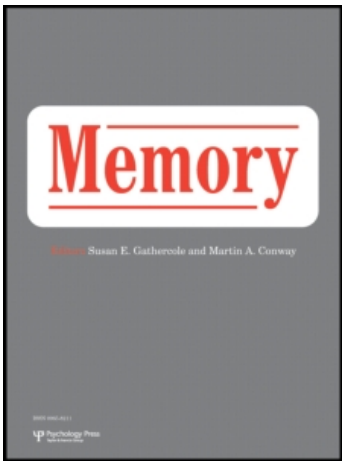

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Script knowledge modulates retrieval-induced forgetting for eyewitness events

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Script knowledge modulates retrieval-induced forgetting for eyewitness events

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To determine the influence of knowledge schemata on inhibitory processes we analysed how the typicality of the actions of an event modulated retrieval-induced forgetting (RIF). Participants were presented with a realistic videotape of a bank robbery. Based on a normative study, high- and low-typicality actions of the event were determined. After watching the video, participants practised retrieving either half of the high- or half of the low-typicality actions, and their performance was compared against a no-practice control group. Tests given immediately after the event and after a 1-week retention interval demonstrated significant RIF for low-typicality actions exclusively when low-typicality actions were practised, but a comparable forgetting effect did not emerge for highly schematic actions. These findings confirm that highly integrated script knowledge protects high-typicality actions of an event from inhibitory processes, and demonstrate that RIF's effects last far longer than has been previously found.

Keywords: Retrieval-induced forgetting (RIF); Script knowledge; Eyewitness memory.

Selective retrieval of episodic memories can impair later retention of related contents that compete for access during memory retrieval, a phenomenon called *retrieval-induced forgetting* (RIF; Anderson, Bjork, & Bjork, 1994). The inhibitory processes thought to underlie RIF fulfil a double function: facilitating the retrieval of information needed at a specific time, and inhibiting contents that interfere during retrieval. The procedure used to investigate RIF comprises four phases: study of category–exemplar pairs (e.g., fruit–orange, fruit–banana, drink–gin); retrieval practice of half of the studied exemplars from half of the categories (e.g., fruit–or___); a distractor task, and recall of all the exemplars from all of the categories. Recall performance is assessed on practised items (e.g., orange; often referred to as Rp+ items), unpractised items from practised categories (e.g., banana; known as Rp− items), and on items from Nrp unpractised categories (e.g., gin) that provide a baseline recall performance. On the final memory test, facilitation is typically observed for practised exemplars (Rp+ > Nrp), whereas impairment is observed for unpractised exemplars from practised categories (Rp− < Nrp).

RIF is often assumed to reflect the effects of inhibitory processes engaged during retrieval practice to assist in the selective retrieval of target items (see Anderson, 2003, and Levy & Anderson, 2002, for reviews). The situation thought to trigger inhibition arises when the cue

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(e.g., fruit) guiding search for a target memory (e.g., orange) also activates other associates (e.g., banana) in memory. Activation of other associates hinders retrieval of the target, either because those associates consciously intrude into awareness, or simply because their preconscious activation impedes the shift in attentional focus to the target (Anderson & Bjork, 1994). In response, inhibitory processes suppress those associates to facilitate target retrieval, causing RIF. Several functional properties of RIF favour this view. For instance, observations that RIF is retrieval specific (Anderson, Bjork, & Bjork, 2000), interference dependent (i.e., moderated by the amount of interference caused by competing items; Anderson et al., 1994), and cue independent (Anderson & Spellman, 1995; because RIF has been found across a wide range of tests including those that employ independent probes not used in previous phases of the experiment; Anderson & Spellman, 1995; Saunders & MacLeod, 2006), support the inhibitory account. Some have argued that non-inhibitory mechanisms may also contribute to RIF (see, e.g., MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003; Perfect et al., 2004).

RIF has been demonstrated across a broad range of materials whenever selective retrieval is required. For instance, retrieving one meaning of a homograph inhibits alternative meanings, especially if dominant (Johnson & Anderson, 2004); retrieving a foreign language term in response to a picture inhibits the dominant native language term (Levy, McVeigh, Marful, & Anderson, 2007); retrieving some facts associated to a topic inhibits other facts associated to that same topic (Anderson & Bell, 2001; Macrae & MacLeod, 1999); and retrieving some details of a crime event inhibits other details associated to that same event (MacLeod, 2002; Migueles & Garcia-Bajos, 2007; Saunders & MacLeod, 2006; Shaw, Bjork, & Handal, 1995). Thus, across content varying widely in type and complexity, retrieving some associates of a cue impedes the later retrieval of other things attached to that cue, suggesting that selective retrieval is an important factor that shapes what we retain of our past experiences.

