

## Retrieval-induced forgetting in recall and recognition of thematically related and unrelated sentences

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In three experiments, we assessed the effects of type of relation and memory test on retrieval-induced forgetting of facts. In Experiments 1 and 2, eight sets of four shared-subject sentences were presented for study. They were constructed so that half were thematically related and half were unrelated. A retrieval practice phase required participants to recall a subset of the studied sentences. In the final test, the participants were prompted to recall all the sentences (character cued in Experiment 1 and character plus stem cued in Experiment 2). The results showed that the retrieval-induced forgetting (RIF) effect was similar for thematically related and unrelated sentences, indicating that the presence of episodic relations among the sentences was sufficient to produce the effect. In Experiment 3, a recognition task was introduced and the RIF effect emerged in accuracy as well as in latency measures. The presence of this effect with item-specific cues is difficult to accommodate for noninhibitory theories of retrieval.

A number of findings suggest that the very act of retrieving information may be a source of forgetting (see, e.g., M. C. Anderson, E. L. Bjork, & R. A. Bjork, 2000; M. C. Anderson, R. A. Bjork, & E. L. Bjork, 1994; Blaxton & Neely, 1983; Brown, 1981; Roediger, 1978; see M. C. Anderson, 2003, and M. C. Anderson & Neely, 1996, for reviews). Although prior retrieval increases the probability of retrieving the recovered items in a subsequent memory test, those items that were not initially recovered and that were associated with the same retrieval cue are less likely to be recalled in a subsequent memory test relative to control items. This phenomenon is known as *retrieval-induced forgetting* (RIF; see M. C. Anderson, 2003, for a review).

One of the procedures for studying this effect is the retrieval practice paradigm designed by M. C. Anderson et al. (1994). The procedure consists of three phases. In the first phase, participants study a list of category-exemplar pairs (e.g., *Fruit-Orange*). In the retrieval practice phase,

participants are asked to cue-recall half of the exemplars of half of the presented categories (hereafter referred to as *Rp+ items*). For example, participants are presented with the cue *Fruit-Or*\_\_\_\_ and are asked to produce the complete name of the exemplar. After a retention interval, participants are presented with all the studied category names and asked to recall as many exemplars as possible from each of the presented categories. The effect of retrieval practice on subsequent recall is observed by comparing the probability of recall of unpracticed exemplars belonging to practiced categories (henceforth referred to as *Rp- items*) with the probability of recall of exemplars from unpracticed categories (henceforth referred to as *Nrp items*). RIF is observed when the probability of recalling the *Rp- items* is significantly lower than the probability of recalling the *Nrp items*.

The most common interpretation of RIF is in terms of inhibition (see, e.g., M. C. Anderson, 2003; M. C. Anderson & Bell, 2001; M. C. Anderson & McCulloch, 1999; M. C. Anderson & Spellman, 1995; see also Blaxton & Neely, 1983; Carr & Dagenbach, 1990). For example, M. C. Anderson proposes that inhibition in memory retrieval works in a manner similar to that of the inhibitory processes that act in other cognitive domains, such as language processing or selective attention (see, e.g., M. C. Anderson et al., 1994; Neill, Valdes, & Terry, 1995; Posner & Presti, 1987). Inhibitory processes would be in charge of suppressing the “internal distraction” caused by competing items during memory retrieval. Thus, during the retrieval practice phase, unpracticed exemplars from

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practiced categories are inhibited to reduce their competition effects (M. C. Anderson et al., 1994; M. C. Anderson & Spellman, 1995). Hence, when later tested in the memory test, their representations are inhibited and it would be harder to recover them. According to this account, the lower levels of recall of the Rp- items are caused by the inhibition of their memory representations, and this inhibition is triggered by the presence of competition.

Theoretically, competition could come from preexisting associations or from newly acquired episodic associations created during the study phase. However, although retrieval-induced forgetting has been studied with different types of materials and procedures, most of them have involved semantic preexisting associations. For example, M. C. Anderson and Bell (2001, Experiment 2) used propositions instead of category-exemplar materials to study the RIF effect. However, although the propositions were not generated from semantic categories, they were constructed so that the relation between subject and predicate was constant and functional categories could be created. For example, participants studied and recalled sentences such as *The box is in the hotel*, *The box is in the pub*, and *The box is in the airport*; these sentences can therefore be thought of as belonging to the functional category "places where a box can be." Similarly, M. D. MacLeod and Macrae (2001) also used propositional materials, but their materials described the personality traits (e.g., *sensible*, *cultivated*, *sociable*, *creative*) of two different persons. In contrast, more episodic relations were introduced by Ciranni and Shimamura (1999), who introduced visuospatial materials. In their study, participants learned the spatial locations of geometric figures. Since the relation between the cues (the geometric figures) and the location was arbitrary, the participants had to learn episodic associations—that is, associations created during the learning episode. However, this study has several shortcomings. First, the authors used the anticipation procedure with lots of retrieval practice occurring as early as the learning phase of the experiment. Second, similar to the studies of M. D. MacLeod and Macrae (2001) and M. C. Anderson and Bell (2001), the relation between the cue (e.g., *triangle*) and the target (e.g., *The triangle is at position A*, *The triangle is at position B*) was constant, and therefore all items associated with a cue shared the same type of relation. Hence, although the relation between the cue and the target was episodic, the relation among the associates could be considered semantic. Thus, none of the reported studies has provided clear evidence of RIF effects when both the relation between the cue and the target and the relation among the associates are episodic.

