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***Retrieval-Induced Forgetting and Its Effects on
Episodic Memory***

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Abstract

Remembering and forgetting are closely related and paradoxically it seems as if the very act of remembering in some cases can lead to forgetting. The aim of present study is to examine if there is a difference in retrieval-induced-forgetting effect concerning different types of binding in long-term-memory. To investigate any potential differences two different associations were chosen; face-face and face-place. To investigate a potential impact of an emotionally loaded stimulus, both item types could appear as either neutral or negative. We found that the between-domain binding (place) generated more interference than the within-domain binding (face) and this in turn resulted in a greater RIF effect for item type place in trial type consisting of a neutral face and a neutral place compared to item type face in trial type consisting of a negative face and a neutral place. Furthermore, results indicate that a negative item type greatly reduces memory performance for both the neutral and the negative items.

Keywords: Retrieval-induced forgetting, RIF, Episodic Memory, Faces, Places

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Introduction

Memory is not static; it changes constantly over time, not only with newly acquired semantic knowledge and novel personal experiences, but also with the weakening and – in some cases - forgetting of existing memories. Remembering and forgetting are closely related and paradoxically it seems as if the very act of remembering in some cases can lead to forgetting. An important property of a well working memory is the interaction between a certain cue and its designated memory trace (Tulving, 1983). Although it is not the encoding of new memories that affects forgetting per se, complications rather arise at retrieval from memory. The main reason for this is that the cues - generated either externally or internally - to specific memories work independent and do not automatically update their bonds to the most recently acquired memories. This results in a co-activation of several competing memory traces of which only one may be relevant given the present cue.

For example might the retrieval of a relative's birthday co-activate competing irrelevant memory traces in long term memory (LTM) of other relatives birthdays. In order to minimize the distraction from these competing irrelevant traces they must be inhibited which in some cases can result in a brief loss of memory concerning another relative's birthday. In this example - the amount of interference and thus - forgetting depends on several factors such as closeness to the particular relative and also proximity in time to the different birthdays. The above mentioned factors both contribute to a varied degree of interference which in turn substantially affects the likelihood of forgetting a related memory while retrieving a specific memory (Levy & Anderson, 2002; see Wixted, 2004, for a review).

The idea of forgetting due to interference is not new and was already experimentally tested by Müller and Pilzecker (1900) in the beginning of the twentieth century. There has been an ongoing debate about different kinds of interference (e.g. proactive interference

(Keppel & Underwood, 1962)) and to what extent they contribute to impairments in memory ever since (see Anderson, 2003, for a review).

Given the co-activation of several irrelevant memory traces, the recollection of a desired memory trace should be facilitated by some sort of mechanism that is able to control or even inhibit the competing traces. Indeed, according to a study conducted by Anderson (1994), inhibition of irrelevant traces is exactly what occurs. In order to achieve this Anderson et. al developed a memory test that takes advantage of the way knowledge - in terms of categories and exemplars - is organized in the brain. The memory test was divided into three phases; Study phase, retrieval-practice phase and finally a test phase. In the first phase participants studied a combination of different category-exemplar pairs (e.g. Fruit-Orange, Fruit-Apple, Tree-Oak, Tool-Hammer). In the next phase, the retrieval-practice phase, participants were instructed to retrieve half of the studied items from half of the categories with a cue-stem recall-test (e.g. Fruit-Or_____). The final test phase had much resemblance with the previous retrieval-practice phase with the exception that all items which had been presented in the study phase now were tested with the same type of cue-stem recall-test used in the practice phase. Not surprisingly practiced items were easier to retrieve than non-practiced items but the most interesting finding is that unpracticed exemplars from practiced categories had worse performance than exemplars from unpracticed categories. In other words did the practice of Fruit-Orange not only lead to an impairment in performance of the related exemplar Fruit-Banana but it also resulted in worse performance of the related exemplar compared to exemplars from unpracticed and unrelated categories (e.g. Tree-Oak). It is this specific phenomenon that Anderson termed as retrieval induced forgetting (RIF).

As a side note it might be worth mentioning that the advantage of using a cued-recall test in this kind of memory tests is the possibility to minimize the output interference (Smith et. al, 1970) effect. Without this kind of control participants would be tempted to recall the

practiced items first and thereby generate output interference on the remaining unpracticed pairs.

