Positive Consequences of False Memories

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Abstract

Previous research is replete with examples of the negative consequences of false memories. In the current research, we provide a different perspective on false memories and their development and demonstrate that false memories can have positive consequences. Specifically, we examined the role false memories play in subsequent problem-solving tasks. Children and adults studied and recalled neutral or survival-relevant lists of associated words. They then solved age-normed compound remote associates, some of whose solutions had been primed by false memories created when studying the previous lists. The results showed that regardless of age: (a) survival-related words were not only better recollected but were also more susceptible than neutral words to false memory illusions and (b) survival-related false memories were better than neutral false memories as primes for problem solving. These findings are discussed in the context of recent speculation concerning the positive consequences of false memories, and the adaptive nature of reconstructive memory.

Keywords: Memory development, False memories, Adaptive memory, Priming problem solutions

Positive Consequences of False Memories

Memory illusions have long been viewed as a negative consequence of the reconstructive nature of our memory system. Nowhere is this view more prominent than in the forensic arena where serious problems can arise when triers of fact (e.g., judges, jurors) attempt to discern whether a witness' testimony is based mainly on recollections of events that were in fact experienced or on recollections whose memorial base may be distorted or false. Worse, if we reasonably conclude that what people "remember" is often a blend of some truth as well as some fiction, then our remit becomes one of determining which part of someone's testimony is "correct" and which part is "false." This becomes a most difficult dilemma indeed given that to date there is no litmus test by which we can determine the veracity of a witness' memory (see Bernstein & Loftus, 2009).

Recently, researchers have argued that there may be positive consequences to false remembering (see Howe, 2011; Schacter, Guerin, & St. Jacques, 2011). In fact, there is a school of thought that is emerging in which memory illusions are viewed as adaptive, having a certain fitness relevance that may even be related to our survival. Consistent with this idea, investigators have shown that information encoded for its importance to survival is remembered better than information encoded in other contexts (Nairne, 2010). For example, memory is better for items rated for their importance to survival (e.g., usefulness when surviving in the grasslands) than to other forms of semantic processing (e.g., surviving in a city). This memory benefit is said to arise because human memory systems are primed to remember survival-related information better than other types of information due to its greater adaptive value (Nairne, 2010).

Several questions have arisen concerning this adaptive memory effect. First, if human memory benefits from survival processing, then does this benefit extend to reduced susceptibility to memory illusions? Although research to date has focused primarily on correct recollection, if survival processing leads to more distinctive encoding of information that is processed at an *item-specific* contextual level, then intrusions and false memory rates should be low. However, if survival-related processing of information primes networks of strongly interrelated concepts, then once activation spreads to these highly interconnected concepts, they should become active and serve as the basis of false memory illusions (e.g., Collins & Loftus, 1975; Karpicke, McCabe, & Roediger, 2008; Roediger, Balota, & Watson, 2001). Therefore, if survival processing promotes more *relational* processing, then false memory rates should be higher for survival-related terms than nonsurvival items. Of course, there is evidence that under certain conditions, survival processing enhances both item-specific and relational processing and that it is the interplay between item-specific and relational processing that controls trace elaboration and discrimination which in turn drives the adaptive memory effect (e.g., Kroneisen & Erdfelder, 2011).

Second, it may not just be the processing of information that is critical to this adaptive memory effect, but also the nature of the information itself that is being memorized. Specifically, survival-related concepts (e.g., *injury, death, struggled, virus, battle*) should be remembered differently than concepts that are not directly related to survival, regardless of whether they are explicitly processed for their survival value. Indeed, survival information may be more distinctive (inducing greater levels of item-specific processing of information; e.g., Hunt, Smith, & Dunlap, 2011) and may be represented in memory in denser, more highly integrated and organized associative networks (inducing more relational processing of information). Thus, if adaptive memory prioritizes survival information, then whether this survival priority is invoked by the type of processing or type of material being processed may not matter.

