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True (but not false) memories are subject to retrieval-induced forgetting in children

Heather L. Price [a,*], Thomas L. Phenix [b]

[a] Department of Psychology, University of Regina, Regina, Saskatchewan S4S 0A2, Canada
[b] Campion College at the University of Regina, Regina, Saskatchewan S4S 0A2, Canada

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ABSTRACT

Veridical and false memories of children aged 6 to 15 years were studied in two experiments with the retrieval-induced forgetting paradigm. Using the Deese–Roediger–McDermott (DRM) false memory word lists, children's reports of true, but not false, memories showed evidence of retrieval-induced forgetting. These differences were observed across delays as long as 2 days following word list presentation. The lack of observation of retrieval-induced forgetting in children's false memories provides evidence that a key assumption in the theory of retrieval-induced forgetting, cue independence, might not consistently apply. These experiments underscore the need for both practical and theoretically motivated study of true and false memories.

Introduction

The long-standing debate regarding the nature of false memories in children has substantial practical and theoretical implications (see Brainerd, Reyna, & Ceci, 2008). The sometimes marked differentiations between veridical and false memory representations are increasingly being explored across a variety of retrieval paradigms that both inform us about how such memories are represented and can test the assumptions of associated theories (e.g., Howe, 2005). In the current experiments, we explored children's true and false memories using a particular partial retrieval paradigm—the retrieval-induced forgetting paradigm.

* Corresponding author.
E-mail address: heather.price@uregina.ca (H.L. Price).

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Retrieval-induced forgetting

Cuing with part of the to-be-remembered material can be an effective method of facilitating recall. Indeed, partial retrieval cues are suggested regularly in investigative interviewing techniques with both adults and children as a way to assist with recollection of important event details (e.g., cued recall questions; Lamb, Orbach, Hershkowitz, Esplin, & Horowitz, 2007). However, there is a well-developed area of research that has demonstrated that partial retrieval can increase the difficulty in accessing associated memories not initially targeted for retrieval. This retrieval-induced forgetting (RIF) phenomenon is proposed to be a result of targeted memories inhibiting semantically related memories that compete for retrieval. These suppressed non-retrieved memories are subsequently more difficult to access (Anderson, Bjork, & Bjork, 1994).

Forgetting associated with partial retrieval is especially concerning in a forensic context. Suppose that during a police interview of a witness only a limited number of specific questions are asked. The theory of RIF predicts that this partial retrieval may suppress future recall of other strongly associated details. The negative effects of partial retrieval have been observed beyond basic laboratory tasks (i.e., word lists), in children's autobiographical memory (Phenix & Price, 2012), and in eyewitness memory for salient events (e.g., MacLeod, 2002; Migueles & Garcia-Bajos, 2007; Shaw, Bjork, & Handel, 1995).

Researchers who have studied partial retrieval phenomena such as RIF have often done so with the use of word lists. For instance, during the initial *study phase* of the RIF paradigm, participants study a list of CATEGORY–exemplar pairs (e.g., FRUIT–apple, FRUIT–banana, DRINKS–rum). Later during the *partial retrieval practice phase,* they practice retrieving half of the exemplars using word stems (e.g., retrieve and say aloud "apple" when presented with A P _ _ _) from half of the categories. During the final *test phase,* participants attempt to recall all exemplars from all categories shown during the original study phase. Retrieval-induced forgetting is found when the unpracticed exemplars (e.g., banana) from practiced categories (e.g., FRUIT) are recalled less often than the baseline condition of non-retrieved exemplars (e.g., rum) from unpracticed categories (e.g., DRINKS). This difference in performance between non-retrieved exemplars from practiced and non-practiced categories is the RIF effect and is theorized to result from the practiced exemplars (e.g., apple) inhibiting related non-retrieved exemplars (e.g., banana) relative to a baseline (e.g., rum).

The RIF phenomenon is remarkably robust, although it is subject to several boundary conditions. For instance, when items are conceptually integrated, or strong interconnections between items are formed, RIF is attenuated (Goodmon & Anderson, 2011). Another factor that may attenuate RIF is the duration of delay between the practice and test phases. RIF does not appear consistently across long delays, with some researchers finding it to be a very short-lived phenomenon (Chan, 2009; MacLeod & Macrae, 2001; Saunders & MacLeod, 2002) and others finding RIF after as long as 24 h or a week (Garcia-Bajos, Migueles, & Anderson, 2009; Migueles & Garcia-Bajos, 2007; Storm, Bjork, Bjork, & Nestojko, 2006). It is likely that the nature of the to-be-remembered details affect the durability of any memory phenomena.

The RIF literature focuses mainly on adults' memory. However, the work with children may be particularly interesting because RIF is theorized by many (e.g., Anderson et al., 1994; but see, e.g., Jonker, Seli, & MacLeod, 2013) to be a result of inhibition stemming from competition between items. The development of inhibitory control during childhood has implications for children's performance on many memory tasks because controlling initial temptations to provide a particular response (e.g., one that is socially appropriate or well-practiced) may mean that children will instead be more likely to rely on memory to make accurate decisions. Because of children's developing inhibitory control, researchers have posited that even when RIF is observed, the mechanisms underlying RIF may differ across different developmental spans (e.g., Aslan & Bäuml, 2010).