While the most common way to test the RIF paradigm is by using variations of Anderson's semantic memory test (MacLeod & Macrae, 2001; Johansson et. al, 2006), Shimamura and Ciranni (1999) managed to find evidence that the paradigm also is applicable on episodic memory. In order to achieve this they designed a set of experiments to test newly formed episodic memories which consisted of combinations of different shapes and colors associated to a spatial location. They used four kinds of shapes which could appear in different colors and these objects would then be presented in one of twelve possible locations. The participant's task was to remember shape, color and location for each presented item. In the following retrieval-practice phase the participants were given instructions to practice either shape, color or location depending on experiment. What diverges their retrieval-practice phase from similar experiments is the immediate feedback the participants get when choosing the requested attribute (e.g. color, shape or location). This feedback benefits not only the performance of the practiced items but also enhances the RIF effect of the related unpracticed items.

Although both Anderson's and Shimamura's studies report substantial behavioral evidence of RIF effects in their experiments the question about which neural correlates are involved in forgetting still remain unanswered.

There have been numerous studies (Kuhl et. al, 2007; Johansson et.al, 2006; Wimber et. al, 2008) since Anderson established the RIF paradigm whose goal have been to try to shed light on which neural mechanisms actually are involved in the process of forgetting. It is suggested (see Kuhl & Wagner, 2009, for a review; Wimber et. all, 2008) that due to the competition among memory traces that co-activate when given a certain cue a conflict arises which is automatically detected by the anterior cingulate cortex (ACC). ACC then notifies the

prefrontal cortex (PFC) about the conflicting traces which in turn selects - and thereby strengthens - the desired memory trace and inhibits the remaining irrelevant traces. The finding that the PFC plays an important role in the process of forgetting does not come as a surprise as it has been widely accepted that the PFC directs attention resources to the desired memory trace during the retrieval of episodic memory (see Cabeza et. al 2008 for a review). But a consequence of PFC:s selection process is the weakening of the remaining irrelevant traces and they are thus less likely to be activated in case they should become relevant in the future. Furthermore did Johansson et. al (2006) in an event-related potential (ERP) study manage to establish a connection between the amount of activity in PFC during retrieval in their retrieval-practice phase and the later forgetting of unpracticed related items. Not only were they able to confirm old findings regarding which areas were involved in forgetting but most importantly they were able to predict the RIF effect from the observed magnitude of activation in the PFC during the retrieval-practice phase.

Even though it may seem tedious to forget related memories while retrieving there are several benefits for future retrievals, concerning both energy cost and also response time (Kuhl et. al, 2007). If all memory traces would remain at a constant strength the PFC and ACC would have been obligated to undergo an intense selection process every time we were presented a specific cue.

Given the associative nature of the long-term-memory system as suggested by Mayes et. al (2007) the current study was designed to examine whether the RIF paradigm is applicable on different kinds of binding.

Mayes et. al proposes three different kinds of associative bindings in long-term memory; Item memory, within-domain and between-domain. For example does the item memory association describe the type of binding that is formed between the word monkey and the object monkey; within-domain is a binding between two similar objects, like two faces

and lastly between-domain describes the binding that occurs between two dissimilar objects like a house and a face. While item memory and within-domain associations only require involvement of the perirhinal cortex to establish an effect of familiarity the between-domain association demands the engagement of the hippocampus in order to achieve recollection.

Due to the above mentioned differences in neural processes that are involved in the binding of within-domain and between-domain associations it is assumed that the less effortful within-domain binding should cause more interference than the between-domain binding. This in turn should lead to an increased demand of inhibition regarding the within-domain association and should therefore result in a larger retrieval-induced-forgetting effect for within-domain associations in cases where the between-domain association has been practiced compared to the other way around.

Furthermore, several studies (Dolcos & Cabeza, 2002; Maratos et. al, 2000) have reported that emotionally loaded stimuli enhance memory performance. The mentioned enhanced memory performance should result in an increased amount of interference generated by an emotionally loaded stimulus compared to a neutral stimulus. Taking these findings into consideration an emotional component was implemented to further control the interference from practiced items.

