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BRIEF REPORT

Incidental retrieval-induced forgetting of location information

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Abstract Retrieval-induced forgetting (RIF) has been studied with different types of tests and materials. However, RIF has always been tested on the items' central features, and there is no information on whether inhibition also extends to peripheral features of the events in which the items are embedded. In two experiments, we specifically tested the presence of RIF in a task in which recall of peripheral information was required. After a standard retrieval practice task oriented to item identity, participants were cued with colors (Exp. 1) or with the items themselves (Exp. 2) and asked to recall the screen locations where the items had been displayed during the study phase. RIF for locations was observed after retrieval practice, an effect that was not present when participants were asked to read instead of retrieving the items. Our findings provide evidence that peripheral location information associated with an item during study can be also inhibited when the retrieval conditions promote the inhibition of more central, item identity information.

Keywords Retrieval-induced forgetting · Inhibition · Memory for location · Covert cuing

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Our memories are assumed to consist of multimodal attributes of the entities that we experienced in the past, including contextual information of various kinds (Barsalou, 1999). Thus, when we recall a past experience, we not only retrieve individual entities such as objects, people, or words, but also peripheral information associated with the particular experience with that entity. Thus, if we think of the last class we taught, we may recall the question that a particular student asked, but also the place where this student sat in the class or the fact that it was early in the afternoon. A general conception of how the memory system is able to automatically encode spatial, temporal, and frequency information was advanced by Hasher and Zacks (1979), and subsequent studies have provided more specific corroborating evidence, particularly in regard to the encoding of location information. For example, Köhler, Moscovitch, and Melo (2001), in an incidental-learning task for object locations, found that making judgments on attributes related to object identity enhanced memory performance not only when the identity of the objects was tested, but also when the retrieval task tested memory for the object locations. Similarly, Lachmair, Dudschig, De Fillippis, de la Vega, and Kaup (2011) showed that location information was activated when processing words. They asked their participants to perform lexical tasks on concepts that referred to entities associated with an up or down location (e.g., ROOF and ROOT). The results showed that responding was faster when the responses (e.g., the positions of the response keys) were congruent with the locations on the object to which they were related (e.g., ROOF above ROOT). This suggests that spatial location is automatically bound to item identity and is accessed when retrieving words and objects.

In the present article, we aim to further illuminate the encoding and retrieval mechanisms underlying the incidental acquisition and use of spatial information, providing

evidence that peripheral location information associated with a word during study can also be inhibited when retrieval conditions promote the inhibition of more central, item identity information.

Evidence from experimental studies has suggested that inhibitory executive control is involved in the retrieval of information from long-term memory (Levy & Anderson, 2008; Ortega, Gómez-Ariza, Román, & Bajo, 2012; Román, Soriano, Gómez-Ariza, & Bajo, 2009). Inhibition in memory selection has been studied via the retrieval practice (RP) paradigm (Anderson, R. A. Bjork, & E. L. Bjork, 1994), a procedure in which participants first study cue–item pairs wherein each cue is associated with several items (e.g., fruit–banana, fruit–kiwi, tool–hammer, tool–pliers). Next, in the RP stage, participants are cued to recall half of the items from half of the cues (e.g., fruit–ki__; Rp + items, hereafter). Finally, their memory for all studied items is tested (e.g., fruit–ba__, fruit–ki__, tool–ha__, tool–pl___). The result of interest is that unpracticed items associated with practiced cues (e.g., banana; Rp– items, hereafter) are poorly recalled, as compared to unpracticed items with unpracticed cues (e.g., hammer and pliers; Nrp or control items). According to the inhibitory account of this retrieval-induced forgetting (RIF) effect, Rp– items become competitors during the RP phase, and inhibitory control is triggered to overcome interference. Hence, when these competitors become targets in a later memory test, they are less accessible than targets from categories that were never practiced.

RIF has been studied with different types of materials involving both semantic, preexisting associations and newly constructed, episodic associations (e.g., Anderson, E. L. Bjork, & R. A. Bjork, 2000; Bajo, Gómez-Ariza, Fernandez, & Marful, 2006; Ciranni & Shimamura, 1999; Gómez-Ariza, Lechuga, Pelegrina, & Bajo, 2005). However, the impairment observed during RP procedures has always been tested on the items' central attributes, and there is no information on whether inhibition (like activation) also extends to peripheral features of the events in which the items are embedded.

