# A Brighter Side to Memory Illusions:
# False Memories Prime Children's and Adults' Insight-based Problem Solving.

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Abstract

Can false memories have a positive consequence on human cognition? In two experiments we investigated whether false memories could prime insight problem-solving tasks. Children and adults were asked to solve compound remote associate task (CRAT) problems, half of which had been primed by the presentation of Deese/Roediger-McDermott (DRM) lists whose critical lure was also the solution to the problem. In Experiment 1 the results showed that regardless of age, when the critical lure was falsely recalled, CRAT problems were solved more often and significantly faster than problems that were not primed by a DRM list. When the critical lure was *not* falsely recalled, CRAT problem solution rates and times were no different than when there was no DRM priming. In Experiment 2, without an intervening recall test, children and adults still exhibited higher solution rates and faster solution times to CRATs that were primed than CRATs that were not primed. This latter result shows that priming occurred as a result of false memory generation at encoding and not at retrieval during the recall test. Together these findings demonstrate that when false memories are generated at encoding they can prime solutions to insight-based problems in both children and adults.

Keywords: False memory; Problem solving; Compound remote associates task; Memory and reasoning

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It is well known that memory is error-prone and that errors frequently lead to false memory illusions (i.e., an illusion that takes the form of a belief that something had actually been present when in fact it was not – Deese, 1959; Roediger & McDermott, 1995). Such spontaneous errors of commission can be studied using the Deese/Roediger-McDermott (DRM) paradigm where participants are given word lists (e.g., *nap, doze, dream, pillow*) whose members are all associates of an unpresented item or critical lure (e.g., *sleep*). Despite never having been presented, participants often falsely remember the critical lure as being presented in the list. When studied developmentally, these spontaneous false memories increase with age (e.g., Howe, Wimmer, Gagnon, & Plumpton, 2009).

By now, we are all too familiar with the darker or negative side of false memory illusions. From experts being more prone to false memories in their domains of expertise (Castel, McCabe, Roediger, & Heitman, 2007), to miscarriages of justice (Loftus, 2003), to the outright memory wars of the 1990s (Crews, 1995). However, we argue that there is also a brighter, more positive side to false memories, one that is similar to that usually attributed to true memories. This positive aspect of false recollection is the role they can play in more complex cognitive processes such as insight-based problem solving.

To see this brighter side, consider the notion that false memories like false beliefs (e.g., McKay & Dennett, 2009) may be the consequence of some creative process. For example, Castel et al. (2007) found that because experts have rich and highly interconnected memory networks in their area of expertise they are more prone to memory errors related to that expertise. It may be, then, that generation of related information, including information not presented (i.e., false memories), is related to the discovery of creative solutions to problems (Sio & Ormerod, 2009), solutions that may depend on spreading activation through well-integrated associative networks that are said to serve as a foundation for human thought (Anderson, 1983; Reder, Park, & Kieffaber, 2009).

One way to investigate this brighter side to false memories is by asking whether false memories can prime solutions to insight-based problems such as those found in the Compound Remote Associates Task (CRAT). Originally developed by Mednick (1962), these tasks involve the presentation of three words, for example, *apple, family, house,* all of which can be linked by a single word, in this case *tree.* In order to gain insight and solve this problem, theorists have suggested a process involving spreading activation, one that continues until the correct concept has been activated (Bowden, Jung-Beeman, Fleck, & Kounios, 2005). If we also assume that false memories are caused by a spreading activation mechanism (Howe et al., 2009; Roediger & McDermott, 1995), then priming becomes an ideal area of investigation (Anderson, 1983).

In true memory, priming has been interpreted in terms of an enhanced speed and tendency to complete tasks, such as stem completion tasks, when their completion involves the use of a word previously studied (e.g., Graf, Shimamura, & Squire, 1985). McDermott (1997) found that critical lures could also be used to prime word-stem and fragment-completion tasks, although priming occurred at a level lower than if the items had actually been studied (see Diliberto-Macaluso, 2005, for similar findings with child participants). Similarly, McKone and Murphy (2000) showed that critical lures could prime solutions to both implicit (stem-completion) and explicit (stem-cued recall) memory problems. The question addressed here is whether false memories can also prime more complex cognitive tasks.

