

Retrieval-Induced Forgetting in Perceptually Driven Memory Tests

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Recent data (T. J. Perfect, C. J. A. Moulin, M. A. Conway, & E. Perry, 2002) have suggested that retrieval-induced forgetting (RIF) depends on conceptual memory because the effect is not found in perceptually driven tasks. In 3 experiments, the authors aimed to show that the presence of RIF depends on whether the procedure induces appropriate transfer between representations and competition rather than on the nature of the final test. The authors adapted the standard paradigm to introduce lexical categories (words that shared the first 2 letters) at study and practice. Direct and indirect fragment completion tests were used at retrieval. The results showed significant RIF effects in perceptually driven tasks. Furthermore, they indicated that the presence of RIF effects depended on using adequate cuing to induce competition during the retrieval practice and on the final memory test tapping the inhibited representation.

Keywords: retrieval-induced forgetting, inhibition, competition, transfer appropriateness, perceptually driven memory test

It has been proposed that forgetting of irrelevant information plays an important role in everyday life (Bjork, Bjork, & Anderson, 1998). Many of our goals often require the recall of specific events in long-term memory, but to retrieve them we have to overcome interference from other related memories. Thus, if we want to read a book, we might need first to retrieve from memory the place where we last left our glasses, but to do that we need to overcome the interference from other memories of the many places in which we have left the glasses in the past. How do we overcome interference from irrelevant memories and recover the specific event that we want? Anderson and colleagues (M. C. Anderson, 2003; M. C. Anderson & Bell, 2001; M. C. Anderson & McCulloch, 1999; M. C. Anderson & Spellman, 1995) have proposed that this kind of interference is resolved by means of inhibitory control processes that are in charge of suppressing competing memories during memory retrieval.

This proposal is supported by a number of findings suggesting that the very fact of retrieving information may be a source of forgetting (e.g., M. C. Anderson, Bjork, & Bjork, 1994, 2000; Blaxton & Neely, 1983; Brown, 1981; Roediger, 1978; see M. C.

Anderson & Neely, 1996, for a review). Although previous retrieval increases the probability of retrieving the recovered items in a subsequent memory test, certain nonretrieved items can become less available to recall from long-term memory (M. C. Anderson & Bell, 2001; M. C. Anderson et al., 1994; Ciranni & Shimamura, 1999; Gómez-Ariza, Lechuga, Pelegrina, & Bajo, 2005; Levy & Anderson, 2002; Macrae & MacLeod, 1999). This phenomenon is known as *retrieval-induced forgetting* (RIF).

The RIF effect has been studied in the retrieval practice paradigm. This paradigm consists of three phases (M. C. Anderson et al., 1994). In the study phase, participants are asked to study a list of category-exemplar pairs (e.g., Fruit-Orange) for a later memory test. In the retrieval practice phase, participants are cued to recall half of the exemplars from half of the presented categories (Rp+ items) by means of a category-plus-word-stem cue (e.g., Fruit Or_ _ _). This creates a subset of items that were from the practiced category, but they themselves were not practiced (Rp- items), and a third subset of items that were not practiced and belong to an unpracticed category (Nrp items). After a retention interval (from 5 to 20 min), the final phase of the paradigm is conducted: Participants are presented with all the studied category names, and they are asked to recall as many exemplars as possible from each of the presented categories. M. C. Anderson et al. (1994) demonstrated that the probability of recalling the Rp- items was significantly lower than the probability of recalling the Nrp items, that is, retrieval of some members of the category (Rp+) had the effect of reducing the probability of recalling the unpracticed members of that category. They also claimed that inhibition of competing memories was the mechanism producing the RIF effect: During the retrieval practice phase, Rp- items are inhibited to reduce their competing effects and to facilitate recall of the Rp+ items.

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Evidence for this inhibitory account has come from research manipulating the strength of both practiced and unpracticed competitor items (M. C. Anderson et al., 1994), the type of cues used to test memory of the Rp- items (M. C. Anderson et al., 2000; M. C. Anderson & Spellman, 1995), and the type of memory tests (Gómez-Ariza et al., 2005; Perfect, Moulin, Conway, & Perry, 2002) in the retrieval practice paradigm. In fact, the effects of these three manipulations have been used as criteria to test the inhibitory account. First, because inhibition depends on the presence of competition, Rp- items that are strongly associated to the categorical cue (strong competitors) produce larger RIF effects than the more weakly associated Rp- items, and this occurs irrespective of the strength of the Rp+ items (M. C. Anderson et al., 1994).

Second, because inhibition is supposed to act on the memory representations, RIF effects appear not only when the final recall test involves cues presented during the study and retrieval phases but also when recall of the Rp- items is tested with cues that were not present during these two phases. Consistent with this prediction, M. C. Anderson and Spellman (1995) and M. C. Anderson et al. (2000) showed that forgetting occurs even when the cues at the final memory test differ from those used during the study and retrieval practice phases.

