RUNNING HEAD: Priming Analogical Problem Solutions

Priming Children's and Adults' Analogical Problem Solutions with True and False Memories

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Abstract

We investigated priming of analogical problem solutions with true and false memories. Children and adults were asked to solve nine verbal proportional analogies, three of which had been primed by Deese-Roediger-McDermott (DRM) lists where the critical lure (and problem solution) was presented as the initial word in the list (true memory priming), three of which were primed by DRM lists whose critical lures were the solution to the verbal proportional analogies (false memory priming), and three that were unprimed. We controlled for age differences in solution rates (knowledge base) in order to examine developmental differences in speed-of-processing. As anticipated, the results showed that adults completed the problems significantly faster than children. Furthermore, both children and adults solved problems primed with false memories significantly faster than either those primed with true memories or unprimed problems. For both age groups there was no significant difference between solution times for unprimed and true primed problems. These findings demonstrate that (a) priming of problem solutions extends to verbal proportional analogies, (b) false memories are more effective at priming problem solutions than true memories, and (c) there are clear positive consequences to the production of false memories.

Keywords: Priming, Analogical Reasoning, False memory, Memory development, DRM paradigm.

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True and False Memories

That the human memory system is a fallible system is without question (e.g., see Howe, 2011a; Schacter, Guerin, & St. Jacques, 2011). Although a number of paradigms have established that memory is a powerful yet reconstructive system that is prone to error, it is perhaps the Deese/Roediger-McDermott (DRM) paradigm that has provided us with the quintessential evidence for this in terms of spontaneous false memory illusions (Deese, 1959; Roediger & McDermott, 1995). In this paradigm, participants are presented with associated words (e.g., *snooze, doze, wake, rest*) that are all semantic associates of an unpresented critical lure (e.g., *sleep*). When subsequently asked to remember the words on the list, both children, and to a greater extent adults, frequently remember many of the presented words along with the unpresented critical lure. Thus, like true memories, false memory production also increases with age (see Brainerd & Reyna, 2012; Howe, 2011b).

Typically, false memories are viewed as a negative consequence of our reconstructive memory system, a type of memory that might lead to miscarriages of justice (Loftus, 2003). However, recent research has demonstrated that the production of false memories need not always have negative implications (see Howe, 2011a; Newman & Lindsay, 2009; Schacter et al., 2011). For example, research has demonstrated that false memories (i.e., DRM critical lures) are capable of priming performance on implicit memory tasks such as word-stem completions (McDermott, 1997; McKone & Murphy, 2000) or anagrams (Lövdén and Johansson, 2003).

Extending these findings, Howe, Garner, Dewhurst, and Ball (2010a) demonstrated that false memories also prime solutions to more complex tasks, namely, insight-based problem-solving tasks. Using the compound remote associate task (CRAT) initially developed by Mednick (1962), participants were required to generate a single word that linked three presented words (e.g., *board/mail/magic* where the linking solution word is *black*). Howe et al. (2010a) demonstrated that adult participants solved more CRATs more quickly when primed with a false memory than when no prime was presented. This finding has been replicated and extended to include priming in children (Howe, Garner, Charlesworth & Knott, 2011).

Like the generation of spontaneous false memories in the DRM paradigm, solving CRAT problems is believed to involve a process of spreading activation, a link shared with the associative-activation account of false memories (Howe, Wimmer, Gagnon, & Plumpton, 2009; Howe et al., 2010a, 2011). If both CRAT problems and false memories utilize the same spreading activation mechanism, it seems as if CRAT problems provide an ideal platform from which to demonstrate priming effects with false memories (Howe et al., 2010a). However, despite these novel findings, one could argue that the priming of CRAT problems within this paradigm is not necessarily the priming of complex problem solving per se, but rather, simply the priming of more distant word associations.

The aim of the present research was to establish whether priming with false memories could also be applied to more complex reasoning tasks, ones that go beyond "simple" word associations. To this end, we selected verbal proportional analogies of the type "*a is to b, as c is to d*" (e.g., *"grass is to green as banana is to yellow"*). In analogical reasoning tasks, participants are usually presented with "*a is to b, as c is to ?"* and are expected to generate the *d* term. These types of analogies are frequently used in intelligence tests (Sternberg, 1977) and academic examinations such as the statutory assessment test. Several permutations of this basic proportional analogy exist, including pictorial analogies (Goswami & Brown, 1990), as well as multiple-choice versions that rely on participants' discriminating the correct *d* term rather than generating it themselves. According to Green, Fugelsang, and Dunbar (2006), analogical reasoning problems are solved by mapping the relationship between terms *a* and *b* onto the *c* term in order to generate the answer, *d*.

