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RUNNING HEAD: FALSE MEMORIES AS PRIMES

Priming Older Adults and People with Alzheimer's Disease Analogical Problem-solving with True and False Memories

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Abstract

We investigated the extent to which activation of specific information in associative networks during a memory task could facilitate subsequent analogical problem solving in healthy older adults as well as those with early onset Alzheimer's disease. We also examined whether these priming effects were stronger when the activation of the critical solution term during the memory task occurred when the item was actually presented (true memories) or when this item arose due to spreading activation to a related but nonpresented item (false memory). Older adult controls (OACs) and people with Alzheimer's disease (AD) were asked to solve 9 verbal proportional analogies, 3 of which had been primed by Deese/Roediger-McDermott lists where the critical lure (and problem solution) was presented as a word in the list (true memory), 3 of which were primed by DRM lists whose critical lures were spontaneously activated during list presentation (false memory), and 3 of which were unprimed. As expected, OACs were better (both in terms of speed and accuracy) at solving problems than people with AD and both groups were better when false memories were primes than when true memories were primes or there were no primes. There were no reliable differences between unprimed and true prime problems. These findings demonstrate that (a) priming of problem solutions extends to verbal proportional analogies in OACs and people with AD, (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: Alzheimer's disease, analogical reasoning, DRM paradigm, false memory, priming problem solving

Introduction

Alzheimer's disease (AD) has been described as a progressive neurodegenerative disorder where learning and memory performance has been reduced, as well as rapid forgetting of new information (Malone, Deason, Plumbo, Heyworth, Tat, & Budson, 2018). As well as memory loss, patients with AD also have a higher rate of memory distortions and false memories, in which patients remember an incorrect memory that is believed to be true. For example, people with AD may have thought that they had turned off their stove when they simply misremembered that they turned off the stove.

The DRM paradigm has become an essential procedure used to study false memories (e.g., Akhtar, Howe, & Hopestine, in press; Gilet, Everard, Colombel, et al., 2017). Typically, the memory task consists of a study phase during which participants are presented with lists of associatively related words (e.g., vehicle, keys, ford, road) that are also strongly associated with a critical lure (CL) that is never presented (i.e., car), followed by a free recall or recognition task. The typical result is that participants falsely remember the CL at a rate commensurate with that for memory for the actually presented items.

In healthy participants, results robustly show a strong tendency to recall and recognize the CLs falsely, thus creating false memories (e.g., Akhtar et al., in press; Balota, Watson, Duchek, & Ferraro, 1999; Deese, 1959; McDermott, 1996). Research using the DRM paradigm in healthy older adults regularly shows an increase in false recall and recognition of CLs relative to healthy younger adults (e.g., Balota et al., 1999; Dehon & Bredart, 2004: Dennis, Kim, & Cabeza, 2007; but see McCabe & Smith, 2002 and Thomas & Sommers, 2005, for contradictory results). Several studies have used the DRM paradigm in people with AD (see Akhtar et al., in press). Whilst some studies have shown that AD people recall more CLs thus producing more false memories than healthy older adults (e.g., Devitt & Schacter

2016; Watson, Balota, & Sergent-Marshall, 2001). Several other studies have found contrasting results, thus showing that AD patients produce or recognize fewer or as many CLs as older healthy participants (Akhtar et al., in press; Balota et al., 1999; Budson et al., 2002; Gallo 2006; Waldie & Kwong See, 2003). Although this discrepancy exists in the literature, in the present study we were not concerned with examining this directly. We are interested in whether false memories can be elicited in OACs and people with AD, and if so whether they can be useful in a subsequent task (e.g. Akhtar et al., in press) as they are in children (Howe et al., 2011, 2013, 2016).

A number of theories have been proposed to explain how false memories are formed. The activation-monitoring theory (see Roediger, Watson, McDermott, & Gallo, 2001) is considered the more dominant theory (see Gallo 2010 for a review). The theory proposes false memories are produced because of two distinct processes; an activation process and a source-monitoring process. If we consider the DRM task, because the presentation of each of the lists of words automatically activates the related but unpresented CL, the CL is activated many times through an automatic spread of activation within the associative network. It's this activation that increases the feeling of familiarity for the item, whilst at the same time reducing the ability to remember the source of its activation (source-monitoring process). Thus, according to this theory, in order for OACs and people with AD to form false memories, they must have intact associative networks.