Our aim was specifically to test for the presence of RIF in a recall task in which peripheral information was tested. We adapted the RP paradigm used by Ciranni and Shimamura (1999) to observe RIF for visuospatial information, by including orthography-based categories for participants to perform RP on the words' identities. Specifically, the exemplars belonging to a particular category did so only by virtue of the orthographic overlap between them: They shared the first two letters and were not semantically related. In Experiment 1, participants studied cue–target pairs from different orthographic categories [e.g., PE–Pedazo ("piece"); PE–Pelota ("ball"); CA–Cabello ("hair"); CA–Canario ("canary")], a type of material previously shown to produce robust RIF effects (Bajo et al., 2006). During study, items that would later be Rp+ and Rp– from the same orthographic category appeared in different locations and in different colors. Thus, in the example provided in Fig. 1, the Rp+ item Pedazo was presented on the lower center part of the screen and in yellow, whereas the Rp– item Pelota was presented on the upper left side of the screen in red. In addition, a given color was linked to Rp– items from a specific category, as well as to their baseline items (Nrp) from another specific category (e.g., red was associated with the Rp– items from the category PE as well as with their control items from the category CA), resulting in each orthographic category being associated with two different colors (e.g., PE was associated with both yellow and red). An important feature of this arrangement was that each color was associated with one location linked to an Rp– item and with another location linked to an Nrp item (see Fig. 1). Participants were instructed to study the cue–word pairs for a later memory test, but they were not explicitly instructed to pay attention to the color or the location of the stimuli. In the practice phase, participants performed a typical identity-oriented RP task: They were presented with the orthographic category cue (e.g., PE), followed by the three first letters of the study word (e.g., Ped__), and then they were asked to recall the corresponding studied word. From an inhibitory approach, presenting participants with the cue PE should activate members of this orthographic category, leading to retrieval competition. When the three-letter stem is displayed (Ped__), a specific target trace must be isolated for retrieval, and this would be accomplished by inhibition acting on the competitors. Assuming that the episodic traces of the competitors include contextual features such as location (Hasher & Zacks, 1979; Köhler et al., 2001), the question is whether inhibition acting on the competitors should have an effect on the various features included in the memory traces. If this were the case, we would expect that RP of some of the items in an orthographic category would produce not only inhibition of the identity, but also of the implicitly activated spatial location of the Rp– items.

To make sure that RIF for locations was due to inhibition and not to other possible associative interference factors, we used independent cues in the final test (cues different from those used during study and RP). This is important because, according to noninhibitory associative views, RIF is a consequence of the strengthening of the association between the cue and the repeatedly retrieved items (Rp+). This strengthening decreases the relative strength between the cue and other items (Rp–) associated with it, making their retrieval harder when the shared cue is provided at the final test. In contrast, the inhibitory account proposes that the item representation is what is inhibited, independently of the changes in the cue–target association (see Anderson, 2003, for a discussion). Hence, in this view, impairment of Rp– items should be evident regardless of the cues and memory tests used.

In our first experiment, memory for spatial locations of the studied items was tested by providing colors as cues (e.g., the color red to recall left and center locations). The rationale underlying this procedure was that participants, when provided