The exact processes that underlie children and adults analogical problem solving are believed to change with development (e.g., Ball, Hoyle, & Towse, 2010; Goswami, 1991, 1992, 2001; Sternberg & Nigro, 1980). Whereas it is believed that children solve proportional analogies by a process of semantic association (much like the spreading activation processes thought to underlie CRAT solutions; see Sternberg & Nigro, 1980), adults are believed to employ processes of analogical reasoning where the link between *a* and *b* placed onto the *c* term to generate *d*. Although it is well known that it is possible to prime abstract analogical relations (see Green et al., 2006), to the best of our knowledge, the present experiment provides the first demonstration of priming analogical solutions using both true and false memories in children as well as in adults.

Because there are well-established differences in how children and adults solve analogical problems (see earlier discussion), we were not interested in these developmental changes in the rates at which problems can be solved. That is, most theories of memory development, including associative-activation theory (e.g., Howe et al., 2009) and theories concerning the role of knowledge representations in memory processing (e.g., Ceci, Fitneva, & Williams, 2010), acknowledge the existence of important differences in the structure and content of children's and adults' knowledge base that can affect performance on memory tasks (also see Howe, 2011b). However, our interest is in whether children's and adults' speed-of-processing during problem solving can be affected by primes independent of age differences in problem difficulty. That is, given that knowledge base differences are eliminated in a problem-solving task, do adults still process information more rapidly than children. Moreover, we were interested in whether priming affects both children's and adults' problem solution rates and if so, whether these effects are developmentally invariant both qualitatively in terms of prime type (i.e., true memory primes versus false memory primes) and quantitatively (i.e., speed performance by the same magnitude).

Thus, the purpose of this experiment is to examine whether true and false memory priming enhances the speed of analogical reasoning in both children and adults when solution rate (problem difficulty) is equated across age. To this end, we used analogical reasoning problems that both adults and children were able to complete relatively easily (hence no solution rate differences were expected) and examined whether priming speeds solution times. In addition, because false memories have been shown to serve as better primes than true memories (see Howe, Wilkinson, & Monaghan, 2012), we speculated that spontaneous, self-generated, false memories would be better primes for analogical problem solving than experimenter-provided true memories for both children and adults.

Method

Participants

A total of 41 individuals (20 male and 21 female) participated in the experiment: twenty-five 9-year-olds (*M* = 9 years, 4 months, *SD* = 9 months) and 16 adults (*M* = 22 years, 3 months, *SD* = 2 months). Parental consent was obtained for each child participant, as well as the child's own assent on the day of testing. Adult participants provided written informed consent prior to taking part in the study. All participants were fluent in English. Adult participants were debriefed after participating in the experiment.

Design

A 2 (Age: 7- or 18-year-olds) x 3 (Priming: true memory prime, or false memory prime, or unprimed) mixed design was employed. Age was a between-participants and priming of solution a within-participant factor. Primed problems were analyzed for those participants that either correctly recalled the presented critical lure (true memory priming), falsely recalled the critical lure (false memory priming), or where the solution was unprimed.

Materials and Procedure

There were 9 DRM lists selected for use in this experiment. DRM lists were either selected from standard sources of DRM list materials (e.g., Roediger, Watson, McDermot, & Gallo, 2001) or were constructed based on normed associates by Nelson, McEvoy, and Schrieber (2004). Each DRM list consisted of 12 words (e.g., *shoe, hand, toe, walk*) each of which is associated with an unpresented target or "critical lure" item (e.g., *foot*) (see Appendix). The lists for false memory primes contained 12 associates of the unpresented critical lure, whereas the lists for true memory primes contained 11 of these associates with the lowest associate being replaced with the critical lure for that list in the first presentation position. The first serial position was chosen for the critical lure to ensure that this term was "other" generated rather than "self" generated. That is, the processing of prior related items before presentation of the critical lure could cause activation of the critical lure before it was actually presented, something that would lead to it being self rather than other generated. By using the first serial position in the DRM list, we ensured that in our true memory priming condition, the critical lure was other generated, whereas in the false memory priming condition, the critical lure was self generated by the participant. The final item of the list was removed in the true memory condition in order to ensure that the overall backward associative strength (BAS; a key factor determining the probability of producing false memories) of the list did not vary greatly between the true and false memory priming conditions. Associate words that overlapped with the items presented in the analogical problems were removed and replaced with another associate. In this way, DRM list items were not also part of any subsequent analogy items (see Appendix).