Hence, the principal aims of the present article were (1) to further explore the extent to which the RIF effect depends on the nature of the relation among the targets that are associated with a given cue and (2) to directly compare the effect of the relation among the associates (episodic vs. semantic) on RIF. Although in different experiments RIF has been obtained with materials that varied in the type and degree of their relations (e.g., *orange* and *apple* vs. *It is in the hotel* and *It is in the airport*), to our knowl-

edge none of these studies has directly compared the magnitude of the effects as a function of the type of relation among the associates. With this purpose in mind, in Experiments 1 and 2 participants learned simple sentences in the form character plus activity (e.g., *The professor has finished his work*). During the study phase, each of the characters was associated with four different activities and the relation among these activities was manipulated. Thus, half of the characters had associated activities that were thematically related to each other, whereas the other half were linked to activities that were completely unrelated (see the Appendix for examples). In this sense, in the thematically related condition the relation between the character and the activity was episodic but the relation among the different associates to the cue was semantic; in the unrelated condition, in contrast, the relation between the cue (character) and the target (activity) and the relation among the different targets associated with a given cue (activities) were both episodic. Thus, one of the novelties of our experiments was the possibility of directly comparing the magnitude of the RIF effect in conditions that are similar in terms of the relation between the cue and the target (episodic) but very different in terms of the relation among the associates (episodic vs. semantic). The presence of RIFs of the same magnitude in the related and unrelated conditions would more clearly support the claim of Ciranni and Shimamura (1999) that the establishment of episodic relations between the cue and the associates during study can be a sufficient condition to generate competition and trigger inhibition during retrieval practice.

Although the inhibitory account is the most widely accepted explanation of RIF, other explanations have also been offered. For example, some memory theories (J. R. Anderson, 1983, 1993; Raaijmakers & Shiffrin, 1981; see M. C. Anderson & Neely, 1996, for a review) propose that the probability of retrieving a target is determined by that item's strength of association with a cue relative to the strength of association of all items associated with the same cue. Thus, when an alternative response is strengthened, the relative strength of the remaining items declines; consequently, when the participant tries to recall the target, the strengthened item has a retrieval advantage that will lead it to compete with the target and to intrude so persistently that the participant may stop attempting to recall the target. Thus, retrieval practice would strengthen the association between the cue and the practiced items, inducing strong competition and the occlusion of the Rp- targets during the retrieval test.

In addition, a third type of theoretical account attributes the negative effect of retrieval practice to the disruption of retrieval strategies by retrieval practice of a subset of items (C. M. MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003). Since retrieval practice forces a specific recall order of a subset of items, the original organization of studied words into categories would be disrupted. This inconsistency between the organization during study and that during retrieval practice would make nonpracticed items associated with practiced categories more difficult to recall. Items from unpracticed categories are easier to recall because

the organization of these items has not been disrupted by the practice session.

An additional aim of the present study was to provide further evidence of the inhibitory nature of the obtained effects and to rule out possible explanations based on occlusion or disruption strategies. With this purpose, we manipulated the specificity of the cues provided at retrieval across experiments. Thus, in Experiment 1 the cues consisted of each of the different studied characters (e.g., *professor*, *doctor*), and the participants were asked to recall as many of the studied activities for each of the characters as possible. In Experiment 2, more specific retrieval cues were provided. For example, if the sentence *The fireman has played tennis* was one of the studied sentences, at retrieval the participants were presented with *The fireman has pl\_\_ t\_\_* as a cue to recall. Finally, in Experiment 3 the studied sentences were mixed with new ones and the participants were asked to identify the studied sentences.

The inhibitory account predicts that the presence of RIF effects should be cue independent and should be present even when specific cues are provided at test. If forgetting of the Rp- items is due to the inhibition of their memory representations, they should be less accessible and more difficult to recover. In contrast, theories based on strength-dependent competition or on the disruption of retrieval strategies would predict that the RIF effect should not appear when specific cues are provided at test (see, e.g., Dyne, Humphreys, Bain, & Pike, 1990; Raaijmakers & Shiffrin, 1981; Ratcliff, Clark, & Shiffrin, 1990). The presentation of the Rp- targets at retrieval, as in recognition, would liberate them from the blockage produced by stronger Rp+ targets and eliminate RIF. Hence, if RIF effects are obtained in recognition, this cannot be the result of blockage. On the other hand, the presence of specific retrieval cues induces the retrieval of item-specific information rather than that of relational information (Hunt & Einstein, 1981). Therefore, relational strategies and knowledge would play a small role when very specific cues are provided. Hence, the presence of RIF effects in recognition cannot be caused by inconsistencies in organization at study and at retrieval.

Studies conducted to find RIF effects with retrieval cues that varied in specificity have produced mixed results. In recall tasks, some experiments report RIF effects with item-specific cues such as *Fruit-Or\_\_\_\_\_* (e.g., M. C. Anderson & Bell, 2001; M. C. Anderson, E. L. Bjork, & R. A. Bjork, 2000; Bäuml, 2002; Bäuml & Hartinger, 2002), whereas others have failed to find them (Butler, Williams, Zacks, & Maki, 2001; Perfect, Moulin, Conway, & Perry, 2002). The evidence is similarly mixed in recognition tasks. In some experiments, the usual RIF effect has been found in recognition tests (M. C. Anderson, De Kok, & Childs, 1997; Hicks & Starns, 2004; Veling & van Knippenberg, 2004), but in other experiments it was not (Koutstaal, Schacter, Johnson, & Galluccio, 1999). An important feature common to all the experiments in which recognition tests were used is that they did not take responses to the distractors into account and, therefore, variations in the results might have been due to variations

in the criteria used by the participants to respond. In our experiments, we attempted to determine whether the RIF effect is independent of the specificity of the retrieval cues by using the same types of materials and study/retrieval practice procedures, but different memory tests. In addition, when testing recognition, signal detection analyses were performed to capture true recognition independently of other decision factors.

## EXPERIMENT 1

The purposes of Experiment 1 were to replicate the RIF effect with noncategorical propositional material and to explore the extent to which this effect depends on the type of relation among the associates to a given cue. Thus, the relation among the activities associated with a given character was manipulated so that half of the characters had associated activities that were thematically related to each other, whereas the other half were associated with completely unrelated activities. In this experiment, non-specific retrieval cues were used.

### Method

#### Participants

Thirty-two students (mean age, 20.4 years) from the University of Jaén participated in the experiment. They received course credit for their participation.

#### Design

Two independent variables were manipulated within participants: (1) the status of the sentence after the retrieval practice phase (practiced sentences [Rp+], unpracticed sentences associated with practiced characters [Rp-], and unpracticed sentences associated with unpracticed characters [Nrp]) and (2) the type of relation among the activities associated with the character (related or unrelated).