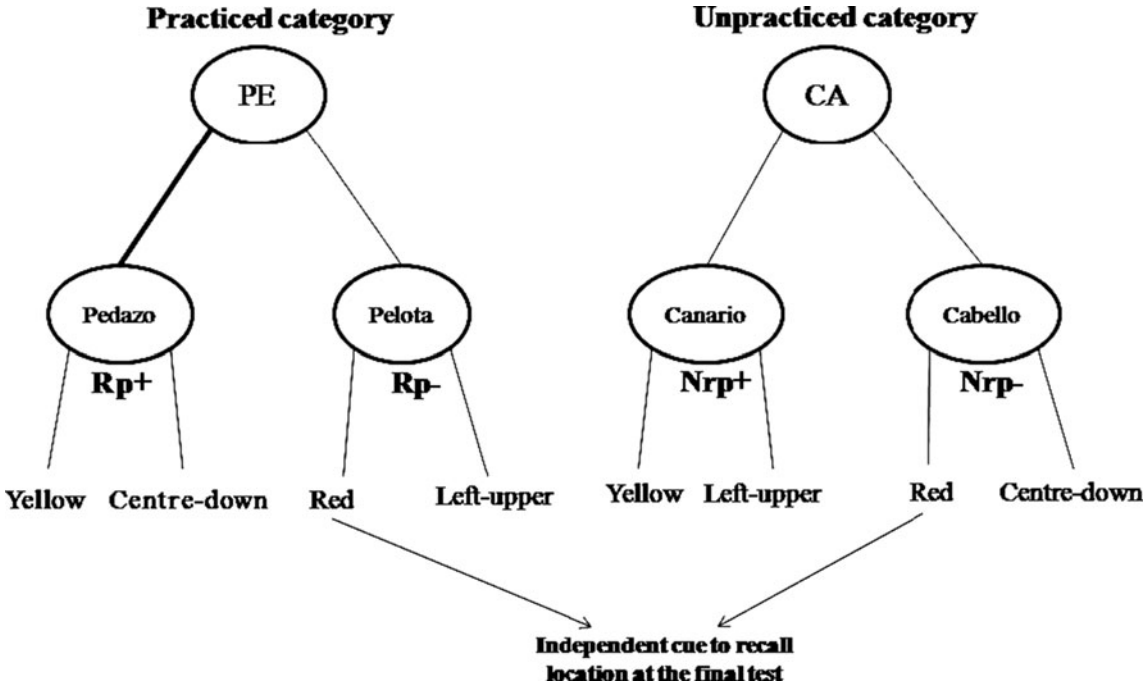

Fig. 1 Example of categories and items reflecting the different experimental conditions with regard to practice status. Illustrated here are also other attributes of the items (color and location), as well as their distributions across conditions. Note that the practiced item (Rp+) does not share a color or location with its competitor (Rp–). However, the Rp– item and its control (Nrp–) do share a color, which was used as an independent cue to recall locations in Experiment 1. The same rule applies to Rp+ and Nrp+ items

with color cues, would directly retrieve locations linked to the colors on the basis of color–location associations. Since colors were not presented during the RP phase, the associations between the practiced items and the colors were not strengthened, and therefore, colors could be considered independent cues.

In addition, to be sure that any observed forgetting of locations was due to competition during retrieval, we introduced a control condition wherein participants read the targets aloud instead of retrieving them from the cues (see Anderson et al., 2000). Although reexposure should produce strengthening of the cue–target association, according to the inhibitory account RIF should be found only when retrieval is involved, because only in that condition would competition arise and trigger inhibition (Anderson, 2003).

In summary, if peripheral information is activated and inhibited during selective retrieval, retrieval practice (but not reexposure) of some of the items of the orthographic category should inhibit the identity and location of the Rp– items, and RIF for locations should be observed.

Experiment 1

Method

Participants A group of 36 undergraduate students from the University of Jaén participated in the experiment for course credit.

Design The status of practice of items at test (Rp+ vs. Rp– vs. Nrp) was manipulated within participants, whereas the type of practice task (retrieval practice [RP] vs. reading-aloud practice [RA]) was manipulated between participants, who were randomly assigned to these conditions.

Materials Thirty-six Spanish words from six different orthography-based categories were chosen from the Alameda and Cuetos (1995) database. The words in each set shared their first two letters [e.g., Cabello ("hair"), Camarero ("waiter"), Categoría ("category"), Canario ("canary"), Capellán ("chaplain"), and Caracol ("snail") for the category CA]. The words were selected according to the following constraints: (1) Their third letter was unique. (2) No semantic relationships existed among the words. (3) They were three or four syllables in length. Two additional categories were used as fillers to control for recency and primacy and to separate practice cycles. Special attention was paid to the lexical frequency of the items within each category. The aim was to make the Rp– items competitive enough to trigger inhibition (Anderson et al., 1994). Thus, for every category, three medium- to low-lexical-frequency words (M = 17.5, range = 10–36) were selected to be used as practiced (Rp+) or low-frequency Nrp control words (hereafter, Nrp+ items) (Pedazo and Canario, respectively, in Fig. 1), and three medium- to high-frequency words (M = 51.5, range = 34–98) were selected to be used as Rp– or high-frequency Nrp control words (hereafter, Nrp– items) (Pelota and Cabello,

respectively, in Fig. 1). The rationale was that the more-frequent Rp– items would produce strong competition when participants were trying to retrieve the less-frequent Rp+ items during the RP phase, and that this, in turn, would result in strong inhibition of the competitor Rp– items. Two counterbalanced versions of the materials were created, so that every high-frequency item became both Rp– and Nrp– on different lists, and every low-frequency item became both Rp+ and Nrp+. Half of the participants were assigned to each of these versions. Notice that, to check for RIF, Rp– items should be compared to the equivalent Nrp– items, whereas to check for facilitation, Rp+ items should be compared to their equivalent Nrp+ items.