We suspect they can because problems requiring a high level of insight may be aided by the spreading activation of concepts in memory, a process similar to the mechanisms proposed in spreading activation models of false memory effects (e.g., Howe et al., 2009; Roediger & McDermott, 1995) as well as Underwood's (1965) original implicit associative response model. For example, Kershaw and Ohlsson (2004) discovered that insight problem solving involves searching through related concepts in memory for relevant information. Bowden et al. (2005) also suggested that insight-related problem solving involves the activation of concepts in memory, including ones that are unrelated to the solution, followed later by the weak activation of concepts that are critical to the solution. Indeed, research has already shown that true memories can be used to prime problem solving and reasoning tasks successfully (e.g., Kokinov, 1990), so it may not be too far-fetched to anticipate that false memories might also prime problem solutions. In fact, some evidence has recently emerged showing that at least for adults, false memories can and do prime solutions to CRAT problems. However, this priming only occurred when the critical lure was falsely remembered on a recall test and not simply due to the presentation of a DRM list whose critical lure was not falsely recalled (Howe, Garner, Dewhurst, & Ball, in press).

In the current research, we wanted to replicate this finding with adults but more importantly, extend these priming effects to children. This question is important developmentally for any number of reasons. For example, recall that children are less susceptible than adults to spontaneous false memory illusions especially those induced using the DRM paradigm (e.g., Howe et al., 2009). One reason for this may be because spreading activation is less automatic in children's than adults' memory networks (see Howe, 2005; Howe et al., 2009; Wimmer & Howe, 2009, 2010). Interestingly, these differences are often attenuated (although not always eliminated) when age-appropriate materials (ones that are congruent with children's knowledge base) are used (e.g., Anastasi & Rhodes, 2008). To the extent that spreading activation is also important to solving CRAT problems we were interested in whether limitations in automaticity might also constrain children's problem solving abilities even when age appropriate problems were used.

We examined this question by using CRATs whose baseline solution rates were relatively high for both children and adults. That is, we used age-appropriate CRATs as determined by a norming study that we present next. Thus, although we predicted there might exist the usual age increases in false recall despite using age-appropriate lists, we were interested in whether we could attenuate (or eliminate) age differences in problem solving rates by using age-appropriate problems. Indeed, age differences in problem difficulty were not, in and of themselves, of interest in this study. Rather, we wondered whether false memories could serve the same priming function for children as they can for adults when problem difficulty was equated across age.

## Pilot Study: Norming CRAT Problems for use with Children

Before turning to the main experiments, we report a pilot study in which we collected norms for CRAT problems for use with children. Although the other experiments in this article concern only one child age group (11-year-olds) in contrast to adults, the norming study examined CRAT solution rates and times for 7-, 9-, and 11-year-olds.

### Method

*Participants*

A total of 60 participants (Males = 28, Females = 32) took part in this experiment, 20 7-year-olds ($M$ = 7 years, 3 months; SD = 5 months), 20 9-year-olds ($M$ = 9.5, SD = 3 months), and 20 11-year-olds ($M$ = 11 years, 3 months; SD = 4 months). The children, mostly White and from middle class families, were tested following parental consent and their own assent on the day of testing.

*Materials*

Children were presented with 20 CRAT problems. Although the majority of these were taken from Mednicks (1982) original problems and Bowden and Jung-Beeman's (2003) normative data collection, some problems were added or modified to suit the age range that was tested. The items on the CRAT all required a solution that was a word associated with all three words of the triad through the construction of a compound word or common phrase (e.g., *cream/skate/water* form compounds using the word *ice,* thus; *ice-cream, ice-skate, ice water*). Bowden and Jung-Beeman provided normative data for 144 problems, however due to the age-range being tested in this sample and the level of difficulty of a number of the problems we only selected the problems that met the following criteria: Solutions to the presented problems must have been used previously as critical lures to associative and categorized word lists. Only problems with solution rates of above 30% (in the adults norms) and solved within 30 sec by adults were selected for norming with children. All the solution words had familiarity ratings of 500 or higher (with the maximum entry of 645, and a mean of 566; Coltheart, 1981) and a word frequency of 10 or higher (maximum entry 686, and a mean of 126; Kucera and Francis 1967).