#### Materials

**Study sentences.** Forty Spanish sentences were constructed for study (see the Appendix). Each of them contained a single proposition, and their grammatical subjects always consisted of a character identified by his or her profession (e.g., *the policeman*, *the fireman*). All of them were composed of six words. The predicates of the sentences were constructed so that all the activities were familiar and plausible. In addition, in the selection of the verbs to be used in the sentences care was taken that each verb started with a different letter. This was important because the cues during the retrieval practice phase consisted of the subject of the sentence and the first letters of the verb.

Twenty-four of the predicates were generated in such a way that the activities they described were unrelated to each other (e.g., *has played the piano*, *has written a letter*), and they were randomly assigned to one of four possible groups, each consisting of four predicates. Thus, in the unrelated condition there were four groups of four sentences. The remaining 8 predicates were divided in two to form the two groups of filler sentences. Additional sentences were constructed to form the thematically related condition. To construct these sentences, we proceeded in the following manner. First, four themes were selected that could be easily identified with familiar scripts (*travel by car*, *visit a bar*, *wake up in the morning*, *go to the movies*). Second, four predicates were constructed for each of these scripts. For example, the predicates for the *go to the movies* script were *has arrived at the cinema*, *has bought the tickets*, *has watched a movie*, and *has eaten the popcorn* (see the Appendix). As in the



example, all the predicates linked to a theme followed a necessary temporal order. Hence, they belonged to the same script but also had temporal organization, and they were presented so that the natural order of the familiar theme was preserved.

Once the 10 sets of predicates (4 unrelated, 4 thematically related, and 2 fillers) were constructed, they were randomly assigned to 10 common professions from Goikoetxea (2000). In assigning characters to sets of predicates, care was taken to avoid possible unwanted associations between the characters and the predicates. This was done so that the relations between the cues and the targets in both the related and the unrelated conditions would be episodic (constructed during the study episode), whereas the relations among the activities linked to a character would vary depending on the condition (related or unrelated).

Therefore, the materials for the study phase consisted of 32 experimental sentences (16 related and 16 unrelated) and 8 filler sentences. These sentences were presented on a computer screen one at a time. The order of presentation of the experimental sentences was blocked and randomized as follows. To prevent two adjacent sentences from sharing the same character, four blocks of sentences were created by randomly assigning sentences from each of the selected characters. The sentences within each of these blocks were randomized, so that each participant received a different within-blocks order. However, the order of the blocks was constant so that the temporal structure of the thematic sentences was maintained for all the participants. To avoid possible recency and primacy effects, filler sentences were included at the beginning and end of the study phase.

**Retrieval practice.** Retrieval practice consisted of the presentation of individual sentence fragments as cues to recall the study sentences. The fragments always consisted of the character, the first three letters of the verb, and the first two letters of the complement (e.g., *The policeman has arr \_ \_ \_ ci \_ \_* as a cue for *The policeman has arrived at the cinema*).

Forty-two trials composed the retrieval practice phase. Two of the four characters that composed each experimental condition (related and unrelated) were presented during the practice phase. Only two of the four sentences associated with the selected character were included for practice. In this way, half of the sentences in each experimental condition were practiced. These sentences were presented three times in different positions and orders for retrieval. Two of the four propositions associated with the filler characters were also presented for practice. Four different versions of these materials were generated so that the sentences assigned to the Rp+, Rp-, and Nrp conditions were different for each of them. Therefore, each of the versions was presented to one fourth of the participants. As in the study phase, each block was composed of sentences from each of the to-be-practiced characters, thereby avoiding repetition of the same character in two adjacent trials. Also as in the study phase, filler sentences were included at the beginning and end of the practice phase. They were also used to separate blocks of experimental sentences.

Presentation of the sentences in both the study and retrieval practice phases was controlled by software in the Experimental Run Time System (ERTS; Beringer, 1997).

**Final recall test.** Nine-page booklets were prepared for the final test. Each page contained the name of one of the characters (e.g., *the fireman*). These names were the cues to recall the sentences associated with each character. All the booklets started with a character presented in the filler sentences; the remaining eight pages contained a character from the experimental sentences. The order of presentation of these eight characters was randomized for each participant.

### Procedure

The experiment consisted of four phases: study, retrieval practice, distractor task, and final recall. The participants completed these four phases individually. Upon arrival, the participants were informed that they were going to perform a set of memory and reasoning tasks, and they were given more specific instructions at the beginning of each phase. At the beginning of the study phase, the

participants were told to pay as much attention as possible to the sentences because they were going to be asked about them later. They were told to try to memorize the sentences so that they would be able to recall the activity if the relevant character was presented. Immediately after a 1,200-msec fixation point, each of the sentences appeared in the center of the computer screen for 10 sec. The inter-trial interval was 2 sec. Before the study phase started, two sentences were provided as examples.

After finishing the study phase, the participants received instructions for the retrieval practice phase. The participants were told that they were going to perform a memory test regarding the studied sentences. During this phase, each sentence fragment in the Rp+ condition (e.g., *The policeman has arr \_ \_ \_ ci \_ \_*) was presented for 8 sec. The inter-trial interval was 2 sec. Each fragment was preceded by a 1,200-msec fixation point. The participants were informed that the sentences would be tested more than once. In addition, they were told that they should try hard to recall the complete sentence before it disappeared from the screen. Two filler sentences were presented as examples. The participants wrote their responses in a booklet.

Once they finished the retrieval practice phase and before starting the final recall test, all the participants performed a distractor task. This consisted of a standard reasoning task (D-70 test) that the participants performed during 15 min. After finishing it, the participants were presented with the final recall booklet containing nine pages with the names of nine characters from the study sentences (the eight experimental characters and one filler). The participants were told that they should write down as many of the activities associated with each character during the study phase as possible. They were told that they had 60 sec to write the activities for each character and that they would be told when to turn to the following page to recall the activities for the next character. A filler character was provided as an example, and the experimenter helped the participants to recall the actions associated with this character.

## Results and Discussion

Significance levels of .05 were used for all analyses in the three experiments. Correct recall averaged over the three repeated trials in the retrieval practice phase was at 93% for the thematically related sentences and 89% for the unrelated sentences.