Although RIF appears to be a general phenomenon there are clear boundary conditions under which it has been shown not to occur. For example, Anderson and McCulloch (1999) found that RIF was eliminated when participants integrated the exemplars of a category on their own or when they were explicitly instructed to do so (see also Anderson & Bell, 2001). In addition retrieval interference is also reduced when materials are organised, for instance, in high-integration conditions using causally linked sentences (Myers, O'Brien, Balota, & Toyofuku, 1984), or in high associative DRM lists when the critical thematic item was part of the studied items (Bäuml & Kuhbandner, 2003). In fact, all traces of RIF disappear when information is organised, such as in an event composed of a natural sequence of actions (Conroy & Salmon, 2006; Migueles & Garcia-Bajos, 2007). In these cases, knowledge schemata might modulate RIF's effects.

The processing of many of our everyday activities is guided by schemata (Alba & Hasher, 1983; Bower, Black, & Turner, 1979). These knowledge structures are made up of highly organised information; they guide processing, and are thought to be particularly resistant to inhibitory processes (Anderson & McCulloch, 1999). Consistent with this idea, RIF is reduced when participants encode schema-based materials, such as stereotypical personality traits (e.g., Dunn & Spellman, 2003). In the domain of event knowledge, Migueles and Garcia-Bajos (2006) found that schemata also protect the contents of an event script from the negative after-effects of retrieval practice. They presented participants with two lists containing high- and low-typicality actions of a mugging script, and only found RIF for low-typicality actions. Nevertheless, few studies have analysed the effects of schematic knowledge on RIF, and those that have done so have primarily used simple verbal lists; none has used eyewitness events.

One of the primary objectives of this study is to use a realistic video depicting a robbery to analyse the effects of prior knowledge on RIF. Based on the idea that people have prior knowledge about the characteristics of the most common crimes and that there is broad consensus on the actions involved in such crimes (Garcia-Bajos & Migueles, 2003; Greenberg, Westcott, & Bailey, 1998; Holst & Pezdek, 1992; Migueles & Garcia-Bajos, 2006), we chose the script of a bank robbery. Scripts and real events consist of both schema-typical actions and less representative actions. When people's perception of an event is guided by a script, it is assumed that the actions that take place are associated to the script representation. If so, then each of the high- and low-typicality actions constitutes associates to the script event, and thus would be activated upon mention of the event.

Given this, attempts to selectively retrieve some of the component actions might induce forgetting of other, non-retrieved actions that may momentarily hinder selective retrieval of the particular event. To examine this possibility we used data from a previous normative study, to identify which actions in the bank robbery video were high typicality and which were low typicality. This allowed us to study the effects of retrieval practice of high- or low-typicality actions on the later recall of the remaining actions of the event, whether high or low typicality. RIF can have important consequences when recalling an event. The selective retrieval of particular contents about the crime could cause eyewitnesses to forget other information relevant to the case. The practical implications of this study are evident.

There are good theoretical reasons to expect that the disruptive effects of RIF will be more pronounced when low-typicality actions are practised, compared to when high-typicality actions are practised. Although initial research on RIF found that the strength of the to-be-practised items did not moderate the amount of RIF observed on competitors (Anderson et al., 1994), subsequent empirical and theoretical work suggests that this conclusion may have been premature. For instance, Storm, Bjork, Bjork, and Nestojko (2006) found evidence suggesting that the more difficult retrieval practice was for participants, the more RIF was observed, with relatively little RIF found when practice was quite easy. This view fits with recent theoretical models of RIF, according to which RIF should diminish as to-be-practised items approach asymptotic strengthening (Norman, Newman, & Detre, 2007), as well as previous proposals that postulated a special involvement of inhibition to retrieve weakly activated codes (Dagenbach, Carr, & Barnhardt, 1990). The common theme in these proposals is that the stronger the association becomes between a cue and a to-be-practised target, the more quickly the target will achieve retrieval threshold, minimising the potential for other associates to impede the retrieval process and trigger inhibitory mechanisms. If this view is correct, then retrieval practice on low-typicality actions, which are more weakly associated to the script, might be expected to trigger inhibitory processes more effectively, inducing greater RIF on competing items than when high-typicality actions are practised.

The typicality of non-practised actions may also influence the observed magnitude of RIF, independent of the typicality of the practised actions. Prior work suggests that not all component actions of a script-related event should be equally vulnerable to the disruptive effects of inhibition. As noted previously, when the associates of a cue are integrated with one another, RIF is reduced and often eliminated entirely (Anderson & McCulloch, 1999). To the extent that high-typicality actions are well integrated with other high-typicality actions through their shared knowledge schema (Migueles & Garcia-Bajos, 2006), and through established causal interconnections (Myers et al., 1984), they should suffer little RIF. On the other hand, low-typicality actions are specific facts that are not as well organised into the script. To the extent that such actions are poorly integrated within the event script and with high-typicality actions, they should be vulnerable to RIF. Thus, in general, low-typicality actions ought to be more vulnerable to RIF than high-typicality actions, due to the effects of integration.