To answer these questions, Howe and Derbish (2010) conducted a series of experiments that exploited the Deese/Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995). Here, participants were presented lists of words (e.g., *bed, rest, awake*) that contained associates of a critical unpresented word (e.g., *sleep*). Although *sleep* never appeared on the list, when tested, participants often falsely remembered *sleep* as having been presented. In order to examine the accuracy (both true and false recollection) of adaptive memories when survival is induced via processing instructions, the materials themselves, or both, Howe and Derbish (2010) used DRM-like materials that were controlled for other between-list factors that could affect true and false memory performance (backward associative strength [BAS], imageability, concreteness, familiarity, semantic density, meaningfulness, word length, number of attributes). As well, because survival-related words were more emotionally charged than neutral words, nonsurvival-related words that were similarly emotionally (negative) charged were included to control for both valence (negative) and arousal.

Howe and Derbish (2010) found that both processing items for their survival relevance as well as survival materials themselves contributed to poorer, not better, recollection. That is, both true and false recollection rates were higher for survival materials, regardless of processing (survival or pleasantness), and for survival processing, regardless of materials (neutral, negative, or survival). Thus, type of material and type of processing made independent contributions to memory performance. Similar findings have been obtained with child participants (Otgaar & Smeets, 2010).

In the current study, we address two additional questions. First, many of the adaptive memory findings have been obtained using *incidental* memory tasks – that is, participants rate words for their relevance to some dimension (e.g., survival, pleasantness) and are not expecting to have to remember the words later on a surprise memory test. In the current experiment, we wanted to know to what extent these findings generalize to other memory situations in which participants are instructed to *intentionally* remember survival-relevant information.[1] This is critical because the use of incidental memory tasks may have inflated false recollection rates, hence reduced accuracy. For example, some studies have shown that in incidental memory tasks, levels-of-processing instructions can increase both false recall and recognition rates (e.g., Rhodes & Anastasi, 2000; Thapar & McDermott, 2001). In order to extend the generalizability of the findings, we conducted an intentional memory study in which participants were instructed to memorize neutral and survival-relevant information.[2]

We were particularly interested in whether children's memory benefitted from the study of survival-related information because all of the developmental survival memory studies to date have examined incidental memory for neutral information when processed for its survival relevance (Aslan & Bauml, 2012; Otgaar & Smeets, 2010). Specifically, although young children are generally poorer at recollecting information (lower true and false memory rates) than older children and adults, if memory is specially adapted for survival, we could see an "advantage" for recollection of survival-related concepts relative to other concepts at all ages. Indeed, Otgaar and Smeets (2010) found similar effects of survival processing on children's and adults' true and false recollection. Thus, despite quantitative age differences in memory performance, survival-related information might exhibit higher relative rates of true and false recollection regardless of age.

It is important to point out that although there exist strong arguments to the effect that if survival-relevant processing (and by extension, survival-relevant information) is truly adaptive, such effects should be seen in childhood (see Aslan & Bauml, 2012), we do not subscribe to that view. This is because the timing of the emergence of an adaptation does not determine whether that behavior is or is not adaptive (see Howe & Otgaar, 2012). However, we believe that discovering the developmental course of adaptive memory is still probative and may help uncover the proximate mechanisms driving such behavior.

Second, if one consequence of having a powerful, reconstructive memory system is a propensity to generate false memories when studying associatively related information perhaps there are some adaptive consequences to these memory illusions (see recent arguments by Howe, 2011, and Schacter et al., 2011). Howe and Derbish (2010; Howe, 2011) suggested that correlated increases in true and false memory rates for survival information arise because such information is more densely represented in memory, making spreading activation to related concepts (including list themes) more rapid and efficient, something that might have adaptive value. One such advantage might be the ability to solve problems more rapidly given enhanced access to information in memory in a survival-related context, something that may be a crucial evolutionary trait (see Porter & Leach, 2010).

