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Retrieval-induced forgetting in normal ageing

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Abstract : The retrieval-induced forgetting (RIF) paradigm was used to assess the integrity of unintentional inhibitory functioning in normal ageing. The paradigm was adapted to explore the RIF effect under conditions that allow us to differentiate the contribution of intentional and automatic retrieval processes to performance. The results showed the presence of equivalent and significant RIF effects in young and older adults, for both the intentional and automatic retrieval performance. These results suggest that unintentional inhibitory processes are spared in normal ageing and confirm that RIF effect is independent of the kind of memory processes involved in task performance.

Introduction

Impaired inhibitory functioning is well documented in normal ageing. For example, an age-related decline has been observed with various inhibitory tasks in which inhibitory processing is triggered intentionally such as the Stroop (e.g. Hartman & Hasher, 1991; Spieler, Balota, & Faust, 1996), directed forgetting (Earles & Kersten, 2002; Zacks, Radvansky & Hasher, 1996), stop-signal (Bedard *et al.*, 2002), and anti-saccade tasks (Olincy Ros, Young, & Freedman, 1997). These findings have led some authors to the conclusion that inhibitory functioning is globally impaired in normal ageing (Hasher & Zacks, 1988).

However, recent cognitive, neuropsychological, and functional neuroimaging studies have suggested that inhibition is a construct that can be divided into several distinct mechanisms (Conway & Fthenaki, 2003; Friedman & Miyake, 2004; Liu, Banich, Jacobson, & Tanabe, 2004; Shilling, Chetwynd, & Rabbitt, 2002). One of the most widely supported - and most promising - proposals in the literature is the distinction between intentional (effortful) and unintentional (automatic) inhibitory processes (see, for example, Harnishfeger, 1995). Based on this distinction, Conway and Fthenaki (2003) proposed that intentional inhibitory processes are modulated by executive control and are triggered voluntarily to prevent or reduce interference from competing or distracting information. On the other hand, unintentional inhibitory processes are triggered automatically during a cognitive activity and require less (or maybe no) modulation by executive control. Because of their independence from executive control, unintentional inhibitory processes are assumed to be more resistant to brain damage (Conway & Fthenaki, 2003; Moulin *et al.*, 2002) and to the effects of normal ageing (Asian, Bauml, & Pastotter, 2007; Faust & Balota, 1997; Langley Vivas, Fuentes, & Bagne, 2005).

The retrieval-induced forgetting (RIF) paradigm, which allows one to assess unintentional inhibition in the episodic memory domain, was introduced by Anderson, Bjork, and Bjork (1994). The RIF paradigm is composed of three phases. First, participants are asked to study exemplars of several taxonomic categories. Exemplars are typically presented once, accompanied by a category cue *(e.g. fruit - banana).* The participants then perform retrieval practice on half of the exemplars from half of the presented categories, by completing a cued stem-recall test *(e.g. fruit - ba___?)* several times for each practiced item. After a retention interval of a few minutes, participants are given a final cued recall test that concerns all the categories and all the items in each one. Recall performance is then compared for three types of items: practiced items (RP +); unpracticed items from the practiced categories (RP —); and unpracticed items from unpracticed categories (Nrp). Typically, the recall of RP + items is better than that of the two other types. More interestingly, the recall of Nrp items is also significantly better than that of RP — items, despite the fact that both types of items are encountered equally frequently during the experiment (namely only once, during the initial study phase), which suggests that the repeated presentation of RP + items makes the RP — items less available to consciousness.

This effect has been observed with various materials such as categorized words (Anderson *et al.*, 1994), personality features (Macrae & MacLeod, 1999), and visuo-spatial figures (Ciranni & Shimamura, 1999). In the context of spreading activation theory, the interpretation of the RIF effect is that the retrieval practice leads to

automatic inhibition of irrelevant information that is semantically related to the target information, in order to prevent potential interference (Anderson & Spellman, 1995; Anderson *et al.*, 1994; see Anderson & Neely 1996, for a review). The retrieval-induced forgetting is generally assumed to rely on an unintentional (or automatic) inhibitory mechanism because it develops without instructions to forget and without conscious awareness, and because it requires little attentional effort (Bjork, Bjork, & Anderson, 1998). Consistent with this view, recent studies have found intact RIF in brain-damaged populations known to have executive control difficulties, such as frontal patients (Conway & Fthenaki, 2003) and patients with Alzheimer disease (Moulin *et al.*, 2002).