Third, and also because inhibition acts on the memory traces for the Rp- items, reducing their activation level and decreasing their accessibility, RIF effects should appear independently of the type of test used for retrieval, as long as this test taps the inhibited representations (M. C. Anderson, 2003). Recent experiments have shown that RIF effects occur not only in recall tests but also in recognition (Gómez-Ariza et al., 2005; Hicks & Starns, 2004; Veling & van Knippenberg, 2004), and in some indirect memory tests such as lexical decision (Veling & van Knippenberg, 2004), category generation, and category verification (Perfect et al., 2002). Therefore, one could conclude that the impairment of recall for Rp- items appears with many different types of tests, indicating that the memory representation of those items has been inhibited, and it is therefore less accessible. However, there are a few cases in which RIF effects were not found when tested by means of indirect memory tests (Butler, Williams, Zacks, & Maki, 2001; Perfect et al., 2002). In five experiments, Perfect et al. (2002) tested the inhibitory account of RIF by using indirect memory tests that were either conceptually driven or perceptually driven. In their experiments, participants studied category-exemplar pairs as in the standard procedure. They also completed a standard retrieval practice phase. However, in the final phase, different direct and indirect memory tests were used: cued recall, category generation, category-exemplar pair verification, degraded stimuli identification, and word stem completion tasks. Their results indicated that the RIF effects were present in conceptually driven tasks (cued recall, category generation, and category verification), but they were absent when memory was tested by using either direct or indirect perceptually driven tests (perceptual identification and word stem completion tasks). According to Perfect et al., these results are consistent with an inhibitory account of RIF but are restricted only to conceptual representations.

However, it might be premature to draw this conclusion. There are not a priori reasons to expect that inhibition would affect only conceptual representations. There is some evidence that lexical competition impairs retrieval in a generation task (Brown, Zoccolli, & Leahy, 2005) and in fragment completion (Lustig & Hasher,

2001; Smith & Tindell, 1997). In addition, research on other cognitive areas such as visual attention or language comprehension and production has found that selection might be achieved by means of inhibition. For example, popular explanations of the inhibition of return effect (e.g., Tipper, Grison, & Kessler, 2003) have suggested that already-sampled spatial locations are inhibited to facilitate visual search. In addition, many theories of language production assume that lexical selection is achieved by means of inhibitory connections at the level of lexical representations (e.g., Berg & Schade, 1992; Cutting & Ferreira, 1999; Stemmer, 1985). Hence, research in different cognitive domains has suggested that both lexical and perceptual representations can be inhibited. In fact, it is possible to explain the lack of RIF effects in Perfect et al.'s (2002) lexical and perceptual tests (word fragment completion and perceptual identification) by calling on a well known memory principle: *transfer appropriate processing*. According to this principle, words will be remembered to the extent that processing at encoding is appropriate for the particular test (Morris, Bransford & Franks, 1977; Tulving & Thomson, 1973). Memory representations are multifaceted, and different retrieval cues may provide access to different aspects of these representations. Accordingly, the presence of inhibitory effects should depend on the degree to which the memory trace tapped by the test matches the memory trace that was inhibited during retrieval practice. To distinguish this from other transfer appropriate interpretations that place emphasis in the match between the cues at encoding and test, we are referring to this version of the transfer appropriate principle as *appropriate transfer between representations* (see Ratcliff & McKoon, 1995, for a related idea). Because in Perfect et al.'s (2002) experiments participants studied and conducted retrieval practice of category-exemplar pairs, conceptual encoding and conceptual inhibition was induced; hence, RIF effects were found only when the final memory task also tapped conceptual representations. However, when they tapped other aspects or types of representations (lexical or perceptual), RIF effects were not found. Thus, RIF effects might have not been found because the final perceptually driven tests were simply tapping noninhibited aspects of the memory traces, an argument that is consistent with M. C. Anderson's (2003) suggestion that transfer inappropriate testing might in some cases mask the RIF effects.

The aim of the experiments reported here was to further explore the extent to which RIF effects may be restricted to conceptual representations or, on the contrary, whether they extend to perceptually driven direct and indirect memory tests. There are some indications that inhibition may appear with visuospatial stimuli (Ciranni & Shimamura, 1999) and with lexically oriented tests such as lexical decision (Veling & van Knippenberg, 2004). However, Ciranni and Shimamura (1999) used a direct cue-recall task, and therefore conceptual search could also be involved; and Veling and van Knippenberg (2004) used an indirect test that is not strictly perceptually driven, as shown by the many experiments reporting semantic priming in lexical decision (e.g., Meyer & Schvaneveldt, 1971). Therefore, it is still necessary to find clear and direct evidence that RIF can be found in a test that it is both indirect and perceptually driven.

