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Episodic Inhibition

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Six experiments examined the proposal that an item of long-term knowledge can be simultaneously inhibited and activated. In 2 directed forgetting experiments items to-be-forgotten were found to be inhibited in list-cued recall but activated in lexical decision tasks. In 3 retrieval practice experiments, unpracticed items from practiced categories were found to be inhibited in category-cued recall but were primed in lexical decision. If, however, the primes and targets in lexical decision were taken directly from the study list, inhibition was observed. Finally, it was found that when items highly associated with a study list were processed in between study and test, no inhibition in recall was present. These, and a broad range of other findings, can be explained by the concept of "episodic inhibition," which proposes that episodic memories retain copies of semantic knowledge structures that preserve patterns of activation/inhibition originally generated in those structures during encoding.

Keywords: inhibition, retrieval, practice, cued recall, lexical decision, forgetting

An emerging and important finding in the study of inhibitory processes in human memory is that manipulations that apparently induce inhibition in explicit remembering do not have the same effect when memory is assessed implicitly. This was originally observed by Bjork and Bjork (1996, but see also Basden, Basden, & Gargano, 1993), who conducted a list-method directed-forgetting experiment in which participants were instructed to forget the first list learned (TBF items) prior to learning a to-be-remembered (TBR) second list. In a novel manipulation, a word fragment completion test, which included TBF and TBR items, was interposed between study and free recall. Although a standard directed forgetting effect was observed in free recall, there was no directed forgetting effect in word fragment completion. In order to explain this unusual finding, Bjork and Bjork (1996) suggested that the word fragment completion test could be completed by accessing long-term memory conceptual/semantic or lexical representations of the to-be-completed word fragments. Because there was no directed forgetting effect in word fragment completion, it follows that if word fragments were completed by accessing conceptual/lexical representations, then no inhibition would have been present in those representations and, hence, there would be no effect of the directed forgetting instruction in fragment completion. In contrast, the free-recall test explicitly requires access of a memory of the episode in which the word lists were learned. However, the episodic memory of the TBF list is inhibited by the forget instruction and consequently cannot be easily accessed, leading to impaired memory performance. According to Bjork and Bjork (1996), "the inhibition involved in the directed-forgetting situation appears to be a type of retrieval inhibition that impairs conscious access to the original learning episodes" (p. 192). In the experiments below, we systematically explore retrieval inhibition in directed forgetting and retrieval-induced forgetting experiments using both explicit and implicit tests of memory. First, however, we introduce a modification to the notion of retrieval inhibition.

Retrieval inhibition proposes that episodic memories are inhibited. A slightly different version of this is that rather than memories being inhibited it is their contents that are inhibited. It is, after all, the case that at least some items from the TBF list are always recalled, and no one forgets that there were in fact two lists—even patients with quite severe brain damage show this pattern (Conway & Fthenaki, 2003). It is not then as though the TBF list has been rendered wholly inaccessible and, given that it can be accessed apparently completely normally in a recognition rather than a free-recall test (see, e.g., Conway, Harries, Noyes, Racsmány, & Frankish, 2000), its accessibility is clearly not severely compromised. Instead, we suggest that the effect of a forget instruction on an episodic memory of a list of items recently and normally acquired is to impose a pattern of activation/inhibition over the contents or features of the memory. In order to distinguish this view from that of retrieval inhibition we refer to it here as *episodic inhibition*. Episodic inhibition emphasizes the idea that for every episodic memory there is a pattern of activation/inhibition over the contents of the memory, and this strongly influences access to specific features of the content, that is, representations of words in a memory of a recently acquired word list. The pattern of activation/inhibition over the features of an episodic memory initially

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reflects processing that occurred during encoding but can be changed by subsequent access of the memory and processing of its content. Later we show how this concept of episodic inhibition might be used to provide a common basis for understanding attenuation of memory in directed forgetting and retrieval practice.

One implication of the notion of episodic inhibition, which derives from Bjork and Bjork (1996) and which we also emphasize here, is that the effect of inhibition on the contents of episodic memories is long lasting. In contrast, the effects of inhibition on other types of long-term knowledge representations may be less enduring and more transitory (see Neely, 1991, for a review). Thus, for example, patterns of activation/inhibition over conceptual, lexical, and perhaps other types of representations, generated for example while words on a list are read, will dissipate in periods measured in seconds and milliseconds. Because these patterns of activation/inhibition are rapidly changing they are unlikely to influence performance on a memory test given some time (often minutes) later. In contrast, it is suggested that representations of items in episodic memories, which are themselves derived from conceptual, lexical, and other types of processing present during encoding, maintain the patterns of activation/inhibition that characterized the epoch an episodic memory represents, (cf. Conway, 2001). Indeed, one possibility is that the patterns of activation/inhibition present over features in an episodic memory will remain unchanged until the contents of the memory are accessed and subjected to further processing (see MacLeod & MaCrae, 2001, for highly relevant findings, and Tipper, 2001, and Tipper, Grison, & Kessler, 2003, for related findings from the study of attention).

Our account of episodic inhibition makes a strong claim, namely, that the same representation (item) can be processed independently according to whether it is accessed in conceptual, lexical, or other knowledge structures or in an episodic memory (see too Perfect, Moulin, Conway, & Perry, 2002). An episodic memory, however, preserves a pattern of activation/inhibition from a previous processing episode whereas other knowledge structures, in which the original pattern of activation/inhibition was first established, do not. According to this reasoning a particular pattern of activation/inhibition will be detected when an episodic memory of an item is accessed. However, when a conceptual, lexical, or other representation of the *same* item is accessed, a different pattern of activation/inhibition will be observed. A representation may then be both inhibited (in an episodic memory) while being noninhibited or even activated in conceptual, lexical, or other knowledge structures. It is this prediction of episodic inhibition that is the main focus of the series of experiments reported below, which investigate the phenomenon first in directed forgetting (Experiments 1 and 2), next in retrieval practice (Experiments 3 through 5), and finally in a novel study suggested by the earlier experiments (Experiment 6).

Experiment 1

The present experiment and Experiment 2 both used a directed forgetting by lists procedure. In this procedure participants learn a list of words. Halfway through the list they receive a mid-list instruction. For half the participants—the F group—this is an instruction to forget the words they have learned thus far and instead to concentrate on the upcoming words, which will have to be recalled. The other half—the R group—are instructed to keep remembering the words they have just studied and to learn the next set of words that will have to be recalled. In this procedure the directed forgetting effect consists of poorer recall for List 1 by the F group relative to their List 2 performance and to the performance of the R group for List 1 (see Conway et al., 2000, for further discussion of this particular pattern of directed forgetting). One current view is that the directed forgetting effect (at least in the lists method) is due to inhibition of the List 1 TBF items in the F group triggered by the intention to forget and by learning List 2 (Bjork, 1989; Bjork, Bjork, & Anderson, 1998; Conway et al., 2000). Other accounts in terms of, for instance, selective rehearsal have not received empirical support (Geiselman, Bjork, & Fishman, 1983; Geiselman, & Bagheri, 1985) and it is also acknowledged that the inhibitory account may not extend to other forms of directed forgetting, that is, by items rather than by lists (see Basden & Basden, 1998, and MacLeod, 1998, for reviews).

The novel procedure introduced here is to interpose an apparently unrelated lexical decision test between study and test. This is a test that includes all items from the study phase in the context of new nonstudied filler words and a matching set of nonwords. A clear prediction of the episodic inhibition view detailed earlier is that performance decrements should be present for F group List 1 items in free recall, but these may not necessarily be present for the same items in lexical decision times. Indeed, episodic inhibition predicts that performance decrements of inhibited List 1 items will only be present if the lexical-decision task is mediated by an F group episodic memory of List 1. If, however, lexical decisions are mediated by lexical and conceptual representations of List 1 items, which do not themselves preserve the inhibition induced by the directed forgetting procedure, then no slowing of lexical decision times should be observed. There is some evidence both in support of this prediction and against it. Against the prediction are findings by MacLeod (1989; see also Fleck, Berch, Shear, & Strakowski, 2001) showing that lexical decision times were slowed for F items in an item-by-item directed forgetting procedure, that is, when the F and R instructions followed presentation of each individual word. However, as directed forgetting effects in item-by-item procedures are thought to reflect changes in rehearsal strategies rather than inhibitory processes (Basden & Basden, 1996), there is no reason why episodic inhibition should provide an account of these particular effects. In contrast, experiments involving the list-directed forgetting procedure have revealed that on a range of implicit tasks (none of which were lexical decision tasks) interposed between study and test, there are often no effects of directed forgetting despite a reliable effect in free recall (Bjork & Bjork, 1996; Perfect et al., 2002). It is this pattern that is predicted by episodic inhibition and that is assessed in the present experiment.