False memories and the DRM paradigm

To examine whether reports of true and false memories differ in children as a function of partial retrieval practice, we decided to use the well-established Deese–Roediger–McDermott (DRM) paradigm known for generating false memories (Deese, 1959; Roediger & McDermott, 1995). This paradigm involves the presentation of several lists of strongly related words for study and, during a later memory test, often results in false recall of words that are related but not on the studied list (often referred to as *lure words*). The DRM paradigm is useful for studying retrieval-induced forgetting because the word lists have a strong associative structure among items, as evidenced by the high rates of falsely recalled lure words (Stadler, Roediger, & McDermott, 1999). With strong associative relations among items, false items should be activated during cuing and produce intense interference that should consequently be strongly suppressed. The inhibitory account of RIF, therefore, predicts that retrieval of targeted memories from the DRM lists will induce forgetting of the related false lures associated with each list. In fact, any activated items, including both false memory lures and veridical items, that interfere with the targeted memory during the partial practice phase should be suppressed during recall. Thus, it is hypothesized that veridical and false memories will be similarly affected by inhibition, specifically that both false and veridical memories that are related to memories targeted for retrieval will be suppressed.

There is evidence in research with adults that both veridical and false memories are subject to RIF. For instance, Bäuml and Kuhbandner (2003, Experiment 2) found that partial retrieval practice suppressed reports of false memories from DRM lists (see also Kimball & Bjork, 2002; Starns & Hicks, 2004). Bäuml and Kuhbandner (2003) argued that false recall was a result of activation of false memory during study and that the resulting RIF effect was observed because the falsely recalled items were not practiced during the initial partial practice phase and were consequently suppressed by the retrieved items. Interestingly, when the word lists included the lure words (i.e., no false memories for lures were possible; Experiment 1), no RIF was observed for list words in high false memory rate lists. The authors hypothesized that integration of list items was enhanced substantively with the inclusion of the lure words and ultimately concluded that veridical recall, but not false recall, shows integration effects (see also McDermott, 1996; McDermott & Watson, 2001). Thus, although false memories were subject to RIF in adults, there was some indication that false and veridical representations differed.

False memories in children

Theoretical explanations for the development of false memories are varied, but a prominent theory that has been used to explain these processes in children is fuzzy trace theory (Brainerd & Reyna, 1995). Fuzzy trace theory proposes that each experience lays down two parallel memory traces; a verbatim trace represents the precise details of the experience, and a gist trace represents the more general meaning of the event. Fuzzy trace theorists have hypothesized that false memories develop when false details are introduced that are consistent with a gist representation. If verbatim memories are not accessible to allow for rejection of this new inaccurate information, the consistency between the new false information and the gist representation allows for the incorporation of the false memory to the gist-consistent representation. Thus, fuzzy trace theory proposes that veridical and false memories are created differently (see also Howe, 2005, for a hypothesis that veridical and false memories differ at encoding).

Although retrieval-induced forgetting for DRM list words has been demonstrated in adults (e.g., Bäuml & Kuhbandner, 2003; Starns & Hicks, 2004), there is reason to suspect that children's experience and monitoring of false memories may be qualitatively different from that of adults. Theoretical support for this idea can be found in what appears to be a counterintuitive increase in false memory reports in older children relative to younger children. That is, whereas we have largely accepted that younger children are typically more susceptible to suggestion than older children (e.g., Bruck & Ceci, 1999), false memory development in some contexts is consistently more likely in older children than in younger children.

In their thorough review and analysis, Brainerd and colleagues (2008) distinguished between spontaneous and implanted false memories (see also Otgaar & Candel, 2011, for an experimental comparison of these two processes). Implanted false memories are often observed in suggestibility paradigm research and are the source of the oft-cited conclusion that younger children are more suggestible than older children (e.g., Bruck & Ceci, 1999). The focus in the current work was on spontaneous false memories for which false memory is driven by endogenous processes ("meaning-driven reconstruction"). Brainerd and colleagues (2008) argued that such false memory development is enhanced by procedures that increase reliance on gist. For example, in connected meaning paradigms, category-consistent details are presented together and a false memory is likely to develop for related, but not experienced items. Thus, the connected meaning promotes reliance on gist, which increases the likelihood that false memories will develop. Because older children are better able to make meaning connections, false memory development will be more likely as children develop (into young adulthood) as long as the development of the false memory relies on making meaning connections between true and false memories. The body of research supporting this developmental reversal in false memory is robust across a number of different paradigms and age comparisons (Anastasi & Rhodes, 2008; Brainerd, Reyna, & Forrest, 2002; Connolly & Price, 2006; Howe, Cicchetti, Toth, & Cerrito, 2004; Sugrue & Hayne, 2006).

There is also direct empirical evidence for developmental differences in false memories specifically created through the DRM paradigm. For instance, Dewhurst and Robinson (2004) argued for a developmental shift from phonological (rhyming) to semantic false memories with age. Furthermore, Dewhurst, Pursglove, and Lewis (2007) found that although 5-year-olds reported fewer false memories than 8- or 11-year-olds in response to DRM word lists, when the words were embedded within a story context, the 5-year-olds reported *more* false memories than the older children. The authors concluded that the story context facilitated young children's ability to connect the lure word to the gist (i.e., increased meaning connections) but that their underdeveloped ability to access verbatim traces at retrieval relative to older children resulted in higher rates of false recall.

The reliance on development of particular cognitive abilities to create false memories suggests that patterns might not replicate across different ages of children or between children and adults. Thus, although it is clear that veridical and false memories may act similarly at times (e.g., Bäuml & Kuhbandner, 2003), it is also the case that they can differ qualitatively during different periods of development.