Some researchers have reported an absence of RIF effect when memory performance is assessed with implicit memory tasks (Butler, Williams, Zacks, & Maki, 2001; Perfect, Moulin, Conway & Perry, 2002). This finding leads them to question the nature of the inhibitory mechanisms involved in the effect, because if the RIF effect was really dependent upon automatic inhibition of irrelevant semantic information, any memory test measuring the accessibility of studied items should demonstrate the effect. However, it seems that the RIF effect appears only when implicit memory tasks are based on access to conceptual representations, as it is the case with category generation and category verification tasks (Perfect *et al.*, 2002), but not with tasks based on access to perceptual or lexical representations (Butler *et al.*, 2001; Perfect *et al.*, 2002). Thus, the RIF effect could be considered as an inhibitory phenomenon restricted to the conceptual level of representation. The reason why the effect appears only at this condition is unclear at this time, but the pattern is somewhat compatible with the specificity of encoding principle (Tulving & Thomson, 1973), according to which the probability of successful retrieval of a target item is dependant on the matching between the contextual features of encoding and retrieval. In other words, it is possible that RIF appears only with implicit tasks that require conceptual retrieval because items are encoded at the conceptual level all along the task, by means of the category cues given during the encoding and the retrieval-practice phases.

Consequently, the main aim of this study was to confirm whether the preservation of unintentional inhibitory processes reported in normal ageing for perceptual tasks (Faust & Balota, 1997; Langley *et al.*, 2005) is also manifested within the episodic memory domain. Moreover, we were also interested to replicate the findings of a previous study which demonstrated the presence of an RIF effect with implicit tasks involving access to conceptual representations (Perfect *et al.*, 2002), but with a procedure that allow us to separate the contribution of automatic and intentional retrieval processes to performance.

Indeed, the explicit and implicit memory tasks are not process pure. So, even if intentional ('recollective-based') retrieval processes are mainly involved in explicit tasks and automatic retrieval ('familiarity-based') processes in implicit tasks, the performance on such tasks rely nevertheless on these two kinds of processes but in various proportions (see for example Jacoby, 1991). In order to obtain a purer measure of the influence of these two retrieval processes on the RIF effect, the process dissociation procedure was applied (PDP; Jacoby, 1991).

For that purpose, the RIF effect was assessed in two conditions: (1) the inclusion condition (corresponding to the classical RIF paradigm) in which the participants have to recall words that they have previously encountered following the presentation of the category cue; in this condition the intentional and non-intentional retrieval processes act in concert and (2) the exclusion condition in which the participants are asked to produce any word related to the category cue, provided that they had not previously encountered it during the task (a condition in which intentional and automatic retrieval processes act in opposition).

The PDP allows one to dissociate and quantify, within the same memory task, the respective contributions of automatic (familiarity-based) and intentional (recollective-based) retrieval by placing these two forms of memory in opposition to one another. According to this procedure, in the inclusion condition both the controlled and automatic processes act in the same way to produce the correct answer. Conversely, in the exclusion condition the controlled and automatic processes have opposing effects, with one process acting to produce the correct answer, and the other acting to produce an error. For each condition, and considering that automatic and controlled processes contribute independently to performance, an equation can be written that represents how the two processes act together to determine performance. On the basis of these two equations, the contributions of automatic and controlled processes to task performance can be estimated using simple algebra.