Importantly, increases in memory illusions for survival information may not necessarily be maladaptive if they can have positive consequences (e.g., prime solutions to complex problems) just as true memories. In fact, Howe and colleagues (Howe, Garner, Charlesworth, & Knott, 2011; Howe, Garner, Dewhurst, & Ball, 2010) have demonstrated that false memories can prime solutions to problems found on the compound remote associates test (CRATs). That is, for children and adults who studied DRM lists and falsely recalled the critical lure (one that was also the solution to a CRAT problem), their problem solution rates and solution times were significantly improved over those who did not falsely remember the critical lure or for CRATs whose solutions were not primed. Because these experiments did not vary the type of material being remembered (using only neutral DRM lists and CRATs), in our experiment, we extended these priming effects to lists that were survival relevant. If somehow false memories generated for survival information serve as better primes for problem solving, then CRATs whose solutions involve survival-relevant terms should be more easily solved than neutral CRATs given that participants have generated the relevant false memory. As well, if our memory systems are functionally designed and evolved to enhance fitness (e.g., survival, reproduction), and we see early evidence of this "tuning" in children, then perhaps we will also see these advantages when it comes to children's problem solving. That is, all other things being equal (i.e., controlling for age differences in solution rates), qualitative aspects of priming effects should be developmentally invariant.

Thus, in the current research we examined questions concerning the priming of survival-relevant versus neutral problem solving using an adaptive memory procedure that involved an intentional, rather than the more usual incidental, memory paradigm. That is, we wondered whether increased false memories for survival information might be advantageous for both children and adults in tasks other than memory, specifically, solving insight-based CRAT problems. What our previous research has shown is that false memories are effective in priming solutions to CRATs that are relatively neutral in valence and arousal (Howe et al., 2010, 2011). What the current experiment asks is whether false memories based on survival information serve as better primes for CRATs whose solutions involve these same survival-relevant terms than CRATs whose solutions involve false memories based on neutral information.

Current Study

Because our concern was with whether survival-relevant CRAT solutions were more easily primed than neutral CRATs, and not with whether there were age differences in CRAT solution rates, we used CRATs whose baseline solution rates were relatively high for both children and adults. Therefore, although we predicted the usual quantitative age differences in true and false recall, we used age appropriate CRAT problems so that any age differences in CRAT solutions were attenuated (or eliminated) because age differences in problem difficulty were not of interest in this study. Rather, we wondered whether false memories for survival information served as better primes for solving CRAT problems for both children and when problem difficulty was equated across age.

Method

Participants

A total of 60 participants were tested in this experiment. The children, predominantly White and middle class, consisted of 30 (15 male, 15 female) 11-year-olds (*M* = 11.4 years, SD = 4 months) and 30 (15 male, 15 female) 18-year-olds (*M* = 18.6 years, SD = 7 months). The parents/guardians of the children gave written consent and the child's assent was obtained on the day of testing. The adults all gave informed, written consent.

Design, Materials, and Procedure

A within participant design was used where each participant was primed on half of CRAT problems, two survival and two neutral lists. Both the order of the DRM lists and CRATs was counterbalanced across participants within each age group. A total of 16 CRATs (8 neutral, 8 survival) were selected from the normative data produced by Bowden and Jung-Beeman (2003). For each participant, a random set of four neutral and four survival CRATs were selected. Each CRAT consisted of three words, all of which could be solved by a single linking word. Efforts were made to eliminate any solution rate differences between the survival and neutral CRATs using the Bowden and Jung-Beeman (2003) norms and equating the percentage of participants solving the problem across problem type. A paired t-test revealed no significant differences in problem difficulty between survival and neutral CRATs, $t(7) = .66$, $p = .56$.