### Facilitation Effects

To assess possible facilitation effects, the Rp+ and Nrp conditions were compared for each of the type-of-relation conditions. Thus, a  $2 \times 2$  ANOVA was performed with type of relation (related vs. unrelated) and status during practice (Rp+ vs. Nrp) as within-participants factors. The results of this analysis indicates that both type of relation [ $F(1,31) = 22.9$ ,  $MS_e = 769$ ] and practice status [ $F(1,31) = 11.8$ ,  $MS_e = 537$ ] were significant. As is shown in Table 1, the participants recalled more sentences from the thematically related condition ( $M = 59\%$ ) than from the unrelated condition ( $M = 36\%$ ) and more Rp+ sentences ( $M = 55\%$ ) than Nrp sentences ( $M = 41\%$ ).

The interaction between type of relation and status during practice was also significant [ $F(1,31) = 3.9$ ,  $MS_e = 408$ ]. The difference between the Rp+ and Nrp conditions was not equal for all type-of-relation conditions, and it was significant for the unrelated condition (22%) [ $F(1,31) = 15.5$ ,  $MS_e = 427$ ] but not for the related condition (7%) [ $F(1,31) = 1.5$ ,  $MS_e = 544$ ]. The explanation of this interaction is not evident, but it is possible that more difficult (unrelated) items benefited more from practice than did easier

**Table 1**  
**Experiment 1: Mean Percentage of Correctly Recalled Sentences as a Function of Status During Retrieval Practice and Type of Relation Among the Propositions Linked to the Same Character**

Type of Relation	Retrieval Practice Status			RIF
	Rp+	Rp-	Nrp	
Related	63	45	56	11
Unrelated	47	15	25	10
<i>M</i>	55	30	41	11

Note—RIF, retrieval-induced forgetting.  $RIF = Nrp - Rp-$ .

ones. In the easier (related) condition, participants can use the theme as a retrieval route to recover particular sentences, and this could make the effect of practice less relevant.

### Retrieval-Induced Forgetting

To assess the negative effect of retrieval practice on unpracticed items with practiced characters, we compared the Rp- items with the Nrp items. Thus, a  $2 \times 2$  ANOVA was performed with type of relation (related vs. unrelated) and practice status (Rp- vs. Nrp) as within-participants factors. The results of this analysis show that the main effect of type of relation was significant [ $F(1,31) = 49.7$ ,  $MS_e = 583$ ], indicating that the probability of recall for thematically related sentences was greater ( $M = 50\%$ ) than the probability of recall for the episodically related sentences ( $M = 20\%$ ). The effect of status during practice was also significant [ $F(1,31) = 8.1$ ,  $MS_e = 507$ ]. Thus, the probability of recall of the Rp- sentences ( $M = 30\%$ ) was smaller than the probability of recall of the Nrp sentences ( $M = 41\%$ ). More importantly, the interaction between the two variables was not significant ( $F < 1$ ), indicating that the magnitude of the RIF effect was similar for the two type-of-relation conditions.

Clearly, Experiment 1 replicated the RIF effect with materials different from those used in previous studies (M. C. Anderson & Bell, 2001; M. D. MacLeod & Macrae, 2001). We used sentences in which the relations were not categorical and the predicates associated with each character differed from each other. Despite these differences, unpracticed sentences associated with practiced characters (Rp-) were recalled less frequently than the unpracticed control sentences (Nrp). More importantly, this effect was present when the activities associated with a character were thematically related to each other, but also when these activities were unrelated and linked only during the study episode. In both related and unrelated conditions, we found similar RIF effects. This is especially important because other studies in which noncategorical materials have been used (M. C. Anderson & Bell, 2001; Ciranni & Shimamura, 1999; Macrae & MacLeod, 1999) did not introduce different types of relations among the associates in the same experiment and, therefore, direct comparisons were not possible. In addition, in all those studies the relation between the cue and the target remained constant, and therefore, even with unrelated associates, functional or perceptual categories could be easily created. Therefore,

the results of Experiment 1 more clearly support the claim that RIF can be found when competition comes solely from newly acquired episodic links among the associates. They also suggest that the presence of preexisting associations among the Rp+ and Rp- targets does not produce changes in inhibition, since the effects were equivalent for the related and unrelated conditions.

In this experiment, nonspecific cues were used. This made the experiment similar to other RIF experiments with categorical material in which the name of the category is provided as a cue to recall the associated exemplars. However, the use of these nonspecific cues left open theoretical explanations of the RIF effect. Thus, the difference between the Rp- and the Nrp sentences can be explained as the result of inhibition, but also as the result of the strengthened relation between the cue and the Rp+ sentences, or even as due to the disruption of encoding strategies.

## EXPERIMENT 2

The purpose of Experiment 2 was twofold. First, we wanted to replicate the results of Experiment 1, indicating RIF effects of similar magnitudes for thematically related and unrelated sentences. Hence, the two types of materials were included in this experiment. Second, we wanted to use a recall procedure that minimized the effect of the possible disruption of retrieval strategies and occlusion. With this in mind, in Experiment 2 we introduced item-specific cues in the final recall test. The use of this type of cue precludes the possibility that disruption of coding and retrieval strategies would have an effect at the time of recall, since these cues would minimize the importance of relational information and organization at the time of recall. In addition, the use of these cues helps minimize blocking effects by reducing output interference (see, e.g., M. C. Anderson, Green, & McCulloch, 2000; Bäuml, 2002; Bäuml & Hartinger, 2002; see M. C. Anderson, 2003, for a review). In Experiment 1, the presentation of the characters as cues for recall could activate the stronger practiced activities (Rp+), which in turn block the retrieval of unpracticed activities (Rp-). If this were the case, practiced activities would be recalled before unpracticed ones, producing output interference. In Experiment 2, we tried to avoid output interference by presenting first the fragment cues corresponding to unpracticed sentences and then the fragment cues corresponding to the practiced sentences. The finding of RIF effects under these more restricting conditions would favor a theoretical explanation based on inhibitory mechanisms.