More generally, false memories have traditionally been viewed as negative, particularly in aging adults (e.g., Devit & Schacter, 2016; Malone et al., 2018). However, recent research has demonstrated that the production of false memories need not always have negative implications (Akhtar et al., in press; Howe, 2011; Howe, Garner, Dewhurst, & Ball, 2010; Howe, Garner, Charlesworth, & Knott, 2011; Howe, Threadgold, Wilkinson, Garner, & Ball, 2017). Akhtar et al. (in press) were the first to carry out research investigating the role that false memories play in priming insight-based problem solving using compound remote associate tasks (CRATs) (see Mednick, 1962) in OACs and people with AD. CRAT problems, originally developed by Mednick (1962), involve the presentation of three words (e.g., *pal*, *tip*, and *knife*) and the task is to come up with a word (i.e., *pen*) which, when combined with each of the three original words, creates compound words or common phrases (i.e., *pen pal, pen tip, pen knife*). Akhtar et al. (in press) presented OACs and people with AD with DRM lists whose critical lures served as potential primes for half of the subsequent CRAT problems that participants had to solve. They found that when participants falsely remembered the CLs of the studied DRM lists, the corresponding CRATs were solved more frequently and significantly faster than CRATs that had not been primed or cases in which DRM lists had been presented but CLs were not falsely remembered. Howe et al. (2010, 2011) showed similar findings in young adults and children. This research demonstrates that like true memories, false memories can successfully prime higher order cognitive tasks (i.e., insight-based problem solving).

The aim of the current research was to establish whether priming with false memories could also be applied to more complex reasoning tasks 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., *ring* is to *finge*r as *bracelet* is to *wrist*). 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 (Stenberg, 1977) and academic examinations such as statutory assessment tests. Importantly, Howe, Threadgold, Norbury, Garner, and Ball (2013) showed that false memories can prime analogical problem solving in both child and young adult populations (also see Howe, Garner, Threadgold, & Ball, 2015).

We were also interested in whether true and false memory priming both enhance the speed and accuracy of analogical reasoning in OACs and people with early onset AD when problem difficulty is equated across groups. We know from Akhtar et al. (in press) that people with AD produce false memories that they can subsequently use in a positive way to help solve insight-based problems. Here, we extend these findings in two ways. First, we examined whether OACs and people with AD have intact associative networks that lead to the activation of false memories that can be used to prime analogical problem solving. Recent research (e.g., Akhtar et al., in press; Evrard, Colombel, Gilet, & Corson, 2016; Gilet et al., 2017; Roediger et al., 2001) has shown both older adults and people with AD do have intact associative networks that lead to the activation of false memories. Second, we examined whether OACs and people with AD can use not only false memories as primes when solving analogies but also true (actually presented words) memories as effective primes when solving analogies.

Experiment 1: Norming Verbal Analogies

Norms for the relative difficulty of various analogical reasoning problems have been produced using either children or young adults as participants. In order determine the relative difficulty of analogical reasoning problems for older adults, we first had to create our own age-appropriate norms for older adults. We did this by having an independent sample of older adults solve various analogies and then selected ones whose baseline solution rates were moderate (30% to 80%; see Appendix) for older adults for use in our second experiment.

Method

Participants. A total of 45 healthy older adults (10 males and 35 females) took part in this experiment. Their mean age was 74.77 (*SD* = 5.56). The older adults had normal cognitive functioning (as assessed by the Mini Mental State Examination, MMSE; Folstein, Folstein, & McHugh, 1974) with a mean score of 28.39 (*SD* = 1.01), normal activities of daily living, and most importantly, did not meet diagnostic criteria for dementia. These older adults were volunteers who were community dwelling and were tested in their own home or local community centre.

Materials. Older adults were presented with, in randomized order, 20 analogical problems. The format of the problems was '*a* is to *b* as *c* is to ?' Participants were instructed to provide one response and had a maximum time of 60 seconds after which the next analogical problem appeared on the screen. If participant could not think of a response, they were instructed to click next. (Note that only problems with solution rates above 30% and solved within 30 seconds were selected for subsequent use in Experiment 2.) All the solution words had a familiarity rating of 500 or above (with a maximum entry of 645 and a mean of 566 (Coltheart, 1981)) and a word frequency of 10 or above (with a maximum entry of 686 and a mean of 126 (Kucera & Francis, 1967)).