By reference to previous studies of unintentional inhibitory processes in normal ageing (e.g. Asian *et al.*, 2007; Faust & Balota, 1997; Langley *et al.*, 2005), we hypothesized that elderly participants would experience a normal RIF effect in the inclusion condition, despite their overall poorer memory performance. With regard to the exclusion condition, because the retrieval is category driven as it was in the inclusion task, we also expected RIF effect to emerge, for both the young and elderly adults (see Perfect *et al.*, 2002). However, previous studies using a word recognition task (Jennings & Jacoby, 1997) and an action slip paradigm (Hay & Jacoby, 1999)

found that elderly participants made more errors when they were explicitly told not to recall information previously presented, because they suffer from a deficit in the controlled process of recollection of information that lead to a proportionally greater tendency to produce these items automatically. Then we expected an overall larger recall of items for elderly adults in the exclusion condition. However, and despite this larger recall of items, we also expected an equivalent RIF effect for both groups in this condition, as in the inclusion condition, because of the unintentional nature of the inhibitory process involved in the effect. Concerning the PDP analyses, we also expected RIF effect on both intentional and automatic measures of memory retrieval, again because of the category-driven nature of the retrieval. We also expected these effects to be equivalent across the two groups of participants. However, we expected age-related differences for intentional retrieval, while automatic retrieval performance should be equivalent across age (see for example Jennings &Jacoby 1997).

Methods

Subjects

In this experiment, 30 young and 25 elderly healthy adults participated. Young participants (Mean = 23.5 years old; *SD* = 5.06) were mostly undergraduate students. Elderly adults *(M = 66.6* years old; *SD* = 5.26) were selected to match the younger ones in terms of education (level of education: young participants: *M* = 13.9 years; *SD* = 1.79; elderly participants: *M* = 13.4 years; *SD* = 3.24; $t(53) = 0.74$, $p = .46$). Moreover, and as expected, elderly participants performed better on the French adaptation of the Mill Hill vocabulary test (Deltour, 1993; *M* = 25.96; *SD* = 3.65) than younger ones did *(M* = 23.8; *SD* = 3.38; $t(53) = -2.61$, $p < .05$). All elderly participants had a total score of greater than 130 on the Mattis Dementia Rating Scale (Mattis, 1976; range 133-144), which constitutes a cut-off score to discriminate normal ageing from dementia (Monsch *et al.*, 1995). All participants had normal or corrected-to-normal visual acuity.

Material

The material consisted of 12 exemplars of 4 taxonomic categories (birds, insects, tools, and musical instruments) that were drawn from the category norms established by Dubois (1982) for the French language. Six strong and six weak exemplars were chosen from each of the categories, which were matched for word frequency [$F(3, 44) = 0.028$, $p = .99$], typicality rank of the exemplars [$F(3, 44) = 0.07$,$p = .97$], and the numbers of graphemes in the exemplars [$F(3, 44) = 1.29$, $p = -29$] · Care was taken to ensure that none of the exemplars in a specific category shared the same two first letters. Two filler categories (fruits and buildings) were also used to eliminate primacy and recency effects.