The present study decided to use two types of associations to examine any potential differences between within-domain and between-domain associations concerning a retrieval-practice effect; face-face as within-domain binding and face-place as between-domain binding. Furthermore, to investigate a potential impact of an emotionally loaded stimulus, both face and place could appear as either neutral or negative. Considering existing research we predict that the memory performance of face is less likely to be affected by interference from place than the other way around as the face-place association requires a more effortful encoding. The thought behind the implementation of an emotional component is that an

emotional irrelevant item (Rp-) should interfere more with a practiced neutral item (Rp+) during the retrieval-practice phase. This should result in a higher demand of inhibition and thus a greater retrieval-induced-forgetting effect for emotionally loaded Rp- items. Although current research (Dehli & Brennen, 2008) have reported somewhat ambiguous results concerning the impact of emotion on RIF effects, we hope to be able to shed some light on this matter.

The chosen design of the experiment gives us not only an excellent opportunity to examine if there is a difference in RIF effect concerning different types of binding but also to what extent an emotional component affects the memory performance. Possible findings may not only have an impact on current research regarding the interaction between retrieval and forgetting but may also be significant for both witness psychology and the research about post-traumatic-stress-disorder (PTSD).

Methods

Participants

A total of 20 (12 females) students at Lund University participated in the study. All had corrected-to-normal eye vision and were right handed. Their age ranged between 19 and 36 with a mean of 25. All participants gave written consent prior to participation in the study.

Stimuli

A total of 90 colored pictures (Kasiński et. al, 2008) of neutral faces, 45 male and 45 female, were chosen to serve as cue image. Ten colored pictures of faces were chosen from the NimStim database, five male and five female, which could appear with both neutral and negative face expressions were used for the associative face. Furthermore, ten colored context images showing different places of which five were neutral (e.g. a plaza) and five negative (e.g. a car crash) were used as background.



Figure 1. Left image (1a) is an example of a study trial. Right image (1b) is an example of a test trial.

As figure 1a shows images from these three categories were combined into a situation consisting of a context image as background, the face that would later serve as cue positioned in the bottom left quadrant and the associative face positioned in the bottom right quadrant. Table 1 displays all possible combinations that can appear.

Table 1. Possible combinations concerning emotional load and retrieval-practice of items.

Trial type	Face	Place	Practice
A	Neutral	Neutral	Face
B	Neutral	Negative	Face
C	Negative	Neutral	Place
D	Neutral	Neutral	None
E	Neutral	Negative	None
F	Negative	Neutral	None

Procedure

Each participant studied a total of 90 different situations. These 90 situations were split up into 15 study-practice-test blocks. Each block consisted of six study situations where each trial type shown in table 1 would appear once per block.

Each block had three phases; Study, retrieval-practice and finally a test phase. The first phase, the study phase, always began with instructions to memorize all three attributes (e.g. the two faces and the place) and also that the left face would work as a cue in the

upcoming retrieval-practice and test phases. Each study trial started by displaying a focus cross in the middle of the screen and after 800 ms a situation as described above was presented during a time span of 5000 ms.

In the intermediate retrieval-practice phase half of the situations were practiced with a cued-recall test. The face which was presented in the bottom left quadrant during the study phase was presented in the middle of the screen and after 1000 ms a text appeared giving instructions whether the participant should recall the related face or otherwise the place. The different pictures containing the possible faces or places depending on what was asked for were shown around the cue image (figure 1b) and the participant was instructed to indicate the correct image by clicking on it with the mouse. Participants had indefinite time to give their answer. In order to measure a potential decrease in response time this task was repeated three times in a randomized order for each of the three practiced situations. No feedback was given during this phase.

The last phase, the test phase, had much resemblance with the practice phase with the exception that each situation would appear only once and that the participant was instructed to recall both face and place for all situations which had appeared in the study phase. The order regarding what was asked first was determined by which attribute was practiced in the intermediate phase (e.g. if face was practiced in the retrieval-practice face then participants would have been asked about place prior to face). Question order was randomized for the unpracticed situations.

Data analysis

A potential retrieval-practice effect is calculated as the accuracy of unpracticed items from unpracticed trial types (Nrp) minus the accuracy of unpracticed items from practiced trial types (Rp-). In order to examine the significance of possible differences between Nrp and Rp- items, a paired-samples t-test was utilized.

The impact of emotional items was analyzed by using a two-way repeated measures ANOVA employing the factors ItemType (Face, Place) and TrialType (D, E, F). Potential significant pair-wise comparisons found were further examined by using paired-samples t-tests.