Sixteen DRM lists were used, consisting of 10 associates of the critical lure. The lists taken were selected because their critical lure was the same as the solution word used in the selected CRATs. These lists were again taken from the normed associates created by Nelson et al. (1998). These lists were then randomly split into two groups of four, so participants would be primed on half the DRM lists, while completing all eight of the CRATs. Each group of four DRM lists contained two neutral and two survival[3] lists. Mean arousal and valence levels for the survival critical lures and the neutral critical lures differed from one another according to the affective norms for English words (ANEW; see Bradley & Lang, 1999). The mean arousal levels were 5.93 for the survival lists and 2.99 for the neutral lists (where higher values equal higher arousal) and the mean valence levels were 2.80 for the survival lists and 5.18 for the neutral lists (where lower values represent negative valence and higher values positive valence). The mean BAS was .28 for the neutral lists and .25 for the survival lists. A sample of the materials used in this experiment can be found in the Appendix.

Participants were given four (two neutral and two survival) out of the eight DRM lists relevant to half of the later presented CRATs in a randomized order. In this way, we could make comparisons between those CRATS that were primed and those that were not. Each of the four DRM lists was administered to each participant verbally, followed by a distracter task (circling random letter pairs in a randomized alphabet strings) before they were then asked to recall as many words as they could remember from the list. Once this had been repeated for each word list, participants were then asked to complete eight CRATs, half of which could be solved using the critical lure from the DRM lists previously administered. Participants were first given an example, followed by two practice CRATs before they began. Each CRAT was presented on a computer screen, in a randomized order, and asked to provide a solution verbally. If participants failed to correctly solve a CRAT, they were given feedback as to the correct answer after each problem. Participants were given a maximum of 60 seconds to complete each problem. The experimenter recorded response latencies using a computerized timing device. Timing started with the presentation of the CRAT and was terminated by a keystroke from the experimenter when the participant gave their answer.

Results and Discussion

There was no effect due to gender and because there were no theoretical predictions concerning this variable, it was removed from subsequent analyses. We begin by reporting the memory data and then turn to the results for problem solving.

True and False Recall

The proportion of targets correctly recalled and critical lures falsely recalled were calculated and analyzed in separate 2(list type: neutral vs. survival) x 2(age: 11- vs. 18-year-olds) analyses of variance (ANOVAs). For true recall, there was a significant main effect of age, F (1, 58) = 44.92, $p < .001$, ($_p^2$ = .436, where 11-year-olds (M = .57) recalled fewer items than 18-year-olds (M = .72). There was also a main effect for list type, F (1, 58) = 106.59, $p < .001$, ($_p^2$ = .648, where items on survival lists (M = .75) were better recalled than neutral lists (M = .55). Finally, there was a significant Age x List type interaction, F (1, 58) = 10.08, p = .002, ($_p^2$ = .148. As can be seen in Figure 1, and was confirmed by post-hoc tests, regardless of age, all participants recalled survival items better than neutral items, and the magnitude of this difference was almost twice as large for adults than for children (all differences significant, $p < .001$).

For false recall, there was a significant main effect of age, F (1, 58) = 22.32, $p < .001$, ($_p^2$ = .278, where 11-year-olds (M = .17) falsely recalled fewer items than 18-year-olds (M = .30). There was also a main effect for list type, F (1, 58) = 61.05, $p < .001$, ($_p^2$ = .513, where items on survival lists (M = .32) exhibited higher false recall rates than items on neutral lists (M = .18). Finally, there was a significant Age x List type interaction, F (1, 58) = 4.74, p = .034, ($_p^2$ = .076. As can be seen in Figure 2, and was confirmed in post-hoc tests, regardless of age, all participants recalled survival items better than neutral items, and the magnitude of this difference was almost twice as large for adults than for children (all differences significant, $p < .001$).

Finally, as in previous studies (e.g., Otgaar & Smeets, 2010) we analyzed net accuracy scores [true recall/(true recall + false recall)]. Here, the ANOVA revealed a single effect, that for list type, F (1, 58) = 18.23, $p < .001$, ($_p^2$ = .239. As anticipated, and consistent with previous research, items on survival lists (M = .72) exhibited lower net accuracy than items on neutral lists (M = .80).