Our second objective was to examine the durability of RIF; specifically whether such effects could be observed at very long retention intervals. Migueles and Garcia-Bajos (2007) measured recall for the characteristics of criminal offenders and found significant RIF on both an immediate test and a test delayed by 24 hours. These findings diverge from previous work on personality traits, in which RIF was found to dissipate after 24 hrs (MacLeod & Macrae, 2001). However, they are consistent with a recent study by Storm et al. (2006), which found significant RIF after 1 week, using category–exemplar pairs. One explanation of this discrepancy is that both Migueles and Garcia-Bajos and Storm et al. tested memory twice for each participant, both on the immediate and the delayed tests, whereas MacLeod and Macrae tested items for the first time only after the 24-hour delay. Perhaps in the former two studies the immediate recall test caused retrieval-based learning of the successfully recalled items, causing a persisting advantage for the better recalled Nrp items over Rp− items at a delay. By this view, it is not the RIF itself that endures over 24 hrs (or over 1 week), only the differential effects of retrieval-based learning. Alternatively, RIF may endure for much longer intervals than has been supposed. To address this discrepancy the present study used the repeated testing procedure, but also included a group of participants in which RIF was tested for the first time after a week, with no initial test. If RIF only persists when an initial test is given, we should not

observe RIF in this week-only group. However, if RIF endures longer than previously supposed, RIF should be observed after a week, regardless of whether there was an initial test.

METHOD

Participants and design

A total of 120 psychology students from the University of the Basque Country participated in this study: 100 women and 20 men (age, $M = 22.57$ years, $SD = 6.62$). They were divided into six groups of 20 participants, and a 3 (Type of Action Practised: High-typicality, Low-typicality or Control, no retrieval practice) $\times$ 2 (Retention Interval: Immediate-plus-1-week, vs 1-week-only) between-participants factorial design was used. Facilitation of practised actions (Rp+ > Control) and impairment on unpractised actions (Rp− < Control) were analysed in repeated testing (immediate, 1 week) and independent testing (immediate, week only).

Materials

We used a 1 minute 45 second sequence from a bank robbery video. It begins when two security guards walk into a bank carrying cash boxes. Next, two armed robbers come in and hold up the bank. One of them tells the security guard to hand over the money and put it in a bag, while the other one keeps watch over the rest of the people in the bank. After one of the bank robbers shoots a security guard, the other robber grabs the bag of money, and the two of them leave the bank. At the end they run towards a car and drive away. The first 15 s and last 15 s were used to control for primacy and recency effects, and memory for the actions contained in them was not measured.

Normative data from a previous study on a bank robbery script were used to determine the typicality of the actions in the bank robbery video. A group of 80 psychology students from the University of the Basque Country took part in the study, 72 women and 8 men (age, $M = 20.56$ years, $SD = 3.85$). They were given 10 minutes to list in chronological order the most typical or common actions in a bank robbery, and two judges coded the actions based on frequency of production. Following the criteria put forth by Bower et al. (1979) and adopted by other authors (e.g., Garcia-Bajos & Migueles, 2003; Greenberg et al., 1998; Holst & Pezdek, 1992; Migueles & Garcia-Bajos, 2006), high-typicality actions were defined as actions mentioned by over 25% of the participants and, to discriminate from more fuzzy medium-typicality actions, low-typicality actions were those listed by less than 5% of the participants. General actions (e.g., enter bank, 87.5%; or exit bank, 92%) without more specific information of the event were not considered because they may be deduced in terms of schema-based reconstruction of the event.

Based on this prior study, 10 high-typicality actions and 10 low-typicality actions were identified in the videotape. Both types were then divided into two sets, A and B, of five actions each to counterbalance them in the retrieval practice phase. Table 1 shows the actions of the event, frequency of mention in the normative study, and time of occurrence and duration (in seconds) of the actions within the videotape. There were no significant differences between sets A and B in any of the measures. Nor were there differences between high- and low-typicality actions with regard to either time of occurrence or duration.

We also examined the clustering of high- and low-typicality actions within the event sequence. Clustering refers to the tendency for the actions to take place next to one another in time. To quantify clustering we applied the *Adjusted Ratio of Clustering* (ARC; Roenker, Thompson, & Brown, 1971), in which chance clustering is set at 0, perfect clustering at 1, and negative scores indicate clustering below chance. The ARC values were negative for the high-typicality (−.44) and low-typicality actions (−.33), showing that the high- and low-typicality actions were interleaved within the event.

Procedure

Participants performed the experiment in small groups. All of them were instructed to pay close attention to the event because afterwards they would be evaluated. After viewing the event, all of the participants performed two written retrieval practice tasks. The experimental groups either practised retrieving half of the high- or half of the low-typicality actions of the event. First they completed five sentences about five event actions (e.g., As they leave, one of the robbers threatens the people not to ____), and then answered five