Method

Participants. The participants were 32 undergraduate Hungarian students from the University of Szeged, who participated in return for partial credit in a lower division psychology course. Their age varied between 18 and 24 years. There were 20 women and 12 men

Procedure. Participants were tested individually and were informed that they were participating in an experiment on memory that would test their ability to recall words. The experiment was conducted in four phases: a list learning phase, a distractor phase, a lexical decision phase, and a free-recall phase. Words were presented visually on a computer screen. Each word was displayed for 2 s with a 2-s inter-item interval. After the words of the first list (12 words) had been presented, participants were instructed to stop. At this point, participants in the F group were given the forget instruction and those in the R group were given the R instruction. For the F instruction, the experimenter gave spoken instruction that the previous presentations had been a practice list to familiarize the participants with the method and stimuli and that they should now forget the words they had just studied, put them out of mind, and concentrate on the upcoming experimental list, which they would have to remember. For the remember instruction, also spoken, R-group participants were informed that they had now completed studying a first list, and this was to be followed by a second list that also had to be remembered later in the experiment. Allocation to groups was random. After all words had been studied, participants were given a 5-min arithmetic distractor task. The distractor task was followed by a lexical-decision task. The experimental lists were randomly selected from four study lists, each of which contained 12 high-frequency words naming common objects (see Racsmány, 2003, for the full lists).

The design of the lexical-decision task was the same as that used by MacLeod, (1989). There were 15 practice trials, made up of seven words and eight nonwords not included in the experimental sets. Each trial began with a 250-ms warning ****, followed by a 250-ms blank period prior to the item. Each item was presented in uppercase letters at the center of the screen either until the participant pressed a key to indicate the chosen response or for a maximum of 2 s. There was a 250-ms blank period before the next warning stimulus. The 96 experimental trials were made up of 24 studied words (List 1 and List 2 words), 24 unstudied words, and 48 nonwords. Participants were encouraged to respond as rapidly as possible and at the same time to avoid errors. After the lexical-decision task was completed, participants took part in a free-recall task. For this, they were given a sheet of paper and were instructed to try to recall any words they could first from the first list, then from the second list. The forced order of recall served to eliminate output interference from the second list.

Results and Discussion

Lexical-decision task. There were fewer than 1% errors and most participants made no errors. There was no systematic distribution of errors to conditions and the few errors were, for the purposes of analysis, replaced by the mean for that participant in that condition. We conducted a 2 (group) × 3 (words) mixed analysis of variance (ANOVA) on the reaction time data; the reaction times of nonword items were not included in the analyses because they were not pertinent to the predictions. The main effect of group was not significant ($F < 1$), whereas the main effect of words was significant $F(1, 60) = 18.20$, $p < .01$. Studied words were reliably responded to more quickly than unstudied words (see Table 1), and there was no significant Group × Words interaction, $F(1, 60) = 0.98$, $p > .10$. Planned comparisons between F-group Lists 1 and 2, and between F-group List 1 and R-group List 1, showed no reliable differences.

Free-recall performance. The main effect of group was not significant $F(1, 30) = 1.84$, nor was the main effect of List ($F < 1$). There was, however, a significant Group × List interaction, $F(1, 30) = 16.10$, $p < .01$. Planned comparisons confirmed that the recall of List 1 words was significantly lower than the recall of List 2 words in the F group, $F(1, 15) = 8.27$, $p < .01$. The recall performance of List 1 words in the F group was significantly poorer than the recall of List 1 words in the R group, $F(1, 30) = 13.57$, $p < .01$ (see the lower section of Table 1). Thus, a powerful directed-forgetting effect was present in free recall, but this effect was absent in lexical decision.

The findings of this first experiment are then highly consistent with the predictions of the episodic inhibition account. By this view, representations of the List 1 items in the F group are in an inhibited state in an episodic memory of learning the list. When this episodic memory and its contents are accessed, during the list-cued-recall test, relatively few items from List 1 for the F group can be accessed because their representations are inhibited. This inhibition occurs after the memory has been constructed and representations of the items copied into it. Just prior to presentation of the F instruction, the items would presumably be highly activated and accessible, but the F instruction and the second list learning trigger inhibition of the contents of the memory. It is perhaps important to note that no participant failed to recall that there had been a first list, indicating that the memory itself was not in a state of lowered accessibility. An alternative to the episodic inhibition account of the present experiment might focus on the fact that lexical decision preceded free recall and, perhaps, it is this

Table 1
Mean Lexical Decision Times and Percentage Recalled in Experiment 1

Group	Type of target words: List 1 words	List 2 words	New words	Nonwords
	Mean latencies in the lexical decision task			
F group	581.2 (54.1)	586.9 (67.2)	625.7 (79.5)	630.2 (80.1)
R group	576.4 (70.4)	574.2 (60.3)	611.8 (71.4)	627.2 (70.3)
	Mean percentage recall of List 1 and List 2			
	List 1		List 2	
	M	*SD*	*M*	*SD*
F group	24.2	13.2	36.5	15.1
R group	40.1	20.0	30.9	22.9

Note. F group refers to those participants told to forget the words they have learned; R group refers to the participants told to remember the words they have learned. Latencies are presented in milliseconds.

fixed order that is in some way influencing the findings. In the next experiment, we tested this alternative by giving an additional free-recall test just before the lexical-decision task. This strategy should ensure that to-be-forgotten items would be under active suppression at the beginning of the reaction time task and thus maximize the conditions for a directed-forgetting effect in lexical decision.

Experiment 2

Method

The participants were 42 undergraduate Hungarian students from the University of Szeged, who participated in return for partial credit in a lower division psychology course. Their ages varied between 18 and 22 years, with the mean age being 20.1 years. There were 26 women and 16 men. Experiment 2 followed the same procedure as Experiment 1, with one difference. The experiment was conducted in five phases: a list learning phase, a distractor phase, the first list-cued recall phase, a lexical decision phase, and a (second) list-cued recall phase.

Results and Discussion

First free-recall performance. A 2 × 2 (Lists × Group) mixed-factor ANOVA was conducted on the number of words recalled by each subject in the first free-recall phase. Table 2 (upper section) shows the mean probabilities for groups and lists. To compare the critical differences between means, we performed a series of planned comparisons on pairs of means, as in Experiment 1. The main effect of groups was significant, $F(1, 40) = 5.49$, $p < .05$. The main effect of list was not significant ($F < 1$). The analysis of recall scores yielded a significant Group × List interaction, $F(1, 40) = 27.14$, $p < .01$. Planned comparisons confirmed that the recall of List 1 words was significantly lower than the recall of List 2 words in the F group, $F(1, 20) = 15.42$, $p < .01$. The recall performance of List 1 words in the F group was significantly poorer than the recall performance of List 1 words in the R group, $F(1, 40) = 23.70$, $p < .01$. These results, the List × Group interaction, and the critical contrast of F-group List 1 versus R-group List 1 demonstrate a robust directed forgetting effect.