### Method

#### Participants

Thirty-eight students from the University of Jaén (mean age, 19.1 years) participated in the experiment. None of them had participated in Experiment 1.

#### Design and Materials

The design and materials were similar to those used in Experiment 1. The only difference was the type of cue used during the final

recall test. The participants were provided item-specific information as cues for recalling the studied items. Thus, beside the name of the character in the sentence, the first two letters of the verb and the first letter of the complement were also presented as test cues (e.g., *The fireman has pl\_\_\_\_\_ t\_\_\_\_\_*). These fragment cues were presented in the center of the computer screen.

### Procedure

The procedure was identical to that of Experiment 1 with the exception of the final memory test. In this phase of the experiment, the participants were informed that they should complete each of the presented fragments with one of the studied sentences. Each fragment was presented for 10 sec on the computer screen, and the participants were instructed to provide a vocal response while the fragment was still on the screen. To avoid the possible effect of output interference, the set of fragments was divided into two blocks: The first included the fragment corresponding to the unpracticed items (Rp- and Nrp), and the second included the fragments corresponding to the practiced sentences (Rp+). The participants were always presented with the unpracticed fragments first, followed by the practiced ones. Within each of the blocks (unpracticed or practiced), the order of the items was randomized for each participant.

## Results and Discussion

Correct recall in the retrieval practice phase reached 91% for the thematically related sentences and 93% for the unrelated sentences.

### Facilitation Effects

A  $2 \times 2$  ANOVA was performed with type of relation (related vs. unrelated) and practice status (Rp+ vs. Nrp) as within-participants factors. The results of this analysis (see Table 2) indicate that there was a significant practice effect [ $F(1,37) = 173$ ,  $MS_e = 212$ ]. The percentage of recall of the practiced sentences was larger ( $M = 87%$ ) than that for the unpracticed sentences ( $M = 56%$ ). As in Experiment 1, there was a significant interaction between type of relation and status [ $F(1,37) = 5.75$ ,  $MS_e = 301$ ], indicating that the magnitude of the practice effect was larger for the unrelated sentences (38%) than for the thematically related sentences (25%).

### Retrieval-Induced Forgetting

A  $2 \times 2$  ANOVA was performed with type of relation (related vs. unrelated) and practice status (Rp- vs. Nrp) as within-participants factors. The results of this analysis indicate that the effect of status was significant [ $F(1,37) = 13.9$ ,  $MS_e = 215$ ]. Thus, the probability of recalling the Rp- sentences ( $M = 47%$ ) was smaller than the probability

of recalling the Nrp sentences ( $M = 56%$ ). The effect of type of relation did not reach significance [ $F(1,37) = 2.8$ ,  $MS_e = 711$ ]. More importantly, as in Experiment 1, the interaction between type of relation and practice status was not significant ( $F < 1$ ), indicating that the magnitudes of the RIF effects were similar for the two types of relations (8% for related, 10% for unrelated).

This pattern of results replicates that obtained in Experiment 1, indicating that RIF effects can be found with unrelated materials linked only by episodically constructed associations and that the presence of preexisting associations among the Rp+ and Rp- targets does not change the magnitude of the effects. These results also suggest that RIF can be found when item-specific cues are provided at test so that the influence of factors such as output interference and disruption of retrieval strategies are minimized. These results go against recent suggestions that RIF effects can be reliably found only with nonspecific recall tests (Butler et al., 2001) or with procedures that disrupt coding/retrieval strategies (C. M. MacLeod et al., 2003). Interestingly, the magnitudes of the RIF effects in Experiments 1 and 2 were very similar despite the fact that the two experiments differed in the type of cues used in the memory test (nonspecific vs. specific).

## EXPERIMENT 3

Taken together, the results of Experiments 1 and 2 support interpretations of the RIF effect that place their main emphasis on the presence of inhibitory mechanisms at the time of retrieval practice (M. C. Anderson, 2003; M. C. Anderson, E. L. Bjork, & R. A. Bjork, 2000; M. C. Anderson et al., 1994). If this interpretation is correct, RIF effects should be present with every type of memory test and measure and, therefore, they should also be present in recognition tests. If the competitors (Rp-) are inhibited during the retrieval practice phase, reactivation of their representations would be harder at test, and the accuracy of the recognition responses should decrease and their latency should increase in comparison with those for unpracticed items. Experiments in which recognition tests were used have shown mixed results. Thus, Hicks and Starns (2004) and Veling and van Knippenberg (2004) found an RIF effect in recognition, whereas Koutstaal et al. (1999) did not. Results of experiments with similar paradigms, such as part-set cuing (see, e.g., Slamecka, 1975; Todres & Watkins, 1981) and directed forgetting (see C. M. MacLeod, 1999, for a review), have also shown some difficulties in finding RIF in recognition tests. In Experiment 3, we explored this issue by using the unrelated materials that were used in Experiments 1 and 2 and introducing a recognition test. An important advantage of using propositional material is that it allowed us to construct independent Rp+ and Rp- lures. Previous experiments (e.g., Hicks & Starns, 2004; Veling & van Knippenberg, 2004) that have explored the RIF effect in recognition have used category exemplars. The use of this type of material makes it difficult to construct independent lures for Rp+ and Rp-, and therefore it was not possible for them to obtain target-lure discrimi-

**Table 2**  
Experiment 2: Mean Percentage of Correctly Recalled Sentences as a Function of Status During Retrieval Practice and Type of Relation Among the Propositions Linked to the Same Character

Type of Relation	Retrieval Practice Status			RIF
	Rp+	Rp-	Nrp	
Related	84	51	59	8
Unrelated	91	43	53	10
<i>M</i>	87	47	56	9

Note—RIF, retrieval-induced forgetting.  $RIF = Nrp - Rp-$ .



nation values to compare the Rp– and Nrp conditions. Hence, an important novelty of our study with respect to other recognition experiments was the use of discrimination indices ( $d'$ ). This feature is theoretically important because the inhibition of the Rp– representation should produce not only decrements in recognition of the targets, but also difficulties in the discrimination of targets and lures.