Integration and connected meaning

A critical consideration in both the study of children's false memory development and retrieval-induced forgetting literature is the presence of instructions issued prior to the introduction of stimuli. Although both areas of research use different terminology to discuss this phenomenon—fuzzy trace theory refers to this as gist-cuing, whereas the RIF literature refers to this as integration instructions—the concepts are similar. The instruction essentially directs children to think about ways in which the stimuli "go together," thereby enhancing the strength of the gist relative to the verbatim representation. Increasing associative strength via gist-cuing has been repeatedly demonstrated (e.g., Brainerd et al., 2008; Lampinen, Leding, Reed, & Odegard, 2006) by substantive increases in DRM lure reports. Importantly, these instructions also eliminate the well-established developmental reversal effects in lure reports, thereby indicating that the support provided by such instructions induces the youngest children to engage in organizational processes that come naturally to older children (i.e., meaning connections).

This integration or gist-cuing instruction should affect the presence of retrieval-induced forgetting in a predictable way. If RIF is a result of high levels of semantic associativity between items, increasing the associativity should make for a stronger RIF manipulation. That is, with integration instructions, the effect of RIF should be more prominent. However, this intuitive conclusion is countered by data from the RIF literature that support high levels of integration as a boundary condition of RIF. Consistent observations in the RIF paradigm have made it clear that such integration instructions reduce or eliminate the presence of RIF (Anderson & McCulloch, 1999; Goodmon & Anderson, 2011). It has been argued that with strong semantic associations, retrieval of a targeted memory no longer encounters retrieval interference from its related competitors. Although initially counterintuitive, an increase in overlap between list words that can be induced through semantic integration may also increase the likelihood of successful retrieval of all list words (semantic generalization hypothesis; e.g., Anderson, Green, & McCulloch, 2000). That is, retrieval practice that strengthens features of practiced items that overlap with competitors can increase the likelihood that competitors will be recalled. In the current experiments, we also included a manipulation of integration instructions to further explore the level of associativity.

The current experiments

In the current experiments, we combined the RIF and DRM paradigms to study children's true and false memories. During a children's summer science camp, a magician visited and performed four magic tricks. Interspersed within each magic trick was a video of a man reading word lists. These word lists were drawn from the traditional DRM paradigm. Children then practiced retrieval of some of the words and later completed a cued recall task. Our aim was to explore retrieval-induced forgetting for children's true and false memories. That is, we were interested in whether the source of a competing item's activation affected inhibition of that item. We also sought to explore the durability of these effects after periods of time that would be more akin to delays that may be observed in autobiographical memory interviews in an applied setting (e.g., investigative interviews). Thus, the delays to initial retrieval practice are longer than those typically implemented in either DRM or RIF studies. Finally, we included conditions in which children either did or did not receive integration instructions prior to word list presentation.

Pilot

The procedures used in the following experiments were initially tested with 117 children aged 6 to 15 years. In the pilot study, a man read four different word lists, one for each of four separate videos. In each of the videos, the man wore a different hat to allow for cuing of the appropriate list. To cue the word lists, we presented the photograph of the man wearing the hat that corresponded with the list we were attempting to cue. However, this cue did not sufficiently allow children to target the correct list, which ultimately resulted in a recall floor effect (42 children did not recall a single baseline item). This floor effect, relative to other studies of the DRM effect with children, is likely due to our lengthy delay to recall. Thus, in the following experiments, we cued recall of each word list with both the photograph cue and the first word presented from each list. This methodological difference is a distinct departure from prior studies using DRM lists with children.

Experiment 1

Method

Participants

We recruited 105 children aged 6 to 15 years (M = 10.13 years, SD = 1.61, 61 boys and 44 girls) to participate in this experiment. Although race/ethnicity information was not obtained from participants, the population from which participants were drawn was predominantly Caucasian/non-Hispanic. All sessions took place during the children's university summer science camp.

Materials and procedure

The design was a 2 (Instructions: integration or no integration) × 2 (Age: 6–9 years or 10–15 years) × 5 (Item Type: RP+, RP−, Nrp, $RP–^{L}$, or Nrp^{L}) mixed-model design with instructions as a between-participants manipulation. The within-participants variable of item type included the three item types typical of an RIF study (RP+ [practiced items], RP− [items from a practiced list that were not practiced], and Nrp [baseline list words that were not practiced]) and two additional item types that represented reports of the lure words ($RP–^{L}$ [lure from a practiced list] and Nrp^{L} [lure from an unpracticed list]). The superscript L denotes reports of a lure word.

Day 1: Magic show and word list videos. Children attended a 5-day science camp. On the second day of the camp, a "magician" visited the children's camp to perform a magic show. To begin the magic show, the female magician told the children that while she was getting set up, they would watch a brief video about the upcoming activities. The introductory video depicted a male research assistant who introduced himself and informed the children that throughout the magic show, he would intermittently be shown in four additional videos (i.e., between each magic trick) in which he would read four separate lists of words to the children. He also informed the children that their memories for the words would be later tested, so it was important to pay close attention. Half of the children were also instructed that each list of words "went together" and the children should pay attention to how the words on the list were related (integration condition). Specifically, children were told the following: "For each list of words you will hear, the words go together somehow. While you are listening to the word lists and trying to remember them, you should pay attention to how the words on each list go together." For the other half of the children, this instruction was excluded.