Our expectations were that forgetting in perceptually driven memory tests would be found if retrieval practice specifically required suppressing perceptual/lexical traces. Our aim in the three experiments that we report here was to create lexical competition

during the retrieval practice phase so that inhibition would directly act on the lexical representations of the presented words. With this purpose in mind, we selected lexically oriented study and retrieval material. Six sets of semantically unrelated words were created. All the words within a set started by the same two letters, and therefore each set constituted a lexical category with the items lexically related. In this sense, our experiments differed from previous studies with conceptual categories and semantically related items. Our experimental procedure was similar to the standard RIF procedure. In the first study phase, participants were shown pairs consisting of the first two letters of the word and the word itself (PE–Pelota), and instructions emphasized paying attention to the first two letters because they would be helpful in recalling the items in a later memory test. During retrieval practice, participants were simultaneously shown the lexical cue (the first two letters) and the first three letters of each to-be-recalled word (e.g., PE–Pel__). As in the standard procedure, participants practiced retrieving half of items from half of sets. Because the main goal of the study was to replicate the standard RIF effect, but with lexical categories, in the final test of Experiments 1 and 2 participants were explicitly instructed to try to remember the studied words, and they were presented with the first three letters of the studied words (e.g., Pel__) as retrieval cues. In Experiment 3, we aimed to extend these results to an indirect memory task, and therefore the final test also required the production of a word in response to a fragment, but, this time, without any reference to the previously studied materials. The demonstration of RIF effects in indirect tests is important for the inhibitory account not only because it demonstrates that forgetting appears in different types of memory tasks but also because it allows testing of the memory representation with independent cues. For example, in a fragment completion task, it is not necessary to present the category cue used at study (e.g., FRUIT) or to present the word fragment used at the retrieval practice phase (e.g., or__); it is possible to present a different word fragment (e.g., __ange) and to ask the participants to fill in the blank with the first word that comes to mind. Thus, the use of indirect tests meets two of the criteria put forward to support the inhibitory account: RIF effects with independent cues and RIF effects with different types of memory tests. The presence of lexical RIF effects under these conditions could then be explained as the result of inhibition. Hence, in Experiment 3 we used the same procedure as in Experiment 2 but changed the type of cue and the instructions given to the participants in the final recall test. To do this, the first syllable of all of the tested items was removed, and the resulting fragments (e.g., __calao for Bacalao) were presented to the participants with instructions to say the first word that came to mind that finished with the presented word fragment.

In the three experiments, participants were oriented to (a) encode the lexical features of the items, (b) practice retrieving the items with a lexical cue, (c) and finally, recall the lexical representation of the item by means of a lexical cue (the first two letters of the items, Experiments 1 and 2) or by filling a word fragment (Experiment 3). Therefore, encoding, practice, and retrieval required the same type of data-driven lexical processing. Under these conditions, we expected that the recall of Rp– items (unpracticed items from the practiced lexical set) would be impaired relative to the control condition (Nrp items), independently of the nature of the test (direct or indirect).

Experiment 1

The purpose of Experiment 1 was to attempt to show that inhibition is not restricted to an item's conceptual representation but can also act on its lexical representation if the conditions of encoding and retrieval practice also induce lexical processing. Consequently, we used the standard RIF procedure but with lexical categories; that is, instead of using conceptual categories, we introduced lexical sets (words starting by the same two letters) as study and retrieval practice materials. During the final test, participants were presented word stems as recall cues (the first three letters of the word and a blank space), and they were asked to fill in the blank with one of the words from the study list. As a result, lexical processing was required during the three standard phases of the RIF procedure so that appropriate transfer between representations could occur. Under these conditions, we expected to find lexical RIF effects.

Method

Participants. Twenty participants from the University of Jaén (range = 18–35 years of age, $M = 21.4$) participated in this experiment. They received course credit for their participation.

Materials. Six sets of six words were created to be learned by the participants. The words in each set shared the first syllable, which was always composed of two letters (see Appendix). The words were common Spanish terms chosen from Alameda and Cuetos (1995), a word frequency normative database for Spanish, according to the following constraints: (a) The third letter had to be unique, so that no more than one word began with the same first three letters; (b) there were no evident semantic or associative relationships among them, and no lexical relations between words pertaining to different sets; and (c) the words were formed by more than two syllables and less than five. Two more sets of three words each were created to be used as fillers.

Because we wanted to make sure that competition would be at work during retrieval practice, special attention was paid to the lexical frequency of the items within each lexical set. The aim was to make the Rp– items competitive enough to trigger inhibition. Thus, for every lexical set, three medium-low lexical frequency words (range = 10–36, $M = 17.5$) were selected to be used as practiced items (Rp+ items), and three medium-high frequency words (range = 34–98, $M = 51.5$) were selected to be used as unpracticed items (Rp–). Two counterbalanced versions of the materials were created, so that every high frequency item appeared in both unpracticed conditions (Rp– and Nrp). Approximately half of the participants were assigned to one of these counterbalanced versions.

Procedure. Participants were tested individually in a quiet room. They were told that they were participating in a memory experiment and that their memory would be tested after studying a list of words. At the beginning of the study phase, participants were informed that eight sets of unrelated words sharing the first two letters were to be presented and that their task was to try to learn them as well as possible in preparation for an upcoming memory test. The items were presented individually on the center of the computer screen for 5 s. There was a 1 s interval between consecutive items. To match the original category–exemplar retrieval practice procedure (e.g., ANIMAL–Horse) as much as possible, each item was presented along with the corresponding syllable category (e.g., BA–Bacalao), and participants were told to pay attention to the syllable because it would become a retrieval cue during the subsequent memory test. The complete list of lexical-category-plus-exemplar pairs was presented twice for study. The order of presentation of the experimental items was random for each participant. However, to reduce primacy and recency effects, the first and last three words of the study list were always items belonging to the two filler lexical categories.