TABLE 1
Actions of the bank robbery

Actions of the bank robbery	*%*	*Time*	*Duration*
High-typicality actions. Set A for retrieval practice			
Two bank robbers walk in the bank wearing ski masks	36.25	17	2
They shout, ''Don't anyone move! Hands up!''	38.75	19	5
One of them demands the money and threatens to open the till	41.25	33	6
He forces the security guard to put the money in a bag	28.75	53	6
As they leave, he threatens the people not to move	31.25	79	2
Mean	35.24	40.20	4.20
SD	5.19	26.02	2.04
High-typicality actions. Set B for retrieval practice			
The bank robbers threaten the people at gunpoint	48.75	20	4
One of them keeps an eye on the people	33.75	29	4
The other one is nervous and constantly tries to speed things up	32.50	51	6
The robber takes the bag and leaves with the money	25.00	78	2
They rush out of the bank	31.25	84	3
Mean	34.25	52.40	3.75
SD	8.77	28.51	1.70
Low-typicality actions. Set A for retrieval practice			
The robber carrying a bag jumps over the counter	1.25	21	3
He shouts at the security guard to lay his gun on the floor	1.25	26	4
The people watch in silence	2.50	43	6
One of the security guards tries to pull out his gun	3.75	66	2
The other one calls them murderers	1.25	77	3
Mean	2.00	46.60	3.60
SD	1.11	24.46	1.51
Low-typicality actions. Set B for retrieval practice			
The people get out of the way and put their hands up	3.75	28	6
A robber points his gun at a security guard's neck	1.25	39	4
The other security guard appears from behind	2.50	63	3
The robber keeping watch shoots and kills him	3.75	70	3
The other robber says, ''Let's get out of here!''	2.50	80	3
Mean	2.75	56.00	3.80
SD	1.04	21.27	1.30

High- and low-typicality actions of the bank robbery, percentage of participants mentioning each action in the normative study, and time of occurrence of each action in the event and duration of the actions in seconds.

questions on the same contents (e.g., As they leave, what does one of the robbers do?). The participants in the control group spent the same period of time retrieving world capitals. First they completed a cued-recall task, followed by questions to retrieve the names of capital cities of the world. Each retrieval practice trial was performed on a separate sheet of paper. After all trials were completed, as a distractor task participants had 5 minutes to generate exemplars for different semantic categories unrelated to the material in the videotape. Next, half of the participants from each group were tested on immediate recall of the bank robbery. On a sheet of paper numbered 1 to 20, they wrote down all of the actions they could remember from the event. The other half of the participants from each retrieval practice group followed a similar procedure, but they were instead told to recall the actions from a recent film they had seen, other than the videotape. Finally, 1 week later all of the participants returned and they were asked to recall all of the actions of the event. The participants took 8 to10 minutes to complete recall on each of the immediate and delayed recall tasks.

RESULTS AND DISCUSSION

For the measures reported here (retrieval practice or final recall performance), there were no significant interactions of any of our experimental

manipulations with item counterbalancing (A or B), so discussion of this factor will be omitted for simplicity.

Retrieval practice success

The success rate for retrieval practice was over 90% ($M = 93.1\%$, $SD = 8.8$) in all of the groups. There were no reliable differences in recall accuracy between participants who practised high-typicality actions (92.4%) and low-typicality actions (95.6%) from the bank robbery; the same was true for the control groups (91.3%), who did retrieval practice using world capitals.

Final recall performance

Table 2 shows recall performance for high- and low-typicality Rp+ practised actions, Rp− high and Rp- low-typicality unpractised actions, Control group unpractised actions (both high- and low-typicality), together with facilitation and RIF effects measured on the immediate test, at 1 week after the initial test, and at 1 week only.

Recall performance in the control groups was better for high- than for low-typicality actions: immediate, $t(19) = 2.53$, $p = .02$, $d = .57$; 1-week, $t(19) = 4.07$, $p = .001$, $d = .91$; week only, $t(19) = 7.31$, $p < .001$, $d = 1.63$. Whereas the low-typicality actions showed significant forgetting at 1 week, both in repeated testing, $t(19) = 3.33$, $p < .01$, $d = .74$, and independent testing, $t(38) = 3.44$, $p < .01$, $d = 1.09$, recall for high-typicality actions after 1 week was maintained in both cases. This pattern shows the erosion of the low-typicality actions of an event over time and the relevance of schematic knowledge in the maintenance of typical facts (Anderson & Bell, 2001; Garcia-Bajos & Migueles, 2003).

Effects of retrieval practice in the repeated testing condition. First we sought to determine the effects of facilitation and impairment in the immediate and delayed recall tests for the repeated testing condition. The facilitation effects for high- and low-typicality actions were analysed using two 2 (Rp+, Control) × 2 (Immediate, Week recall) ANOVAs with repeated measures in the interval factor. Recall was greater for Rp+ actions than for Control actions for both high-typicality actions, $F(1, 38) = 17.67$, $p < .001$, $\eta^2 = .32$, and low-typicality actions, $F(1, 38) = 41.75$, $p < .001$, $\eta^2 = .52$. These facilitation effects appeared in immediate recall—high-typicality: $t(38) = 4.54$, $p < .001$, $d = 2.43$; low-typicality: $t(38) = 5.97$, $p < .001$, $d = 1.11$—and at 1 week—high-typicality: $t(38) = 2.87$, $p = .007$, $d = .91$; low-typicality: $t(38) = 6.02$, $p < .001$, $d = 1.63$. The interval factor was significant only when low-typicality actions were practised, $F(1, 38) = 4.4$, $p = .043$, $\eta^2 = .104$. This effect was due to the control group's poorer performance for low-typicality actions at 1 week than immediately, $t(19) = 3.33$, $p = .004$, $d = .74$, as there were no differences in Rp+, nor in the amount of facilitation. There were no significant interactions with retention interval in this or any of the subsequent analyses. Finally, the facilitation