Procedure. Participants were tested individually in a quiet room. Instructions similar to those used by Howe et al. (2013) were given. Specifically, participants were told that they will be presented with a word analogy (e.g., *hat* is to *head* as *sock* is to _____) and are advised to attempt to solve the analogy (i.e., *foot*). Participants were first given three demonstrations by the experimenter followed by two practice problems prior to the experiment itself. The analogical problems were presented on a computer laptop screen simultaneously in a horizontal orientation. Participants were given 30s to produce the solution (this was a verbal solution) and their first response was recorded. If the solution was produced within the time limit, both the solution word and solution time were recorded and the next problem was presented. If participants did not produce the correct response within the time limit, the solution was provided by the experimenter and the program automatically moved to the next problem.

Results

Table 1 shows the average solution rates and times to the 20 problems separately. As can be seen, older adults were able to solve most of the analogical problems. Importantly, for the next experiment, there was a good range of solution rates and times to the analogical problems. What this means is that priming effects, should they exist, can be measured without constraints imposed by floor and ceiling effects.

INSERT TABLE 1 ABOUT HERE

Experiment 2: Examining Priming Effects in Older Healthy Adults and those with AD

With these norms in hand, we now turn to the main questions. That is, can both true and false memories prime solutions to analogical problems in healthy older adults and people with AD.

Method

Participants. A new sample of 60 participants was recruited whose demographic and other characteristics are shown in Table 2. Thirty participants had a clinical diagnosis of probable or possible AD (McKhann, Drachman, Folstein, Katzman, Price, & Stadlan 1984). Thirty participants made up an older adult control (OAC) group. These people were community dwelling and were recruited from a panel of older adults who had expressed an interest in participating in research. Nine participants were excluded from analysis due to Mini-Mental Status Exam (Folstein, Folstein, & McHugh, 1975) scores indicated moderate AD rather than early AD (< 20; Rosa, Deason, Budson & Gutchess, 2014). Six controls were also excluded from analysis due to age (<60 years, and thus not aged matched), leaving 24 OACs (8 males and 16 females) and 21 early onset AD (5 males and 16 females) participants. Older healthy adults gave their written informed consent. For people with AD, written informed consent was given either by them or their primary caregivers.

There were no significant differences between OAC's and AD participants on age and years of education, but the groups differed on most cognitive tests (see Table 2).

Design

A 2 (Group: AD or OAC) x 3 (Priming: true memory prime, false memory prime, or unprimed) mixed design was employed. Group was a between-participants factor, and priming of solution was a within-participant factor. Primed problems were analysed for those participants who either correctly recalled the presented critical lure (true memory priming) or falsely recalled the critical lure (false memory priming) or when the solution was unprimed.

INSERT TABLE 2 ABOUT HERE

Materials and procedure. We followed the same procedure as Howe et al., (2013), see figure 1. There were nine DRM lists selected to use in this experiment selected from Roediger, Watson, McDermott, & Gallo, 2001). Each DRM list consisted of 12 words (e.g., shoe, hand, toe, walk) and was associated with an unpresented target or 'critical lure' item (e.g., foot). The lists for false memory primes contained 12 associates of the unpresented critical lure. Lists for true memory primes (words actually presented) contained 11 of these associates, with the lowest associate being replaced with the critical lure to that list in the first presentation position (see Howe et al., 2013). 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, a situation that would lead to it being self-generated 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 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 in determining the probability of producing false memories) of the list did not vary greatly between the true and false memory priming conditions. Associative 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 part of any subsequent analogy items (see Appendix). The Experiment had 3 stages: study phase, recognition test, and analogy problem task.

Study phase. 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 to three of the subsequently presented analogies (i.e., the first presented item in the list was the critical lure/analogy solution) and three of the lists did not contain the critical lure to three of the subsequently presented analogies (i.e., the critical lure/analogy solution would be the associated but unpresented critical lure to 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). Following this, the next list was presented and this sequence of study-distractor continued until all six lists were completed.