Following the introductory video, the live magician performed her first trick. She then introduced the first word list video and reminded children that their memory for the word list would be later tested and so they should pay close attention. This pattern repeated for the remaining three magic tricks and word list videos. Four word list videos were shown, each with the male research assistant reading a list of 14 words at a rate of one word every 1.5 s (see Appendix). Words lists were presented in decreasing associativity and were taken from Stadler and colleagues (1999). In each video, the assistant was wearing a different hat to facilitate cuing of the appropriate list later (a baseball hat, a Viking hat, a jester hat, or an ice hockey helmet). Two random orders of video presentation were made, and approximately half of participants received each order. Each magic show session lasted approximately 15 min.

Day 2: Word stems. One day following the magic show and presentation of the word lists, children were presented with a retrieval practice task in which half of the words on two of the four lists were practiced (i.e., 6 words per list for a total of 12 practiced items). Word stems were presented for each hat-cued category separately in the order that the word list videos were presented on Day 1. To assist children in identifying the appropriate list, a picture of the male research assistant wearing the appropriate hat was presented and the children were reminded of the temporal order of the list (e.g., "When Jordan read the first list, he was wearing a Viking hat"). Two versions of the word stems were created, with one cuing half of the word list and the other cuing the remaining half. Word stems were read out to children, and they were assisted with recalling the word through verbal cuing if needed. A research assistant recorded each child's responses.

Day 3: Cued recall. One day following the word stem task, children were asked to recall all of the words they could from *any* of the lists. Once children could not recall any additional words, they were cued to each of the four lists with the presentation of a photograph of the actor who had read the word list wearing the special hat worn during the to-be-cued list (the same photo as was used in the word stem task) and the first word presented from each list. Children were then asked to report all words they could remember from the list cued by the picture.

Results

Children's responses in cued recall are presented in Table 1. Because there were an unequal number of RP− and Nrp items, all analyses were conducted on the proportions of words reported per item type. For some children, age was not available ($n = 7$ due to parental misreport); thus, we conducted

Table 1
Mean proportions (and standard deviations) for item types in Experiment 1.

	No integration	Integration
RP+	.33 (.17)	.28 (.18)
RP−	.07 (.09)	.11 (.10)
Nrp	.10 (.08)	.10 (.09)
$RP-^{L}$	.56 (.37)	.59 (.41)
Nrp^{L}	.52 (.38)	.50 (.45)
Baseline	.00 (.00)	.03 (.11)
Non-list words[a] (*M*)	1.39 (1.38)	3.86 (4.26)

Note: The superscript "L" denotes a lure word.
[a] There was no maximum number of non-list words provided.

an initial analysis including age, and if age did not interact with any of the variables, we collapsed across age for the subsequent analyses.

RIF in word list recall

There were no effects of age in the analysis (*ps* > .22) of children's veridical recall; thus, we report analyses without age as a variable. Cued recall responses were entered into a 2 (Instructions: integration or no integration) × 2 (Item Type: RP– or Nrp) mixed-model analysis of variance (ANOVA). There was no main effect of item type, $F(1, 103) = 1.27$, $p = .26$, $\eta^2 = .01$, and no main effect of instructions, $F(1, 103) = 2.28$, $p = .13$, $\eta^2 = .02$, and the interaction between item type and instructions was not significant, $F(1, 103) = 3.00$, $p = .09$, $\eta^2 = .03$. However, because of our a priori hypothesis about this interaction, we explored the RIF effect within each instructions condition and applied a Bonferroni correction to our alpha level (set at .025 for these tests; Howell, 2012). In the integration condition, there was no RIF effect, $t(50) = 0.44$, $p = .66$, Cohen's $d = 0.06$. However, in the no-integration condition, there was a marginal RIF effect, $t(53) = 1.98$, $p = .054$, Cohen's $d = 0.27$.

RIF in lures

Lures in the DRM lists were words that were never presented to participants but in DRM paradigms are often falsely retrieved during subsequent recall tests due to their high associativity with other items on the list. Theoretically, lures that are associated with a practiced list during the partial retrieval practice stage should be candidates for suppression ($RP–^L$). Lures that serve as a baseline (Nrp^L) are theoretically not candidates for suppression given that these items in the list were never subject to partial practice. In this analysis, we compared recall of $RP–^L$ lures with that of Nrp^L lures. There was an overall main effect of age in lure reports, $F(1, 96) = 5.38$, $p = .02$, $\eta^2 = .02$, with older children reporting significantly more lures than younger children (see Table 2). However, age did not interact with any of the other variables, so we collapsed across age for the subsequent analysis (to allow for inclusion of all participants) and found no RIF effect, $F(1, 103) = 1.75$, $p = .19$, $\eta^2 = .02$, no main effect of instructions, $F(1, 103) = 0.01$, $p = .91$, $\eta^2 = .00$, and no interaction between the two variables, $F(1, 103) = 0.29$, $p = .59$, $\eta^2 = .003$.