*Procedure*

Participants were tested individually in a quiet room. Instructions similar to Bowden and Jung-Beeman were given. Participants were told that they would see three items and that they should try and produce a fourth word, which, when combined with each of the three items, would make up a common compound word or phrase. The participants were also given three demonstrations by the experimenter followed by two practice problems prior to the experiment itself. The three problem words were presented on a computer laptop screen simultaneously in a horizontal orientation, one above, below, and at the center point. The participants were given 40 sec (the longest time limit used by Bowden and Jung-Beeman was 30 sec) to produce the solution. If the solution was produced within the time limit, both the solution and the solution time were recorded and the next problem was presented. If the participant did not produce the correct response within the time limit, the solution was provided by the experimenter and the program automatically moved on to the next problem.

## Results

Although in the experiments reported in this article we only used the norms for 11-year-olds, we present the results for all three ages in Table 1. Here we present the average solution rates and times for the 20 problems separately for 7-, 9-, and 11-year-olds. With these norms in hand, we turn now to the main questions concerning the role of false memories in priming solutions to insight-based problem solving in children and adults.

## Experiment 1

## Method

*Participants*

Sixty participants, 30 11-year-olds (*M* = 11 years, 2 months; *SD* = 4 months) and 30 adults (*M* = 18 years, 5 months; *SD* = 8 months) participated in the experiment. Parental consent was obtained for all child participants as well as their own assent on the day of testing. Adult participants provided written informed consent prior to the study. Child participants were drawn from predominantly White, middle-class schools. All participants were fluent in English.

*Design, Materials, and Procedure*

A 2(Age: 11- and 18-year-olds) x 2(Priming: primed and unprimed) mixed design was used where the first factor was between-participants and the second factor was manipulated within-participant. For purposes of the analyses, primed items were further divided according to whether participants falsely remembered the critical lure (designated “primed/FM”) or failed to falsely remember the critical lure (designated “primed/No-FM”) resulting in a 2(Age) x 3(Priming) design. Each participant was primed on half of the CRAT problems with a preceding DRM list whose critical lure was also the solution to one of the CRAT problems. Following study-test trials on four DRM lists, participants attempted to solve all eight CRAT problems. Each participant was randomly assigned four DRM lists, and both the order of the DRM lists and CRAT problems were carefully counterbalanced to eliminate order effects. The DRM lists and CRAT problems used in this article are provided in the Appendix.

Eight CRAT problems were selected from the normative data produced by Bowden and Jung-Beeman (2003) for adults and the norms we collected for children. We selected those CRATs whose solution rates were 30% or more for inclusion in these experiments. The CRATs selected for the adults have similar solution rates. For each of the selected CRATs, a DRM list was also used, each consisting of 13 associates of the critical lure (associates that overlapped with the CRAT cue words were eliminated from each DRM list so that none of the presented DRM associates overlapped with the three cue words used in the CRAT problems; see Appendix). Lists were selected because their critical lure was the same as the solution word used in the selected CRAT problem. DRM lists were taken either from standard sources (Roediger, Watson, McDermott, & Gallo, 2001) or were developed based on the normed associates created by Nelson, McEvoy, and Schreiber (1998). Lists were randomly divided into two groups of four. Participants were primed on half the DRM lists first and then completed all eight CRAT problems. The two sets of four DRM lists were equated on backward associative strength (BAS) (List set 1 BAS = .189; List set 2 BAS = .186).

