Can False Memories Prime Problem Solutions for Healthy Older Adults and those with Alzheimer 's Disease?

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OBJECTIVES

Recent research has shown that false memories can have a positive consequence on human cognition in both children and young adults. The present experiment investigated whether false memories could have similar positive effects by priming solutions to insight-based problems in healthy older adults and people with Alzheimer's disease.

METHODS

Participants were asked to solve compound remote associate task (CRAT) problems, half of which had been preceded by the presentation of Deese/Roediger-McDermott (DRM) lists whose critical lures were also the solutions to those problems.

RESULTS

The results showed that regardless of cognitive ability, when the critical lure was falsely recognized, CRAT problems were solved more often and reliably faster than problems that were not primed by a DRM list. When the critical lure was not falsely recognized, CRAT problem solution rates and times were no different from when there was no DRM priming.

DISCUSSION

These findings are consistent with predictions from theories of associative activation and demonstrate the importance of automatic spreading activation processes in memory across the lifespan.

Key words: False memory, Priming problem solving, Compound remote associates task, DRM paradigm, Alzheimer's disease

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Alzheimer's disease is characterised by a progressive deterioration of cognitive functioning, and memory disorders are considered to be the earliest and the more serious clinical symptoms of this disease. At the beginning of the disease people with AD commonly exhibit impairments in episodic memory and rapidly forget newly learned information (Baudic, Tzortzis & Barba, 2004). However, numerous neuropsychological studies have reported evidence that semantic memory impairment may occur relatively early in the course of Alzheimer's disease. For example, people with AD retrieve fewer items from a given semantic or letter category on timed verbal fluency tasks (Ober, Dronkers, Koss, Delis, & Friedland, 1986) and perform more poorly on object naming tasks, particularly those involving less common objects with lower frequency names (Kirshner, Webb, & Kelly, 1984). Despite the unequivocal evidence of semantic deficits in Alzheimer's disease, a controversy remains as to whether the semantic deficit stems from a loss of information in the semantic store (Chertkow, Bub & Seidenberg, 1989), or whether the store of semantic memory remains intact in Alzheimer's disease, and the deficit is related to a disturbance in an Alzheimer's disease patient's ability to access and manipulate semantic information (Nebes, 1989).

The semantic priming paradigm has been used to look at changes in semantic memory in Alzheimer's disease. Most studies of semantic priming use a lexical decision task. The lexical decision task is a computerized task composed of a number of trials, each of which is composed of two events: a prime and a target. The prime is often a word for which no response is required. Later, when the target appears on the screen, the participant has to decide as quickly and accurately as possible if it is a real word (e.g., chair) or not (e.g., ignul).

The temporal interval between the presentation of the prime and the presentation of the target is called the stimulus onset asynchrony (SOA). The SOA ideally is short, from a few tens to a few hundreds of milliseconds. When the targets are words, a few of them share a semantic relationship with the prime (e.g., the prime "table" followed by the target "chair"), whereas the others are not related to the prime (elephant-table). The priming effect correspond to the reduction of the response time or the percentage of errors in the trials where the prime and the target are related compared to those where the words do not share a semantic relationship.

Semantic priming effects are generally viewed within the framework of automatic spreading activation in the semantic network. That is, the related prime word activates the subsequently presented target word through their associative links in semantic memory (e.g., Collins & Loftus, 1975). Thus, the presentation of a prime automatically activates related nodes, increasing their accessibility. Therefore, when the prime and target are related, the target word is likely to have received this prior activation and will be recognized more quickly and accurately. This automatic pre-activation of the related words in the semantic network is the cause of the observed facilitation.

Semantic priming effects have been investigated in patients with Alzheimer's disease, with conflicting results. For example, some researchers have found less-than-normal priming (Ober & Shenaut, 1988), other studies report equivalent priming for Alzheimer's disease patients and healthy older adults, with researchers concluding that semantic memory structures are relatively intact in people with AD (Balota & Duchek, 1991; Chertkow et al., 1989, 1994; ; Nebes et al., 1989). Some studies have reported a combination of no priming and normal priming effects (Albert & Milberg, 1989), other studies have reported both normal priming and hyperpriming (greater than normal priming) with researchers concluding either that attentional abnormalities play a role in performance on semantic priming tasks (Hartman, 1991) or that degradation of the semantic network is responsible, where degraded concepts have more to gain from spread of activation than non-degraded concepts (e.g. Chertkow, Bub, & Seidenberg, 1989).