Overall, then, the results of this experiment are consistent with the findings using incidental memory paradigms with children and adults (Howe & Derbish, 2010; Otgaar & Smeets, 2010). Again, survival lists produced more true and false recall than neutral lists, something that results in lower net accuracy. That false recall rates were highest for survival lists suggests that survival-related information itself may be processed differently in memory than other material regardless of whether that processing is brought about by intentional or incidental memory instructions. This is true regardless of age and, although adults exhibited higher rates of true and false recall, all participants exhibited quantitatively similar levels of net accuracy, levels that were lower for survival than neutral materials.

Problem Solving Results: Solution Rates

The mean CRAT solution rate was calculated separately for both survival and neutral lists for each participant. As well, because previous research has shown that it is only when participants falsely remember the critical lure that problem solving is enhanced (Howe et al., 2010, 2011), for primed problems, we conditionalized solution rates on whether the participant falsely remembered the relevant critical lure. Thus, the priming factor had three levels, primed-FM (primed with the DRM list and falsely remembered the critical lure), primed-No-FM (primed with the DRM list but did not falsely recall the critical lure), and unprimed.

Because we used age-appropriate CRAT problems, there were no developmental predictions. Thus, we conducted separate 3(Priming: primed-FM vs. primed-No-FM vs. unprimed) x 2(Materials: neutral vs. survival) within-participant ANOVAs separately for children and adults. We report the analyses for the children first followed by the adults. As will be seen, and statistical tests confirmed, there were no differences in solution rates as a function of age.

Children's Problem Solving Rates. There was a significant main effect of priming, $F(2, 58)$ = 46.44, $p < .001$, (${}^{2}_{p}$ = .616. Post-hoc tests showed that when children who were primed falsely remembered the critical lure (primed-FM) they solved more CRATs (M = .79) than when they did not falsely remember the critical lure (primed-No-FM, M = .51, $p < .01$) and when the problems were unprimed (M = .50, $p < .01$). The latter two conditions did not differ. There was also a main effect of list, $F(1, 29) = 24.96$, $p < .001$, (${}^{2}_{p}$ = .463, where more problems were solved if they were survival-relevant (M = .65) than if they were neutral (M = .56). Finally, there was a Priming x List interaction, $F(2, 58) = 7.98$, $p = .001$, (${}^{2}_{p}$ = .216. As can be seen in Figure 3, and was confirmed by post-hoc tests, although there were no significant differences in priming as a function of list type for unprimed and primed-No-FM conditions, primed-FM solution rates were reliably higher for survival than neutral problems.

Adults' Problem Solving Rates. There was a significant main effect of priming, $F(2, 58) = 8.00$, $p = .001$, (${}^{2}_{p}$ = .216. Post-hoc tests showed that when adults who were primed falsely remembered the critical lure (primed-FM) they solved more CRATs (M = .75) than when they did not falsely remember the critical lure (primed-No-FM, M = .53, $p < .01$) and when the problems were unprimed (M = .54, $p < .01$). The latter two conditions did not differ. There was no main effect of list, but there was a Priming x List interaction, $F(2, 58) = 6.82$, $p < .05$, (${}^{2}_{p}$ = .103. As can be seen in Figure 4, and was confirmed by post-hoc tests, although there were no significant differences in priming as a function of list type for unprimed and primed-No-FM conditions, primed-FM solution rates were reliably higher for survival than neutral problems.

Problem Solving Results: Solution Times

The mean CRAT solution time was calculated separately for both survival and neutral lists for each participant. As well, like the analysis of solution rates, we conditionalized solution times on whether the participant falsely remembered the relevant critical lure. Thus, again, the priming factor had three levels, primed-FM (primed with the DRM list and falsely remembered the critical lure), primed-No-FM (primed with the DRM list but did not falsely recall the critical lure), and unprimed.