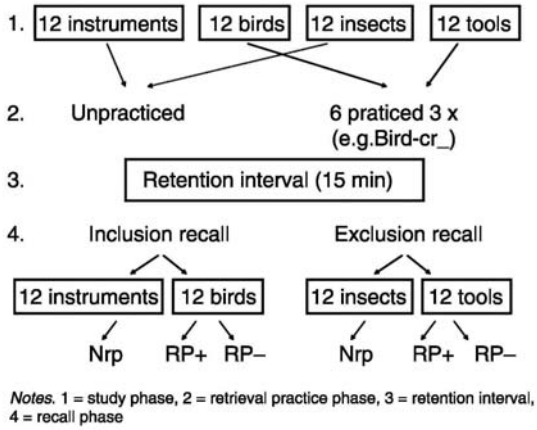
Procedure

The participants were tested individually in a quiet testing room. They were told that they would be participating in a memory test on a computer screen. The procedure for this experiment followed the general paradigm described earlier except that the number of categories was doubled to assess retrieval-induced forgetting in both the inclusion and exclusion conditions within the same sample of participants. At the study phase, the participants learned the 48 exemplars belonging to 4 semantic categories (and 8 exemplars from the 2 filler categories). Items were presented once and one at a time in a category-exemplar paired associate format (e.g. *bird - crow*). The category cue appeared alone on the screen for 2 seconds first, and was then accompanied by a specific exemplar presented just below the category cue, which remained on the screen for 8 seconds. The inter-stimulus interval was set at 1.5 seconds. The participants were shown an example of the category-exemplar association before the beginning of the study phase. They were told to learn each exemplar, and it was emphasized that the category cue was displayed to promote this learning. The order of exemplar presentation was pseudo-randomized, but it was ensured that no more than two exemplars from the same category were presented in succession. At the retrieval-practice phase, participants practiced retrieval for half of the exemplars of half of the categories. That is, they were told to retrieve specific exemplars based on their first two letters displayed along with their category cue (e.g. *bird - cr___*). The category cue appeared alone on the screen for 2 seconds, and was then accompanied by the first two letters of an exemplar, that remained on the screen just below the category cue for 10 seconds. The participants gave their response orally, and the correct response was displayed on the screen once they had done so. The categories were counterbalanced between the participants in order to ensure that each exemplar was used as RP +, RP — , and NRP items approximately the same number of times. This retrieval-practice procedure was repeated three times with the same exemplars, but in a random fashion. During the retention interval, the participants were given an unrelated cognitive task that lasted 15

minutes.

Finally, the recall phase of the experiment was divided into two distinct category-cued recall tasks, in which the participants were asked (1) to recall items that they had previously learned for two of the four categories (inclusion condition) and then (2) to give items that they had not previously learned for the other two categories (exclusion condition). The participants were given a maximum of 3 minutes for each category, but the recall time for a specific category was closed once they had given 12 exemplars. Within each condition, we compared the number of items retrieved that (1) belonged to practiced categories AND were practiced during the retrieval-practice phase (RP + items); (2) belonged to practiced categories BUT were not practiced during the retrieval-practice phase (RP — items); and (3) belonged to unpracticed categories (Nrp items). An RIF effect was found when the participants recalled more Nrp than RP — items (see Figure 1). With regard to the measure of performance in the exclusion condition, we did not take into account the responses spontaneously identified after their production as 'already encountered', since these responses cannot be considered as an unintentional recall of previously studied information.

Figure I: *A schematic description of our adaptation of the retrieval-induced forgetting paradigm.*



Notes. 1 = study phase, 2 = retrieval practice phase, 3 = retention interval, 4 = recall phase

In the inclusion condition, intentional and automatic processes converge to retrieve the target word since the participants might recall an earlier studied word either because they consciously recollected having seen the word before (*C*), or because it was the first word that came to mind automatically 04), without any recollection that the word had been presented earlier (1 — *C*). Thus, the probability of giving a previously studied word in the inclusion condition can be represented as: inclusion = $C + A(1 - C)$. Following the presentation of the cue 'new' (exclusion condition), the participants were asked to give exemplars that had not been presented in the learning phase. Consequently, in the exclusion condition, intentional and automatic processes have opposing effects on performance since the participants might incorrectly recall exemplars that had been studied earlier only if that word came automatically to mind 04), without any controlled recollection that it had been presented earlier (1 — *C*). Thus, the probability of making an error (i.e. recalling an exemplar that had been studied earlier) in the exclusion condition can be represented as: exclusion = $A(1 - C)$. Following Jacoby (1991), the contribution of controlled processes to the task can be estimated by subtracting the probability of recalling a studied word in the exclusion condition from the probability of recalling an old (i.e. studied) word in the inclusion condition. Once an estimate of controlled processes has been obtained, the contribution of automatic processes corresponds to the probability of recalling a studied word in the exclusion condition divided by one minus the probability of recalling a studied word by a controlled recollection.

Results

All effects were assessed for significance at the $p = .05$ level. The proportion of words recalled in the inclusion and exclusion conditions was analysed with two separate 2 (young vs. older) × 3 (Nrp vs. RP — vs. RP +) ANOVAs. The mean proportions of Nrp, RP — , and RP + items recalled in the inclusion and exclusion conditions according to age group are presented in Table 1. For the inclusion condition, the results showed a main effect of group [$F(1, 53) = 20.34$, $p < .0001$], which indicated that older participants recalled fewer items than younger ones did. There was also a significant overall effect of type of item [$F(2, 106) = 64.38$, $p < .0001$]. Planned comparisons revealed that all participants (young and older adults together) recalled more RP + than