Procedure Participants were told to study the displayed words for an upcoming memory test and were informed that the words belonged to various orthographically defined categories. Items were presented in three different locations on the screen during the study phase: in the upper left third, the upper right third, and the lower center third of the screen. Items from the Rp+, Rp–, and Nrp conditions appeared in all of the locations. Thus, every location became linked to these three experimental conditions, and location could not later be estimated from the practice statuses of the items. To avoid color interference between practiced and unpracticed items, they were printed in different colors: pink, purple, and yellow for low-frequency items (Rp+ or Nrp+), and blue, green, and red for high-frequency items (Rp– or Nrp–). Hence, each category became linked to two different colors: one associated with low-frequency items, and the other associated with high-frequency items (e.g., in Fig. 1, Pedazo is in yellow and Pelota is in red). Crucially, here each color was linked to both a practiced category and an unpracticed one. Thus, blue, green, and red colors could later work as recall cues for the Rp– items from a category, as well as for the Nrp– items from another category (see Pelota and Cabello in Fig. 1). This is important because, in the final test, participants were asked to recall the locations at which each color was initially presented, and for the inhibitory view it would be critical to show that, given the same color cue, the Rp– locations were recalled less than the corresponding Nrp– locations. The same rationale applied to the colors pink, purple, and yellow, regarding the Rp+ and Nrp+ items. In this way, the items with the same color (and belonging to the two crucial experimental conditions, Rp– and Nrp–) were always displayed in two different locations. In addition, the unique combinations of color and location were specific to each RP condition. Two balanced versions of category–location pairs were created. Each word was presented for 5 s, preceded by its corresponding category cue (e.g., PE–Pelota). The whole set of items was randomized and presented twice at study, to maximize good overall memory performance. Participants were told to study the words, but no mention of locations or colors was made at this point.

After study, participants performed five practice cycles of either RP or RA with the Rp+ items. To maximize interitem competition in each RP trial, participants were presented first with the two-letter orthographic cue (e.g., PE) for 2 s, and then the three-letter cue that signaled the exact word to be remembered was presented for 6 s. Participants were asked to orally recall the target item when the three-letter cue was shown. To focus the target items' retrieval on orthographic features as much as possible, the retrieval cues were always presented in black (a color never presented at study) at the center of the screen (a location never used at study). Random blocks of items from different categories were created.

As for the RA condition, the only difference was that the whole target word (e.g., Pedazo) rather than its three-letter stem was presented after the category cue in each trial, and participants were told to read the word aloud.

In the final test, participants were to recall the spatial locations on the screen where they had seen specific colors at study. Every previously used color was presented, and participants had to report the two locations where items of that color had appeared during study. The color cues were provided as sentences printed in color at the center of the screen ("Please, point with your finger to the locations where items in this color were displayed at study"). Participants were told that they could report no, one, or two locations on the screen and that they should never point to a location unless they were sure. Two blocks of color probes were created: One contained the colors of the Rp– and Nrp– items and was shown first (this was done to avoid output interference for the unpracticed items), and the other contained the colors of the Rp+ and Nrp+ items. Within each block, the colors were presented randomly.

Results and discussion

Analyses of variance (ANOVAs) were carried out on the percentages of locations correctly recalled. For each trial, there were two possible correct locations for each color cue, and participants could respond by recalling one, two, or none of them. In both the RP and RA conditions, participants tended to point to only one of the two possible locations (71.33% of trials in the RP group, and 66.75% in the RA group, with no difference between the conditions; two-tailed $p = .65$). In addition, the error rates were quite low and statistically equivalent for the two groups ($M = 11.21$, $SD = 13.56$, in the RP condition; $M = 12.68$, $SD = 7.30$, in the RA condition; $F < 1$).