In addition to semantic and episodic deficits, people with AD exhibit a higher incidence of memory distortions compared to their cognitively healthy older peers. These memory distortions can be severe, such as confabulation (Nedjam, Devouch, & Dalla Barba, 2004), though generally they are more mundane. 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. Organizational strategies, such as using pillboxes for medication, can help in the remembering of daily living activities. However, this type of strategy does not help when people with AD experience false memories – not looking in their pillbox, for example, because they falsely remember taking their medication.

The Deese/Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995) is probably the most popular and commonly used paradigm to study false memories in a laboratory setting. Here, participants are presented with a list of words all of which are associatively related (e.g., *table*, *sit*, *legs*) and are also associated with a critical lure (CL) word that is never presented (i.e., *chair*). When memory is subsequently tested using recall or recognition tasks, healthy participants show a tendency to falsely recall and recognize the CLs as having been presented on the list (Balota, Cortese, Duchek, Adams, Roediger, McDermott, & Yerys, 1999; McDermott, 1999).

Several studies have used the DRM paradigm with AD people and shown that they tend to produce fewer CLs than control participants (e.g., Balota et al., 1999; Budson, Sullivan, Mayer, Daffner, Black & Schacter, 2002; Gallo, Bell, Beier & Schacter, 2006; Waldie & Kwong See, 2003), although the reverse has also been observed (see Watson, Balota, & Sergent-Marshall, 2001). Some studies have shown no reliable differences in CL production in people with AD and healthy controls (Roediger, Balota, & Watson, 2001).

There are a number of theories that can explain the lower production of CLs in people with AD. The activation-monitoring theory (see Roediger, Watson, McDermott, & Gallo, 2001) is one of the more dominant explanations (see Gallo 2010 for a review). According to this theory, false memories arise due to two distinct processes: an activation process and a source-monitoring process. For example, in the DRM task, because the presentation of each of the lists of words automatically activates the related but unpresented CL, the CL is activated multiple times via an automatic spread of activation within the associative network. The sum of this activation increases the feeling of familiarity for this item, while simultaneously reducing the ability to remember the source of its activation (source-monitoring process). Thus, the production of the CL may result from its erroneous attribution to an external source. In healthy aging, any increase in false memories is often explained by a source-monitoring failure (Schacter et al., 1997).

The activation-monitoring theory can also be used as a framework to explain the low production of CLs in people with AD in the DRM task. Several studies have reported a failure of the source-monitoring process in AD people (Rosa, Deason, Budson, & Gutchess, 2015). Thus, it seems implausible to attribute their lower production of CLs, compared with healthy older adults, to a more efficient source monitoring. Budson, Daffner, Desikan, and Schacter (2000) and later Gallo (2010) proposed that the activation of target items in people with AD during the presentation of the DRM lists does not spread toward the CL, due either to a disturbance of the semantic network or an attentional overload. Therefore, if the CL has not been activated during list presentation, the CL could not later be falsely remembered. However, Evrard, Colombel, Gilet, and Corson (2015) suggested that the activation of the CL is preserved in people with AD, but that its mnemonic trace does not persist long enough in memory to enable its later production, due to a decline in episodic memory.

By way of summary then, healthy older adults and those with AD both experience declines in episodic memory. However, semantic memory is thought to be better preserved in healthy older adults than it is in those with AD. Thus, on the one hand, differences between these groups in false memory production may be mediated more by differences in semantic than episodic memory (Madore, Addis, & Schacter 2015; Madore, Jing, & Schacter 2016). That is, perhaps people with AD experience greater difficulty than their healthy counterparts with associative activation of related information within semantic networks (Budson et al., 2000; Dewhurst, Thorley, Hammond, & Ormerod, 2011; Gallo et al., 2006). On the other hand, perhaps the CL does get activated, but the time course for the decline in this activation is faster for those with AD than those without.

One way to test these proposals is to introduce a second task where performance improvements on that task are predicated on the earlier production of the CL from the DRM list presentation. By way of background, there are a number of studies that have found that false memories have positive consequences on subsequent task performance. For example, McKone and Murphy (2000) showed that false memories generated using the DRM paradigm could prime performance on related memory tasks (e.g., stem-cued recall). Studies like these have prompted researchers to examine the possible beneficial effects of false memories on cognitive tasks other than those related to memory (Howe, 2011; Schacter, Guerin, & St. Jacques, 2011).