TABLE 2
Mean proportion of actions recalled

	Retrieval practice conditions			*Control*		*RIF*		
Retention interval	*Rp+*	*Rp− high*	*Rp− low*	*High*	*Low*	*Facilitation*	*High*	*Low*
Immediate								
High typicality	.78 (.03)	.67 (.04)	.46 (.03)	.57(.04)	.45(.03)	.21***	.10	.01
Low typicality	.82 (.04)	.61 (.04)	.32 (.03)	.57(.04)	.45(.03)	.37***	.04	−.13**
Week								
High typicality	.72 (.03)	.65 (.04)	.42 (.04)	.58(.04)	.41(.04)	.14**	.07	.01
Low typicality	.77 (.04)	.54 (.04)	.29 (.04)	.58(.04)	.41(.04)	.36***	−.04	−.12*
Week only								
High typicality	.73 (.03)	.54 (.04)	.27 (.03)	.55(.04)	.28(.03)	.18**	−.01	−.01
Low typicality	.60 (.04)	.52 (.04)	.19 (.03)	.55(.04)	.28(.03)	.32***	−.03	−.09*

Mean proportion of actions recalled (and standard errors in parentheses) by typicality of the practised actions, retention interval, retrieval practice conditions and control group (without retrieval practice), and facilitation and RIF. Rp+, actions that received retrieval practice; Rp− high and Rp− low, unpractised actions of high and low typicality. In examining facilitation or RIF effects, Rp+ or Rp− items should be compared to Control unpractised items that match for typicality. * $p < .05$ ** $p < .01$ *** $p < .001$.

effects (Table 2) were larger for low- than for high-typicality actions both in the immediate recall, $t(38) = 2.08$, $p = .05$, $d = .64$, and in the 1 week repeated recall, $t(38) = 2.78$, $p = .008$, $d = .88$.

To analyse the RIF effects of practising high- and low-typicality actions on the later recall of high- and low-typicality unpractised actions we used four 2 (Rp−, Control) × 2 (Immediate, week recall) ANOVAs with repeated measures in the interval factor. Practising high-typicality actions did not generate reliable RIF of other high- or low-typicality actions. In fact, for high-typicality unpractised actions we found the opposite: high-typicality actions were facilitated, especially in immediate recall, although this retrieval-induced facilitation was only marginally significant, $t(38) = 1.94$, $p = .059$, $d = .61$. Practising high-typicality actions did not cause RIF for low-typicality actions, $F < 1$. The interval factor was significant, $F(1, 38) = 14.05$, $p < .01$, $\eta^2 = .27$, primarily because participants were better at recalling low-typicality actions immediately (.46) than they were after 1 week (.41). Thus, retrieval practice on high-typicality actions led to no RIF on either high- or low-typicality actions.

However, highly reliable RIF was found for low-typicality actions, whenever low-typicality actions were practised, $F(1, 38) = 7.96$, $p = .008$, $\eta^2 = .17$, both immediately, $t(38) = -2.77$, $p = .009$, $d = .88$, and at 1 week, $t(38) = -2.47$, $p = .018$, $d = .78$. The interval factor was also significant, $F(1, 38) = 4.35$, $p = .044$, $\eta^2 = .103$. This effect was because the control group performed worse for low-typicality actions at 1 week than immediately, $t(19) = 3.33$, $p = .004$, $d = .74$, since there were no reliable differences in the recall of low-typicality Rp− actions, nor in the amount of forgetting, as a function of delay, $F < 1$. However, practising low-typicality actions did not cause RIF for high-typicality actions, $F < 1$. Thus, high-typicality actions appear to be resistant to RIF, irrespective of whether high- or low-typicality actions receive retrieval practice.

How do facilitation and inhibition change with a 1-week delay?. The repeated testing groups showed clear evidence that RIF persists for a week, at least for low-typicality actions, replicating our earlier work (Migueles & Garcia-Bajos, 2007). But what happens when recall is tested after a week for the first time, with no initial test? To examine this issue, independent groups were used to compare immediate and week-only recall.