We also controlled for other word characteristics known to affect children’s and adults’ memory. Word frequency values were taken from the English Lexicon Project (Balota et al., 2007), and concreteness, familiarity, and meaningfulness values were obtained from the Colorado norms (Toglia & Battig, 1978). Analyses of variance (ANOVAs) were conducted in order to insure that the DRM lists chosen for each age group were matched across ages for BAS, word frequency, concreteness, familiarity, and meaningfulness (all *F*s < 1). Like the DRM lists, we also controlled the CRATs for word frequency (the English Lexicon Project, Balota et al., 2007) as well as concreteness, familiarity, and meaningfulness (the Colorado norms, Toglia & Battig, 1978). ANOVAs were conducted to insure that CRAT problems were matched across age groups for BAS, word frequency, concreteness, familiarity, and meaningfulness (again, all *F*s < 1).

Participants were given four out of the eight DRM lists in a randomized order. Each list was presented verbally, followed by a distractor task (counting backwards by threes for 30 seconds for adults and a symbol matching task for children), and were then asked to orally recall as many words as they could remember from the list. Recall was self-paced and was terminated after participants were unable to remember any new items, even when prompted for more items. Once this had been repeated for each of the four lists, participants completed all eight CRAT problems. Participants were first given an example, followed by two practice CRAT problems before they began. Each CRAT was presented on a computer screen and verbally, in random order, and participants were asked to provide a verbal solution. If participants failed to correctly solve a CRAT, they were given feedback as to the correct answer after each problem. Solution times were measured from the problem onset to the time the participant gave their response, with participants having a maximum of one minute to complete the problem before they were considered to have failed to solve the problem.

## Results and Discussion

False memory rates were comparable to other studies using recall measures (e.g., Howe et al., 2009) with adult participants falsely recalling the critical lure an average of 68% of the time and children 52% of the time. This difference was statistically reliable, $t(59) = 4.58$, $p < .01$, and confirms the usual increase in spontaneous false memories from childhood to adulthood. The mean CRAT solution rates (proportions) and the mean CRAT solution times (seconds) were calculated for each participant and analyzed separately in a series of 2(Age: 11- and 18-year-olds) x 3(Priming: primed/FM, primed/No-FM, and unprimed) analyses of variance (ANOVAs). For primed CRAT problems, solution rates and solution times were conditionalized on whether the participant had produced the critical lure during recall (i.e., primed/FM = critical lure produced and primed/No-FM = no critical lure produced). Thus, both solution rates and solution times were subjected to separate ANOVAs where the only factor was solution type (unprimed vs. primed/No-FM vs. primed/FM). The data are shown in Table 2.

Concerning solution rates, there was a main effect for priming, $F(2, 64) = 16.80$, $p < .001$, $(^{2}_{p} = .344$, where post-hoc tests (Tukey's LSD) showed that solution rates were higher for primed/FM problems ($M = .86$) than primed/No-FM ($M = .67$; $p < .01$) and unprimed ($M = .64$; $p < .01$) problems, and the latter two did not differ. As expected given our use of child-normed CRATs, there was no main effect for age, where children ($M = .70$) and adults ($M = .76$) solved similar numbers of CRATs.

Concerning solution times, there was a main effect for priming, $F(2, 64) = 13.04$, $p < .001$, $(^{2}_{p} = .289$, where post-hoc tests (Tukey's LSD) showed that solution times were faster for primed/FM problems ($M = 18.02$) than primed/No-FM ($M = 24.67$; $p < .01$) and unprimed ($M = 28.49$; $p < .01$) problems, and the latter two did not differ. Like solution rates, we did not expect any effects of age on solution times given the child-friendly nature of our CRATs. Indeed, no age differences were observed with children's average problem solving time being 23.33 seconds and adults' being 24.12 seconds.