Table 2
Mean Percentage Recalled and Mean Lexical Decision Times in Experiment 2

	Type of target words			
	List 1		List 2	
Group	*M*	*SD*	*M*	*SD*
Mean percentage recall in the first free-recall task				
F group	19.8	11.1	32.5	12.1
R group	42.1	17.8	27.3	16.3
Mean latencies in the lexical decision task				
	List 1 words	List 2 words	New words	Nonwords
F group	569.6 (62.1)	568.7 (52.8)	610.7 (78.7)	613.2 (84.6)
R group	588.1 (66.3)	584.3 (54.5)	597.3 (79.8)	616.6 (63.5)
Mean percentage recall in the second free-recall task				
	List 1		List 2	
	M	*SD*	*M*	*SD*
F group	26.6	15.8	37.5	16.6
R group	45.8	22.5	34.2	22.4

Note. F group refers to those participants told to forget the words they have learned; R group refers to the participants told to remember the words they have learned. Latencies are presented in milliseconds.

Lexical-decision task. We conducted a 2 (group) × 3 (words) mixed ANOVA on the reaction time data; the reaction times of nonword items were not included in the analyses. The main effect of group was not significant ($F < 1$), the main effect of words was significant, $F(1, 80) = 16.80$, $p < .01$, and overall studied words had faster lexical decision times than new words (see the middle section of Table 2). There was no significant Group × Words interaction ($F < 1$).

Second free-recall performance. The main effects of group and lists were not significant. However, as in the first recall phase, a highly reliable Group × List interaction, $F(1, 40) = 14.60$, $p < .01$, was observed (see the lower section of Table 2). Planned comparisons confirmed that the recall of List 1 words was significantly lower than the recall of List 2 words in the F group, $F(1, 20) = 7.56$, $p < .01$. Recall of List 1 words in the F group was significantly poorer than the recall of List 1 words in the R group, $F(1, 40) = 10.46$, $p < .01$. These results, the List × Group interaction, and the critical contrast of F group List 1 versus R group List 1 indicate that the directed forgetting effect was not released by the lexical-decision task or by the earlier recall. The moderate increase in recall overall in the second recall indicates a weak hyperamnesia effect.

Whether lexical decision precedes or follows recall does not appear to influence the presence of the directed forgetting effect in recall or the lack of it in lexical decision times. Indeed, even when a second recall is undertaken, the pattern of the directed-forgetting effect remains intact. Thus, neither prior recall nor encountering the inhibited items in another processing context was sufficient to overcome the effect. According to the episodic inhibition account, these effects occur because the extended dynamic pattern of activation/inhibition that evolved in perceptual, conceptual, motivational, and affective systems during encoding becomes represented in an episodic memory, or set of such memories, and this pattern determines recall. If, however, items inhibited in the episodic memories are encountered in contexts in which they can be processed without accessing the episodic memories, then no inhibition will be observed. The present findings not only support this view but also show that the episodically inhibited items are in fact primed in lexical decision times. In both Experiments 1 and 2, lexical decision times to studied items, including the critical List 1 F-group items, were quicker than to previously unstudied new words. This paradoxical effect is predicted by episodic inhibition, which proposes that the pattern of activation/inhibition induced by the study phase is preserved only in episodic memories of the study phase. It seems that for conceptual or lexical representations, prior exposure to the words in all lists gave rise to enduring activation or priming.

Experiment 3

The episodic inhibition view proposes that by accessing knowledge in an episodic memory, the pattern of activation/inhibition over representations in the memory can be altered for at least some time after encoding. Indeed, this malleability provides an important mechanism for reevaluating memories in response to later experience. An experimental procedure that has extensively examined this is the retrieval practice procedure (Anderson, Bjork, & Bjork, 1994; Anderson & Bell, 2001; Anderson & Spellman, 1995). In the retrieval practice procedure, inhibition is induced by selectively rehearsing a subset of items from a recently learned list. Typically, the first list to be learned consists of several categories, for example, fruits, birds, vehicles, and so forth, and paired with each category are several exemplars, for example, orange, apple, banana. Having studied the list, the participant enters a second phase in which practice is undertaken in the form of cued recall of some of the categories and their exemplars. Items previously learned are recalled to word-stem cues such as "fruit/or_?" In the third phase that follows retrieval practice, an attempt is made to recall all the originally acquired items to the category cues, for example, "fruit: ____, ____, ____?" The typical pattern of findings is that category-cued recall of unpracticed items from categories that were practiced (rp items) is reliably lower than that of items from categories that were not practiced (nrp items) and which constitute the baseline for gauging retrieval-induced forgetting (RIF) in this procedure. Finally, recall of items that were practiced (rp+ items) is reliably greater than that of items from practiced categories that were themselves not retrieval practiced (rp−) and items that were not from categories that contained an item that received retrieval practice (nrp items). Thus, the beneficial effects of rehearsal are shown in the high levels of rp+ recall, and the inhibition of unpracticed highly related category members caused by the practice is reflected in the low recall of the rp− items relative to the nrp items.

There are several explanations of the memory effects in retrieval practice, and we consider these later in the General Discussion. The episodic inhibition approach we have developed here makes much the same predictions for retrieval practice as it did for directed forgetting, namely, that the effects of practice will be to set up a particular pattern of activation in an episodic memory of processing the study list, and it is this pattern that will determine later recall. Thus, the study list items will be represented with varying degrees of accessibility in the episodic memory of learning the list. It seems reasonable to assume that most items will be activated and accessible; after all, the goal set for participants is to learn the study items for a later memory test. Practice of one item from a category in which all the items are at roughly similar levels of activation will have the effect of increasing the activation level of that item (rp+ items) in the memory and perhaps of decreasing and even inhibiting the closely associated items (rp− items). The activation levels of episodic memory representations of items from unpracticed categories (nrp items) will presumably undergo little change, as they are not directly accessed during the practice phase. As with directed forgetting, however, if items that are inhibited in an episodic memory can be processed in a new processing context that does not require or induce access to the episodic memory, then no inhibition and even activation of these inhibited items may be observed. Thus, a lexical-decision task interposed between study- and test-containing words inhibited by retrieval practice, words that cannot be recalled, may show no slowing of lexical decision times and even a speeding of reaction times relative to new previously unstudied words. Such a pattern of findings would generalize our findings in directed forgetting to retrieval practice and provide convergent evidence for the episodic inhibition account.

The present experiment uses the retrieval practice procedure of Anderson et al. (1994), with two modifications. After the category cued recall phase, a lexical-decision task was undertaken in which word/nonword judgments were made of previously studied words, new words, and previously unstudied nonwords. Following this, a second cued-recall test was taken and this was to examine the effect of implicit reexposure on the pattern of cued recall. This sequence of tests will establish whether an RIF effect is (a) present in the first cued recall phase, (b) absent in the lexical-decision task, and (c) present again in the second recall phase. By the episodic inhibition view, the RIF pattern should be present at least in the first recall test and very possibly in the second test as well; this is because both involve access of an episodic memory of the study list in which the RIF pattern of activation/inhibition has been induced by retrieval practice. However, the episodic inhibition account predicts that RIF effects will not be present in the lexical-decision task because this task can be completed by accessing semantic representations that are not inhibited.

Method

Participants. Twenty-five undergraduate Hungarian students from the University of Szeged, Szeged, Hungary, participated in return for partial credit in a lower division psychology course. The students' ages varied between 18 and 24 years, with the mean age being 20.3 years.

Materials. Following Anderson et al. (1994), we constructed 10 categories, 2 of which were used as fillers. Each category contained six examples, the words being drawn from several published Hungarian norms (Füredi & Kelemen, 1989; Kónya & Pintér, 1985), of moderate to high frequency and highly typical members of their category (see Appendix A).

Procedure. Participants were tested individually and were informed that they would be participating in an experiment on memory. The experiment was conducted in six phases: a learning phase, a retrieval-practice phase, a distractor phase, a category-cued recall phase, a lexical decision phase, and a second surprise category-cued recall phase. The learning phase was controlled by a Pentium III personal computer. The participants saw category–exemplar pairs on the monitor screen, which they were to try to remember as best as they could for a later memory test. Each category exemplar pair was presented in uppercase letters at the center of the screen for 5 s. We presented the category–exemplar pairs in an unsystematic intermixed order. When participants completed the learning phase, the experimenter distributed practice booklets. Each page in the booklet contained one of the category names studied in the previous phase of the experiment and the first two letters of one of the members of that category, which they had to complete. They were encouraged not to guess but to retrieve an item studied in the previous phase. Participants were warned that some of the category–exemplar pairs might be repeated and that when this occurred they should again recall the item from the original list. The participants practiced 3 exemplars from half of the 8 learning categories. The practice booklet contained every critical exemplar three times and thus contained 66 category–exemplar stem pairs. The practiced categories were counterbalanced between experimental groups. After the retrieval practice phase had been completed, the booklets were collected, and participants were given an unrelated arithmetic task for 5 min.