Results

The results from the present experiment are divided into two separate sections. The first section investigates any potential retrieval induced forgetting effects over all conditions. The second part examines to what extent an emotional component influences the general memory performance.

Effects of retrieval-practice

An overview of memory performance in the retrieval-practice trials is given in table 2. The use of a paired-samples t-test revealed a significant ($t_{19} = -2.431, p < 0.05$) retrieval-induced-forgetting effect (-7.3%) for the item type place in trial type A. Although the memory performance in trial type C showed a small (-2.7%) difference between Rp- and Nrp, neither trial type B nor C provided any significant RIF effect (B: $t_{19} = 0.560, n.s.$, C: $t_{19} = -0.890, n.s.$).

Table 2. Behavioral data over retrieval-practice trial types conditions.

Trial type	Face	Place	Practice	Rp+	Rp-	Nrp	Difference
A	Neutral	Neutral	Face	0.547	0.577	0.650	0.073
B	Neutral	Negative	Face	0.513	0.557	0.540	-0.017
C	Negative	Neutral	Place	0.557	0.480	0.507	0.027

RP+ are practiced items from practiced trial types, RP- are unpracticed items from practiced trial types, Nrp are unpracticed items from unpracticed trial types. Differences are calculated as Nrp minus Rp-.

Effects of emotion

An overview of memory performance for the non-retrieval-practice (Nrp) trial types is presented in figure 2.

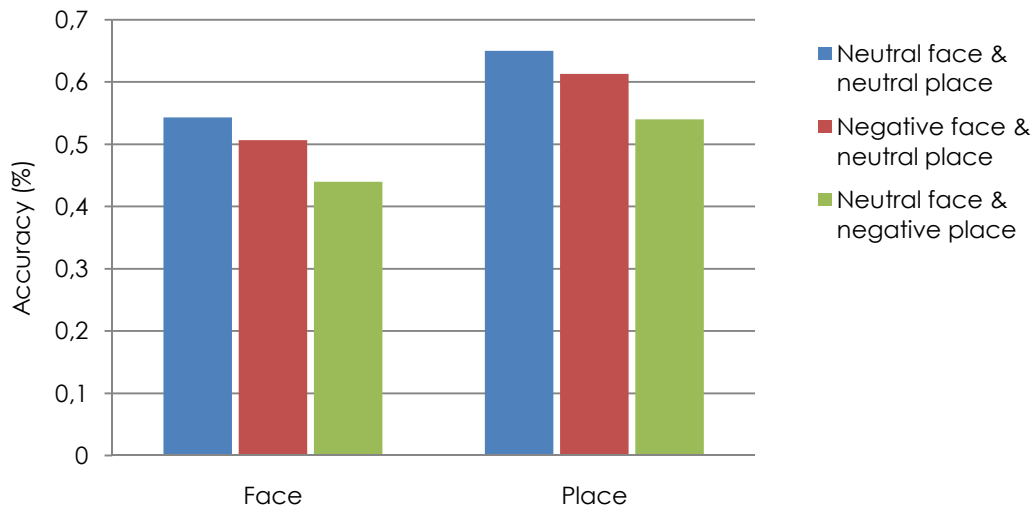


Figure 2. Impact of emotional load on memory performance for both face and place.

Interestingly, figure 2 shows that the memory performance for both item types peaked when no emotional component was present. As presented in table 3, a negative face resulted in a small decrease in performance (-3.7% for face and -3.7% for place) compared to trial types where both items were neutral. Furthermore, a negative place (trial type F) reduced the memory performance even more; -10.3% for face and -11% for place compared to performance in trial type D where both item types were neutral.

Table 3. Behavioral data over non-retrieval-practice trial types.