First, we performed analyses for forgetting effects (RIF for locations). An ANOVA showed a significant interaction

between practice status (Rp– vs. Nrp–) and type of practice (RP vs. RA), $F(1, 34) = 4.25$, $p = .04$, $\eta_p^2 = .11$. In the RP condition, locations for Rp– items were recalled significantly less than those for Nrp– items, $F(1, 17) = 8.70$, $p = .008$, $\eta_p^2 = .33$. However, in the RA condition, the levels of recall for the Rp– and Nrp– items were similar, $F(1, 17) = 0.24$, $p = .63$, $\eta_p^2 = .014$. (See Fig. 2.)

Second, for completeness, we performed analyses to check for facilitation effects. No differences between Rp+ and Nrp+ items were found in the RA and RP groups (Fs < 1; see Fig. 2). The lack of facilitation in this experiment was not a deviation from normal results. In general, and consistent with the encoding specificity principle (Tulving & Thomson, 1973), the use of independent probes in the final test produces small to null benefits of repeated practice, as compared to the use of the practiced cue (Gómez-Ariza et al., 2005; see Levy & Anderson, 2008, for a review).

In summary, repeated retrieval of some of the items from some orthographic categories led to lower recall of the locations of the nonretrieved items from these categories, relative to recall of the locations of the baseline items. This suggests that the competing Rp– locations were inhibited during retrieval practice and became less accessible for later recall.

Experiment 2

Since RIF for an implicitly activated contextual property of the memory trace (our RIF for location) is a novel and important result, we conducted a second experiment that was an exact replication of Experiment 1, except for the final test used: Participants were presented with all of the studied words and asked to recall the locations where they were originally presented at study. The idea was to replicate the results of Experiment 1 and to show that, similar to standard RIF, RIF for locations appears with different types of tests and cues. In essence, we wanted to show that the impairment of the Rp– locations was not tied to the presentation of specific contextual cues (e.g., color) during the final test, but also occurred when the cue consisted of the items themselves.

Method

Participants and design A group of 48 new undergraduate students from the University of Jaén participated in the experiment for course credit. The experimental design was identical to that of Experiment 1.

Materials and procedure The unique critical variation from Experiment 1 was the final memory test. Instead of presenting colors as retrieval cues to recall the spatial locations, participants were given each studied word, printed in black for 7 s at the center of the screen, and were asked to recall the specific location where that word was seen at study. Consequently, for each trial there was a single correct response.

Results and discussion

As in Experiment 1, we performed an ANOVA to check for differential forgetting effects as a function of the type of practice. Although the interaction did not reach significance in the omnibus test, $F(1, 46) = 1.65$, $p = .20$, $\eta_p^2 = .035$, simple analyses revealed differences between the practice conditions. Whereas RIF for locations was reliable after RP, $F(1, 23) = 6.07$, $p = .02$, $\eta_p^2 = .209$, it was not after reading practice, $F(1, 23) = 0.36$, $p = .55$, $\eta_p^2 = .015$ (see Fig. 3).

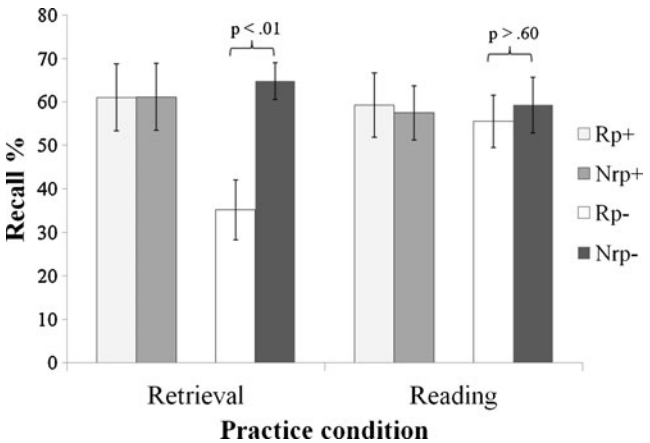

Fig. 2 Mean recall percentages of locations for the items in Experiment 1, as a function of practice status (Rp+, Nrp+, Rp–, or Nrp–) and practice condition (retrieval or reading). Error bars represent the standard errors of the means. The p values for the Rp–-versus-Nrp– tests are shown