Again, we conducted separate 3(Priming: primed-FM vs. primed-No-FM vs. unprimed) x 2(Materials: neutral vs. survival) within-participant ANOVAs separately for children and adults. We report the analyses for the children first followed by the adults. Although adults (M = 17.7-s) were faster overall than children (M = 27.1-s) [$F(1, 29) = 21.99$, $p < .001$, (${}^{2}_{p}$ = .553], age effects for speed of problem solving did not interact with any of the other variables.

Children's Problem Solving Times. There was a significant main effect of priming, $F(2, 58)$ = 16.79, $p < .001$, (${}^{2}_{p}$ = .296. Post-hoc tests showed that when children who were primed falsely remembered the critical lure (primed-FM) they solved CRATs more quickly (M = 21-s) than when they did not falsely remember the critical lure (primed-No-FM, M = 30-s, $p < .01$) and when the problems were unprimed (*M* = 31-s, *p* < .01). The latter two conditions did not differ. There was also a main effect of list, *F*(1, 29) = 15.48, *p* < .001, (${}^2_p$ = .244, where problems were solved more quickly if they were survival-relevant (*M* = 24-s) than if they were neutral (*M* = 30-s). Finally, there was a Priming x List interaction, *F*(2, 58) = 9.78, *p* < .001, (${}^2_p$ = .115. Post-hoc tests showed that although there were no significant differences in priming as a function of list type for unprimed and primed-No-FM conditions, primed-FM solution times were reliably faster for survival than neutral problems (see Table 1).

Adults' Problem Solving Times. There was a significant main effect of priming, *F*(2, 58) = 18.22, *p* < .001, (${}^2_p$ = .275. Post-hoc tests showed that when adults who were primed falsely remembered the critical lure (primed-FM) they solved CRATs more quickly (*M* = 12-s) than when they did not falsely remember the critical lure (primed-No-FM, *M* = 20-s, *p* < .01) and when the problems were unprimed (*M* = 21-s, *p* < .01). The latter two conditions did not differ. There was no main effect of list and no Priming x List interaction.

Together these results show that regardless of age, solution rates (children and adults) and times (children) were superior when survival-relevant problems were being solved than when the problems involved neutral information. However, in all cases, solution rates and times were only enhanced when the relevant prime was falsely remembered. Thus, like previous research, false memories can and do prime problem solutions. The discovery that is new is that priming is superior when problem solutions are survival-relevant than when they are not.

Discussion

We began this article by inquiring whether memory illusions might have a less sinister, perhaps more positive effect than what has typically been attributed to them. To do this, we examined the adaptive memory effect and wondered if this effect was as robust when using survival-related information in an intentional memory paradigm as it is when rating neutral information for its survival relevance using an incidental memory paradigm (e.g., Nairne, 2010; Otgaar & Smeets, 2010). Although there is preliminary evidence that these effects are similar when the participants are adults (Howe & Derbish, 2010; Experiment 3), there is no evidence with child participants.

The results confirmed our suspicions. That is, the adaptive memory effect was developmentally invariant when survival information was used and memory was tested in an intentional memory task. This extends other developmental research where neutral information has been rated for its survival relevance and memory is tested using an incidental paradigm (Aslan & Bauml, 2012; Otgaar & Smeets, 2010). The current results extend the domain of adaptive memory effects by showing that for survival information itself, both true and false recall is greater than for neutral information, something that results in a decline in net accuracy. Although adults exhibited higher rates of true and false recall than children, as is typically the case in studies such as these (e.g., Howe et al., 2011; Otgaar & Smeets, 2010), there were no age differences in the decline of net accuracy. Thus, despite quantitative differences in true and false memories, children and adults both exhibit age invariant declines in net accuracy when processing survival-relevant information.