The findings from this study are the first to demonstrate that false memories can prime insight-based problem solving in both children and adults. It was clear that when problem solutions were primed by the prior presentation of DRM lists whose critical lures were falsely remembered and that were the solution to that problem, both the probability of, and speed with which, such problems were solved improved significantly. This was true regardless of whether the problem solvers were children (11-year-olds) or adults (18-year-olds). Key to this finding is that it was not simply the presentation of the DRM list that primed the problem solution, but rather, the participant must also have falsely remembered that item as one having been presented in the list. That is, the false memory must become part of the "presented" list and be recalled along with the items that were actually presented. Importantly, we are not claiming that it is the memory test itself that is key to priming CRATs, although such testing does "reactivate" DRM associates and critical lures that are remembered. Rather, activation of the critical lure due to priming from the DRM list must have achieved sufficient strength to exceed a threshold that produces false remembering. Thus, the memory test serves simply as a proxy measure for activation strength of the critical lure that was primed by the DRM associates, activation which in turn primes solutions to CRAT problems.

These findings are important in two senses. First, they extend the domain of false memory priming from their benefits on other (implicit and explicit) memory tasks to benefits in higher cognitive (problem solving) processes. Second, they have uncovered an important, developmentally invariant precondition for the effectiveness of false memories as primes (at least for problem solving tasks), namely, that false memories must become sufficiently activated that they become part of the output queue on memory tests.

How can we know whether the observed effects are due to the generation of false memories at encoding, the activation of the critical lure during retrieval, or both? To answer this question we need to establish that priming occurs even when the recall test is absent. The conundrum here, however, is that changes in problem solving were observed only when the critical lure was sufficiently activated in memory that it was falsely remembered. Because problem solving is only enhanced under these conditions, the recall test is needed to determine which problems will benefit from priming. Because such tests must come after encoding but before problem solving, the act of retrieval is confounded with changes in CRAT solutions. To show that these effects are due to priming from the activation of the critical lure during list encoding and not during retrieval, we need to find a way to dissociate these effects.

## Experiment 2

To resolve this problem, consider three issues. First, because there is a growing consensus that false memories are generated during the encoding phase of the DRM task and not during retrieval (see Dewhurst, Bould, Knott, & Thorley, 2009), the likelihood that the critical lure was generated only during the recall test itself is relatively low. Although there is little doubt that the act of recalling an item during a memory test enhances its activation at that time, we argue that the main priming effect came from the generation of the critical lure during encoding.

Second, Experiment 1 showed that in order to properly conditionalize problem-solving success there needs to be a prior test of memory. The problem here is that simply switching the type of test (e.g., using recognition rather than recall) will not help. Indeed, recognition tests can cause additional problems because they require the problem solution (i.e., the critical lure) be presented prior to the problem itself. Thus, if problem solving is enhanced we cannot know whether this was due to the critical lure being generated during encoding, it having been presented on a recognition test, or both. It was because of this additional problem associated with recognition tests that we chose to use recall in Experiment 1.

Third, rather than interpose a memory test between DRM list presentation and the CRAT task, we could have followed list presentation with the CRAT task and then conduct the memory (recall or recognition) test. Unfortunately, this too introduces a new set of problems. Specifically, performance on the memory test (i.e., false recall or recognition of the critical lures in question) is now confounded with both of the prior tasks, list presentation and the CRAT. Here, any increased acceptance rates for critical lures on a later memory test could be due to generation of the critical lure during list encoding, generation of the critical lure as the solution to the CRAT during problem solving, or both. It was because of this addition problem that we opted to administer the recall test between list encoding and problem solving in Experiment 1.

Given these considerations, it may be that the methodology used in Experiment 1 is the least problematic. However, this does not alleviate the problem that falsely recalling the critical lure on the memory test can increase its activation level and may have contributed to the findings we obtained in the first experiment. In order to avoid this inevitable confound, we conducted an experiment without the intervening memory test where participants were presented DRM lists and then solved problems. Unfortunately, although this solution does remove the memory test confound, it is not ideal because we cannot discriminate between problems that were solved when false recollection of the critical lure occurred versus when it did not. However, in light of prior evidence that participants are likely to generate a sufficient number of false memories during encoding even in the absence of a memory test, we anticipated that the primed CRATs should be solved at a higher rate and more quickly on average than those CRATs that were not primed. By removing the possibility that priming could be an artifact of a preceding memory test, we can evaluate the role of priming at encoding but we lose the analytical precision of our first experiment.