Immediately after the learning phase, participants carried out the retrieval practice phase, which involved repeated retrieval of three items from three of the studied lexical sets (i.e., the Rp+ items). Retrieval cues containing the syllable defining the lexical category plus a three-letter word stem were presented individually on the screen for 6 s (e.g., BA-Bac_ _ _). Participants were asked to orally recall the studied word that started with the same three letters as the stem cue (in this example, Bacalao). Random blocks of items were created so that each block was composed by one item from each of the three to-be-practiced sets. In this way, repetition of the same syllable in two adjacent trials was avoided. As in the study phase, filler items were included at the beginning and end of the practice phase. They were also used to separate blocks of target words. The list of to-be-practiced items (nine target items and six fillers) was presented six times to the participants. Right after the retrieval practice phase, participants answered a set of questions regarding their age, course, reasons to study psychology, and favorite topic in psychology. These questions were introduced to fill out the 5-min interval between the practice phase and the final memory test.

At the final memory test, participants were asked to complete each of the word stems with one of the items (e.g., Bac_ _ _). Each fragment was presented for 10 s on the computer screen with 1s intervals between consecutive stems. Participants were instructed to provide a vocal response during the time the fragment was on the screen. To minimize the possible effect of output interference, the set of fragments was divided in two blocks so that the block presented first contained the fragments corresponding to the unpracticed items (Rp- and Nrp) and so that the block presented second contained the fragments corresponding to the practiced items (Rp+). The order of the items within each of these blocks was randomized for each participant.

Presentation of the items in the three phases of this and the following experiments was controlled by Experimental Run Time System software (Beringer, 1997).

Results and Discussion

To check for facilitation and forgetting effects, in this and the following experiments, we performed two within-participants analyses of variance on the percentage of words recalled in the final test. The first analysis involved comparing memory for Rp+ and Nrp items (facilitation), whereas the second analysis involved contrasting memory for Rp- and Nrp items (forgetting). The alpha level for significance was set at .05 in all the reported analyses.

For this experiment, the mean percentage of correct recall for the retrieval practice phase was 57.51. Results regarding the final recall test are shown in Table 1. The facilitation effect of practice was significant, $F(1, 19) = 15.44, MSE = 97.27, p < .01$, with participants recalling more Rp+ than Nrp items. However, no RIF

effect was found. The percentages of recall for Rp- and Nrp items were virtually the same, $F(1, 19) < 1$.

Hence, contrary to our predictions, we did not find RIF effects despite having induced lexical processing at study, retrieval practice, and final test. Because participants were presented the lexical category names and the word stems (e.g., PE-Pel_ _ _) as cues to recall during the retrieval practice phase, and because possible competitors were those items starting with the same two letters (lexical competitors), inhibition should have acted on these lexical representations. However, the results of Experiment 1 indicated that this was not the case, suggesting that inhibition may indeed be restricted to conceptual representations.

Overall, the retrieval practice success rates in this and the following experiments were low, compared with what they usually are in RIF studies. This was probably because of the difficult low frequency stems that we selected to maximize competition. However, these low success rates should have not changed the probability of finding forgetting effects because successful retrieval practice seems not to be essential for obtaining RIF effects. As Storm, Nestojko, Bjork, and Bjork (2005) have recently found, even when retrieval practice is impossible (i.e., the retrieval practice cues did not match any possible item), significant inhibition is observed. Hence, the lack of effect in this experiment can not be attributed to the low success rate during retrieval practice.

Therefore, the results of this experiment seem consistent with Perfect et al.'s (2002) data and conclusions. However, a different interpretation is also possible. In this experiment, we presented the lexical category (PE) and the word stem (Pel_ _ _) simultaneously, and because the lexical category (PE) was already contained in the word stem (Pel_ _ _), participants might have ignored the lexical category cue and use the unique 3-letter word stem to directly access the target representation, a strategy in which competition from other items from the set is unlikely to occur. This possibility was already put forward by M. C. Anderson (2003) as a possible moderating factor of RIF. In M. C. Anderson's words, "Any factor that reduces attention to the shared cue and focuses it in the distinguishing cue is likely to reduce activation of competitors" (p. 428). If this was the case, RIF effects should not be expected because retrieval and competition during the retrieval phase are necessary conditions to trigger inhibition (M. C. Anderson et al., 2000). With the aim of testing the plausibility of this line of argumentation, in the experiment that follows an attempt was made

Table 1
Correct Percentage of Recall in the Final Test by Practice Status of the Items

Experiment	Practice status condition					
	Rp+		Rp-		Nrp	
	M	SE	M	SE	M	SE
Experiment 1	61.69	2.61	48.34	3.36	49.44	3.65
Experiment 2	60.18	3.64	38.24	3.73	49.43	2.85
Experiment 3	97.87	1.07	76.51	2.71	83.35	1.87

Note. Rp+ = study phase items also presented in the retrieval practice phase; Rp- = study phase items not presented in the retrieval practice phase; Nrp = unpracticed items.

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to more effectively induce interitem competition during the retrieval practice phase.