Lure strength

A proportionally higher rate of lures ($M = .54$, $SD = .32$) was recalled compared with Nrp items ($M = .10$, $SD = .08$), $t(105) = 15.83$, $p < .01$, Cohen's $d = 1.54$, RP– items ($M = .09$, $SD = .10$), $t(104) = 15.41$, $p < .01$, Cohen's $d = 1.50$, or RP+ items ($M = .31$, $SD = .18$), $t(104) = 8.53$, $p < .01$, Cohen's $d = 0.83$. Furthermore, there was a significantly higher rate of reported RP– lures ($M = .57$, $SD = .39$) than of reported RP– items ($M = .09$, $SD = .10$), $t(104) = 13.55$, $p < .01$, Cohen's $d = 1.32$.

Experiment 1 discussion

In Experiment 1, there was some evidence of classic retrieval-induced forgetting effects; children showed a marginal RIF effect for veridical memories when given no-integration instructions, but no RIF was observed when children received integration instructions. Interestingly, we found no RIF effect in children's false memories (i.e., memory for lures). Lures were remembered extremely well by children; they were reported at a higher rate than any other item type in Experiment 1.

Table 2
Means (and standard deviations) of lure reports across ages.

	Ages (years)	*n*	$RP–^L$	Nrp^L	Total lures
Experiment 1	6–9	47	1.02 (0.79)	0.89 (0.84)	1.91 (1.25)
	10–15	53	1.32 (0.73)	1.17 (0.80)	2.49 (1.22)
Experiment 2	6–9	46	0.80 (0.72)	0.72 (0.75)	1.52 (1.22)
	10–15	54	1.15 (0.86)	1.33 (0.70)	2.48 (1.21)

Because of the evidence for RIF in adults' false memories (Bäuml & Kuhbandner, 2003; Kimball & Bjork, 2002; Starns & Hicks, 2004), we wanted to continue exploring this null RIF effect for false memories with children using a different experimental context. There has been some indication that RIF in children's autobiographical memory is dependent on delay to memory test. For instance, Phenix and Price (2012) observed that the delay between retrieval practice and recall influenced the likelihood of observing RIF; children in the shorter delay condition (15 min) showed a reliable RIF effect, whereas children in the longer delay condition (2 h) showed no RIF (for children experiencing a single presentation of the to-be-remembered event). Thus, in Experiment 2 we introduced a delay manipulation. We anticipated that we may be more likely to observe RIF at a shorter delay between the two memory tests, so all children in Experiment 2 received back-to-back partial retrieval practice and recall tasks. In addition, we introduced a manipulation in which the initial recall test took place either 1 or 2 days following presentation of the word lists.

Experiment 2

Method

Participants

We recruited 110 children aged 6 to 15 years (M = 10.29 years, SD = 1.95, 68 boys and 42 girls) for the second experiment. All sessions took place during the children's university summer science camp (the same camp from which participants were drawn in Experiment 1).

Procedure

The procedure for Experiment 2 was the same as for Experiment 1 with the exception that two changes were made to the timing of the three experimental components. All children experienced the magic show on Day 1. However, instead of separating the word stem and cued recall conditions by a day (as in Experiment 1), all children in Experiment 2 experienced the two retrieval tasks during the same session. Children completed the word stems, answered questions about the magic component of the show for approximately 1 min, and then completed the cued recall task. Children were randomly divided into two delay conditions. In the 1-day delay condition, both recall tasks took place the day immediately following the magic show. In the 2-day delay condition, participants completed both recall tasks 2 days following the magic show.

Thus, this was a 2 (Instructions: integration or no integration) × 2 (Delay: 1 day or 2 days) × 2 (Age: 6–9 years or 10–15 years) × 5 (Item Type: RP+, RP−, Nrp, RP–^{L}, or Nrp^{L}) mixed-model design.

Results

Children's responses to cued recall are presented in Table 3. As with Experiment 1, all analyses are conducted on the proportions of words reported per item type. For some children, age was not available (n = 10 due to parental misreport); thus, we conducted an initial analysis including age, and if age did not interact with any of the variables, we collapsed across age for the subsequent analyses.

RIF in word list recall

Initial analyses indicated that there was a main effect of age, $F(1, 92) = 7.31$, $p = .01$, $\eta^2 = .07$, with older children reporting more list words than younger children. Because there was no interaction with age, cued recall responses were entered into a 2 (Instructions: integration or no integration) × 2 (Delay: 1 day or 2 days) × 2 (Item Type: RP− or Nrp) mixed-model ANOVA. There was no main effect of instructions, $F(1, 106) = 0.02$, $p = .88$, $\eta^2 < .001$, but there was an overall RIF effect, $F(1, 106) = 19.01$, $p < .001$, $\eta^2 = .15$, that was qualified by two interactions: one between item type and instructions, $F(1, 106) = 5.79$, $p = .02$, $\eta^2 = .05$, and the other between item type and delay, $F(1, 106) = 4.11$, $p = .045$, $\eta^2 = .04$. No evidence of a three-way interaction among instructions, item type, and delay was observed, $F(1, 106) = 0.41$, $p = .53$, $\eta^2 = .004$.

Table 3
Mean proportions (and standard deviations) for item types in Experiment 2.

	No integration		Integration	
	1-Day delay	2-Days delay	1-Day delay	2-Days delay
RP+	.47 (.25)	.45 (.21)	.48 (.18)	.36 (.20)
RP–	.07 (.09)	.06 (.07)	.08 (.08)	.09 (.09)
Nrp	.14 (.08)	.10 (.07)	.12 (.07)	.08 (.08)
$RP\text{–}^{L}$	.54 (.47)	.60 (.40)	.50 (.33)	.35 (.38)
Nrp^{L}	.63 (.39)	.58 (.39)	.52 (.38)	.35 (.38)
Baseline	.03 (.11)	.04 (.09)	.00 (.00)	.01 (.09)
Non-list words[a] (*M*)	3.15 (3.36)	3.23 (4.57)	3.04 (3.74)	2.53 (4.59)

Note: The superscript “L” denotes a lure word.
[a] There was no maximum number of non-list words provided.