## Method

### *Participants*

A new sample of 11 children (*M* = 10 years, 8 months; *SD* = 4 months) and 11 adults (*M* = 18 years, 5 months; *SD* = 8 months) participated in the experiment. Parental consent was obtained for all child participants as well as their own assent on the day of testing. Adult participants provided written informed consent prior to the study. Child participants were drawn from predominantly White, middle-class schools. All participants were fluent in English.

### *Design, Materials, and Procedure*

The same basic design, materials, and procedure were employed here as in Experiment 1. A within-participant design was used where each participant was primed on half of the CRAT problems with a preceding DRM list whose critical lure was also the solution to one of the CRAT problems. No memory tests were administered so participants first studied a list that was presented verbally and were then given the age-appropriate distractor task. Once this had been repeated for each of the four lists, participants completed all eight CRAT problems as before.

## Results and Discussion

Because no memory test was administered, we cannot assess false memory rates. The mean CRAT solution rates (proportions) and the mean CRAT solution times (seconds) were calculated for each participant (see Table 3) and analyzed separately in a series of analyses of variance (ANOVAs). Again because there was no memory test, the analyses focused solely on primed (list presented) versus unprimed (no list presented) CRAT solution rates and solution times. For purposes of comparison, we have added collapsed primed and unprimed statistics from Experiment 1 in Table 3. As anticipated, the trends were similar regardless of whether or not a memory test preceded CRAT problems. Below, we present the analyses for the Experiment 2 data.

Concerning solution rates, there was a main effect for priming, $F(1, 20) = 86.81$, $p < .001$, ($^{2}_{p}$ = .813, where solution rates were higher for primed problems (*M* = .79) than unprimed problems (*M* = .56). Concerning solution times, there was also a main effect for priming, $F(1, 20) = 64.67$, $p < .001$, ($^{2}_{p}$ = .764, where solution times were faster for primed problems (*M* = 18.76) than unprimed problems (*M* = 28.79). As expected given the use of age-normed materials, there were no main effects for age or any Age x Priming interactions.

What these results show is that even in the absence of an intervening memory test, participants performed better on CRATs that were primed than those that were not primed. Apparently, the problem solving advantage observed in Experiment 1 was due mainly to false memory generation at encoding and was not the result of retrieval processes on an intervening recall test.

## General Discussion

Together, these results are consistent with earlier findings with adults (Howe et al., in press) and are the first to show that false memories, if sufficiently activated during encoding to be erroneously produced on a retrieval test, can prime both children’s and adults’ insight-based problem solving. Moreover, these developmentally invariant priming effects are not due to administering a recall test prior to the problem-solving task, but rather, are due to participants generating the critical lures at encoding.  These effects were observed both in terms of problem solving success rates as well as the speed with which problems were solved.

This outcome is similar to findings in which falsely recalled critical lures facilitate performance on related implicit and explicit memory tests (McDermott, 1997; McKone & Murphy, 2000) and are consistent with spreading activation models of false memory illusions (e.g., Howe et al., 2009; Roediger & McDermott, 1995; Underwood, 1965).  Here, critical lures become highly activated during encoding of related list items ("superadditive priming" – see Hancock, Hicks, & Marsh, 2003) and this activation causes participants to, at the very least, falsely remember them as part of the studied list and at most to consciously think of the critical lure word.  The importance of the present research is that it extends the domain of false memory priming effects beyond changes on related memory tests to priming answers on more complex, problem-solving tasks.  Moreover, these findings are the first to demonstrate that false memories not only prime adults' problem solving but serve the same purpose in children's performance on insight-based problem-solving tasks.  Although we intentionally used CRATs that were age-normed, ones that were rated by both children and adults as being relatively easy to solve, these age invariant effects are nonetheless important.  Indeed, these findings are consistent with the idea that similar spreading activation mechanisms may be operating in both DRM memory illusions and insight-based problem solving in children as well as adults.