Recognition test. Once participants had completed all six DRM lists, they completed a recognition task whereby participants were verbally presented with the 6 critical lure words (3 true and 3 false words) from the studied DRM lists, 6 unstudied and unrelated critical lure words (these were critical lures taken from unrelated and non-presented DRM lists), 32 list items (these were studied words from the presented DRM lists), 32 unrelated words (these were words taken from unrelated and non-presented DRM lists; unrelated foils), and 6 related but unpresented items (these were weakly related words that were from the presented DRM lists but that had not been presented during study; weakly-related foils). All items in the recognition test were taken from Roediger et al. (2001). A recognition test was implemented rather than a recall test to reduce effects of priming during retrieval (Olszewska & Ulatowska, 2013). For each word presented in the recognition task, participants had to select either [O], indicating that the word was Old and that they recognize the word from the previously presented lists, or [N] if they thought the current word presented was a new word that they did not hear in the previous word lists.

Analogy problems task. Finally, participants solved a practice analogical reasoning problem before completing nine test analogical reasoning problems (using the same procedure as Experiment 1). Participants were presented with, in a randomized order, the nine analogical reasoning problems in the format of '*a* is to *b* as *c* is to ?' For example, the analogy for the critical lure 'foot' was '*hat* is to *head* as *sock* is to _____.' 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. 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 s to provide an answer. 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 group in each solution-type condition. A diagram of the entire procedure is depicted in Figure 1.

INSERT FIGURE 1 ABOUT HERE

Results

Recognition task

The recognition task showed that both the OACs and people with AD created false memories for the critical lure words, with people with AD falsely recognizing the critical lure 63% (M = 1.91, SD = 0.67) of the time and the OAC group 61% (M = 1.85, SD = .81) of the time. There were no reliable group differences (t ns).

Overall recognition scores were analyzed using a 2 (Group: AD vs. OAC) x 4 (list type: critical lures, unstudied unrelated critical lures, foils, and list items) mixed model ANOVA. Analysis revealed a significant main effect of list type, $F(1, 44) = 492.19$, $p < .001$. Pairwise comparisons revealed greater recognition for list items (78.8%) compared to foil items [correctly identifying these as 'New' items, (70.5%) (M = 25.21, SD = 3.16 vs M = 22.58, SD = 6.115)] and greater recognition of CL words (73.6%) compared to unrelated CL words (44.5%) (M = 4.42, SD = 1.18 vs M = 2.67, SD = 1.22). There was a main effect of group $F(1, 44) = 18.76$, $p < .001$. To investigate this further we ran separate t-tests on list types; for list items the OAC group recognised significantly more items (M = 26.61, SD = 2.27) than people with AD (M = 23.6, SD = 3.31) t (44) = 3.5, p<.001. Concerning Foil items again the OAC group recognised significantly more items (M = 24.48, SD = 6.62) than people with AD (M = 20.4, SD = 4.74), t (44) = 2.28, p<.05. There were no reliable group differences for critical lures and unrelated critical lures t (44) = 1.18, P>0.05.

Signal detection measures

Because false alarm rates for recognition tests often require a correction for response bias, we analyzed discrimination and response bias scores using signal detection analysis. We used the Snodgrass and Corwin (1988) correction for signal theory (SDT), whereby 0.5 was added to hit and false alarm rates and the corrected score was divided by $N + 1$. This was used in order to prevent values of 1.0 and 0. For discriminability (d'), larger values indicate better memory performance, and for criterion value C, values greater than 0 represent a conservative bias and less than 0 represents a liberal bias. The calculation of d' and C for critical lures and hits used the common false alarm rate for unrelated critical lure.

The values of d' and C are shown in Table 3. Signal detection measures for hits and critical lures were analysed in separate 2 (Group: AD vs OAC) X 2 (list type: critical lures vs studied items) mixed-model ANOVA. The analysis of d' revealed a main effect of list type, where by discriminability was better for critical lures compared to list items, $F(1, 44) = 46.67$, $p < .001$, $\eta^2_p = .17$. There was no main effect of group and no interaction (p ns).

Analysis of the criterion C revealed a more liberal bias for the critical lures $F(1, 44) = 8.301$, $p < .001$, $\eta^2_p = .53$ compared to studied items. There was a main effect of group $F(1, 44) = 26.53$, $p < .001$, $\eta^2_p = .39$ whereby people with AD revealed a more liberal bias compared to OACs. There was no significant interaction.