Facilitation effects for high- and low-typicality actions were analysed using two 2 (Rp+, Control) × 2 (immediate, week-only recall) between-participants ANOVAs. Recall was greater for Rp+ practised actions than for Control in both high-typicality actions, $F(1, 76) = 34.65$, $p < .001$, $\eta^2 = .313$, and low-typicality actions, $F(1, 76) = 73.88$, $p < .001$, $\eta^2 = .49$. These facilitation effects appeared in immediate recall—high-typicality: $t(38) = 4.54$, $p < .001$, $d = 1.43$; low-typicality: $t(38) = 5.97$, $p < .001$, $d = 1.89$—and at 1 week—high-typicality: $t(38) = 3.79$, $p = .001$, $d = 1.20$; low-typicality: $t(38) = 6.26$, $p < .001$, $d = 1.98$. The interval factor was significant only when low-typicality actions were practised, $F(1, 76) = 24.57$, $p < .001$, $\eta^2 = .24$. Recall performance for low-typicality actions was poorer at 1 week than it was on the immediate test. Similar to the immediate and 1 week repeated recall, the facilitation effects (Table 2) were larger for low- than for high-typicality actions in the week-only recall, $t(38) = 2.15$, $p = .038$, $d = .68$.

The RIF effects of retrieval practice of high- and low-typicality actions on the later recall of high- and low-typicality unpractised actions were analysed with four 2 (Rp-, Control) × 2 (Immediate, week-only recall) between-participants ANOVAs. Again, no RIF was observed for high- or low-typicality actions as a result of practising high-typicality actions, and this lack of RIF did not vary as a function of interval.

Again, however, robust RIF was found when participants practised low-typicality actions for other low-typicality actions, $F(1, 76) = 12.56$, $p = .001$, $\eta^2 = .14$, both immediately, $t(38) = -2.77$, $p = .009$, $d = .88$, and at 1 week, $t(38) = -2.21$, $p = .03$, $d = .84$. Retention interval also had a significant effect, $F(1, 76) = 23.08$, $p < .001$, $\eta^2 = .23$. This arose because recall performance for low-typicality actions was poorer at 1 week than immediately for Rp− unpractised actions, $t(38) = 3.42$, $p = .002$, $d = 1.08$, and for the control group, $t(38) = 3.44$, $p = .001$, $d = 1.09$, even though there were no significant differences in the amount of forgetting across these delays. However, there was no RIF for high-typicality actions when low-typicality actions were practised, $F < 1$, and this did not vary as a function of retention interval.

One might wonder whether RIF on low-typicality actions could be attributed to output interference occurring at the time of the final recall test. For example, RIF for low-typicality actions might be produced by the fact that highly accessible Rp+ items might be recalled earlier in

the final recall test than the less-accessible Rp− items, diminishing recall performance on these items. To examine this possibility we classified participants by the extent to which they commenced their recall sequences with Rp+ or Rp− items (see the procedure in Macrae & MacLeod, 1999). In none of the conditions did the early Rp+ group produce a larger RIF than the early Rp− group (immediate: −.12, −.14; week: −.11, −.13; week only: −.10, −.08). Therefore the RIF on low-typicality actions appears unlikely to be a consequence of output interference during the final memory task, but rather reflects a RIF effect that has endured for one week.

Clustering of the high- or low-typicality actions in final recall cannot explain the facilitation and forgetting effects either, because the ARC scores were below zero for high- and low-typicality actions immediately (−.42, −.57), at 1 week (−.40, −.58), and week only (−.32, −.67). Therefore the participants interleaved high- and low-typicality actions in the final recall task much the same way as they were clustered within the event itself.

GENERAL DISCUSSION

The present study reveals several important findings concerning the effects of selective retrieval on eyewitness memory for a naturalistic crime event. First, although retrieval-induced forgetting affects people's memory for naturalistic crime events, we found that not all types of actions are equally vulnerable. When the witnessed event conforms to a well-known script, such as bank robbery, witnessed actions that are not especially typical are quite vulnerable to RIF, whereas high-typicality actions are resistant to this form of forgetting: selective retrieval practice of low-typicality actions significantly impaired later recall of other low-typicality actions, whereas high-typicality actions were unimpaired, and sometimes even facilitated by the retrieval of other actions (whether high or low typicality). These findings support the hypothesis that highly schematic actions should be resistant to RIF (Anderson & McCulloch, 1999; Migueles & Garcia-Bajos, 2006), due to their greater integration with script knowledge, and causal interconnections, consistent with past research on integration effects in retrieval-induced forgetting (Anderson & McCulloch, 1999; Conroy & Salmon, 2006; Migueles & Garcia-Bajos, 2007) and in fact retrieval (Myers et al., 1984).

Second, the present study found evidence that the negative effects of selective retrieval may depend on the nature of the material that is selectively retrieved. When participants performed retrieval practice on high-typicality actions, no RIF was observed for competing facts, regardless of whether they were high or low in typicality. In contrast, retrieval practice of low-typicality actions induced significant RIF, at least for other low-typicality actions. This finding is consistent with the view that the magnitude of RIF depends on the degree of competition that participants experience during retrieval practice. Script activation is likely to have allowed for a quick and fluid access to the high-typicality actions during retrieval practice, minimising competition with other contents. If correct, this interpretation fits well with theoretical views of RIF which posit that inhibitory processes are especially likely to be engaged during retrieval of weakly represented contents (Dagenbach et al., 1990; Norman et al. 2007), consistent with the broad principle of interference dependence (Anderson, 2003). However, this finding is not consistent with earlier findings indicating that the magnitude of RIF did not vary with the taxonomic frequency of the practised items (Anderson et al., 1994).