To explore the item type by instructions interaction, we looked at the RIF effect in each instructions condition. As anticipated, when children did not receive integration instructions, there was a strong RIF effect, $t(51) = 4.96$, $p < .001$, Cohen’s $d = 0.69$. When children received integration instructions, the effect disappeared, $t(57) = 1.03$, $p = .31$, Cohen’s $d = 0.13$. In the item type by delay interaction, we explored the RIF effect in each delay condition. There was a clear RIF effect in the 1-day delay condition, $t(49) = 4.31$, $p < .001$, Cohen’s $d = 0.61$, but no RIF effect was observed in the 2-day condition, $t(59) = 1.41$, $p = .17$, Cohen’s $d = 0.18$.

Although there was no three-way interaction, we examined further the relations among delay, item type, and instructions in order to better understand our failure to observe an RIF effect in the 2-day delay condition. We again applied a Bonferroni correction to these tests and set alpha at .025. As illustrated in Fig. 1, in the 1-day delay, RIF was observed in the no-integration condition, $t(25) = 3.79$, $p = .001$, Cohen’s $d = 0.74$, and was marginal in the integration condition, $t(23) = 2.24$, $p = .04$, Cohen’s $d = 0.46$. In the 2-day delay, RIF was observed only in the no-integration condition, $t(25) = 3.21$, $p = .004$, Cohen’s $d = 0.63$, and was not observed in the integration condition, $t(33) = 0.36$, $p = .72$, Cohen’s $d = 0.06$. Thus, our failure to observe a delay by item type interaction in the 2-day delay condition appears to have been a result of the RIF effect being attenuated by instructions; the results imply that the effects of integration are influenced by the delay between practice and test conditions.

RIF in lures

Parallel to the word list analyses above, a 2 (Instructions: integration or no integration) × 2 (Delay: 1 day or 2 days) × 2 (Age: 6–9 years or 10–15 years) × 2 (Item Type: $RP\text{–}^{L}$ or Nrp^{L}) mixed-model ANOVA was performed. There was a main effect of age in lure reports, $F(1, 92) = 9.61$, $p < .01$,

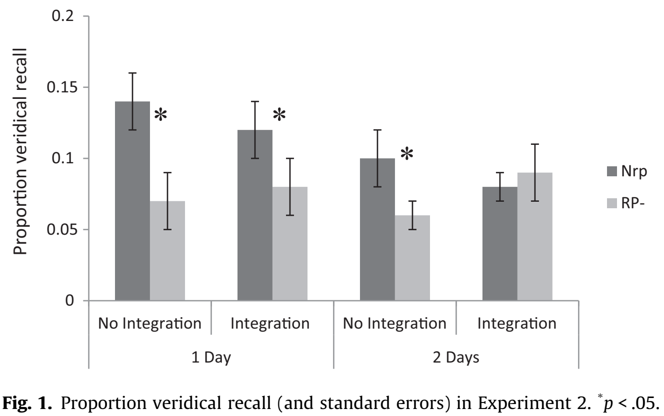

Fig. 1. Proportion veridical recall (and standard errors) in Experiment 2. $^{*}p < .05$.

$\eta^2 = .10$, with older children reporting significantly more lures than younger children (see Table 2). However, age did not interact with any of the other variables, so we collapsed across age for the subsequent analysis to allow for inclusion of all participants. Consistent with Experiment 1, there was no evidence of RIF observed between RP–^{L} and Nrp^L, $F(1, 106) = 0.30$, $p = .58$, $\eta^2 < .01$. In addition, there were no interactions observed between item type and instructions or between item type and delay, $F(1, 106) = 0.10$, $p = .75$, $\eta^2 = .001$, and $F(1, 106) = 0.59$, $p = 44$, $\eta^2 = .01$, respectively, nor was there a three-way interaction, $F(1, 106) = 0.29$, $p = .60$, $\eta^2 = .003$ (see Fig. 2).

There was, however, a main effect of integration in lure reports, $F(1, 106) = 6.51$, $p = .01$, $\eta^2 = .06$, due to the larger number of lures reported in the no-integration condition compared with the integration condition. Thus, false recall was reduced when children were given integration instructions prior to recall.

Lure strength

A proportionally higher rate of lures ($M = .50$, $SD = .33$) was recalled compared with Nrp items ($M = .11$, $SD = .08$), $t(109) = 14.09$, $p < .01$, Cohen's $d = 1.34$, RP– items ($M = .08$, $SD = .08$), $t(109) = 14.29$, $p < .01$, Cohen's $d = 1.36$, and RP+ items ($M = .43$, $SD = .21$), $t(109) = 2.16$, $p = .03$, Cohen's $d = 0.21$. Furthermore, there was a significantly higher rate of reported RP– lures ($M = .49$, $SD = .40$) than of RP– items ($M = .08$, $SD = .08$), $t(104) = 11.23$, $p < .01$, Cohen's $d = 1.07$.