In the first recall phase, participants were given recall booklets with the name of one of the categories studied previously at the top of each page. In each booklet, the order of presentation of the categories was random. The participants worked through the 8-page booklet from first page to last, recalling as many previously studied exemplars as they could in the 40 s allocated for each category. The lexical-decision task followed standard practice, and there were 15 practice trials, consisting of 7 words and 8 nonwords not included in the experimental sets. Each trial began with a 250-ms warning of ****, followed by a 250-ms blank screen prior to presentation of the item. Each item was presented in uppercase letters at the center of the screen until the participant pressed one of two keys to indicate the chosen response or for a maximum of 2 s. The "WORD" key was always operated with the right hand and the "NONWORD" key, with the left. There was a 250-ms blank period before the next warning symbol. The 176 experimental trials were made up of 48 studied words (12 rp+, 12 rp−, 24 nrp words), 48 unstudied words, and 80 nonwords. Order of presentation was random. Participants were required to respond as rapidly as possible while avoiding errors. Response time was recorded from item on screen to keypress in milliseconds. After the lexical-decision task had been completed, participants took a second category-cued-recall test following the procedure of the first test but with the order of cues unsystematic with respect to the first test and original learning trial.

Results and Discussion

Category-cued recall. Table 3 shows the percentages of each type of item that was correctly recalled in the first and in the second category-cued recall phase. Following Anderson et al. (1994), retrieval-induced forgetting was assessed by comparing recall performance on unpracticed items from the practiced categories (rp− items) with recall performance on unpracticed items from the previously unpracticed categories (nrp items). If the latter exceeds the former, then retrieval-induced forgetting has occurred. To determine whether this was the case, we conducted a within-subject ANOVA—with item type as the single variable having the three levels rp+, rp−, and nrp—on the raw scores both for the first- and second-recall performances. In the first-recall phase, a reliable effect of item type was found, $F(2, 48) = 76.10$, $p < .01$. Planned comparisons found that recall of rp+ items was significantly higher than that of nrp items, $F(1, 24) = 637.10$, $p < .01$, confirming the benefit of retrieval practice. Recall of rp− items was significantly lower than that of nrp items, $F(1, 53) = 17.70$, $p < .01$, demonstrating retrieval-induced forgetting. For the second-recall phase, conducted after the lexical-decision task, a reliable effect of item type was again found, $F(2, 48) = 23.40$, $p < .01$. Recall of rp+ items was significantly higher than that of nrp items, $F(1, 24) = 1{,}079.90$, $p < .01$, and recall of rp− items was significantly lower than that of nrp items, $F(1, 24) = 21.50$, $p < .01$. The usual RIF pattern of recall in the recall practice procedure was then present in the standard category cued-recall test and in the same test again after an intervening lexical-decision task that featured exactly the same items.

Lexical decision. The lower section of Table 3 shows the mean RTs by item type condition and for new (unstudied) words. Note that although the means for the nonword trials are also shown in Table 3, these were not included in the analyses, as they were not pertinent to the main questions. Thus, a single factor (item type: rp+, rp−, nrp, and unstudied words) within-subject ANOVA was carried out on the latencies. There was a significant effect of item type, $F(3, 72) = 32.80$, $p < .01$. The latency of rp+ words was significantly shorter than that of the nrp words, $F(1, 24) = 3{,}145.60$, $p < .01$, demonstrating a strong priming effect arising from the original study phase and reinforced by subsequent retrieval practice. Note that these two sources of activation, study and retrieval practice, may sum to produce rp+ items that are more strongly activated than any other items in the set. The latency of nrp words was significantly shorter than that of the previously unstudied words $F(1, 24) = 30.69$, $p < .01$, and this demonstrates that the study phase on its own was sufficient to prime lexical-decision times. Critically, however, there was no significant difference between latencies of the nrp words and rp− words ($F < 1$), and this shows that there was no RIF effect in lexical decision times for items inhibited in category cued recall. Thus, the same items can be both inhibited and primed depending on the type of test used to access the items.

Experiment 4

One way in which the lexical-decision task can be extended is into primed lexical decision. This provides an opportunity to explore, albeit in a different task and different manner, the spread of inhibition originally reported by Anderson and Spellman (1995). Thus, in the present experiment, category exemplars were primed in the lexical decision phase with either a studied or unstudied category. For example, if "orange" was studied in the context of "fruit," then in lexical decision, its studied prime would be "fruit" or, if allocated to the unstudied prime condition, its unstudied prime would be "food." Note that, studied and unstudied

Table 3
Mean Percentage Recall and Mean Lexical Decision Times in Experiment 3

Variable	Rp+ items	Rp− items	Nrp items	New word	Nonword
	Mean percentage of items recalled on first- and second-category cued recall				
First recall	72.6	13.9	33.2		
Second recall	72.5	16.5	43.7		
	Mean (and *SD*) lexical decision times				
Latency	568.5 (42.9)	595.9 (70.2)	597.3 (69.6)	679.4 (52.9)	780.3 (74.8)

Note. Rp+ = Items that received retrieval practice; Rp− = items from practiced categories that were themselves not retrieval practiced; Nrp = items that were not from categories that contained an item that received retrieval practice. Lexical decision times are presented in milliseconds.

primes (all category names) were selected to be equally associated to the target exemplar. Collapsed over prime type, we expect to observe the same pattern of findings for lexical decision and category cued recall as that observed in the previous experiment. For studied primes, it is possible that both episodic and conceptual representations may be accessed and, if so, inhibition may be detected in the form of slower latencies for rp− compared with rp items. For unstudied primes, latency may be mediated mainly, or even solely, by conceptual representations and, if so, no reliable differences in latencies between rp− and nrp items should be observed. On the other hand if there was some spread of inhibition, and this was represented in the episodic memory of the study phase (modified by practice) then it is possible that these unstudied category-plus-studied exemplar pairs might access the memory and thus show some inhibition reflected in slow latencies to rp− items.

Method

Participants. Twenty-six undergraduate Hungarian students from the University of Szeged participated in return for partial credit in a lower division psychology course. Their ages varied between 18 and 25 years, with the mean age being 21.3 years.

Procedure. The procedure was identical to Experiment 3 except that the lexical-decision task was replaced by a primed lexical-decision task. In this task, prior to each visually presented target word, a category name appeared as a prime. There were two different types of prime–target trials: previously studied category–word pairs for example, fruit–orange, or unstudied but related category–word pairs, for example, food–orange (see Appendix B). The 176 trials were made up of 48 studied words (12 rp+, 12rp−, 24 nrp words), 48 unstudied words, and 80 nonwords. There were two category label sets; half of the studied words were randomly assigned to studied category primes and the other half, to unstudied category primes. The unstudied (new) words were primed with associated categories but ones that had not been used for studied words. Nonword trials were primed with studied or unstudied category primes. Each trial began with a 250-ms warning of ****; then the prime was shown for 500 ms, followed by a 500-ms blank period, and finally the target word was presented in uppercase letters at the center of the screen until the participant pressed a key to indicate the chosen response or for a maximum of 2 s. There was a 250-ms blank period before the next warning stimulus. As usual, participants responded as quickly and as accurately as possible.