What these developmentally invariant results suggest is that survival-relevant information is processed differently in memory than other types of information and this different treatment occurs independently of the type (incidental or intentional) of memory task. Perhaps this difference is related to the well-known effects of item-specific and relational processing in true and false memory more generally (e.g., Hunt et al., 2011). Item-specific processing enhances encoding of the individual concepts whereas relational processing enhances the coherence or organization of the items into a set. Because survival materials may be particularly distinctive, item-specific processing can lead to higher rates of true memory. As well, because survival information may also enjoy higher levels of internal organization in memory, making co-activation of items in such associative networks (including ones that are not on the list) more likely, relational processing can also lead to higher rates of false memory (also see Howe & Derbish, 2010). More generally, item-specific and relational processing contribute to trace elaboration and discrimination (distinctiveness), both of which have been found to account for survival processing effects in a variety of experiments. For example, Kroneisen and Erdfelder (2011) demonstrated that when both richness (elaborateness) of encoding and item distinctiveness were controlled, performance differences between survival processing and control tasks disappeared. Thus, perhaps the relevant proximate mechanism for intentional processing of survival materials, like that suggested for incidental processing of materials for their survival value, is the balance between item-specific and relational processing that contribute to both the elaboration and discriminability of traces in memory. As Kroneisen and Erdfelder (2011, p. 1554) argued, maybe "it is not the evolutionary significance of survival per se that explains the survival processing effect. Rather, the degree to which survival processing invites elaborative, distinctive forms of encoding would predict the mnemonic benefit of survival processing."

The second question was whether survival-relevant false memories serve as better primes for problems whose solutions involve survival-relevant terms than neutral false memories do for reasoning about neutral information. As our experiment demonstrated, when participants generated false memories following the presentation of a DRM list, CRAT problems whose solutions were also survival-relevant were more easily and often more quickly (at least for children) solved than neutral problems. Interestingly, there were no differences in solution rates or times (for children anyways) when participants did not generate false memories or were not primed, and these effects did not vary as a function of the type of information being reasoned about.

These results compliment those obtained in previous research using neutral information and demonstrate that false memories, when generated spontaneously by participants, are capable of priming insight-based problems (Howe et al., 2010, 2011). More important, we have discovered two hitherto unreported findings. First, there is a survival advantage in false memory priming of problem solving. That is, problems whose solutions involve survival-related information are more readily primed by false memories than problems whose solutions involve neutral information[4]. Second, these effects are developmentally invariant, at least for solution rates[5]. That is, although there are quantitative age differences in rates of true and false memories between children and adults, when age-appropriate problems are used, both children and adults solve survival-relevant problems better than problems involving neutral materials.

What mechanism might be responsible for these differences in priming effects for neutral and survival-relevant problems? It is clear that these effects are not due to differences in problem difficulty as we intentionally equated this dimension across neutral and survival CRAT problems. Perhaps, as Porter and Leach (2010) have speculated, these problems are more easily primed because survival information, both true and false, affords a more rapid and enhanced access to information in memory, information that is necessary for insight-based problem solving. Indeed, that spreading activation of information is enhanced when remembering or reasoning about information in a survival-related context may be important to adaptation and may well represent a critical evolutionary trait. Regardless of the exact nature of the mechanism(s) underlying this advantage, there is an important and novel message delivered in the current research. Specifically, despite survival processing of information and survival-relevant information itself leading to correlated increases in true and false memories, something which in turn leads to net decreases in memory accuracy, there is an advantage that accrues to survival-relevant false memories, namely, enhanced priming of survival-relevant insight-based problem solving.

Finally, we have attempted to demonstrate that although memory illusions often do exhibit malevolent effects, particularly in the courtroom (e.g., see Howe, in press-a, in press-b), they can also have more positive, adaptive consequences in some contexts. Indeed, what the results of this study highlight is that survival-related material is highly interconnected in memory, something that gives rise to increases in both true and false information. This might be detrimental if one needed to accurately report what one *actually* experienced, but it might be advantageous to the person who is trying to solve a problem related to survival. For example, the person who misremembers seeing a predator while foraging for food might be more cautious upon their return to that same patch to gather more food than the person who accurately remembers that only signs (e.g., feces, scent) of the predator had been present on an earlier visit. That false memories are an inevitable consequence of a powerful, reconstructive memory system, does not make them something to be avoided. Indeed, like many things, memory illusions are neither good nor bad in and of themselves. What determines whether they have a positive or negative consequence depends solely upon how they are later put to use.