One difficulty with the foregoing analysis is the fact that retrieval practice success rates in the current study were uniformly high, and were comparable for high-typicality actions (92%) and low-typicality actions (95%), seemingly at odds with the idea that high-typicality actions were easier to recall, on the whole. One would have expected low-typicality actions to have lower retrieval practice success rates, given their weaker pre-existing strength of association to the event script. However, because retrieval practice performance is nearly at ceiling for all types of actions, and because we did not record response latencies to retrieve the practised items, we cannot rule out the possibility that low-typicality actions were more difficult to recall, despite their apparently equivalent performance. Concern over this possibility is fuelled by the several other features of the data that strongly confirm the greater ease of recalling high-typicality items, such as significantly higher rate of recalling high-typicality items in the control conditions, and the substantial difference in forgetting rate for high- and low-typicality control items over the

1-week delay. These factors indicate that low- and high-typicality actions differ appreciably in memorability, despite their apparent equivalence on the retrieval practice test. Thus, low-typicality items may have required greater engagement of inhibitory control processes than high-typicality actions.

Although retrieval practice on low-typicality actions impaired retention of other low-typicality actions, it did not impair memory for high-typicality actions. This lack of RIF likely reflects high-typicality items' greater resistance to inhibition, arising from the greater integration with the script. Nevertheless, one might argue that some detrimental effect should have occurred, given that low- and high-typicality actions have fewer pre-existing interconnections with one another than high-typicality actions have with other high-typicality actions. Although the data might seem to contradict this possibility, there is some evidence that inhibition was more likely to influence recall of these items than initially might seem apparent. For instance, high-typicality actions showed a tendency towards retrieval-induced facilitation when other high-typicality actions were practised, consistent with retrieval-induced facilitation effects found with highly integratable material (Chan, McDermott, & Roediger, 2006) or with experimental manipulations of integration (Anderson, Green, & McCulloch, 2000). Interestingly, this retrieval-induced facilitation effect was markedly reduced, and in some cases numerically reversed, when low-typicality actions were practised. One interpretation of this finding is that inhibition acted on high-typicality actions when low-typicality items were practised, but they merely offset the facilitation enjoyed by these high-typicality items owing to their superior integration with the event script. This possibility is illustrated in Figure 1, which plots RIF effects in the four conditions for each delay. A consistent pattern emerges at all delays that suggests the influence of two factors contributing to the magnitude of the RIF effect—an effect of the typicality of the action practised, and an effect of the typicality of the action affected. This pattern accords well with the notion that inhibition increases with the difficulty of retrieval practice on the one hand, but decreases with the degree of integration of the affected items. It would be profitable to evaluate this speculation in future research.

The manipulation of action typicality in the present experiment bears some resemblance to prior manipulations of taxonomic frequency in the literature on RIF (Anderson et al., 1994). Like high-frequency exemplars, highly typical actions in a script are likely to have stronger associations to the script event than would lower typicality actions, making high-typicality actions potentially more interfering. Thus, the fact that schema-typical contents were resistant to RIF might at first seem inconsistent with the findings of Anderson et al. (1994) using semantic categories, who observed that high-frequency exemplars suffer more RIF. The current manipulation of typicality differs in important ways from this earlier work, however. One key difference lies in the integrated nature of high-typicality actions. The typical actions of our event were not merely strongly linked to the event schema, but also with one another by causal links, comprising as they do a canonical sequence of actions that flow forward in time, a situation known to reduce RIF (Conroy & Salmon, 2006; Migueles & Garcia-Bajos, 2007). The existence of these inter-action associations provides additional retrieval routes through which memory for Rp− actions can be accessed. Because those inter-action associations will be more accessible for practised categories (owing to the greater accessibility of Rp+ items) than for baseline categories, they provide differential benefit to Rp− items, as suggested by the mediated retrieval account of integration effects (Anderson & McCulloch, 1999). By contrast, in the manipulation of taxonomic frequency conducted by Anderson et al. (1994) inter-item associations between categories exemplars were systematically eliminated, so that the effects on strong associates of the retrieval practice cue could be isolated, independent of integration. Thus the benefits of integration were controlled in that study, while they were present here.

A second way in which high-typicality actions differ from high-frequency exemplars arises due to their occurrence in a highly scripted action sequence. Because the sequence of high-typicality actions follows a well-known causal chain, it increases the chances that high-typicality actions may be listed by participants through reconstructive inference rather than through episodic retrieval. The availability of inference as a strategy may contribute to a (apparent) reduction in vulnerability of these items to RIF, providing an alternative account as to why high-typicality items don't show memory impairment. Thus, although episodic memory for high-typicality actions may truly be resistant to inhibition because of integration, it remains possible that

reconstruction may mask the effects of RIF for these items. Disentangling these contributions to the present effects would provide a profitable area for future research. Whichever mechanism is correct, however, the present findings suggest that in practice people will show more evident memory deficits for low-typicality actions.