Our results have other important implications.  First, although there exist clear differences between true and false memories (Roediger & McDermott, 1995), the current findings add to the growing literature suggesting that false memories can exhibit effects very similar to that observed for true memories (Diliberto-Macaluso, 2005; Kokinov, 1990).  Second, the results add to an emerging consensus that false memories, like false beliefs (McKay & Dennett, 2009), can have beneficial effects in human cognition (Howe & Derbish, 2010) and not simply the negative consequences we are all familiar with in the forensic (e.g., eyewitness memory) literature.  Although some may interpret false memories as negative regardless of their subsequent "use", we believe that this by-product of a powerful reconstructive memory system is positive (also see Howe et al., in press).  Indeed, we think the current research has taken us a step closer to realizing at least one beneficial aspect of false recollection and that it has helped establish that false memories, like true memories, can and do provide significant advantages when it comes to more complex cognitive processes, specifically insight-based problem solving for both children and adults.

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## Appendix: DRM Lists and CRAT Problems

DRM lists and CRAT Problems Used for 11-year-olds.

| DRM | CRAT |
|---|---|
| BLACK – white, dark, cat, charred, night, color, grief, death, ink, bottom, coal, brown, gray. | BLACK – mail, board, jack. |
| COLD – hot, snow, warm, winter, ice, frigid, chilly, heat, weather, freeze, shiver, arctic, frost. | COLD – sore, feet, war. |
| LION – tiger, circus, jungle, den, Africa, mane, cage, feline, roar, fierce, bears, hunt, pride. | LION – cub, tamer, king. |
| SLEEP – bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, yawn. | SLEEP – walk, beauty, over. |
| CHAIR – table, sit, legs, seat, couch, desk, recliner, sofa, wood, swivel, stool, sitting, bench. | CHAIR – rocking, wheel, high. |
| SPIDER – web, insect, bug, fright, fly, arachnid, crawl, tarantula, poison, creepy, animal, ugly, feelers. | SPIDER – widow, bite, house. |
| NEEDLE – pin, eye, sewing, sharp, point, prick, thimble, haystack, thorn, hurt, injection, syringe, knitting. | NEEDLE – thread, pine, knitting. |
| SWEET – sour, candy, sugar, bitter, good, taste, nice, honey, soda, chocolate, cake, tart, pie. | SWEET – tooth, sixteen, heart. |

DRM lists and CRAT Problems Used for 18-year-olds.

| DRM | CRAT |
|---|---|
| APPLE – core, orchard, pear, pie, fruit, banana, rotten, Newton, cobbler, orange, juice, peach, plum. | Apple – pine, crab, sauce. |
| BLACK – white, dark, cat, charred, night, color, grief, death, ink, bottom, coal, brown, gray. | BLACK – mail, board, jack. |
| COFFEE – caffeine, tea, cafe, drip, cup, grind, mug, cream, doughnut, instant, sip, sugar, cups. | COFFEE – break, bean, cake. |
| GUN – pistol, trigger, weapon, bullet, rifle, shoot, shot, bang, hunting, cannon, piston, gangster, violence. | GUN – fight, control, machine. |
| PEN – pencil, write, fountain, leak, quill, felt, Bic, scribble, crayon, Cross, tip, marker, cap. | PEN – knife, light, pal. |
| MOON – crescent, crater, astronaut, star, sun, earth, rocket, midnight, half, | MOON – shine, beam, struck. |

gravity, telescope, sunset, astronomy.
FOOT – shoe, hand, toe, kick, sandals, soccer, yard, walk, ankle, arm, boot, sock, knee.
TREE – oak, sap, stump, leaf, pine, forest, elm, branch, leaves, moss, bush, maple, Christmas.

FOOT – hold, print, stool.
TREE – palm, show, house.

Authors' Note

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