Nrp items [$F(1, 53) = 94.02$, $p < .0001$] and more Nrp than RP - items [$F(1, 53) = 22.53$, $p < .0001$], indicating a significant RIF effect in the two groups [young: $F(1, 53) = 6.5$, $p < .05$; elderly: $F(1, 53) = 16.8$, $p < .01$]. The two-way interaction between group and type of item was not significant [$F(2, 106) = 1.47$,$p > .1$], indicating a similar RIF effect in young and elderly participants. For the exclusion condition, the results showed a main effect of group [$F(1, 53) = 15.42$, $p < .005$], which indicated that older participants recalled more items than the younger ones did. There was also a significant overall effect of type of item [$F(2, 106) = 36.74$, $p < .0001$], withhigher recall for the RP - than the Nrp items, and also for the Nrp than the RP + items. The two-way interaction between group and type of item was also significant [$F(2, 106) = 3.3$, $p < .05$]. Planned comparisons revealed that both young [$F(1, 53) = 19.01$, $p < .0001$] and elderly participants [$F(1, 53) = 58.92$, $p < .0001$] recalled more Nrp and RP - items than RP + items, but the difference between RP + and the other two kinds of items is larger for elderly participants [$F(1, 53) = 7.45$, $p < .01$]. More importantly, both the young and elderly participants presented an inverse RIF effect [Nrp < RP—; respectively, $F(1, 53) = 5.34$,$p < .05$ and F(l, 53) = 12.86, $p < .001$], but this effect was equivalent between the two groups [$F(1, 53) = 1.19$,$p > 0.1$].

Table I: *Mean proportions of Nrp, RP —, and RP + items retrieved in the inclusion and exclusion conditions according to age group*

	Nrp	**RP-**	**RP +**
Inclusion			
Young adults	.80(0.14)	.61 (0.22)	.88 (0.16)
Older adults	.58(0.11)	.42(0.15)	.79 (0.17)
Exclusion			
Young adults	.06 (0.06)	.13 (0.13)	.02 (0.05)
Older adults	.13 (0.09)	.25 (0.16)	.04 (0.07)

Note. Numbers in parentheses are standard deviations.

We also performed two separate ANOVAs in order to compare separately the estimates of controlled and automatic processes in our two samples of participants. Concerning the estimate of intentional memory influences, a 2 (young vs. older) × 3 (Nrp vs. RP — vs. RP +) within-subjects ANOVA showed a main effect of group [$F(1, 53) = 27.06$, $p < .0001$], indicating that young participants recalled more items intentionally than elderly adults. The main effect of the types of items was also significant [$F(1, 53) = 76.79$, $p < .0001$]. Planned comparison revealed a significant RIF effect when items were retrieved intentionally [$F(1, 53) = 13.01$, $p < .005$]. The two-way interaction between group and types of items was not significant [$F(1, 53) = 1.63$,$p > .1$]. Concerning the estimate of automatic memory influences, a 2 (young vs. older) × 3 (Nrp vs. RP — vs. RP +) within-subjects ANOVA failed to show any main effect of group [$F(1, 53) = 0.06$, $p > .5$], while the effect of the kind of items was significant [$F(1, 53) = 4.91$, $p < 05$]. Planned comparison revealed a significant inverse RIF effect when items were retrieved automatically [$F(1, 53) = 8.2$,$p = .007$]. Finally, the two-way interaction between group and types of items was not significant [$F(1, 53) = 1.47$, $p > .1$]. These results are presented in Figure 2.

Since the separate estimates of controlled and automatic processes evidenced an impaired performance for controlled processes only, a 2 (young vs. older) × 2 (intentional vs. automatic processes) within-subjects ANOVA was performed to confirm this dissociation. The analysis revealed a marginally effect of normal ageing onto the processes type [$F(1, 53) = 3.25$,$p = .08$]. Planned comparisons revealed a significant effect of ageing onto the estimates of intentional retrieval [$F(1, 53) = 7.7$, $p < .001$], while there was no effect onto the estimates of automatic processes [$F(1, 53) = 0.06$, $p = .81$]. These results confirm the presence of a specific impairment of controlled processes in normal ageing.