Experiment 2

This experiment was an exact replication of Experiment 1, except for an important modification during the second phase: For each practiced item, participants were presented first with the two-letter lexical cue (e.g., PE), which remained on the screen for 2 s, and only after that precuing period had elapsed, the three-letter cue that signaled the exact word to be remembered was presented. Because the lexical category cue was displayed first, in isolation, and it was formerly associated to six items during the study phase, its presentation should activate the representations of the six studied items and introduce competition. Note that, as described in Experiment 1, the Rp- items were selected to be of higher frequency than the Rp+ items and, therefore, if activated by the lexical category cue, they should produce high levels of competition. Thus, when the remaining of the cue (the three-letter word fragment) was later presented, inhibition would be needed to reduce this competition. If, as expected, this precuing procedure induces activation and competition from the Rp- items, the RIF effects should appear. These results would be important for at least two reasons: (a) They would provide converging evidence that competition is needed to trigger inhibition, and (b) they would demonstrate the efficiency of a new procedure in inducing and maximizing competition.

Method

Participants. Twenty new participants took part in this experiment (range = 18–29 years of age, $M = 22.7$). They all were students from the School of Education at the University of Jaén and received extra credit for their participation.

Materials and procedure. The materials were identical to those used in Experiment 1. As noted above, however, there was a critical variation from Experiment 1 regarding the cuing procedure during the retrieval practice phase. Thus, instead of presenting the lexical category cue plus the three-letter word stem (e.g., BA-Bac_ _ _) simultaneously, in Experiment 2 participants were shown both cue components in two steps. First, the lexical category component was displayed for 2 s. Second, and after a 1-s blank interval, the three-letter word stem was presented for 6 s. Participants were asked to respond when the three-letter stem was presented because the lexical category cue was not restrictive enough to know which item they were being asked for. All other aspects of the procedure were the same as in Experiment 1.

Results and Discussion

The performance level during retrieval practice in this experiment was 52.97. Analysis of the final recall data indicated that the facilitation effect of retrieval practice was significant, $F(1, 19) = 5.22$, $MSE = 221.20$, $p < .05$. Thus, the probability of recalling the Rp+ items was higher than the probability of recalling the control Nrp items (see Table 1). In addition, there was a reliable RIF effect, $F(1, 19) = 8.02$, $MSE = 156.22$, $p < .05$. Participants recalled 49% of the control Nrp items, whereas they recalled only 38% of Rp- items (see Table 1). Thus, when competition was induced during retrieval practice by means of precuing, unpracticed items from practiced lexical categories (Rp-) reduced their probability of being recalled relative to the control items, demon-

strating that inhibition can also act when competition is lexical in nature and the materials are lexically related.

This result goes against Perfect et al.'s (2002) suggestion that the inhibitory processes underlying RIF effects are restricted to conceptual representations. However, they are consistent with psycholinguistic data and theories suggesting that lexical selection is achieved by means of inhibitory processes acting on competing lemmas (Berg & Schade, 1992; Cutting & Ferreira, 1999; Stemmer, 1985). Finally, they are also consistent with results showing RIF effects with perceptual categories such as color, shape, or position (Ciranni & Shimamura, 1999).

A comparison of the results obtained in Experiments 1 and 2 is also important because it lends support to the claim that competition at retrieval is a necessary condition for inhibition to occur (M. C. Anderson et al., 2000). Thus, in Experiment 1, because participants could ignore the lexical category cue during retrieval practice and could directly access the target representation without activating other lexical competitors, RIF effects were not found. However, in Experiment 2, in which the conditions of retrieval practice forced participants to first encode the lexical cue and activate lexical competitors, the RIF effect was present.

Note that, although the level of recall of the Rp- items varied from Experiment 1 to Experiment 2, the percentages of correct recall of Nrp and Rp+ items in the two experiments were almost identical (see Table 1), an indication that the precuing procedure introduced during the retrieval phase in Experiment 2 was successful at changing the opportunity for competition to act. The pattern of results cannot be attributed to changes in the overall strategy used by the participants or to any other factor influencing the overall performance in the task. Most importantly, having this differential RIF effect with a similar amount of Rp+ facilitation supports the strength-independence property of RIF, and it provides evidence against a noninhibitory theory such as blocking, as it will be further elaborated in the General Discussion.

Experiment 3

The results of Experiment 2 demonstrate that it is possible to obtain lexical RIF effects in a lexically oriented recall test when the competition induced during the retrieval practice is also lexical in nature. The presence of this effect in the word fragment cue-recall test suggests that inhibition can also act on nonconceptual memory representations. However, although the cues presented during practice and final recall were not identical, they were highly similar (the word stem contained the lexical category cue), and it could be argued that the obtained RIF effects were not cue independent and could be reflecting the result of other forgetting mechanisms (see M. C. Anderson, 2003, for a discussion of noninhibitory accounts). The purpose of Experiment 3 was to ensure that the obtained RIF effect was the result of inhibitory processes acting on the lexical representations of the Rp- items, introducing an indirect final memory test with fragment cues not presented during the study and practice phases (independent cues). If the results of Experiment 2 were due to the inhibition of lexical competing memories, RIF should be cue independent and occur even when the test was indirect and the cues used during the final test were completely different from those used during retrieval practice.

Method

Participants. Twenty-six students (range = 19–49 years of age, $M = 23.5$) from the University of Jaén participated in the experiment for extra credit. None of them participated in the previous two experiments.