## Method

### Participants

Thirty-eight students from the University of Jaén (mean age, 20.2 years) participated in the experiment. None had participated in either of the previous two experiments.

### Design

The experiment conformed to a  $3 \times 2$  within-participants design. As in Experiments 1 and 2, the status of the items during the practice phase (Rp+, Rp–, and Nrp) was manipulated. In addition, given the nature of the memory test, the type of sentence presented for recognition (studied vs. nonstudied) was manipulated. The accuracies and latencies of the participants' responses were recorded.

### Materials

Thirty-two sentences (24 targets and 8 fillers) were used as study materials. In constructing these sentences, we paired the characters of the fillers and unrelated sentences of Experiments 1 and 2 with newly constructed predicates similar in structure to those of the previous experiments. Special care was taken that the new propositions be unrelated to each other and to the materials previously used. As in the unrelated conditions of Experiments 1 and 2, the 24 predicates of the sentences were randomly assigned to one of six possible characters, so that each character had four unrelated predicates associated with it (see the Appendix). The 24 experimental sentences were randomized for each participant, but the filler sentences were always presented at the beginning and end of the study list.

As in the previous experiments, the retrieval practice phase involved only a fourth of the studied sentences. Four different versions of these materials were generated so that the sentences assigned to the Rp+, Rp–, and Nrp conditions were different for each of them and, therefore, the practiced items varied from one version to the other. The practice phase consisted of 26 trials, since each of the six Rp+ sentences was presented three times and eight fillers were also included for practice. As in the two previous experiments, the filler sentences were included at the beginning and end of the practice phase, and they were also used to separate blocks of experimental sentences.

In the recognition test, the participants were presented with the 24 studied items (targets) and with 24 new items (lures), so for each of the studied sentences in each of the practice conditions we constructed a new sentence that would act as a lure. The lures were constructed by maintaining the character of one of the studied sentences and interchanging the predicate with that of a sentence with a different character presented in the same practice condition. This procedure is similar to that used in other experiments with propositional materials and recognition tests (see, e.g., J. R. Anderson, 1974; Gómez-Ariza & Bajo, 2003), and makes it possible to construct Rp+, Rp–, and Nrp items for both targets and lures. The presentation of targets and lures was randomized for each participant. The participants made their responses by pressing the appropriate key on the computer keyboard.

### Procedure

The procedure was similar to that of Experiments 1 and 2, the only difference being in the type of test provided to the participants. Before starting the final recall phase, the participants were informed of the nature of the test. They were told that they would be presented

with the old sentences and also with new sentences in which characters and activities were exchanged. Their task was to try to recognize the studied sentences and press the “yes” key when they recognized one of the old sentences and the “no” key when the presented sentence was new. The instructions emphasized both the speed and the accuracy of the participants' responses. Four practice trials were included to familiarize the participants with the testing procedure.

## Results and Discussion

Correct recall during the practice phase reached 81%. It is interesting to note that the level of recall during the practice phase was similar for the three experiments reported in the present article. The analyses involving response latencies were performed on the median of each participant in each of the experimental conditions.

### Facilitation Effects

We calculated  $d'$  from the percentages of hits and false alarms for each participant and each condition (Rp+ and Nrp). Results of these analyses indicate that the difference between Rp+ and Nrp did not reach significance [ $F(1,37) = 3.7$ ,  $MS_e = 1.35$ ]. Thus, the participants' recognition did not benefit from retrieval practice, and responses to the Rp+ items were similar in accuracy to responses to the Nrp items.

Similar results were found when the analyses were performed on the latency data. Thus, comparisons of the Rp+ and Nrp items did not yield significant results ( $F < 1$ ; see Table 3).

This absence of facilitation effects in recognition was surprising since other experiments have shown facilitation of Rp+ items in recognition (see, e.g., Hicks & Starns, 2004). Although speculative, we think that some features of our procedure and materials may have caused the absence of effects. Since many of the Rp+ items were presented for recognition after the Rp– or Nrp items, the participants were exposed to some items involving the Rp+ characters before confronting them. Since the Rp+ items would be highly activated, the presence of the Rp+ characters may compete with the correct responses and their representations would probably be inhibited. This inhibition may be enough to compensate for activation and produce a null result. In any case, as we will discuss later, the absence of facilitation makes a strong case against strength-dependent accounts of our data.

**Table 3**  
Experiment 3: Mean  $d'$  Values and Mean Response Latencies (RTs, in Milliseconds) to the Targets as Functions of Retrieval Practice Status

Retrieval Practice Status	$d'$		RT	
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
Rp+	2.17	0.24	2,035	90
Rp–	1.99	0.29	2,166	92
Nrp	2.68	0.27	2,022	86
RIM	0.69	0.32	144	92

Note—RIM, retrieval-induced misrecognition. RIM = Nrp – Rp–.

### Retrieval-Induced Forgetting

We calculated  $d'$  from the percentages of hits and false alarms for each participant and each condition (Rp– and Nrp). An ANOVA on these data showed a retrieval-induced misrecognition effect. The mean  $d'$  was significantly smaller for the Rp– ( $d' = 1.99$ ) than for the Nrp ( $d' = 2.68$ ) [ $F(1,37) = 4.6$ ,  $MS_e = 1.9$ ; see Table 3] items.

In addition, the latencies for correct responses to the target were averaged for each participant in each practice condition and introduced into the analysis. The results were parallel to those for the accuracy data; the participants' responses were reliably slower for the Rp– than for the Nrp targets [ $F(1,37) = 5.3$ ,  $MS_e = 74,434$ ; see Table 3].

Hence, the results indicate that the participants had more problems discriminating the Rp– than the Nrp sentences. This difficulty was evident not only in the analysis of the accuracy data, but also in that of the response time to the targets in that the Rp– targets were responded to more slowly than the Nrp targets. This pattern of results is consistent with inhibitory accounts of the RIF effect. If retrieval practice of some of the activities associated with a character has the consequence of inhibiting the representations of nonpracticed (competitor) sentences, these representations should be less accessible for retrieval independently of the type of cue provided at the time of recall. In addition, suppression of the memory representation of the Rp– items would imply a reduction in the activation levels of these representations so that more time would be needed to reach the response threshold. In accordance with this, recent experiments (Veling & van Knippenberg, 2004) have also shown RIF in response latencies to targets in lexical decision and recognition. As we will discuss later, the presence of an RIF effect in our recognition task is difficult to reconcile with occlusion and strategy disruption theories.