INSERT TABLE 3 ABOUT HERE

The mean analogy solution rates (proportions) and the mean analogy solution times (in seconds) were calculated for each participant and analyzed separately in a series of 2 (Group: OAC vs. AD) x 5 (Priming: primed/FM vs. primed/no-FM vs. primed/TM vs. primed/no-TM vs. unprimed) ANOVAs. Note that these problem solving data are conditionalized on memory performance. That is, primed/FM refers to analogy problems that were solved correctly only when the related false memory was recognized on the memory test and primed/no-FM refers to problems solved when the DRM list was presented but the participant did not falsely remember the critical lure on the recognition test. Primed/TM refers to analogy problems that were solved correctly only when the true memory was recognized on the memory test and primed/no-TM refers to problems solved when the DRM list was presented but the participant did not remember the actually presented critical lure on the recognition test. Of course, unprimed refers to analogy problems that were solved correctly when no DRM priming list was presented.

Analogy Solution Rates

Concerning solution rates, there was a main effect for priming, $F(4, 44) = 48.02$, $p < .001$, $\eta^2_p = .32$, where post-hoc tests (Tukey's HSD) showed that solution rates were higher for primed/FM analogical problems ($M = 2.83$) than for primed/no-FM ($M = 1.96$, p = <.01), primed/TM ($M = 1.93$, $p = < .01$), primed/no-TM ($M = 1.83$, $p = < .01$) and when participants were unprimed ($M = 1.90$, $p = < .01$), with the latter 4 conditions not differing. As expected, there was a main effect of group, $F(1, 44) = 8.16$, $p < .001$, $\eta^2_p = .24$, where post-hoc tests (Tukey's HSD) showed the OACs solved reliably more problems compared to people with AD (see Table 4). There was no significant interaction.

INSERT TABLE 4 ABOUT HERE

Analogy Solution Times

As anticipated, there were significant differences in solution times as a function of group and priming. Specifically there was a main effect for priming, $F(4, 44) = 103.28$, $p <$ .001, $\eta^2_p = .544$, where post-hoc tests (Tukey's HSD) showed that solution times were faster for primed/FM problems ($M = 3.52$ sec) compared to primed/No-FM problems ($M = 5.49$, p

< .01), primed/TM problems (*M* = 5.33 sec, *p* < .01), primed/no-TM problems (*M* = 5.56 sec, *p* < .01), and unprimed analogical problems (*M* = 5.59 sec, *p* = < .01), with the latter 4 conditions not differing. There was a main effect of group, $F(1, 44) = 79.51$, $p < .001$, $\eta^2_p = .694$, where post-hoc tests (Tukey's HSD) showed OAC's solution times were faster (*M* = 4.01 sec) compared to people with AD (*M* = 5.77 sec, *p* < .01), (see Table 4). The interaction was not significant.

General Discussion

The present study set out to extend the positive consequences of false memories using verbal proportional analogies, in healthy older adults and people with Alzheimer's disease. Although this effect has been shown in CRAT problems in OACs and people with AD (Akhtar et al., in press), it is not clear whether such effects extend to problem-solving tasks that are more complex. Nor is it clear whether false memories serve as better primes for problem solving than true memories. To investigate these issues, participants were asked to solve verbal proportional analogies, three of which had been primed by a true memory, three of which were primed by a false memory, and three of which were unprimed. Our findings provide a unique and important demonstration that false memories are more effective at priming solutions to analogical problems than true memories for OACs and people with AD.