Materials. In addition to the experimental words used as targets in the two previous experiments, 24 new stimuli (see Appendix) were selected to be presented as fillers during the final indirect test. These items were all common Spanish words, between two and five syllables in length, and with the restriction that none of them shared the initial syllable with the items in the studied sets.

For the final fragment completion indirect test, the first syllable of all of the items (fillers and targets) was removed so that the test cues consisted of word endings (e.g., *_ _ calao* for *Bacalao*; or *_ _ gato* for *Negativo*). As in the two previous experiments, two counterbalanced versions of the material were created so that the same items worked as *Rp-* and *Nrp* for different participants.

Procedure. The procedure was identical to that used in Experiment 2, except for the instructions given to the participants for the final test. Upon their arrival to the laboratory, participants were informed that they were going to take part in a study exploring the relationship between memory and other verbal abilities. More specifically, they were told that they were to perform a memory task and, after that, one unrelated verbal fluency test. After retrieval practice finished (the only memory task in the experiment from the participants' perspective), participants performed the indirect memory test. They were told that they would see Spanish words missing their first syllable and that their task was to say aloud the first word coming to mind that ended with the presented fragment. They were instructed to try to do this task as fast as possible and to try to fill in the missing fragment with only one syllable. Three examples were shown to participants using nonstudied words as material.

The final test sequence of 51 items was organized into two separate blocks for presentation of the word ending cues. The first block was formed by the cues corresponding to the unpracticed items (9 *Rp-* and 9 *Nrp*) plus 24 cues that did not correspond to any of the studied items (filler cues) with the restriction that the first 5 presented items were always fillers. The proportion of fillers within this block was 57%. The second block consisted of 9 cues corresponding to the practiced items (*Rp+*). The purpose of presenting a fixed order for the blocks was to keep, as much as possible, the implicit sense of the test and to avoid output interference from the practiced items. The blocked structure of the list was not apparent to the participants, who experienced the test as a long list of word prompts. The order of presentation of stimuli within each block was random for each participant, with each cue being presented on the computer screen for 7 s.

Results and Discussion

On average, the recall percentage at the retrieval practice phase (58.34) was similar to that found in the two previous experiments. The results of the analyses performed on the percentage of studied words produced during the indirect memory task indicated that participants generated more *Rp+* than *Nrp* items, $F(1, 25) = 47.22$, $MSE = 58.00$, $p < .01$. Thus, a clear facilitation effect was also found with our indirect test. In addition, participants completed more *Nrp* stems than they did *Rp-* items, $F(1, 25) = 4.55$, $MSE = 133.45$, $p < .05$ (see Table 1), indicating that RIF can also be found in data-driven indirect tests. These results are important because they, once again, indicate that inhibition is not restricted to conceptual tests. Inhibition of competing memories is a strong forgetting mechanism that extends to indirect memory tests and to lexical representations. The RIF effect obtained in this experiment cannot be attributed to the differential strengthening of the *Rp+* items blocking the retrieval of the *Rp-* words because the cues

used at test were different from those used during the practice phase. In addition, because the RIF effect appeared in an indirect memory task, the results of this experiment suggest that explicit search in long-term memory during the final test might not be a necessary condition for inhibition to show its effects. However, this assertion needs to be qualified because the use of fragment completion does not ensure that retrieval is free from explicit contaminations. As we discuss below, this does not undermine the contribution of the present data.

General Discussion

Taken together, the results of the experiments show that RIF is not restricted to conceptually driven tasks or to conceptual mental representations. Most previous studies on RIF have reported competition and inhibition among items sharing the same semantic or contextual category but not between lexical categories. In Experiments 2 and 3, RIF effects were obtained when the retrieval practice phase induced inhibition of lexically related competing memories. Thus, the recall of the *Rp-* items was impaired relative to the recall of the *Nrp* control items, even though the final memory tests (fragment completion) forced participants to retrieve lexical representations either directly (Experiment 2) or indirectly (Experiment 3).

Our claim that the lexical representation of the *Rp-* items is impaired in these experiments is based on the use of lexical cues (word fragments) at study, retrieval practice, and final recall phases. However, it might be argued that fragment completion is not a pure measure of lexical memory and that our findings do not necessarily have to be interpreted as evidence for inhibition acting on lexical representations. Still, convergent evidence that fragment completion is lexically mediated can be found in several studies. For example, Downes et al. (1996) reported data showing cohort priming in an indirect fragment completion task. In their study, participants were presented words in which the initial phonemes could be pronounced in different ways depending on the context provided by the word (e.g., *ba* is pronounced differently in a word like *ball* than in a word like *barn*). In addition to finding the usual priming effect (bias toward completing the fragment with the same word that was seen before), they found a bias toward completing the stem with words with the same pronunciation as the target word when that target was missed and not produced at test. Furthermore, the influence of orthography in fragment completion has been shown in studies reporting interference effects when orthographically similar primes were presented before the word fragment. For example, completing a fragment such as *A_L_ _GY* (for allergy) was impaired if a structurally similar prime such as *ANALOGY* was previously presented relative to a control condition in which the primes were neutral unrelated items such as *UNICORN* (Smith & Tindell, 1997; for similar results see Lustig & Hasher, 2001). Finally, conceptual manipulations such as level of processing have often been found to have little or no effect on fragment completion (e.g., Smith & Tindell, 1997). This pattern of results suggests that lexical representations are tapped when using fragment completion tests and provide independent support to the conclusion that the effects found in our experiments were lexical in nature.