Participants were tested individually and were first presented with six of the nine DRM lists in randomized order. Three of the lists contained the true memory prime for three of the subsequently presented analogies (i.e., the first presented item in the list was the critical-lure/analogy-solution) and three that did not contain the critical lure for three of the subsequently presented analogies (i.e., the critical-lure/analogy solution would be the associated but unpresented critical for each of the three lists). Each list was presented verbally by the experimenter and was followed by a brief distractor task (counting backwards by three's). Participants were then asked to recall as many words as they could remember from each of the lists. Following recall, the next list was presented and this sequence of study-distractor-test continued until all six lists were completed. Once participants had listened to all six DRM lists, they then proceeded to complete a practice analogical reasoning problem, before completing nine test analogical reasoning problems.

Presentation of the DRM lists according to their link to the solution type in the unprimed, true memory prime, and false memory prime conditions was fully counterbalanced, such that each DRM list and associated analogical problem appeared equally often across participants within each age in each solution-type condition. Participants were presented, in randomized order, the nine analogical reasoning problems in the format of "*a is to b as c is to d"*. For example, the analogy for the critical lure *"foot"* was *"hat is to head as sock is to foot"*. Participants provided their answers verbally to the experimenter. The time taken for them to complete the analogical problem, from presentation of the analogical problem to production of the response, was recorded by the experimenter with the use of a stopwatch. The experimenter was blind to which analogies corresponded to which priming condition participants were in, with the experimenter not knowing which analogies were primed with a true memory or which analogies were primed with a false memory. Similarly, the experimenter was blind to whether participants recalled the critical lure or not, until after completion of the study. Participants were given a maximum of 60 seconds to provide an answer. As expected, each participant provided an answer well within this 60-second limit.

Results

We begin, by analyzing recall rates for the critical lure both when it was presented as part of the list (true memory condition) and when it was not part of the list (false memory condition) for adults and children using a mixed analysis of variance (ANOVA). When this recall type (true vs. false) x age (children vs. adults) ANOVA was conducted, there was no effect for age, $F(1, 39) = 1.90$, $p = .18$, and no Age x Recall Type interaction, $F(1, 39) = 3.60$, $p = .065$. However, there was a main effect for recall type $F(1, 39) = 89.18$, $p < .001$, $\eta^2_p = .70$. As expected, recall of the critical lure when it was presented at study (86%; raw mean = 2.60, SD = .59) was greater than recall of the critical lure when it was not presented at study (46%; raw mean = 1.37, SD = .80).

We turn now to an examination of the analogy data. Here, the mean analogy solution rate (proportion) and the mean analogy solution time (seconds) were calculated for each participant and analyzed separately in two ANOVAs. For the primed analogy problems, solution rates and times were divided into the type of solution prime (i.e. unprimed vs. true memory prime vs. false memory prime). Therefore, both the solution rates and solution times were subject to 2 (Age) x 3 (Priming) mixed ANOVAs.

As anticipated, there were no significant effects associated with solution rates. That is, there was no main effect of age, $F(1, 34) = .23$, $p > .05$, or priming, $F(2, 68) = 1.47$, $p > .05$. The Age x Priming interaction also was not significant $F(2, 68) = .51$, $p > .05$. Again, as expected, the participants were at or near ceiling regardless of age or type of priming (see Table 1).

Table 1. Mean proportion and standard error of solution rates according to age and priming.

Priming	Children	Adults
Unprimed	1.0 (.0)	.97 (.15)
True Memory Prime	.97 (.23)	.97(.33)
False Memory Prime	1.0 (.0)	1.0 (.0)

Also as anticipated, there were significant differences in solution times as a function of age and priming. Specifically, there was a significant main effect of age,

$F(1, 34) = 13.44$, $p < .001$, $\eta^2_p = .28$. Solution times were significantly faster for the adults ($M = 2.91$, $SE = .33$) than for the children ($M = 4.40$, $SE = .23$). In addition, there was a significant main effect of priming on solution times, $F(2, 68) = 7.60$, $p < .001$, $\eta^2_p = .18$.