An important aim of the current study was to ascertain whether both true and false memory priming could facilitate speed and accuracy of analogical reasoning for both OACs and people with AD. In order to examine this, we needed to show that participants form false memories for DRM lists and that they can remember items that were actually presented. Consistent with previous research, our study showed no reliable differences in the number of false memories produced in the recognition task for OACs and people with AD (Akhtar et al., in press; Roediger et al., 2001; Waldie & Kwong-See, 2003). This finding can be explained by the fact that both older healthy adults and those with AD show intact semantic networks that automatically activate CLs upon DRM list presentation (Akhtar et al., in press; Evrard et al., 2016; Gilet et al., 2017). Both older healthy adults and those with AD have intact semantic networks that automatically activate CLs upon DRM list presentation. Our findings support existing evidence regarding the underlying mechanisms in the production of false memories (Evrard et al., 2016; Gilet et al., 2017; Roediger et al., 2001). Previous research has shown the generation of false memories from the automatic spread of activation within the semantic networks and the corresponding activations of word associations. The findings from the present study further extend this notion, providing evidence that not only are false memories associated with the spreading activation among semantic associates but that they can exert a positive effect when it comes to priming subsequent task performance (McDermott, 1997). Importantly, when a recognition test is administered in this priming paradigm, endorsement of the false memory item vs. no endorsement is an index of the strength of activation of the critical lure in memory. That is, no recognition means that activation is below threshold whereas recognition indicates that this activation is above threshold. Although false memories arise at encoding, test performance reveals the strength of that activation. It also turns out that presenting the critical lure at test has little or no effect on memory strength of the critical lure because, as already mentioned, false memories arise during the encoding, not retrieval, processing (see Howe, Wilkinson, Garner, & Ball, 2016).

It is important to acknowledge, that despite these findings, there exists a large clinical literature showing that there are important semantic deficits associated with Alzheimer's disease and people with MCI (e.g., Hodges, Salmon, & Butters, 1992; Howard & Patterson, 1992). However, despite these deficits, Nebes (1989) and Evard et al. (2015) have shown that semantic priming in Alzheimer's disease has remained relatively intact. Thus, like these latter priming results, our experiments show that when it comes to tasks in which simple, semantic associative processes are engaged automatically, the results of these processes can be used to facilitate subsequent problem solving.

Just like in Akhtar et al. (in press) and Howe et al. (2011), we found that when problem solutions were primed by the prior presentation of DRM lists whose critical lures were falsely remembered and were solutions to those problems, both the probability of such problems being solved and the speed with which they were solved improved significantly for both OACs and people with AD. Thus, DRM lists can prime and facilitate performance on problem-solving tasks both in terms of the rate and the speed which they are solved. Such facilitation was not found when the CL (false memory) was not remembered. Moreover, priming with true memories resulted in problem-solving rates and times identical to conditions in which there was no priming. This further strengthens the notion that false memories are superior primes to true memories and can successfully prime higher cognitive processes (analogical reasoning). Overall then, false memories can have very positive effects on subsequent cognitive tasks at least in terms of problems involving proportional analogies and insight-based solutions, across the lifespan and with people who have AD (Akhtar et al., in press; Diliberto-Macaluso, 2005; Howe et al., 2010, 2011, 2016).

To summarize, regardless of cognitive abilities, speed and solution rates of problem solving were affected by priming – specifically false memory primes. Despite people with AD being slower than the OACs to solve problems (main effect of group), solution rates were reliably higher and solution times were reliably quicker, and by the same magnitude, for both groups for problems that were primed by false memories. No advantage was obtained for priming true memories. This finding has implications not only for priming work but also for the debate surrounding the differences between, and similarities of, true and false memories (e.g., Diliberto-Macaluso, 2005; Roediger & McDermott, 1995). In terms of priming 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.

The fact that only false memory primes were effective in speeding up analogical problem solving has been documented in children and young adults (Howe et al., 2013). One explanation for this advantage relates to the literature concerning the superiority of self-generated information (e.g., spontaneous false memories) over other-generated information (e.g., experimenter presented true memories) that is seen more generally in memory (e.g., Howe et al., 2013). Self-generated information is better retained than other-generated information in both groups in the present study and has been well documented in young adults (e.g., Howe et al., 2013; Mulligan & Lozito, 2004) and children (Howe et al., 2013). If critical lures from DRM lists are not explicitly presented as part of the list (as they were in the true memory condition), then when they are falsely remembered, they 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. Howe et al. (2013) proposed that false memories are stronger than true memories just like 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.