Results and Discussion

Category-cued recall. As in Experiment 3, the number of items recalled in both category-cued recall phases were each analyzed with a single variable (item type: rp+ or rp− or nrp) within-subject ANOVA. Table 4 shows the percentages of each type of item correctly recalled in the first and in the second category-cued recall phase. In the first-recall phase, there was a significant effect of item type on recall, $F(2, 50) = 206.24$, $p < .01$. Planned comparisons found that recall of rp+ items was significantly higher than that of nrp items, $F(1, 25) = 940.28$, $p < .01$, which confirmed the recollective benefits of the retrieval practice. Recall of rp− items was significantly lower than that of nrp items, $F(1, 25) = 63.61$, $p < .01$, demonstrating retrieval-induced forgetting. In the second-recall phase, which was conducted after the lexical-decision task, we again found a significant effect of item type, $F(2, 50) = 160.43$, $p < .01$. The recall of rp+ items was significantly higher than that of nrp items, $F(1, 25) = 869.12$, $p < .01$, and the recall of rp− items was significantly lower than that of nrp items, $F(1, 25) = 38.29$, $p < .01$ (see Table 4). These results demonstrated the presence of retrieval-induced forgetting after a lexical-decision task involving items of the learning phase. Taken together, the present results and those of Experiment 3 demonstrate powerful and extremely robust effects of RIF recall following the retrieval practice procedure.

Primed lexical decision. Table 4 shows the primed lexical decision data. A 2 × 4 within-subject ANOVA was conducted in which the two variables were prime (studied vs. unstudied) and item type (rp+, rp−, nrp, and unstudied words). Both the prime and the item type main effects were significant, $F(1, 25) = 8.35$, $p < .01$, $F(1, 23) = 16.90$, $p < .01$, respectively. The Prime × Item Type interaction was also significant, $F(1, 23) = 3.60$, $p < .03$. Two separate, single-variable within-subject ANOVAs were then conducted on the raw latencies for studied primes and for unstudied primes. When the prime words were studied categories,

Table 4
Mean Percentage Recall and Mean Lexical Decision Times in Experiment 4

Recall group/ type of prime	Rp+	Rp−	Nrp	Overall	New word	Nonword
Mean percentage of items recalled on first and second category cued recall						
	M(%)	*M*(%)	*M*(%)	*M*(%)		
First recall	80.4	12.9	22.2	43.2		
Second recall	83.6	12.8	32.4	50.8		
Mean (and *SD*) lexical decision times						
	Rp+	Rp−	Nrp		New word	Nonword
Studied category	546.8 (55.3)	594.9 (90.6)	568.1 (82.7)		632.5 (71.9)	714.7 (76.3)
Unstudied category	577.8 (85.8)	570.9 (68.1)	603.8 (75.2)		637.2 (72.5)	719.2 (75.8)

Note. Rp+ = items that received retrieval practice; Rp− = items from practiced categories that were themselves not retrieval practiced; Nrp = items that were not from categories that contained an item that received retrieval practice. Lexical decision times are presented in milliseconds.

there was a significant effect of item type, $F(3, 75) = 26.56$, $p < .01$. The latency of rp+ words was significantly shorter than that of the nrp items, $F(1, 25) = 4.23$, $p < .05$, showing a priming effect of retrieval practice (see Table 4). The latencies of nrp words were reliably faster than that of the previously unstudied words, $F(1, 25) = 59.20$, $p < .01$, demonstrating a priming effect of the learning phase on the lexical decision times. These findings are then highly consistent with the findings of Experiment 3. For the critical contrast, however, a reliable difference was found between latencies of nrp words and rp− words, $F(1, 25) = 8.37$, $p < .01$, and it can be seen from Table 4 that rp− latencies were slower than nrp latencies. This constitutes an RIF effect in the lexical-decision task that was absent in Experiment 3, and it is an RIF effect that (only) occurs when the primes are studied categories. When the primes were unstudied but nonetheless highly associated categories, a significant effect of item type was again observed, $F(3, 75) = 13.17$, $p < .01$. The latencies of rp+ words were significantly shorter than those of the nrp words, $F(1, 25) = 7.50$, $p < .01$. The latencies of rp− words, however, were significantly shorter than those of nrp words, $F(1, 25) = 14.50$, $p < .01$, and did not differ reliably from the corresponding latencies for rp+ items. Why this unexpected "rebound" effect occurred is not known, but what is critical for the present argument is that these findings for unstudied primes, unlike the results for the studied primes, show no evidence of inhibition of rp− items. Finally, in all cases, all studied items were responded to more quickly than the new words ($p < .05$), demonstrating a priming effect of similar magnitude over all conditions.

In the present experiment, the pattern of findings for category-cued recall was highly similar to that found in Experiment 3 at both test phases and constitutes a robust RIF effect. The pattern of lexical decision latencies was also highly similar to that observed earlier when this is collapsed over prime type. The lexical decision data by prime type, however, were more complex: When the prime–target pair contained previously studied items, such as fruit–apple, the RIF pattern of inhibition was present in the lexical decision times, but when the prime–target pair consisted of previously unstudied primes paired with previously studied items, such as food–apple, no RIF inhibition was present, and all items were primed relative to new items. These findings suggest that studied prime–targets accessed a representation of the study list that contained the RIF pattern of activation/inhibition. This representation produced the slowing of latencies to rp− items that would be expected if retrieval practice influenced lexical-decision times. In contrast, unstudied primes paired with studied targets did not show the slowing to rp− items that might be expected to occur when the retrieval practice procedure is used. Thus, whatever representation these cues (unstudied primes plus studied targets) are accessing, it cannot be the same as that accessed by the studied primes and targets.

Experiment 5

In this experiment we repeated the preceding experiment but omitted the category-cued recall administered prior to the lexical-decision task. The reason for this is that it may be the case that the cued-recall test has some (undetected) effect on primed lexical decision, and this might be so even if both tasks access different long-term memory representations (a concern that also applied to Experiment 1).

Method

A new group of 32 undergraduate Hungarian students from the University of Szeged participated in return for partial credit in a lower division psychology course. Their ages varied between 18 and 23 years, with the mean age being 20.1 year. The experiment was the same as Experiment 2 in all other respects.

Results and Discussion

Category-cued recall. The analyses were the same as those conducted previously. Table 5 shows the percentages of each type of item that was correctly recalled in the category-cued recall phase, which was conducted after the lexical-decision task. A significant effect of item type, $F(2, 62) = 53.25$, $p < .01$, was found. The recall of rp+ items was significantly higher than that of nrp items, $F(1, 31) = 26.40$, $p < .01$, and the recall of rp− items was significantly lower than that of nrp items, $F(1, 31) = 50.50$, $p < .01$. These results demonstrate again the presence of a powerful and consistent RIF effect after a lexical-decision task involving items from the learning phase.

Primed lexical decision. Table 5 shows the primed mean lexical decision times. Both the prime and the item type main effects

Table 5
Mean Percentages of Items Recalled and Mean Lexical Decision Times in Experiment 5

Recall group/ type of prime	Rp+	Rp−	Nrp	Overall	New word	Nonword
			Mean percentage of items recalled			
	M(%)	*M*(%)	*M*(%)	*M*(%)		
First recall	69.4	17.4	37.4	53.7		
			Mean (and *SD*) lexical decision times			
Studied category	543.8 (54.6)	596.6 (75.4)	568.3 (66.9)		630.1 (54.7)	720.1 (64.9))
Unstudied category	569.3 (85.2)	600.4 (85.1)	606.7 (79.7)		633.4 (58.8)	718.3 (67.5)

Note. Rp+ = items that received retrieval practice; Rp− = items from practiced categories that were themselves not retrieval practiced; Nrp = items that were not from categories that contained an item that received retrieval practice. Lexical decision times are presented in milliseconds.

were significant, $F(1, 31) = 6.13$, $p < .02$, $F(1, 29) = 30.50$, $p < .01$, respectively. This time the Prime × Item Type interaction was only marginally significant, $F(1, 29) = 2.50$, $p < .08$. As in Experiment 2, when the prime words were studied categories, there was a highly reliable effect of item type, $F(2, 62) = 7.60$, $p < .01$. The latency of rp+ words was significantly faster than that of the nrp items, $F(1, 31) = 4.10$, $p < .05$, confirming the priming effect of retrieval practice. There was again a significant difference between latencies of nrp words and rp− words, $F(1, 31) = 7.50$, $p < .01$, demonstrating an RIF effect in the lexical-decision task when the prime word was a studied category. When the prime word was an unstudied but related category a significant effect of Item Type was found, $F(2, 62) = 4.80$, $p < .01$. The latency of rp+ words was significantly shorter than that of the nrp words, $F(1, 31) = 4.20$, $p < .05$, but there was no significant difference between latencies of nrp words and rp− words ($F < 1.3$). Thus, the curious "rebound" effect detected in Experiment 4 did not occur again and, therefore, this is not a consistent effect. Crucially, however, there was no RIF effect. In addition to this, the latency of nrp words with studied primes was reliably shorter than that of nrp words with unstudied prime, $F(1, 31) = 19.15$, $p < .01$, but there was no significant difference between latencies of rp− words and studied or unstudied primes ($F < 2$). These findings are, for most contrasts, highly similar to those of Experiment 4 and clearly show that an initial category cued-recall test does not influence either lexical decision or a second category cued-recall test. The robust RIF effects induced by retrieval practice were again observed in recall, and again there was an RIF effect in lexical decision latencies when items were primed by studied categories but not when items were primed by unstudied categories.