### GENERAL DISCUSSION

One of the aims of the present experiments was to clarify if the type of relation (episodic vs. semantic) among the associates was an important factor in producing RIF effects of different magnitudes. Thus, character–activity sentences were presented for study and the nature of the relation (thematically related vs. thematically unrelated) among the different activities associated with a character was manipulated. The results of Experiments 1 and 2 show that the magnitude of the RIF effect was equivalent for the related and unrelated conditions, indicating that the mechanism producing RIF also acts when the relation among the associates to a cue is episodic in nature.

The presence of an RIF effect in the unrelated condition is in agreement with the results of other studies in which propositional or perceptual material has been used to create cue–associate episodic links during the experimental session (M. C. Anderson & Bell, 2001; Ciranni & Shimamura, 1999; M. D. MacLeod & Macrae, 2001), but it adds to them by providing clearer evidence of inhibition when the relation among the associates is episodic. This

feature is especially interesting because the inhibitory account of the RIF effect suggests that the degree of inhibition depends on the overlap of the mental representations of the associates. According to this account (M. C. Anderson, 2003; M. C. Anderson, Green, & McCulloch, 2000; Bäuml & Hartinger, 2002), the items are represented in memory as a bundle of distributed semantic features that are shared with other items as a function of the degree of similarity among them. Shared features are influenced by activation and inhibition processes in parallel. Thus, for inhibition to occur, there should be some overlap among the Rp– items. Our data suggest that the episodically created link to the character provides the representational overlap necessary to produce competition. However, it is important to note that, although the presence of episodic relations may be sufficient to induce RIF effects, the results of previous experiments suggest that they are not necessary to produce them (Bäuml, 2002; Johnson & Anderson, 2004). For example, in Bäuml's study participants learned a categorized list (e.g., FRUIT–apple, FRUIT–orange) which they had to recall later in the experiment. In a separate intermediate phase, they repeatedly generated related items from semantic memory (e.g., FRUIT–ba\_\_\_, FRUIT–ki\_\_\_) or were presented the same items intact for study (e.g., FRUIT–bananas, FRUIT–kiwi). Only the semantic generation of items, but not their presentation for study, induced forgetting of the initially learned items. This result indicates that semantic generation can cause recall-specific episodic forgetting and that the sharing of a common learning episode (e.g., presentation of the intact items for further study) is not a necessary condition for RIF to occur.

In addition, the results of Experiments 1 and 2 indicate that the presence of a preexisting semantic association between Rp+ and Rp– did not change the magnitude of the effect. This result is intriguing because experiments in which related and unrelated materials were manipulated with similar procedures (e.g., the fan effect paradigm introduced by J. R. Anderson, 1974) have produced differential effects as a function of the relatedness of the materials. In the fan paradigm, participants learn different numbers of facts about a concept and later have to recognize them. The fan effect consists in the increment in recognition times and errors as the number of facts learned about a concept increases. It is important in this context that when the facts about a concept are interrelated, the competition that occurs during retrieval of one of the facts is circumvented so that the fan effect diminishes or is greatly reduced (see, e.g., Gómez-Ariza & Bajo, 2003; Moeser, 1979; Myers, O'Brien, Balota, & Toyofuku, 1984; Radvansky & Zacks, 1991; Smith, Adams, & Schorr, 1978). The usual interpretation of this pattern is in terms of integration. When the conditions facilitate integration of the facts about a concept, they no longer compete because they become part of a larger and coherent mental representation. The role of integration in reducing competition has also been shown in the retrieval practice paradigm (M. C. Anderson & Bell, 2001; M. C. Anderson & McCulloch, 1999). Thus, M. C. Anderson & McCulloch



found that instructions to interrelate category exemplars during study reduced RIF. These findings would lead one to expect that competition in the related condition of our experiments should have been reduced. However, this was not the case. One possible reason<sup>1</sup> that RIF effects would have been obtained in the related condition of our experiments has to do with procedural differences between our experiments and those of other integration studies. Thus, integration in the retrieval practice paradigm has been achieved with single words and sometimes with instructions to participants to integrate the items. Similarly, although integration in the fan paradigm is induced by presenting interrelated facts, the learning phase involves several study–retrieval cycles and testing starts only when participants have attained perfect recall. Repetition of the related items likely increases the probability of integrating the items. Hence, it is possible that the condition of our experiments with single short presentations of propositional material and without instructions to integrate does not produce significant integration of the related items. Thus, the presence of RIF when the associates were thematically related may be due to the absence of integration. In support of this interpretation, results of experiments recently conducted in our laboratory (Suárez, Gómez-Ariza, Lechuga, Pelegrina, & Bajo, in press) with the procedure and materials of the present experiments indicate that when participants were instructed to integrate the related activities or when the activities linked to each character were blocked and presented in contiguity, the RIF effect disappeared. Thus, the thematic condition of our experiments can be thought to be similar to that of the many RIF experiments in which category–exemplar material has been used without instructions to integrate. For both types of material (category exemplars and thematically related propositions), the associates to the cues (category or character of the proposition) had strong preexisting associations known to the participants before the experiment. What is interesting and novel about our experiments is that they show that these preexisting associations do not change the magnitude of the RIF effect. This suggests that feature overlap by itself does not necessarily produce integration. Intentional processing focused on this overlap might be needed for integration to occur. In addition, the results of our experiments indicate that the presence of RIF was independent of the specificity of the provided cues: Practice in the retrieval of some facts decreased performance on retrieval of other facts linked to the same character when nonspecific cues were provided (Experiment 1), but also in item-specific recall (Experiment 2) and recognition (Experiment 3). This is important because to claim inhibition it is necessary to show that forgetting is independent of the specificity of the provided cues. If forgetting of the Rp– items is due to inhibition of their representations in memory, the Rp– memory representations should be less accessible independently of the type of memory cue provided at the time of test. This pattern replicates the results of M. C. Anderson, E. L. Bjork, and R. A. Bjork (2000) with item-specific cues and those of Hicks and Starns (2004) in recognition tasks. In addition,

results of the discrimination analysis of the data from Experiment 3 suggest that practice in retrieval of Rp+ items produces not only decrements in recognition of the Rp– targets, but also difficulties in the discrimination of targets and lures, as the inhibitory account would predict.