The present study provides the clearest evidence to date for very long-lasting RIF. Previous work showing lasting RIF effects could be explained by differential retrieval-based learning of Rp− and Nrp items on an initial test that persisted in the long-term (Migueles & Garcia-Bajos, 2007; Storm et al., 2006). Consistent with this retrieval-based learning account, participants in the current study who were evaluated both immediately and at 1 week systematically repeated the content of the first recall at the second session, as if the immediate recall had stabilised the retrieved memories. Thus, an initial retrieval event might solidify the detrimental effects of RIF for later recall efforts. Nevertheless, our findings rule out the possibility that such differential learning is the sole basis of persisting RIF's effects. When we contrasted immediate and 1-week recall in a between-participants comparison, RIF for low-typicality actions was well preserved, even after 1 week had intervened with no initial test. We found no signs of recovery from inhibitory effects. Although such effects might reflect the re-creation of inhibitory effects at the time of the final test, by means of output interference, this does not appear to be the case; RIF was observed after 1 week, regardless of whether participants initiated their recall with stronger Rp+ items or instead with Rp- items. These findings are thus the first to indicate that RIF's effects may endure for at least a week, far longer than has been found in other studies (MacLeod & Macrae, 2001). Rapid recovery appears not to be an eventuality in studies of RIF.

On a broader level, the current findings suggest a specific mechanism by which eyewitness memory may become more schematic over time. These findings indicate that the least typical, non-schematic actions that take place during an event ought to be the elements of that experience that are most vulnerable to RIF. Thus, to the extent that an event is recounted frequently, the details of the event that are most likely to drop out and be forgotten are those that are not tightly integrated. Because such details are the ones that make an event distinctive, multiple retrievals ought to render our memories more and more

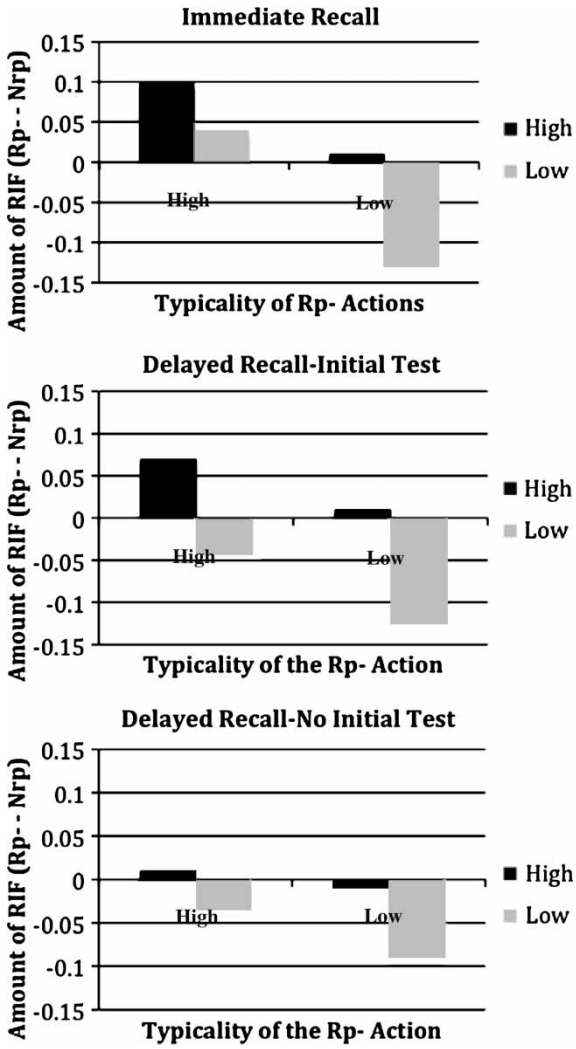

Figure 1. The amount of retrieval induced forgetting (RIF, which = Rp− − Nrp) observed when Rp− competitors were high in typicality (left two bars in each figure) and when they were low in typicality (right two bars in each figure), as a function of whether high-typicality actions were practised (dark bars) or low-typicality actions were practised (grey bars), plotted separately for the Immediate Recall Condition (top panel), the Delayed Recall Condition in which there was an initial test of the items (middle panel), or the Delayed Recall Condition in which there was no initial test of the items (bottom panel). Note the overall greater RIF for low-typicality Rp− items (right two bars) than high-typicality items (left bars), and the overall greater RIF when low-typicality Rp+ actions are practised (grey bars) than when high-typicality actions are practised (dark bars). This suggests two additive factors that contribute to the amount of RIF observed—the typicality of the Rp− action and the typicality of the Rp+ action—and also illustrates a retrieval-induced facilitation effect for high-typicality items (leftmost bar) when high-typicality items are practised.

like the schemas of which they are instances (see Alba & Hasher, 1983; Bartlett, 1932). The interaction of the vulnerability of low-typicality items

with the passage of time, and the additional detriment of disproportionate susceptibility to RIF, leaves these potentially important eyewitness details at huge risk of inaccessibility. Thus, retrieval processes that sculpt our memories may have an enduring impact on what we ultimately retain of our personal past.

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