Experiment 6

In all the experiments reported thus far, we have observed impaired recall of items targeted for inhibition (Tables 1 through 5). For lexical decision, however, the pattern of findings is more complicated. Lexical-decision times have been unaffected by manipulations intended to induce inhibition except when the items featured in the lexical-decision task were exact copies of items from the study lists, for example, studied fruit–apple, later primed with fruit, followed by a lexical decision to apple (Experiments 4 and 5). This pattern can be explained by our proposal that when cues access an episodic memory of the learning event, one that has been affected by retrieval practice, then inhibition is observed. When, however, cues access conceptual representations, no inhibitory pattern is observed and, instead, mainly activation (priming) is observed (Tables 1 through 5). This suggests one further test of the episodic inhibition account. When a task intervenes between study and test, if that task can be completed without accessing an episodic memory of the study phase, that is, by using conceptual knowledge, then no RIF pattern should result regardless of how strong the semantic association is between the study and intervening tasks. This assumes, of course, that the items used in the task do not automatically cue access of the episodic memory. For example, if the study phase containing the usual list of categories and exemplars is followed by a category exemplar generation phase, which although highly related to the study items nevertheless fails to access the memory of the study phase, then no RIF effects should occur. In order to test this, we constructed an experiment in which retrieval practice was replaced by category generation. As usual, category names and exemplars were studied, for example, fruit–apple, fruit–banana, fruit–pear, and this was followed by the generation of exemplars to category exemplar word-stem cues, for example, fruit–or______. The category exemplar word-stem cues were designed so that they featured a highly typical or dominant exemplar from a previously studied category. They were also constructed so that they could not be completed by accessing a memory of the previously studied list.

Method

Participants. Seventy undergraduate Hungarian students from the University of Szeged took part in the experiment. They participated in return for partial credit in a lower division psychology course. Their ages varied between 18 and 25 years, and their mean age was 20.4 years.

Procedure. Participants were tested in groups of 3 to 6 participants. The experiment was conducted in four phases: a learning phase, a generation phase, a distractor phase, and a category-cued recall phase. The learning, distractor, and category-cued recall phases were identical to those used in the previous experiments. The only difference from the standard RIF procedure was that participants took part in a generation task rather than a practice task. In the generation task, immediately after the learning phase, participants received two-letter stems together with a studied category cue and generated a word related to the category cues. The cues were designed to elicit exemplars that, when included in a retrieval practice phase, induced inhibition of words encoded in the study phase (as found in Experiments 3 through 5 in the present series). However, the cues were also designed to elicit exemplars that had not been presented in the study phase (see Appendix C). There was no requirement to recall any items from earlier in the experiment, and the generation task was introduced as a filler task, the main requirement of which was to respond as quickly as possible without error. The generation cues elicited previously unpresented words from half of the eight learning categories, and each cue was repeated three times. Participants generated the same items three times, exactly the same number of practice trials as in the practice phase in the standard RIF procedure. The practiced categories were counterbalanced between experimental groups. After completion of the generation task, participants undertook a numerical filler task for 5 min. Finally, the studied category names were represented, and participants were instructed to recall the items from the study list.

Results and Discussion

In this experiment rp− words were the items from the categories from which participants generated items in the generation phase. If the activation of items from the same categories impairs the representation of related items, then the recall performance of rp− items should be lower than that of nrp items (there was no generation of items from these categories). Note, there were no rp+ items in this version of the RIF procedure. The repeated generation of the items during the semantic generation task was successful, and in over 98% of responses the planned items from the correct categories were generated. As in the previous experiments, retrieval-induced forgetting was assessed by comparing the recall performance of unpracticed items from the practiced categories that is, items from categories later involved in the generations phase (rp− items) with the recall performance of unpracticed items from the previously unpracticed categories, that is, items from those categories that were not included in the generation phase later (nrp items). Mean recall of rp− items was 48% compared with a mean of 46% for nrp items (see Table 6). This difference was not reliable ($t < 1$) and shows that processing of

Table 6
Mean Percentage of Items Recalled in Experiment 6

	Retrieval practice status of item			
	Rp−		Nrp	
Type of recall	*M*(%)	*SD*	*M*(%)	*SD*
Category cued recall	47.79	26.58	45.66	26.25

Note. Rp− = Items from practiced categories that were themselves not retrieval practiced; Nrp = items that were not from categories that contained an item that received retrieval practice.

highly associated semantic items in between study and test does not necessarily induce inhibition (see also Anderson, Bjork, & Bjork, 2000).

General Discussion

In this series of experiments, we have sought to identify the locus of effects in directed forgetting and retrieval practice and, in particular, to isolate the types of mental representations that underlie these effects. Our version of episodic inhibition seeks to account for the findings by distinguishing between episodic and other types of long-term memory representations. We posit that during study, activation/inhibition of several different interacting memory systems mediates comprehension and learning. One result of this goal-oriented processing is an episodic memory or set of such memories which represent the study period. The memory represents the period by containing sensory–perceptual as well as conceptual–affective knowledge that was prominent during the period and that is goal-related (see Conway, 2001). Notably, the content or features of the episodic memory also reflect the processing priorities of the study period and those of any subsequent processing directed at the memory, for example, a directed forgetting instruction or period of selective retrieval practice. Thus, a pattern of activation/inhibition is present over the features of the episodic memory and when the memory is accessed, this pattern determines access of content. Highly active features, representations of rp+ items, for example, are highly accessible whereas other features that are lower in accessibility or, possibly, inhibited, for instance, TBF items and rp− items are more difficult to access. Thus, when an episodic memory of the study phase is accessed, as it has to be in directed forgetting and RIF, the pattern of activation/inhibition over its features powerfully influences what is recalled. The resulting effects, good recall of List 2 and rp+ items (Experiments 1 through 5), reflect high levels of activation of these items in the episodic memory of the study phase. Poorer recall of items from the TBF list and of nrp and rp− items shows either lower levels of activation of these items, as most probably is the case for nrp items, or as others have suggested, their inhibition, which may be the case for List 1 TBF items and rp− items (Anderson & Spellman, 1995; Bjork, 1989).

The critical point, and the purpose of the present research, is that if a poststudy task contains items from the study phase but neither requires access of the memory of the study phase nor automatically cues access, then the pattern of activation/inhibition represented in the memory will not influence performance on the poststudy task. In the present series of experiments, lexical decision was used to test this proposal. Lexical decision times to items from the study list were unaffected by manipulations that nonetheless gave rise to striking and marked decrements in recall performance, and this was the case across Experiments 1 through 5. The exception to this occurred when the lexical decision items were pairs of words (e.g., fruit–apple) from the study phase. These items did show the expected effects of retrieval practice, that is, rp+ items were responded to more quickly than all other items and nrp items were responded to more quickly than rp− items (Experiments 4 and 5). This was the case even though in the same experiments, studied items that were preceded by unstudied primes (e.g., food–apple) showed no RIF effects (Tables 4 and 5). These are problematic findings for those theories of inhibitory effects that argue for semantic processing as the locus of the effects, for example, Anderson and Spellman (1995). It is unclear why the semantic representations of some items should be difficult to access compared with others when all have received the same processing thought to induce inhibition. Even more problematic are the findings that in all the experiments, studied words were primed relative to unstudied words regardless of their status as facilitated or attenuated on other measures.