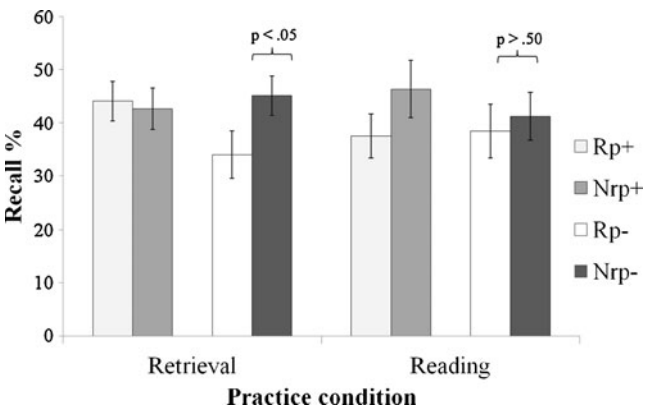

Fig. 3 Mean recall percentages of locations for the items in Experiment 2, as a function of practice status (Rp+, Nrp+, Rp–, or Nrp–) and practice condition (retrieval or reading). Error bars represent the standard errors of the means. The p values for the Rp–-versus-Nrp– tests are shown

Similarly to Experiment 1, the corresponding analyses regarding facilitation showed no differences between Rp+ and Nrp+ items in both practice groups [for RP, $F < 1$; for RA, $F(1, 23) = 2.93$, $p = .10$].

In summary, the results of Experiment 2 showed that RIF occurred only after participants performed RP when the studied words themselves were presented as cues to recall their locations at study. As in Experiment 1, this pattern suggests that inhibition can act during retrieval on implicitly activated aspects of the original episode.

General discussion

In two experiments, we found evidence of RIF of contextual information (spatial location) following retrieval practice of central information (word identity). Forgetting of locations after RP of the items' identities was found both when a contextual feature of the episode (color in Exp. 1) and when the items themselves (Exp. 2) were used as cues in the final test. This finding is interesting because it shows, for the first time, RIF of peripheral features of memory episodes. Since the RP did not require participants to recall peripheral features, the fact that memory impairment for locations was observed indicates that these features were activated together with the items during RP, and as a consequence, they were also affected by inhibition. This is consistent with recent literature that has shown automatic activation of peripheral information, such as location, when processing words and objects (e.g., Lachmair et al., 2011) and extends the previous findings by showing that location information is not only activated when processing the identities of the words and objects, but is also inhibited when the memory traces of the words compete during selective retrieval.

The idea that peripheral information was inhibited is further supported by the fact that we used novel independent cues at test. Thus, the obtained RIF effects for locations cannot be easily attributable to interference processes from strengthened cue–target associations for the Rp+ items, since associative processes are cue-dependent. One could still argue for the possibility that participants might try to covertly recall the orthographic categories to retrieve the spatial locations where a specific color was seen on the screen (see Camp, Pecher, Schmidt, & Zeelenberg, 2009, for covert-cuing explanations of RIF). For example, in this context, covert cuing would occur if, when given a color cue on the final test (e.g., red), participants attempted to think back to remember which orthographic categories were presented in that color (i.e., PE and CA), and they used these categories to try to recall the locations of the items. Although covert cuing is possible in situations in which the independent cues are somewhat related to the categories (e.g., fruit–orange at study and RP, and juice–or___ at test), it is very improbable when the cues are completely unrelated, as was the case in our experiments. In addition, since each orthographic category appeared in two locations, the categories became totally uninformative as cues: Using the color cue (Exp. 1) to covertly recall specific items or categories would not be useful for retrieving the correct locations linked to the color.

Finally, forgetting of Rp– locations was specifically linked to earlier retrieval attempts. When participants were asked to read aloud instead of retrieve the items, forgetting of the unpracticed item locations was not observed, whereas asking participants to retrieve the items at practice did produce RIF. This finding is consistent with previous data showing that RIF is retrieval-specific (e.g., Anderson et al., 2000), and it also rules out any possible associative strategy, since these potential strategies would have similar consequences for both the RA and RP conditions.

In summary, the results from Experiments 1 and 2 have shown RIF for peripheral contextual information after RP of identity information. This pattern seems to agree with recent data suggesting that the contextual factors involved in recollection are crucial for obtaining RIF (Verde & Perfect, 2011). However, this general conclusion needs to be approached with some caution. Although many studies have shown that location information is automatically encoded and bound to an item's identity (Hasher & Zacks, 1979; Köhler et al., 2001), this may not be the case for other contextual features. Hence, further research will need to explore whether inhibition extends to contextual information other than location.

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