From a broader perspective, the lexical nature of the RIF effects found in Experiments 2 and 3 is consistent with research and

theories from other cognitive domains such as attention and language comprehension and production. As stated in the introduction, many theories of language production assume that lexical selection is achieved by means of inhibitory connections at the level of lexical representations (e.g., Berg & Schade, 1992; Cutting & Ferreira, 1999; Stemmer, 1985). In addition, explanations of the inhibition of return effect (e.g., Tipper et al., 2003) suggest that already-sampled spatial locations are inhibited to facilitate visual search. Jointly considered, research in these other cognitive domains suggests that inhibition is not necessarily restricted to conceptual representations and that lexical and perceptual representations can also be inhibited. At first sight, this proposal might seem incongruent with the feature suppression theory proposed by M. C. Anderson and Spellman (1995). According to this model, 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 assumed to be influenced, in parallel, by activation and inhibition processes and, therefore, the inhibition of any given item's representation should affect the representations of similar items sharing semantic features, which would also be inhibited. The restriction of the model to semantic features would make it incompatible with the proposal that lexical and perceptual features can be inhibited. However, as M. C. Anderson (2003) has more recently proposed, the feature suppression model could be extended to episodic, perceptual, and lexical features. In M. C. Anderson's words "Retrieval-induced forgetting is not limited to episodic retrieval, or to taxonomic categories; rather, it is a general consequence arising whenever inhibitory mechanisms are recruited to guide selection in the face of competition from distracting memories" (p. 425).

The overall pattern of results also indicates that RIF can be found with both direct and indirect memory tests. In Experiment 3, we used a fragment completion task to show RIF in an indirect perceptually driven task. In this experiment, we took great care to minimize the participants' awareness of the relation between the encoding and final memory test (by providing incidental instructions, by including a substantial number of fillers, and by organizing the test sequence so that the fillers and unpracticed items were always presented first). Still it cannot be ascertained that indirect tasks like the one used here and those used by Perfect et al. (2002) reflect exclusively the contribution of implicit memory. This is an issue that clearly demands more attention, especially in the light of the initial findings reported by Camp, Pecher, and Schmidt (2005) suggesting that RIF might be modulated by test awareness. But, independently of how this problem is eventually solved, the findings of Experiment 3 are specially important because they clearly show that RIF can be observed on a test in which participants are not oriented to the initial study episode and in which retrieval involves nonconceptual (lexical) representations.

In addition, the results of the experiments reported also point to two important restrictions for the occurrence of the RIF effect. First, comparison of the results obtained in Experiments 2 and 3 with those reported by Perfect et al. (2002) suggests that for the RIF effect to occur it is necessary that the memory trace tapped by the final test matches the memory trace that was inhibited during retrieval practice. Because in Perfect et al.'s experiments participants studied and conducted retrieval practice of category-exemplar pairs, conceptual encoding and conceptual inhibition were induced, and consequently RIF effects were present only

when the final memory task also tapped these conceptual representations. However, these effects were absent when the task tapped other aspects of these representations (i.e., lexical or perceptual). Thus, RIF effects might have not been found in their indirect data-driven tasks because the final test was simply tapping noninhibited aspects of the memory traces. The assumption that inhibition occurs only when there is transfer appropriate processing is not without precedents. Perfect et al. (2004) have suggested that inhibitory effects may be modulated by context. In their experiments, two cues (episodic and semantic) were associated to the target items during study. At practice, items were retrieved by means of category cues plus the stem (Experiment 1 and 3) or with the category plus episodic cues plus the stem (Experiment 2). In the final recall test, participants were tested either with the category cue or with the episodic cue associated to the target items at study (faces or unrelated words). Results showed RIF only when the same retrieval cue was present at practice and test. As the authors of this study suggest, one possible way of explaining these results is to assume that for RIF to occur, transfer appropriate processing must also occur. However, note that their interpretation of the transfer appropriate principle substantially differs from ours in that it is cue dependent (for RIF effects to occur the same retrieval cues have to be present at practice and test), whereas the *appropriate transfer between representations* interpretation that we are claiming is cue independent. That is, for the RIF effect to occur, the final memory test has to contact the representation that was inhibited at practice, independently of whether the retrieval cue at practice was present or absent at the final test. Results of our Experiment 3 support this last interpretation because an RIF effect was obtained with independent cues, as the result of both practice and test tapping the same lexical representations. This is also consistent with results of M. C. Anderson and Spellman (1995) and M. C. Anderson et al. (2000) demonstrating the cue independent properties of RIF. In our view, the apparent cue dependency obtained in Perfect's (2004) experiments could be better interpreted as representation-dependent effects.