We believe that there are several processes at work here. First, the RIF effects in lexical decision in response to the copy cues may arise because these cues automatically access the episodic memory containing the pattern of activation/inhibition that mediates the RIF effect (so prominently present in category cued recall). Second, the absence of an RIF effect in lexical decision for those targets that were not exact copies of studied items may have occurred because these items could be responded to using conceptual/lexical representations, which do not preserve the RIF pattern of activation/inhibition. Third, the overall priming seen for studied words, in both directed forgetting and RIF, may occur because when conceptual/lexical networks dysfacilitate a pattern of activation/inhibition, they do not return to a baseline resting level immediately but rather change to some raised level of activation that sets them in readiness to process the same or similar items. Thus, the priming observed over all conditions in lexical decision may reflect speeded processing of items recently encountered. In other words, the inhibition (and activation) that would have been present during study and again during second-list learning or retrieval practice was only preserved in the episodic memory of the studied items, hence, the term *episodic inhibition.*

Extending the Episodic Inhibition View

A key feature of episodic inhibition is that the nature and pattern of activation/inhibition of the semantic or conceptual knowledge contained in an episodic memory will determine later recall. It has long been known that when a list of categories and their exemplars are studied, activation spreads through the representations of the categories to related knowledge (see, for example, Rosch, 1973). Thus, unpresented associates, features, and interitem relations, as well as those items explicitly presented in the study list may become part of an episodic memory of the study phase. It is, perhaps, in this way that independent cues (cues not presented during study and practice) can prove effective in recall (Anderson & Spellman, 1995). Thus, a cue such as "color" might be effective in eliciting "orange," even though orange was originally encoded in terms of “fruit,” and this is because the semantic attribute of orange, “color,” is activated during the study phase and incorporated into the episodic memory. One advantage of this account is that it shows how, by encoding specificity (Tulving & Thompson, 1973), related but unpresented cues might be either effective or ineffective in eliciting recall. If unpresented cues do not correspond to knowledge in the episodic memory of the study phase and cannot be elaborated into cues that do correspond, then recall will be unsuccessful. Because the experimenter has relatively little control over what additional unpresented knowledge is encoded into a memory (but see Anderson et al., 2000, for manipulations that attempt to impose stronger control), then the effectiveness of independent cues will always fluctuate.

Thus, a useful aspect of the episodic inhibition account is that it offers a way to consider weaker and less consistent retrieval practice effects. For example, Anderson and Spellman (1995) demonstrated that inhibition can spread from an item directly inhibited by retrieval practice to items associated by semantic features but not themselves directly inhibited by retrieval practice. This effect was weaker than the main inhibitory effect and has not been observed in all studies (Williams & Zacks, 2001). Given that this is a relatively small effect it is perhaps not so surprising that it is not always observed. The present account argues that for this effect to occur at all, the semantic feature linking the items must be represented in the episodic memory of the study phase. Therefore, if Foods, strawberry, crackers, and Red, blood, tomato, were studied and Red–blood retrieval was practiced, Foods–strawberry would show some inhibition if the semantic feature “red” was represented in the episodic memory for both “strawberry” and “blood” (in fact the finding of Anderson & Spellman, 1995, and also of Anderson et al., 2000). If this feature was only represented in the episodic memory of the study phase for one of these items and not for both, then RIF should not occur; this is because the items would not under these circumstances compete in terms of overlap of semantic attributes.

Episodic inhibition also provides an account for a wide range of inhibitory findings and not just those limited to aspects of semantic processing. Consider for example the findings of Anderson, Bjork, and Bjork (2000), who replaced the retrieval practice word fragment cues with copy cues, for example, fruit–orange, and simply required that these be read during practice rather than recalled. No inhibitory effects were observed in the reading condition. According to episodic inhibition, this occurs because the read-only copy cues can be read by accessing conceptual/lexical representations in which no extensive representation of processing from the learning phase persists. As there is no requirement to access the episodic memory of the learning phase during the practice phase, knowledge in the episodic memory remains in a form similar to that at encoding, that is, with representations of list items active. When the episodic memory is accessed during category cued recall the pattern of activation/inhibition that would have been present had the standard retrieval practice manipulation been used is not present and therefore memory for RP items is not reliably impaired. Similarly, a study by MacLeod and MaCrae (2001), in which it was found that the effects of RIF dissipated over a 24-hr period, but when a similar retention interval intervened between study and retrieval practice, the usual RIF pattern was observed. This suggests that the pattern of activation imposed on the episodic memory by retrieval practice immediately following study begins to weaken and dissipate over the 24-hr retention interval. Most probably the episodic memory itself is undergoing some process of forgetting. According to the present account, the RIF-inducing effect of the delayed retrieval practice occurs because an episodic memory of the study phase is accessed during the delayed retrieval practice phase, and the RIF pattern of activation/inhibition is then generated by selective practice. If the episodic memory could not be accessed or if information in it was degraded, as may occur at even longer retention intervals, then according to episodic inhibition, no RIF pattern would be observed. Note, that it would be implausible to suggest that these long-lasting effects are mediated by patterns of activation/inhibition in semantic knowledge structures only.

We also note that episodic inhibition can be extended to procedures that induce RIF but that do not use retrieval practice. Directed forgetting is one such procedure, and it is very difficult to envisage how, for example, theories of RIF that are focused mainly on semantic accounts can be extended to directed forgetting and other procedures (Perfect et al., 2002). The findings of Experiments 1 and 2 could not simply be explained by a semantic features account such as that of Anderson and Spellman (1995). This does not mean that the semantic features account has no role in understanding RIF effects; quite clearly, it does (Anderson, 2003). What needs to be added, however, is that it does so by accounting for the pattern of activation/inhibition of conceptual knowledge contained in episodic memories.

According to episodic inhibition, the common mechanism underlying the relatively poor memory performance in directed forgetting and following retrieval practice is the pattern of activation/inhibition that exists over the contents of episodic memories of the study phase. Basden, Basden, and Morales (2003) reported findings that suggest that directed forgetting and retrieval practice might not share a common mechanism or set of processes. In their experiments, retrieval practice was performed several times on the second (remember) list in a directed forgetting experiment. It was reasoned that when List 2 remember items were studied, some List 1 TBF items might be accessed. If this is the case, then practicing recall of List 2 should provide further opportunities to inhibit List 1 and thus increase the directed forgetting effect. No increases in the magnitude of the directed forgetting effect were observed, suggesting that retrieval induced forgetting did not underlie the directed forgetting effect. These findings are not especially problematic for the episodic inhibition view, which simply argues that when an episodic memory is accessed, the pattern of activation/inhibition over the contents of the memory powerfully influences what will be remembered. Thus, retrieval practice in the form of recalling List 2, once or several times, will only influence an episodic memory of the TBF List 1 if that memory is accessed and processed during the retrieval practice phase. There is no guarantee that such access would spontaneously take place. Even if it did take place, it does not follow that inhibition would be increased. For instance, Conway et al. (2000) found that when 50% of the items in the two lists were close associates of each other, so that List 2 powerfully cued access of the TBF List 1 items, then the directed forgetting effect was abolished and instead a paradoxical increase in the recall of TBF List 1 items was observed. Conway et al. argued that this reflected a “release” from inhibition. Thus, the crucial issue is whether the memory is accessed prior to recall. However, we acknowledge that the possibility that different processes may mediate directed forgetting and the effects of retrieval practice, as Basden et al. (2003) argue, remains open. The present work strongly suggests that one feature these two procedures may share is reliance on an episodic memory of the study phase and the pattern of activation/inhibition that exists over the contents of the memory. There may, nonetheless, be other processes differentially associated with the two procedures which have not been considered here.