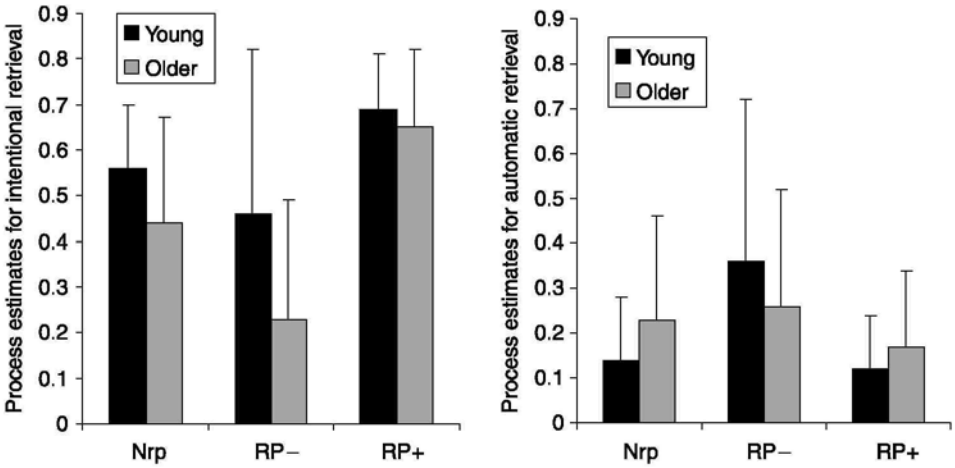
Discussion

The results obtained can be summarized as follows. First, the performance of elderly participants for RP + items on the two cued recall tasks is in agreement with the extensive literature demonstrating episodic memory deficits in normal ageing. Second, RIF effects[1] were observed in both the inclusion and exclusion conditions, as well as

[1] We have computed further analyses in order to insure that RIF effects we observed were not merely due to output interference (namely, the tendency of RP + items to be recalled first; Anderson et al., 1994). The output interference account predicts lower performance for the RP — items whenever there is a robust advantage for the RP + items, because output interference is caused by prior recall of stronger items.

when estimates of the intentional and automatic retrieval processes were used. Third, these RIF effects were similar in young and elderly participants.

Figure 2: *Process dissociation analysis estimates for the intentional and automatic retrieval of Nrp, RP — , and RP + items according to age group.*



The main aim of this study was to assess the integrity of unintentional (automatic) inhibitory functioning in normal ageing. As indicated above, similar retrieval-induced forgetting effects were demonstrated for young and older adults on category-cued recall tasks and on the intentional and automatic estimates of memory performance, despite the fact that PDP analyses showed a reduction of the estimates of intentional retrieval for elderly adults (there was, however, and as expected no effect of ageing on to the estimates of automatic retrieval; see also Jennings & Jacoby 1997, for the same dissociation). These results then indicates that automatic inhibitory processes related to episodic memory performance are preserved in normal ageing, and confirm recent data obtained by Asian *et al.* (2007) who found significant and similar RIF effect for young and elderly adults using a standard cued recall test (Experiment 1) and a cued recall test that used independent probes (Experiment 2). Importantly, we also demonstrated in this study that the RIF effect occurs no matter how the performance was assessed. Moreover, the presence of similar RIF effects in young and elderly participants despite the episodic memory difficulties experienced by the latter seems to indicate that inhibitory effects in memory are relatively independent of the integrity of memory processes. Data supporting the independence of such automatic inhibitory processes from episodic memory functioning were also found in Alzheimer's disease (Moulin *et al.*, 2002). Indeed, these patients demonstrated RIF effects similar to those of normal elderly participants, although they had a high level of intrusion errors in recall tasks. As suggested by Moulin *et al.* (2002), it is possible that the low-level attentional processes needed to inhibit RP — items are intact in both populations, while the conscious control of retrieved items from memory is impaired. In agreement with this hypothesis, impaired performance in healthy elderly participants was reported with list-method directed forgetting tasks, which require a conscious control of previously inhibited information retrieved from memory (Earles & Kersten, 2002; Zacks *et al.*, 1996). Together, these data suggest then that unintentional inhibitory processes are preserved in normal ageing despite overall poorer memory performance, and support the proposal made by several authors that elderly participants are not impaired in all inhibitory tasks (e.g. Burke, 1997; McDowd & Shaw, 2000). However, the reasons why some inhibitory abilities are preserved and others impaired in normal ageing are not well understood at this time.