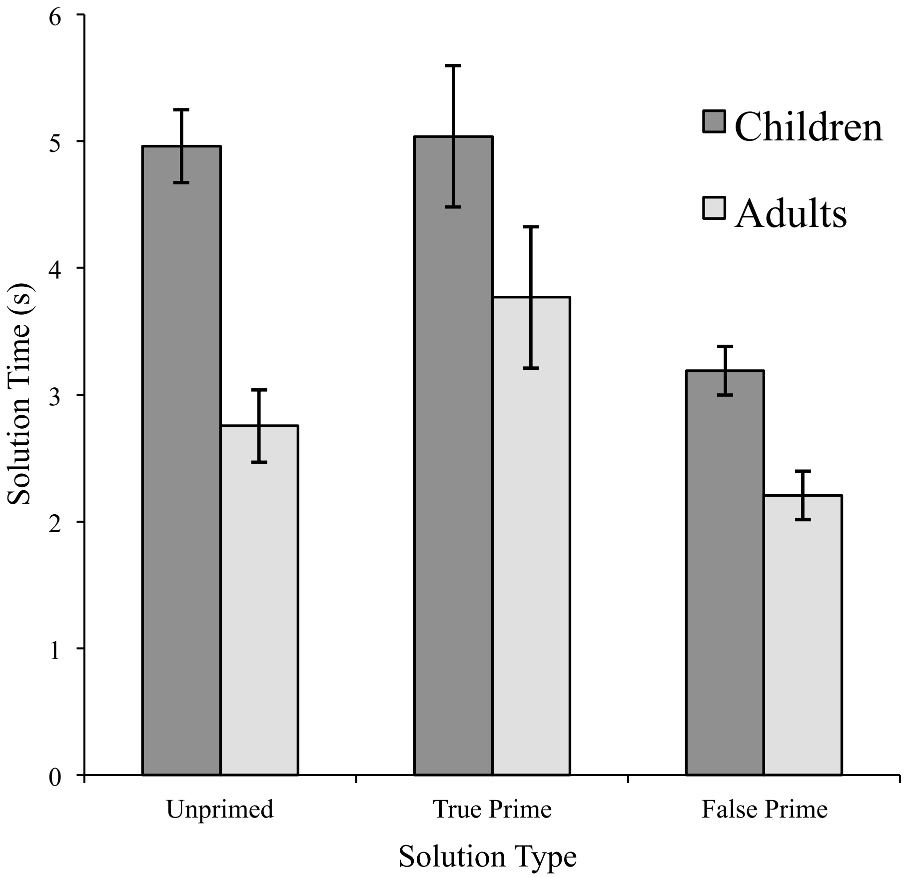

Figure 1. Mean proportion and standard error rates of solution times according to age and type of solution.

Although the Age x Priming interaction was not significant, $F(2, 68) = 1.02$, $p > .05$, it is instructive to examine both the main effect of age and the main effect of priming together in a single context (see Figure 1). As can be seen in this figure, consistent with the main effect of age, age differences were of similar magnitude regardless of the priming manipulation. In terms of the effects for solution times, post-hoc tests (Tukey's LSD) showed that analogical reasoning times were fastest for the false memory primed problems (*M* = 2.70, *SE* = .17). These problems were significantly faster than both the true memory primed problems (*M* = 4.40, *SE* = .48, $p < .001$) and the unprimed problems (*M* = 3.86, *SE* = .17, $p < .001$). There was no significant difference in solution times between the unprimed and true memory primed problems ($p > .05$).

Discussion

These findings provide a unique and important demonstration that false memories are more effective at priming solutions to analogical problems than true memories, both for children and adults. Our specific interest in the current study was with whether true and false memory priming could facilitate children's and adults' *speed* of analogical reasoning and not whether there were age differences in analogical problem solving per se (as these effects are already well established; e.g., see Ball et al., 2010; Goswami, 1991, 1992, 2001). Because of this, we intentionally selected analogies that could be easily solved by both children and adults and did not expect, nor did we obtain, age differences in solution rates. We did, however, anticipate age and priming differences in speed of problem solving given what we know about differences in the structure of children's knowledge base (e.g., see Ceci et al., 2010; Howe, 2011b). That is, despite having the knowledge available to solve analogical problems, children's speed of processing during problem solving is thought to be slower relative to that of adults (see Howe et al., 2009, 2011). The question, then, was whether speed of processing could be affected by true and false memory primes in both children and adults.