As we have already discussed, the finding of an RIF effect in recognition goes against explanations based on occlusion processes at the time of retrieval, since the presence of the to-be-recalled items should eliminate occlusion. Although more sophisticated models, such as ACT–R (J. R. Anderson, 1983; J. R. Anderson & Reder, 1999), are able to handle RIF effects in recognition latencies, the lack of facilitation in Experiment 3 seriously undermines the plausibility of that account in this context. According to the model, when a retrieval cue (e.g., a character–activity sentence in a recognition test) is presented for verification, the concepts in the probe receive a fixed amount of activation. This activation spreads to other concepts associated during study. The more target representations are associated with a cue, the less activation any particular target will receive; the stronger the link between the cue and a particular target, the less activation will reach other linked memory representations. Thus, the strengthening of Rp+ during retrieval practice would result in more activation reaching the Rp+ target representation and less reaching the remaining targets (Rp–). Hence, when an Rp– target is presented for recognition, its lower activation level would make retrieval more costly (slower). However, the fact that in Experiment 3 longer latencies and lower discrimination rates were obtained for Rp– items relative to Nrp items in conditions in which the Rp+ item did not show superior (faster and more accurate) recognition relative to the Nrp items suggests that the obtained RIF effect is not due to the strengthening of the cue–target association of the Rp+ items. In addition, it is not obvious from the theory's assumptions why the Rp– targets and lures are more difficult to discriminate than the Nrp items. Recognition of the Rp– items should be slower, but the lower level of activation reaching these items does not have to produce increments in recognition errors.

The presence of RIF effect in recognition also goes against the disruption of coding/retrieval strategies. The presence of specific retrieval cues would induce the retrieval of item-specific information rather than the retrieval of relational information (Hunt & Einstein, 1981) so that relational strategies and knowledge would play little role when very specific cues are provided (Hunt & Einstein, 1981; Kintsch, 1970; Mandler, 1967). Hence, the presence of specific cues would eliminate or at least diminish the RIF effect. Results of Experiments 1–3 show that this was not the case.

In summary, the results of the experiments reported here indicate that the presence of episodically created relations among the targets associated with a cue was a sufficient condition for competition to arise and for inhibition to act. Previously unrelated targets created episodic links during the study phase, and these nonpreexisting links were sufficient to produce competition during the retrieval phase so that inhibition was triggered. In addition, the presence

of RIF effects was independent of the specificity of the information provided by the retrieval cue at the time of retrieval, indicating that unpracticed items were less accessible for retrieval even when copies of the target items were presented. Hence, Experiments 1–3 suggest that RIF effects are found over a wide range of materials and testing procedures, as the inhibitory account predicts.

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#### NOTE

1. A second possibility was suggested by Michael Anderson and has to do with which facts are practiced. M. C. Anderson (2003) argued that integration may depend on the possibility of linking the Rp+ and the Rp- items. Thus, integration would be maximal when the similarity

between Rp+ and Rp- is also maximal, and it would be minimal when the Rp+ and Rp- are very dissimilar. Although in the related condition of our experiments Rp+ and Rp- were similar because they belonged to the same schema, it was possible that by chance the Rp+ items were not uniformly linked to the Rp- items. We tried to explore this possibility by calculating the percentages of recall for each character in each version of the materials for some combinations of Rp+ items involving sentences that were proximal (e.g., third and fourth) or were not proximal (e.g., first and third) in the temporal sequence. The results of this calculation indicate that when the Rp+ items were next in the sequence the RIF effect was 15.5. However, when the Rp+ items did not follow the temporal sequence the RIF effect was -9.5. Therefore, there is some indication that integration may depend on the possible linkage between the Rp+ and Rp- items. However, this conclusion cannot be drawn without further investigation involving systematic manipulation of the sequences of the Rp+ and Rp- items.

### APPENDIX

#### Translation of the Spanish Propositions Used in the Experiments

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##### Propositions Used in Experiments 1 and 2

###### Fillers

The doctor has (turned on the TV, thrown out the garbage, won a hundred euros, watered the grass).  
The professor has (suffered a heart attack, finished his work, planted a pine tree, traveled by plane).

###### Thematically Related

The mechanic has (walked for eight hours, entered the bar, drunk a soft drink, paid the waiter).  
The lawyer has (heard the alarm clock, made the bed, bathed his son, prepared breakfast).  
The policeman has (arrived at the cinema, bought the tickets, watched a movie, eaten the popcorn).  
The bullfighter has (inserted the keys, started the car, crossed the forest, had a flat tire).

###### Thematically Unrelated

The fireman has (played tennis, recorded a CD, lost his ring, sold his motorcycle).  
The plumber has (done the laundry, taken the elevator, had salad for dinner, used a pencil).  
The butcher has (played the piano, read the newspaper, ridden the bicycle, manufactured a chair).  
The barber has (given a tie, written a letter, blown up a balloon, broken the glasses).

##### Propositions Used in Experiment 3

###### Fillers

The doctor has (turned on the TV, thrown out the garbage, won a hundred euros, watered the grass).  
The professor has (suffered a heart attack, finished his work, planted a pine tree, traveled by plane).

###### Targets

The fireman has (started the car, blown up a balloon, bathed his son, given a book).  
The butcher has (walked for eight hours, recorded a CD, manufactured a chair, sold his motorcycle).  
The lawyer has (ridden his bicycle, talked on the telephone, drawn a house, heard the alarm clock).  
The bullfighter has (read the newspaper, lost his ring, watched a movie, played tennis).  
The barber has (crossed the bridge, played piano, solved a puzzle, taken the elevator).  
The plumber has (had an omelette for dinner, written a letter, done the laundry, gone to the country).

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