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Appendix
Examples of DRM Lists and CRAT Problems.

DRM Lists

Survival
Fire
Blind
Blood
Dead

blaze
deaf
plasma
alive

flame
sight
donor
corpse

inferno
unseen
vein
coffin

torch
shutter
vampire
casket

aim
see
Dracula
living

smoke
bat
cut
bury

dragon
vision
artery
cemetery

log
glare
stain
tombstone

burn
mice
vessel
grave

match
unaware
cell
funeral

Associated CRAT
cracker/fly/fighter
date/alley/fold
hound/pressure/shot
end/line/lock

Neutral
DRM Lists

Chair
Paper
Table
Street

table
newsstand
chair
avenue

recliner
sheet
picnic

|boulevard |
| |
| |
|seat |
|document |
|manners |
|road |
| |
| |
|stool |
|pad |
|tray |
|main |
| |
| |
|wicker |
|folder |
|booth |
|sidewalk |
| |
| |
|desk |
|margin |
|counter |
|elm |
| |
| |
|couch |
|thesis |
|desk |
|alley |
| |
| |
|lounge |
|tissue |
|pool |
|curb |
| |
| |
|sit |
|staple |
|manner |
|lane |
| |
| |
|furniture |
|notebook |
|surface |
|crossing |
| |
|Associated CRAT |
|rocking/wheel/high |
|fly/clip/wall |
|spoon/cloth/card |
|main/sweeper/light |
| |

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Footnotes

[1]Note that Howe and Derbish (2010, Experiment 3) did use an intentional memory paradigm to study the effect of survival materials without survival processing with adults and found that there were materials effects independent of processing effects. However, it is not known whether these effects extend to children's memory for survival-related material.

[2]We did not include negative control lists in the current experiment because as previously discussed research has shown that they contribute little to our understanding of the adaptive memory effects (e.g., Howe & Derbish, 2010). Indeed, when valence and arousal are equated between survival and negative lists, survival lists still exceed negative lists in both true and false remembering (Howe & Derbish, 2010). Therefore, the critical contrasts are between survival and neutral lists.

[3]Survival items were selected based on data gathered by Howe and Derbish (2010). Specifically, in that study we asked an independent group of participants to rate items from the 12 DRM-like lists for their importance to survival. When those judgments were analyzed, participants rated the survival words as more survival relevant ($M = 4.81$) than words on our neutral ($M = 3.93$), a difference that was significant.

[4]It is important to emphasize that this outcome is not a consequence of there being more false memories spontaneously generated for survival than neutral information. This is because solution rate analyses are based on conditionalized proportional response rates, ones that eliminate any absolute differences in performance rates between lists. As well, any difference in solution times is independent of the absolute number of false memories that were spontaneously generated.

[5]Note that for solution times, developmental invariance could not have emerged due to the age differences in problem solving times. Although age differences in processing times are well known in the cognitive development literature, near ceiling effects in speed of problem solving for adults in this study may have obscured differences between survival-relevant and neutral false memory priming effects. Perhaps with harder problems, such effects might have emerged.

Table 1

Means (Standard Errors) for children's response times to the CRATs (in seconds).

Materials	Priming		
	Unprimed	Primed-NoFM	Primed-FM
Neutral	33.2 (2.4)	32.4 (3.2)	25.0 (2.9)
Survival	28.3 (2.5)	26.8 (3.5)	16.7 (2.8)

Figure Captions

Figure 1. Age x List interaction for true recall.

Figure 2. Age x List interaction for false recall.

Figure 3. Priming x List interaction for CRAT solution rates for children.

Figure 4. Priming x List interaction for CRAT solution rates for adults.