This explanation has considerable currency in the child development literature and given the current results, may hold across the lifespan and for people with AD. Indeed, it would seem that one could propose that the mnemonic benefits of self-referencing and self-generation that are seen in children (e.g., Cunningham, Brebner, Quinn, & Turk, 2014; Ford & Lobao, 2018), young adults (e.g., Mulligan & Lozito, 2004), older adults (for a review, see Gutchess & Kensinger, 2018), and should also extend to older adults with AD (at least in the early stages). In fact, there is some data indicating that self-referencing can play an important role in memory for healthy older adults and those with AD (Klein, Cosmides, & Costabile (2003; Rosa, Deason, Budson, & Gutchess, 2015). This is probably not too surprising inasmuch as some theorists (e.g., Humphreys & Sui, 2016; Sui & Humphreys, 2015) view the self as the very "glue" that binds encoded elements together to create strong and durable traces, ones that are particularly well remembered, and that can be used to benefit other perceptual and cognitive processes. Although additional research on the role of the self in memory with aging populations is surely needed, this idea serves these current data well and knits together our findings with those from the child and young adult literatures.

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Table 1 Analogical Problems: Solution Rates and Times

Analogy Problem	Analogy Solution	% Solved	Solution Time (s)
water is to boat as road is to ?	Car	80.00	3.75 (1.48)
moon is to night as sun is to ?	day	97.14	4.25 (2.32)
hat is to head as sock is to ?	foot	100.00	3.75 (1.46)
rock is to hard as pillow is to ?	soft	91.40	4.04 (1.88)
hare is to fast as tortoise is to ?	slow	91.40	5.16 (3.35)
stand is to floor as sit is to ?	chair	74.20	9.97 (6.06)
tooth is to brush as hair is to ?	wash	65.70	4.23 (1.87)
desert is to hot as arctic is to ?	cold	80.01	4.07 (1.76)
eyes is to see as nose is to ?	smell	97.14	3.98 (3.53)
pestle is to mortar as saucer is to ?	cup	78.57	7.76 (2.68)
school is to teacher as hospital is to ?	doctor	54.28	5.06 (3.42)
aunt is to uncle as queen is to ?	king	88.57	6.05 (2.53)
book is to read as thread is to ?	sewing	79.57	4.7 (4.16)
wardrobe is to clothes as bed is to ?	sleep	48.22	4.78 (1.71)
carrot is to vegetable as apple is to ?	fruit	91.43	3.82 (9.05)
poverty is to wealth as sickness is to ?	health	62.85	7.18 (4.54)
dark is to light as short is to ?	long	37.10	5.37 (6.17)
tunnel is to mountain as bridge is to ?	river	60.00	7.47 (12.15)
fire is to hot as candy is to ?	sweet	74.29	9.52 (1.19)
terrified is to scared as mad is to ?	anger	30.01	14.49 (18.8)

Table 2. Means (and Standard Error) Demographic Characteristics of Participants

	Early AD	OAC	Test Statistic	P value
Age	78.25 (1.46)	78.23 (0.81)	2.85	0.35
Education	13.99 (0.54)	14.01 (0.72)	0.67	0.27
NART	114.22 (1.8)	117.28 (0.94)	2.75	0.15
MMSE (out of 30)	24.64 (2.7)	29.11 (1.07)	18.17	0.001
CERAD				
Immediate (out of 30)	11.09 (2.98)	15.44 (4.23)	10.93	0.001
Delayed (out of 10)	3.15 (1.97)	5.19 (2.32)	12.68	0.001
Recognition (out of 10)	7.22 (1.82)	9.59 (0.26)	15.19	0.001
Digit span (out of 10)				
FWD	5.4 (1.0)	6.5 (1.91)	8.72	0.001
BCK	3.09 (1.1)	5.5 (1.4)	7.83	0.001

Notes. CERAD = Consortium to Establish a Registry for Alzheimer 's disease; Early AD = early onset Alzheimer's Disease; OAC = Older adult controls; MMSE = Mini-Mental State Examination

** Significant *p* <.001

Table 3. Means and Standard deviations of Signal Detection Measures of Discriminability (*d'*) and Bias (*C*) for Studied Items and Critical Lures (CL).