Experiment 2 discussion

In Experiment 2, the delay between partial retrieval practice and memory test was minimal. Thus, based on prior observations (e.g., Phenix & Price, 2012), we anticipated that this shortened delay would increase the likelihood of observing retrieval-induced forgetting. We observed a reliable RIF effect in children's veridical memories in Experiment 2, but despite the condensed time frame, we also continued to observe no evidence of RIF in children's reports of false (i.e., lure) memories in Experiment 2. Again, children's recall of the lure words was exceptionally strong, with higher rates of lures than of any other item type being reported. This finding, which was prominent in both experiments, makes it clear that children's false memories were not subject to RIF under the current experimental conditions. We speculate on reasons for the lack of RIF in false memories in the General Discussion.

A particularly interesting finding in Experiment 2 relates to delay and integration instructions. Even with integration instructions, at the 1-day delay there was a marginal effect of RIF for veridical memories. However, at the 2-day delay integration instructions had the expected effect and RIF was eliminated. Thus, the effect of issuing integration instructions during encoding appeared to influence RIF more after a longer delay. Many RIF studies have found that suppression of unpracticed items dissipates after delays of 12 or 24 h (Abel & Bäuml, 2012, 2014; MacLeod & Macrae, 2001). However, it is not yet clear why delays sometimes do and sometimes do not allow recovery from inhibition

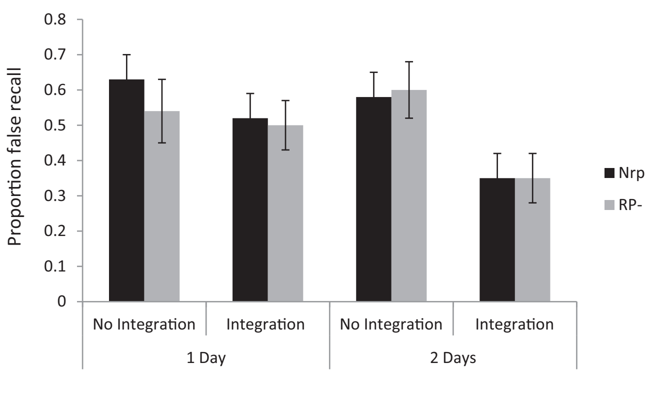

Fig. 2. Proportion false recall (and standard errors) in Experiment 2.

(e.g., Garcia-Bajos et al., 2009; Storm, Bjork, & Bjork, 2012; but see Abel & Bäuml, 2014, for one suggestion). Given that fuzzy trace theory posits that reliance on gist traces increases over time (e.g., Brainerd & Reyna, 1995), children in our 2-day delay condition may have more effectively integrated the list words than children in the shorter delay condition. Perhaps the shortened delay between partial retrieval practice and recall, in addition to the relatively short delay from the study phase (hearing the words) to partial retrieval practice, reduced the effectiveness of the integration instructions. There is other evidence that the effects of integration are delay dependent (e.g., Phenix & Price, 2012), and this effect may be more pronounced in children. This possibility requires further empirical investigation.

There was another intriguing observation in Experiment 2: Integration instructions reduced false memory reports. Although we did not specifically predict an effect of integration instructions on false memory reports, had we developed hypotheses, we would have almost certainly been wrong. Normally, one would anticipate that integration instructions would result in a higher rate of lure reports due to an increased likelihood of acceptance of plausible list words when relying on gist, rather than verbatim, memory. However, we found that integration instructions actually reduced reports of lure words. This finding indicates that lure words were not integrated into list memory in the same way as other list words were and, thus, were treated differently than list words. As a result, false memory does not appear to be vulnerable to inhibition in the same way as verbatim memory for list words.

General discussion

The current experiments provide a novel study of the effects of partial retrieval practice on children's true and false memories. We replicated classic retrieval-induced forgetting effects for studied DRM list words within this new experimental context but failed to observe retrieval-induced forgetting in either experiment for children's memory for lure words. We discuss each of these findings in turn along with considerations of these experimental designs and their relative contribution to the current results.

RIF for DRM list words in children

To date, the inhibitory effects of partial retrieval practice on memory for DRM list words have been reported in adults but not in children. In the current experiments, we were able to observe RIF effects with children's recall of DRM list words. This finding provides further evidence of children's ability to make strong semantic connections between list words and the resulting negative effects of partial retrieval practice on later recall.

Our particular experimental conditions also add to existing data on the durability of the RIF effect. The current experiments extended recall as long as 2 days after the study phase, and RIF was observed in all delay conditions. This is an important observation because it is not yet clear how long RIF effects will last in children and, if this work is to be applied to contexts outside of the laboratory, the durability of the phenomenon is of central interest. However, as we discussed above, the effect of integration instructions appears to be delay dependent and was clearly observed only at the 2-day delay and not the 1-day delay. This pattern of data is worthy of explicit empirical exploration. Interestingly, the strength of the connections between words that provided sufficient semantic associativity for items to compete, and thus result in inhibition (i.e., RIF), did not affect recall of what we anticipated would be the strongest competitors—the lures.

No RIF for DRM lure words in children

In neither experiment did children inhibit unpracticed lure words. This finding was unanticipated because the very reason why lure words are reported so frequently is because of their strong semantic connection with the list words. Thus, it makes sense that this strong association, which is also hypothesized to be a requirement for competition and thus inhibition in RIF, should also act on false memories. Why might lure words have not competed with list words? One possibility is that the lure words were encoded differently than true memories. There are, of course, inherent differences between veridical and false memories in the DRM paradigm. Lures are internally generated, whereas studied list words are externally presented. Although this difference did not appear to matter for adults (RIF for lure words has been observed in adults; Bäuml & Kuhbandner, 2003), in children this may be a critical difference. Young children's relatively more limited ability to "get the gist" of a word list (Brainerd et al., 2008), relative to adults, could further segregate lure words as different from other list words.