Second, the presence of the effect in Experiment 2 and its absence in Experiment 1 also suggest that competition by the Rp-items during retrieval practice is a necessary condition for the effect to appear. The procedures of Experiments 1 and 2 were almost identical: participants initially studied pairs consisting of the first two letters of the word (e.g., PE) and the word itself (e.g., Pelota); during retrieval practice, participants were shown the lexical cue (the first two letters) and the first three letters of the to-be-recalled word (e.g., PE-Pel_ _); and in the final test, participants were presented with the first three letters of the studied words (e.g., Pel_ _) and asked to complete the stem with one of the studied words. The only difference between the two experiments was the cuing procedure used during the practice phase. In Experiment 1, the lexical category cue was simultaneously presented with the word stem cue, whereas in Experiment 2, the category cue was presented 2 s before presentation of the stem cue. This small procedural difference had direct consequences in the recall of the Rp- items without influencing the recall of Rp+ and Nrp items. The simultaneous presentation of the category and stem cues in Experiment 1 may have allowed the participants to ignore the lexical category cue and use the word stem to directly access the target representation. Hence, competition was not present, inhibition was not triggered, and the RIF effect was absent. How-

ever, in Experiment 2, in which the precuing procedure was used, the presentation of the category cue in isolation is likely to have activated the representations of the six items associated to it during study, with the result that, when the remainder of the cue (the three-letter word fragment) was presented, inhibition of the Rp– items was triggered to reduce competition from nontarget-activated memories, leading to a reduction in the probability of recalling the Rp– items relative to the Nrp control items. Therefore, in Experiment 2, because the precuing procedure successfully induced competition during retrieval practice, the RIF effect appeared.

These results are important because they provide converging evidence that competition is needed for the RIF effect to occur. To our knowledge, the main direct demonstrations that competition is needed to trigger inhibition in the retrieval practice procedure comes from manipulations of the strength or dominance of the competitors (Rp– items; see M. C. Anderson et al., 1994; Shivde & Anderson, 2001). For example, in three experiments, M. C. Anderson et al. showed that when the Rp– items were strongly associated to the categorical cue (strong competitors), large RIF effects were obtained; however when the Rp– items were weakly associated to the category cue, their recall was not impaired relative to the recall of the Nrp items. Therefore, the presence of RIF effects depended on the strength of the competing items (Rp–), suggesting that stronger category members are inhibited because they are more likely to compete for retrieval, whereas weaker category members are not inhibited because they do not compete at retrieval. Hence, our results extend previous findings by highlighting the competition-dependency property of inhibition and, furthermore, by introducing a new procedure to induce competition in the retrieval practice paradigm. Comparison of the results from Experiments 1 and 2 demonstrates the efficiency of the precuing procedure in inducing and maximizing competition.

In addition and also of noted importance, our finding that equivalent facilitation for Rp+ items in both experiments along with the lack of impairment and presence of impairment of the Rp– items in Experiments 1 and 2, respectively, rules out blocking interpretations of the RIF effect. 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 to a cue relative to the strength of all items associated to that cue. Thus, when an alternative response is strengthened, the relative strength of the remaining items decline so that when the participant tries to recall the target, the strengthened item will have a retrieval advantage that will lead it to compete with the target and to intrude so persistently that the participants may cease in their efforts 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. According to this explanation, if the Rp+ items in both experiments were equally strengthened by retrieval practice (facilitation effects), similar RIF effects should have been found. However, this was not the case.

In summary then, the results of Experiments 1–3 suggest two important preconditions for RIF: competition and appropriate transfer between representations. Spelling out these and other restricting/modulating factors is important because it will help to understand the conditions under which the effect may or may not

appear (see M. C. Anderson, 2003, for discussion of possible masking effects). It is possible that previously reported unsuccessful attempts to obtain RIF effects were due to failures in meeting criteria like those just described rather than to the operation of alternative noninhibitory mechanisms.

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(Appendix follows)

Appendix

Sets of Target Items Used in Experiments 1, 2, and 3

Item type	Lexical set					
	BA	CA	DI	MA	PE	RE
Practiced (Rp+)	Bacalao	Canario	Digestión	Maquillaje	Pedazo	Rebaño
	Balanza	Capellán	Dilema	Mariscal	Pesimismo	Receta
	Bañera	Caracol	Divorcio	Matanza	Petición	Relámpago
Unpracticed (Rp- or Nrp)	Barrera	Cabello	Diciembre	Madurez	Pelota	Regalo
	Basura	Camarero	Difunto	Maleta	Península	Reserva
	Batalla	Categoría	Diseño	Manifiesto	Pereza	Retorno
Filler items used for minimizing primacy and recency effects in Experiments 1, 2, and 3						
Fidelidad		Juventud			Lejanía	
Filosofía		Jugador			Leyenda	
Filler items used for the implicit test in Experiment 3						
Chimenea					Chocolate	
Ensalada					Escritor	
Fábula					Ferrocarril	
Garaje					Gerente	
Gigante					Hemeroteca	
Herencia					Hidrógeno	
Jeringuilla					Narración	
Negativo					Satélite	
Secuencia					Tenedor	
Totalidad					Velero	
Velocidad					Volumen	
Xenofobia					Zanahoria	

Note. Rp+ = study phase items also presented in the retrieval practice phase; Rp- = study phase items not presented in the retrieval practice phase; Nrp = unpracticed items.

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