	OACs		AD	
	d'	C	d'	C
Studied	0.7 (0.48)	0.93 (0.41)	0.28 (0.6)	0.5 (0.19)
Lures	0.96 (0.54)	0.29 (0.23)	1.03 (0.11)	0.17 (23.4)

Table 4. Mean analogical problem solution rates and solution times for older adults, Early Alzheimer's patients for false memory priming

Participant	Priming				
	Unprimed	Primed/TM	Primed/no-TM	Primed/FM	Primed/no-FM
Solution times (seconds)					
OAC	4.66 (1.92)	4.55 (1.27)	4.65 (0.59)	2.77 (1.65)	4.7 (0.8)
AD	6.65 (1.57)	6.22 (1.22)	6.47 (1.09)	4.3 (1.74)	6.51 (1.08)
Solution rates (proportions)					
OAC	0.73 (0.58)	0.71 (0.79)	0.7 (0.83)	1 (.0)	0.69 (0.69)
AD	0.53 (0.45)	0.56 (0.73)	0.56 (0.65)	0.79 (.31)	0.55 (0.74)

Note: Standard errors are in parenthesis. FM = False Memory

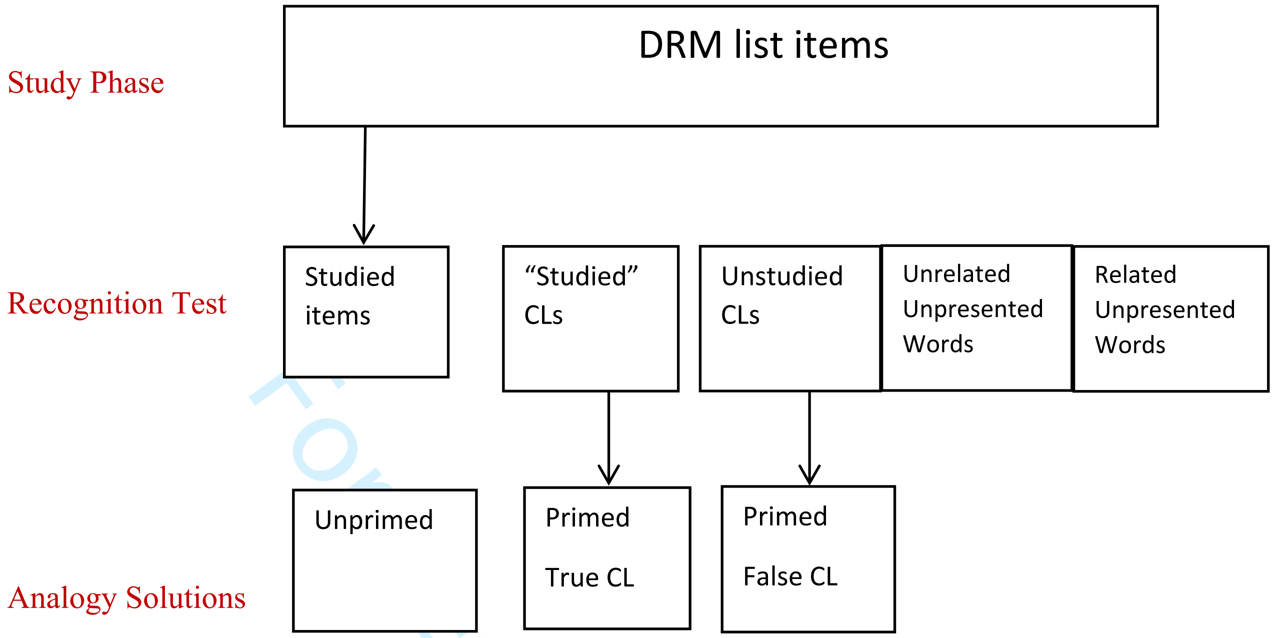

Figure 1. Diagram of the Procedure for Experiment 2 (CL = Critical Lures).

Appendix. Analogies and DRM lists for Experiment 2.

Water:Boat::Road:Car

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

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

Poverty:Wealth::Sickness:Health

Health – sickness, good, happiness, ill, service, strong, disease, body, poorly, pain, vigor, robust

Tunnel:Mountain::Bridge:River

River – water, stream, lake, Mississippi, boat, tide, swim, flow, run, barrage, creek, brook

Fire:Hot::Candy:Sweet

Sweet – sour, sugar, bitter, good, taste, tooth, nice, honey, soda, chocolate, heart, cake

Dark:Light::Short:Long

Long – tall, narrow, John, time, far, hair, island, road, thin, underwear, distance, line

Pestle:Mortar::Saucer:Cup

Cup – mug, tea, measuring, coaster, lid, handle, coffee, straw, goblet, soup, stein, drink