Several theoretical frameworks have recently been proposed in the literature to explain the inhibitory capacities reported in various normal and pathological populations. For instance, Nigg (2000) suggested dissociating

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Correlational analyses on our data do not support this view. Indeed, the amount of inhibition (the difference between Nrp and RP — items) was not related to the recall performance for RP + items (r — . 11, p — .43) nor to the output positions of RP + items (r = —. 19, p = . 17). Moreover, a further analysis revealed that the amount of inhibition was not significantly different between the participants who produced or did not produce an RP + item as first exemplar [t(53) — 0.25, p = .80]. If output interference intervenes as a main explanation of the RIF effect, we would have expected a greater RIF effect for the subject who recalled an RP + item first (namely those subjects who are supposed to experience the most output interference). As a whole, these results suggest that output interference was not responsible for the RIF effect in our sample.

effortful inhibitory processes from automatic inhibition of attention. Harnishfeger (1995) classified inhibitory tasks according to the following three dimensions: (1) intentional versus unintentional; (2) behavioural versus cognitive; and (3) inhibition versus interference. Finally, some authors view inhibition as a general process operating in various cognitive domains. In that context, Dempster and Corkill (1999a, 1999b) have suggested making a distinction between perceptual, verbal, and motor inhibition. With regard to their proposal, the intact performance of elderly participants on the RIF task could be interpreted as reflecting a selective preservation of inhibitory mechanisms related to the processing of semantic information (in this case, in the context of an episodic memory task). Indeed, intact performance by elderly participants has also been observed in negative priming tasks (Connelly & Hasher, 1993; Kramer, Humphrey Larish, Logan, & Strayer, 1994; Langley Overmier, Knopman, & Prod'Homme, 1998; Sullivan & Faust, 1993) that also involve semantic processing. However, this interpretation does not agree with results of other studies that clearly demonstrated the presence of semantic inhibition deficits during normal ageing (e.g. Andrés & Van der Linden, 2000; Bowles, 1989; Connelly, Hasher, & Zacks, 1991; Duchek, Balota, & Thessing, 1998).

Rather, the results of this study could be interpreted as indicating a selective preservation of unintentional (or automatic) inhibitory processes in normal ageing and, as proposed by Conway and Fthenaki (2003), this selective preservation could be due to a reduced need for modulation by executive control. In agreement with this interpretation, several studies have demonstrated that elderly adults had intact inhibitory abilities with other tasks involving automatic or unintentional inhibitory processing, such as the inhibition of return task (Faust & Balota, 1997; Langley *et al.,* 2005), whereas they did encounter difficulties with tasks requiring an inhibitory mechanism that needed to be triggered intentionally (e.g. Olincy *et al.,* 1997; Spieler *et al.,* 1996; Zacks *et al.,* 1996). Another study recently confirmed the same dissociation between preserved unintentional inhibitory processes and impairment when the tasks required intentional inhibition with another group of elderly adults (Collette, Germain, Adam, & Hogge, 2006). In this study, tasks assessing intentional and unintentional inhibitory processes in the domains of working memory, episodic memory, and semantic memory were administered to young and elderly participants. The results showed that elderly participants only performed worse for intentional inhibitory tasks whatever the memory domain. Similar results were also observed with a task that allows assessing intentional and unintentional inhibition within the same paradigm. Indeed, when interference and negative priming effects (which are supposed to require intentional and unintentional inhibitory processes, respectively) were explored within the same Stroop task, a significant difference between young and elderly participants was found only for the former (see Hogge, Adam, & Collette, in press).

