this was highly unlikely for two reasons. First, it is hard to see how retrieving categories of exemplars would be helpful in deciding whether a letter string is a word. Second, the use of many (nine) experimental categories in Experiment 2 reduces the likelihood of spontaneous category activation. Therefore the results of Experiment 2 provide strong evidence that retrieval-induced inhibition is indeed cue independent.

Unlike in Experiment 1, we did not find a reliable difference between the RP+ and NRP items in Experiment 2. This seeming inconsistency may be explained by comparing the respective dependent variables. As a result of retrieval practice, participants may have become more confident (and hence faster) in deciding that they did see an RP+ word before, compared with the NRP words in Experiment 1. In Experiment 2, however, the participants' task was simply to indicate whether the stimulus was a word. Of course, recent repeated retrieval may enhance accessi-

bility, but considering that all study words were shown before at least once, any additional enhanced accessibility effect on the basis of repeated exposure (one vs. four times) would be of minor magnitude and unlikely to be detected in lexical decisions.

General Discussion

Two experiments provided suggestive evidence that retrieval of exemplars from a category leads to a reduction in the activation level of unpracticed exemplars from the same category. In addition, we demonstrated retrieval-induced inhibition in tasks in which exemplars of the experimental categories are presented without category cues. Although this cue independence may be subject to an alternative explanation in Experiment 1, the results of Experiment 2 were more unequivocal: Exemplars are inhibited by prior retrieval of related exemplars, even outside the context of their shared category membership. As mentioned earlier, this is important because it further reduces the plausibility of a noninhibitory account of our data.

The fact that we observed retrieval-induced inhibition even when participants were presented with the exemplars may seem contradictory to earlier research (Butler, Williams, Zacks, & Maki, 2001; Perfect et al., 2002) that did not always find retrieval-induced forgetting when participants were presented with item-specific cues (but see Anderson et al., 1994). The crucial difference between these earlier studies and the present studies is that we used reaction latencies. When (part of) an item is presented, a delayed response latency is a more adequate indicator of inhibition than failure to retrieve, because inhibition may be gradually released when item-specific cues are presented (see also Bjork & Bjork, 1996).

The experiments reported here are not the first to claim that an inhibitory process underlies retrieval-induced forgetting (e.g., Anderson & Spellman, 1995). However, previous experiments have relied

on recall as a dependent measure to assess inhibition. Starting from the definition of inhibition as reduced activation level, we aimed to demonstrate inhibition effects in a more direct way. Adding our direct evidence to earlier indirect evidence considerably strengthens the case for an inhibitory account of retrieval-induced forgetting.

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