Finally, we note that Sahakyan and Delaney (2003) have argued that the directed forgetting effect might be conceptualized in terms of context change rather than in terms of inhibition (others too have expressed reservations about the notion of inhibition as it is used to explain changes in memory performance in directed forgetting, e.g., MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). Our concept of episodic inhibition is entirely compatible with the context change account, the main differences being that we focus on the nature of the episodic memories that are formed in response to context change. We retain the notion of inhibition, however, partly because the greater body of evidence supports this view (Bjork, Bjork, & Anderson, 1998) but also because it allows us to extend our development of theory beyond the directed forgetting task to the retrieval practice task and to other clearly inhibitory tasks such as memory for the inhibition of return (see Tipper, Grison, & Kessler, 2003). Currently, it is not clear how the context-change account of directed forgetting might be extended in this way.

Conclusions

The present series of experiments demonstrated simultaneous inhibition and activation of the same recently learned items in two different experimental procedures: directed forgetting (Experiments 1 and 2) and retrieval practice (Experiments 3 through 5). This can best be explained by postulating fast-changing conceptual/lexical knowledge structures, copies of which become represented in episodic memories. Knowledge in episodic memories is slow changing and preserves that pattern of activation/inhibition derived from the original experience or generated in it by subsequent access of memory details. Thus, an item inhibited in a memory may nonetheless be activated in a conceptual knowledge structure. If the memory is accessed then evidence of inhibition is found. If, in contrast, an item is accessed in a conceptual network, then evidence for inhibition is not detected. We termed this “episodic inhibition” and showed how it can be applied to a wide range of findings using different procedures.

References

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49,* 415–445.

Anderson, M. C., & Bell, T. (2001). Forgetting our facts: The role of inhibitory processes in the loss of propositional knowledge. *Journal of Experimental Psychology: General, 130,* 544–570.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1063–1087.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin and Review, 7,* 522–530.

Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102,* 68–100.

Basden, B. H., & Basden, D. R. (1996). Directed forgetting: A further comparison of the list and item methods. *Memory, 4,* 633–653.

Basden, B. H., & Basden, D. R. (1998). Directed forgetting: A contrast of methods and interpretations. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 139–172). Mahwah, NJ: Erlbaum.

Basden, B. H., Basden, D. R., & Gargano, G. J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 603–616.

Basden, B. H., & Basden, D. R., & Morales, E. (2003). The role of retrieval practice in directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 389–397.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness and Cognition, 5,* 176–196.

Bjork, E. L., Bjork, R. A., & Anderson, M. C. (1998). Varieties of goal-directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 103–137). Mahwah, NJ: Erlbaum.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 309–330). Hillsdale, NJ: Erlbaum.

Conway, M. A. (2001). Sensory perceptual episodic memory and its context: Autobiographical memory. *Philosophical Transactions of the Royal Society of London B, 356,* 1297–1306.

Conway, M. A., & Fthenaki, A. (2003). Disruption of inhibitory control of memory following lesions to the frontal and temporal lobes. *Cortex, 39,* 667–686.

Conway, M. A., Harries, K., Noyes, J., Racsmány, M., & Frankish, C. (2000). The disruption and dissolution of directed forgetting: Inhibitory control of memory. *Journal of Memory and Language, 43,* 409–430.

Fleck, D. E., Berch, D. B., Shear, P. K., & Strakowski, S. M. (2001). Directed forgetting in explicit and implicit memory: The role of encoding and retrieval mechanisms. *The Psychological Record, 5,* 207–220.

Füredi, M., & Kelemen, J. (1989). *A mai magyar nyelv széppрózai gyakorisági szótára* [A frequency dictionary of the literary language of Hungarian]. Budapest: Akadémiai Kiadó.

Geiselman, R. E., & Bagheri, B. (1985). Repetition effects in directed forgetting: Evidence for retrieval inhibition. *Memory and Cognition, 13,* 57–62.

Geiselman, R. E., Bjork, R. A., & Fishman, D. L. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112,* 58–72.

Kónya, A., & Pintér, G. (1985). Kategória norma a verbális emlékezet vizsgálatához [Category norms for verbal memory research]. *Hungarian Psychological Review, 2,* 93–111.

MacLeod, C. M. (1989). Directed forgetting affects both direct and indirect tests of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 13–21.

MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1–59). Mahwah, NJ: Erlbaum.

MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi, U. (2003). In opposition to inhibition. *Psychology of Learning and Motivation, 43,* 163–214.

MacLeod, M. D., & MaCrae. C. N. (2001). Gone but not forgotten: The transient nature of retrieval-induced forgetting. *Psychological Science, 12,* 148–152.

Neely, J. H. (1991). Semantic priming effects in visual word recognition:

A selective review of current findings and theories. In D. Besner, & G. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (264–336). Hillsdale, NJ: Erlbaum.

Perfect, T. J., Moulin, C. J. A., Conway, M. A., & Perry, E. (2002). Assessing the inhibitory account of retrieval-induced forgetting with implicit-memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 1111–1119.

Racsmány, M. (2003). *Episodic and semantic inhibition in directed forgetting and retrieval-induced forgetting.* Unpublished doctoral dissertation, University of Bristol, Bristol, England.

Rosch, E. (1973). Natural categories. *Cognitive Psychology, 4,* 328–349.

Sahakyan, L., & Delaney, P. F. (2003). Can encoding differences explain the benefits of directed forgetting in the list-method paradigm? *Journal of Memory and Language, 48,* 195–201.

Tipper, S. P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integration of conflicting views. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 54A,* 321–343.

Tipper, S. P., Grison, S., & Kessler, K. (2003). Long-term inhibition of return of attention. *Psychological Science, 14,* 19–25.

Tulving, E., & Thompson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352–373.

Williams, C. C., & Zacks, R. T. (2001). Is retrieval-induced forgetting an inhibitory process? *American Journal of Psychology, 3,* 329–354.

Appendix A

Category-Exemplar Pairs Used in Experiment 3

Categories	Items
Instrument (musical)	guitar, cello, piano, violin, flute, harp
Vehicle	train, car, ship, tram, wheeler, bicycle
Clothes	coat, gloves, boots, socks, gown, cap
Colour	red, yellow, black, purple, brown, green
Animal	tiger, deer, cat, horse, dog, cow
Furniture	armchair, carpet, wardrobe, lamp, couch, table
Occupation	lawyer, actor, miner, cook, painter, policeman
Fruit	plum, pear, apricot, grape, raspberry, orange
Filler categories: flower, reading matter	

Appendix B

Category-Exemplar Pairs Used in Experiments 4 and 5

Categories	Items
Instrument (musical) or music	guitar, cello, piano, violin, flute, harp
Vehicle or traffic	train, car, ship, tram, wheeler, bicycle
Flower or fragrant	tulip, narcissus, rose, poppy, carnation, violet
Clothes or fashion	coat, gloves, boots, socks, gown, cap
Color or paint	red, yellow, black, purple, brown, green
Animal or mammal	tiger, deer, cat, horse, dog, cow
Furniture or apartment	armchair, carpet, wardrobe, lamp, couch, table
Fruit or food	plum, pear, apricot, grape, raspberry, orange
Filler categories: occupation, reading matter	

Appendix C

English Translation of Category-Exemplar Pairs and Semantically Generated Items Used in Experiment 6

Categories	Items	Generated items
Instrument (musical)	guitar, cello, piano, violin, flute, harp	trumpet, drum, cymbal
Vehicle	train, car, ship, tram, wheeler, bicycle	underground, lorry, boat
Clothes	coat, gloves, boots, socks, gown, cap	skirt, jacket, sweater
Color	red, yellow, black, purple, brown, green	grey, blue, claret
Animal	tiger, deer, cat, horse, dog, cow	donkey, badger, squirrel
Furniture	armchair, carpet, wardrobe, lamp, couch, table	curtain, coat-rack, bookshelf
Occupation	lawyer, actor, miner, cook, painter, policeman	teacher, joiner, plumber
Fruit	plum, pear, apricot, grape, raspberry, orange	melon, currant, blackberry
Filler categories: flower, reading matter		

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