Large bodies of literature on opponent process theories posit dissociations between true and false memories (e.g., Brainerd & Reyna, 1995). According to fuzzy trace theory, the formation of false memories is supported by reliance on meaning connections and the plausibility of false information, whereas the rejection of false memories results from verbatim-based recollection rejection. Therefore, to develop a false memory in the DRM paradigm, lure words must be connected to the list words with common meanings. This process of developing a connection between the list words and lure words should have provided fertile ground for competition and thus RIF. However, there is also evidence that connections that are extremely strong can interfere with the likelihood of RIF (Goodmon & Anderson, 2011). This strong connection is known as integration, which as a boundary condition of RIF may have contributed to the current findings.

Although somewhat unexpected, the null result for RIF for lure words is consistent with a pattern of data reported by Bäuml and Kuhbandner (2003, Experiment 1). The authors found that the lists with the highest levels of false recall (see Roediger, Watson, McDermott, & Gallo, 2001) evinced a lack of RIF for DRM word lists from high false recall rates relative to lists that had lower rates of false recall. The authors hypothesized that the highly associated word lists essentially induced an effect of integration, thereby making the list words difficult to forget. In our experiments, we selected word lists with very high rates of false recall to ensure that our young participants would create false memories. This selection of high false recall rate lists may have contributed to the null finding for RIF in false memories. This post hoc explanation of the data is somewhat circular and raises critical questions. At what point does integration naturally occur? What level of similarity between words is sufficient to introduce the competition needed for RIF but not so similar that it breaches the threshold for integration? These issues have not been directly addressed in the literature so far and require further articulation.

With the current data, we explored this possibility in a somewhat coarse manner by dividing each DRM list into higher and lower association items. When we did this, we found strong evidence of RIF in both the higher and lower association items in both experiments, thereby indicating that the associative strength of list words did not affect the likelihood of competition and thus inhibition. Of course, the ordering of the list by associative strength refers to the strength of the association between the lure and each word, and not for each word to another, but this proxy for associative strength provides some evidence that even the most strongly associated DRM words did not reach a point at which association was so strong that integration became a factor. Thus, the above integration account of lure words fails to explain why this integration effect did not affect highly related veridical items.

An additional explanation for the lack of RIF for lure words relates to retrieval cues. An important concept developed by Anderson and colleagues is that RIF is independent of cue (e.g., Anderson, 2003; Anderson & Bell, 2001; Anderson & Spellman, 1995). If a concept such as banana is suppressed in the context of FRUIT, it will continue to be suppressed using the novel retrieval cue MONKEY. However, other researchers have challenged the notion of cue independence and instead demonstrated that RIF may be cue dependent (Camp, Pecher, & Schmidt, 2007; Perfect et al., 2004; Williams & Zacks, 2001). In the current work, we observed RIF for veridical items that were presented with consistent retrieval cues but failed to find any evidence of RIF for lures that were never presented with retrieval cues. Consequently, our results support the argument that RIF in children is cue dependent.

Limitations

Our application of the DRM paradigm to RIF included changes to the standard procedure due largely to our decision to explore these effects at lengthy delays to recall. The motivation for this research was both theoretical and practical, and we opted for what we considered to be a delay of more practical relevance (i.e., a longer delay). This decision resulted in at least two important methodological changes. First, we cued with the first word on each list because our pilot work indicated that children were unable to identify the appropriate list to recall. Second, due to anticipated difficulty with a large recall task at a long delay, we included relatively few word lists compared with most other related research. These decisions likely contributed to the high rate of lure reports in the current experiments and may have contributed to the impact of integration on recall. Each of these methodological decisions warrants follow-up studies. To allow for comparison with the adult literature, exploration of both our particular methodology with adults and the more normative adult methodology with children is warranted.

Conclusion

In applying a partial retrieval paradigm to the study of children's true and false memories, we found retrieval-induced forgetting effects for true memories but not false memories. These effects were present after varying delays, including lengthy delays that are much longer than those in much of the extant work. The current experiments indicated that research with RIF in adults might not be consistently replicable in child populations. Furthermore, the lack of observation of RIF in children's false memories provides evidence that a key assumption of RIF, cue independence, might not apply in some circumstances. These findings indicate a need for further exploration of the RIF paradigm with a focus on developmental and practical considerations.

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Appendix.

DRM word lists.

Chair	Doctor
Table	Nurse
Sit	Sick
Legs	Lawyer
Seat	Medicine
Couch	Health
Desk	Hospital
Recliner	Dentist
Sofa	Physician
Wood	Ill
Cushion	Patient
Swivel	Office
Stool	Stethoscope
Sitting	Surgeon
Rocking	Clinic

(*continued on next page*)

Sleep	Sweet
Bed	Sour
Rest	Candy
Awake	Sugar
Tired	Bitter
Dream	Good
Wake	Taste
Snooze	Tooth
Blanket	Nice
Doze	Honey
Slumber	Soda
Snore	Chocolate
Nap	Heart
Peace	Cake
Yawn	Tart

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