Trial type	Face	Place	Practice	Face	Place
D	Neutral	Neutral	None	0.543	0.650
E	Neutral	Negative	None	0.440	0.540
F	Negative	Neutral	None	0.507	0.613

In order to examine the significance of observed differences a two-way repeated measures ANOVA was used. The 2 x 3 ANOVA consisted of the factors ItemType (Face, Place) and TrialType (D, E, F). As Mauchly's test of sphericity had values below 0.75 the corrected Greenhouse-Geisser values were used. Main effects of both ItemType ($F_{1,19} = 17.702$, $p < 0.001$) and TrialType ($F_{1,19} = 5.465$, $p < 0.05$) were discovered. The interaction between the factors ItemType and TrialType was not significant ($F_{2,38} = 0.18$, *n.s.*). Pair-wise comparisons revealed differences between trial type D and trial type F concerning both item

type face and item type place. To further investigate these differences a paired-samples t-test was conducted. The analysis showed significant differences between trial type D and trial type F for both item type face ($t_{19} = 3.037, p < 0.05$) and item type place ($t_{19} = 2.421, p < 0.05$) respectively.

Discussion

As stated earlier, the main focus of the present study was to examine any potential differences regarding RIF effects between the different binding types suggested by Mayes et al (2007). In order to investigate these potential differences two kinds of associations were compared; face-face and face-place. Previous research suggests that a maximum RIF effect is generated when a weak exemplar (between-domain association) is practiced and the stronger related exemplar (within-domain association) has to be inhibited. To further control the interference, an emotional component was implemented. That is both face and place could appear as either neutral or negative.

When we stated our initial predictions we assumed that the within-domain (face) association would be easier to bind and therefore have better memory performance than the between-domain (place) association. But results in table 3 report quite the opposite; place has better accuracy than face. There are several explanations for the observed results. First of all the less effortful within-domain binding is mainly superior in terms of familiarity and the involvement of the hippocampus is still required to succeed with a full recollection of an event (Eichenbaum et. al, 2007; Ranganath et. al, 2007). Considering the design of the present study, recollection is required in order to remember which item belonged to each cue and thus the advantage of the between-domain binding diminishes. Furthermore, the automatic associative binding of faces and scenes was investigated in a study conducted by Cabeza et. al (2009). They used two different conditions; face-face (F-F) and face/scene-face (FS-F). In the first condition, face was presented alone during both study and retrieval, whereas the face

in the FS-F condition was presented with a background image in the study phase and alone during retrieval. Although participants were instructed to focus on the face and to ignore the background image in the FS-F condition, observed results reveal a significant decrease in memory performance concerning the FS-F condition compared to the F-F condition. Taking all this into consideration, the seemingly contradicting results of the RIF effects do not come as a surprise. On the contrary, it would have been quite surprising if our initial predictions still would apply.

The discovered differences in RIF effects regarding face and place coincide well with the previously stated predictions concerning the amount of interference generated by the stronger item type. In this case that would be the item type place. More specifically, that the between-domain binding (place) generates more interference than the within-domain binding (face) and this in turn results in a greater RIF effect for item type place in trial type A compared to item type face in trial type C (see table 2). Although the results deviate from our predictions, the current findings provide sufficient evidence to suggest that the retrieval-induced-forgetting effect indeed differentiates between the within-domain and between-domain binding types suggested by Mayes et. al. Although Shimamura and Ciranni (1999) have shown similar differences by utilizing abstract objects this study is - to our knowledge - the first to show that this also holds for real-life situations.

Interestingly the results presented in table 3 regarding impact of emotional stimuli on memory performance somewhat diverge from previous research concerning emotional stimuli as it is suggested that an emotional load should enhance - and not impair - memory performance for that particular item (Cabeza & Dolcos, 2002; Levens & Phelps, 2008). A possible explanation for the observed results is that most of the participant's attention resources might be allocated to the negative item type (see Corbetta & Shulman, 2002, for a review) and that the participants therefore fail to associate the negative item type to the

presented cue. Furthermore, the cue is always neutral and thus does not activate any emotion. The mentioned absence of an emotional cue aggravates in turn the participant's possibility to establish an emotional bond between the negative item and its designated cue. Taken the two above mentioned explanations into consideration, it does not come as a surprise that a negative item type impairs the memory performance.

Future studies

Considering the observed results regarding emotional impact presented in table 3 it is difficult to make any statements on how and if emotion interacts with the RIF effect. In order to examine to what extent emotion influences the performance in the retrieval-practice trial types some changes in the experimental design regarding the involvement of the cue (e.g. implementing a story-telling component for each study trial) would be required. Other possible changes include adding an emotional component to the cue which would facilitate the binding of emotionally loaded items and another possibility would be to add a trial type consisting of a neutral face, a neutral place and the retrieval practice of place.

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