Despite the empirical evidence supporting the dissociation of spared unintentional inhibitory processes and impaired intentional inhibition in normal ageing, the specific contribution executive control makes to this pattern of performance has not yet been formally assessed. More generally, the exact way in which executive control would influence some inhibitory processes and not others (Conway & Fthenaki, 2003) has not been defined. In a recent study, Kuhl, Dudukovic, Kahn, and Wagner (2007) explored the neural substrates associated to the RIF effect. They demonstrated that the repeated presentation of RP + items leads to the emergence of conflict in the medial temporal lobe structure (and more precisely the hippocampus) between the retrieval of these items and the non-presented RP — items. Once detected (by the dorsal anterior cingulate cortex), the conflict triggers the recruitment of control mechanisms (associated to dorsolateral and ventrolateral prefrontal cortex) that ultimately implement memory suppression of the RP — items. This interpretation is in agreement with the conception of the RIF effect in the context of lateral inhibition theory (Anderson & Bjork, 1994). According to this theory, lateral inhibition provides feedback to enhance differences in activation across exemplars of a single category, in order to resolve response competition. However, on the basis of the results obtained by Khul *et al.,* the presence of normal RIF effects in normal ageing appears quite surprising. Indeed, prefrontal areas, associated to control mechanisms, are particularly vulnerable to ageing (Raz, 2004) and consequently impaired RIF effects should be expected in these participants. It must nevertheless be emphasized that the medial temporal lobe structures are also affected by normal ageing. In that context, we can tentatively propose that the normal RIF performance of elderly comes from a weaker activation of the items in the medial temporal regions and that their control mechanisms are sufficient to suppress the weakly activated traces of RP — items. In agreement with this hypothesis, we recently obtained data on perceptual and motor tasks supporting the idea that preserved inhibitory abilities in normal ageing are observed only when the information/process to inhibit requires few cognitive resources (Collette, Germain, & Stawarczyk, 2007).

In this study, we also adapted the RIF paradigm to explore the effect with the PDP procedure, in order to confirm that the RIF effect is also manifested when information is retrieved automatically (see Perfect *et al.,* 2002). As noted above, we observed significant RIF effect for both the exclusion condition and the automatic estimates of memory performance. The presence of a significant RIF effect in the estimate of automatic retrieval processes confirmed then that the RIF effect observed in category-driven implicit tasks (Perfect *et al.,* 2002) was not due to

a contamination of intentional retrieval processes. However, in our study, we obtained an inverse RIF effect, since more RP — than Nrp items were recalled in the exclusion condition and in the estimates of automatic memory. We could hypothetically explain this effect by proposing that the earlier inhibition of an item (namely the RP — items) leads to a reduction in its propensity to reach conscious recollection, resulting in a greater probability of being recalled in the exclusion condition or on the basis of automatic processes, because participants are more confident about considering these inhibited items as 'non-previously presented' exemplars in that condition.

Some authors have questioned the inhibitory nature of the RIF effect because they failed to find the effect when memory performance was assessed with implicit memory tasks (Butler *et al.*, 2001). The rationale was that if the RP — items are truly inhibited, one could expect that the 'performance impairments arising from that inhibition should generalize to any cue' (Anderson & Spellman, 1995, p. 92) used to test these items. In the present study, we confirmed that, when the task requires conceptual retrieval, the RIF effect emerges with both measures of automatic and intentional retrieval. These data clearly support the inhibitory account of the RIF effect. As it was suggested in the introduction, the reason why the effect appears only when the implicit task requires conceptual retrieval may be found in the specificity of encoding assumption (Tulving & Thomson, 1973), which stipulates that the probability of successful retrieval of a target item is increased when the contextual features of encoding and retrieval are matched. This suggests that the consequences of inhibitory functions are not absolute but rather subordinate to other cognitive processes (i.e. the retrieval circumstances), and may then be released in some circumstances.

To summarize, our results confirmed that elderly adults have spared unintentional inhibitory processes, probably because these processes do not require modulation by executive control in order to perform properly. These results extend those of previous studies that also demonstrated preserved automatic inhibitory processes using perceptual tasks. Moreover, we have demonstrated that RIF effect is independent of the retrieval processes elicited (at least when the tasks are based on access to conceptual representations), since it was found for both automatic and intentional estimates of memory processes.

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