What the current results show is that both children's and adults' speed-of-problem-solving was affected by priming (specifically, false memory primes) and that these effects were age invariant. That is, although children were still slower than adults (the main effect for age), solution times were significantly faster, and faster by the same magnitude, regardless of age for problems that were primed by false memories. No advantage was obtained for priming with true memories. This finding not only has implications for priming work per se, but also for the debate surrounding the differences and similarities of true and false memories (e.g. Diliberto-Macaluso, 2005; Roediger & McDermott, 1995). In terms of priming of higher order reasoning tasks, there appears to be a clear distinction between true and false remembering. Importantly, this provides further evidence for the beneficial effects of false memories in a problem-solving domain.

That only false memory primes were effective in speeding up analogical problem solving in both children and adults is quite interesting given the recent literature on the superiority of self-generated (e.g., spontaneous false memories) over other-generated (e.g., experimenter-presented true memories) information more generally in memory (e.g., Howe et al., 2012). That is, self-generated information is better retained than other-generated information in adults (e.g., Mulligan & Lozito, 2004) as well as children (Howe, 2006). Because critical lures from DRM lists, if not explicitly presented as part of the list (as they were in our true memory condition), when falsely remembered, can be considered to be self-generated information. In contrast to conditions where information is already on the list, or other-generated information, this self-generated information tends to be stronger and more durable in memory. Indeed, there is a considerable literature demonstrating the strength and persistence of false (self-generated) memories over time (ranging from 1-2 days to 1-2 weeks) as well as the rapid decline of true (other-generated) memories over that same delay (e.g., Brainerd, Reyna, & Brandse, 1995; Howe, Candel, Otgaar, Malone,

& Wimmer, 2010b; Payne, Elie, Blackwell, & Neuschatz, 1996; Seamon et al., 2002; Thapar & McDermott, 2001). In fact, we have recently demonstrated that not only do false memories make better primes than true memories for CRAT problem solving over a 1-week retention interval (Howe et al., 2012) but that self-generated information is better at priming these same CRAT problems than experimenter-generated information and these effects are also developmentally invariant (Wilkinson & Howe, 2013). It may be, then, that false memories are stronger than true memories just like self-generated information is more memorable than other-generated information. If the strength of the memory representation is important to the strength or power of priming effects, then false or self-generated memories may be expected to have a greater effect on the speed of problem solving over true or other-generated memories when used as primes.

In summary, the current study not only extends earlier work on false memory priming of problem solving, but also provides a novel test of the hypothesis that false memories can and do have positive consequences on higher-level cognitive processes. By using more difficult analogical reasoning problems, ones that cannot always be solved associatively, we have demonstrated that false memories can aid subsequent problem solving in situations requiring more complex reasoning. Thus, it is clear that the impact of false memory priming on problem solving tasks is not just restricted to children's and adults' CRAT problems (Howe et al., 2010a, 2011), but also extends to more complex reasoning tasks such as verbal analogical reasoning. That is, the current contribution is also important because false memory priming of CRAT solutions might be seen as simply representing the priming of distant word associations in a network of such associations. Importantly, the evidence here demonstrates that priming, and in particular the superior effects of false memory priming, extend to analogical reasoning tasks.

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Appendix

Analogies and DRM Lists

Water : Boat :: Road : Car

Car – truck, bus, train, vehicle, drive, jeep, Ford, race, keys, garage, highway, van.

Moon : Night :: Sun : Day

Day – week, rainy, month, calendar, year, Tuesday, birth, date, Wednesday, evening, hour.

Hat : Head :: Sock : Foot

Foot - shoe, hand, toe, kick, sandals, soccer, yard, walk, ankle, arm, boot, inch.

Rock : Hard :: Pillow : Soft

Soft – light, plush, loud, cotton, fur, touch, feather, furry, downy, kitten, skin, tender.

Hare : Fast :: Tortoise : Slow

Slow - lethargic, stop, listless, snail, cautious, delay, traffic, turtle, hesitant, speed, quick, sluggish.

Stand : Floor :: Sit : Chair

Chair – table, legs, seat, couch, desk, recliner, sofa, wood, cushion, swivel, stool, sitting.

Tooth : Brush :: Hair : Wash

Wash – rinse, dishes, mouth, scrub, laundry, soap, shampoo, dish, soak, cloth, bathroom.

Desert : Hot :: Arctic : Cold

Cold - snow, warm, winter, ice, wet, frigid, chilly, heat, weather, freeze, air, shiver.

Eyes: See :: Nose: Smell

Smell – odour, aroma, scent, stench, skunk, stink, incense, sniff, perfume, fragrance, deodorant, sense.

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