Howe, Garner, Dewhurst, and Ball (2010) 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; Sio). CRAT problems, originally developed by Mednick (1962), involve the presentation of three words (e.g., *apple*, *family*, and *house*) and the task is to come up with a word (i.e., *tree*) which, when combined with each of the three original words, creates compound words or common phrases (i.e., *apple tree, family tree, treehouse*). Howe et al. (2010) presented adults 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 recalled 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, Garner, Charlesworth, and Knott (2011) extended this research to children and found exactly the same results. What this research shows that like true memories, false memories can successfully prime higher order cognitive tasks (i.e., insight-based problem solving).

In the current research, we wanted to see whether these priming effects also occur in healthy older adults and, more importantly, people with AD. If this finding can be extended to people with AD, this would extend our understanding of memory processes in this sub-group of memory-impaired people and importantly, could have positive implications for memory rehabilitation. If people with AD have greater problems with spreading activation than healthy older adults (Budson et al., 2000; Gallo et al., 2006), then they should be less likely to remember the CL than healthy older adults. In addition, if false memories have a shorter "lifespan" for people with AD, then even when CLs are produced on the memory test, priming effects on subsequently administered CRAT problems should be attenuated or absent. However, if as some previous research suggests (Roediger et al., 2001) both healthy older adults and people with AD do have intact semantic networks and CL longevity is not an issue, then it is expected that CLs will be falsely remembered and priming will occur on subsequent CRAT problems.

In the present study, we used CRAT problems whose baseline solution rates were moderate (30% to 80%) for older adults. Because the CRAT norms that are available were based on solutions provided by children and young adults, we created our own age-appropriate CRAT norms prior to conducting the priming experiment. Our rationale for this was that we wanted to eliminate differences of age due simply to knowledge base, a procedure consistent with previous studies (e.g., Howe et al., 2011), as these differences were not of interest in the current research.

Experiment 1: Norming CRAT Problems for use with Older Adults

Before turning to the main experiment, we report a pilot study in which we collected norms for CRAT problems for use with older adults. In line with previous research, age-appropriate CRAT problems were developed in order to eliminate any potential age effects in problem-solving performance due to the use of extant norms which were developed using samples of children and young adults.

Method

Participants. A total of 32 healthy older adults (13 males and 19 females) took part in this experiment; their mean age was 78.19 (*SD* = 5.67). 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 27.31 (*SD* = 2.52), 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 20 CRAT problems taken from the Bowden and Jung-Beeman (2003) norms. The items on the CRATs required a solution that was associated with all three words of the triad through the construction of a compound word or common phrase (e.g., *cream, skate*, and *water* combined with the solution word *ice*, creating the compounds *ice cream*, *ice skate*, and *ice water*). (Note that only problems with solution rates above 30% and solved within 30 seconds were selected for subsequent use with older adults with AD.) 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. (2011) and by Bowden and Jung-Beeman (2003) were given. Specifically, participants were told that they would see three words and that they should try and produce a fourth word that, when combined with each of the three items, would make up a common compound word or phrase. Participants were first 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, with one word above, below, and at the centre fixation point. Participants were given 30s to produce the solution (this was a verbal solution). 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 for the 20 problems separately. As can be seen, older adults were able to solve most of these CRAT problems. Importantly, for the next experiment, there was a good range of solution rates and times for these CRAT problems. What this means is that priming effects, should they exist, can be measured without constraints imposed by floor and ceiling effects.

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

With these norms in hand, we now turn to the main question concerning the role of false memories in priming solutions to insight-based problem solving 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. A statistical power analysis was performed for sample size estimation. The effect size in this study was considered to be medium using Cohen's (1988) criteria. With an alpha = .05 and power = .80, our sample size of 60 (30 participants per group) is considered more than adequate. Thirty participants had a clinical diagnosis of probable or possible AD (McKhann, Drachman, Folstein, Katzman, Price, & Stadlan 1984). Patients were diagnosed as being demented with the Diagnostic and Statistical Manual of Mental Disorders, third edition (DSM III-R; American Psychiatric Association, 1987) criteria as having Alzheimer's disease by the National Institute of Neurological and Communicative Disorder and Stroke and the Alzheimer 's disease and Related Disorders Association (NINCDS-ADRDA) criteria (McKhann et al., 1984). Alzheimer's disease was diagnosed by a clinician using neuropsychological examination, Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), family interview, laboratory screening (i.e.

INSERT TABLE 1 HERE

hematology; B12 and folate levels; renal, liver, and thyroid function; calcium and syphilis serology), and medical examination. If there was a suggestion of a psychiatric disorder, patients were also assessed by a psychiatrist. Patients with a history of stroke or depression were excluded from this study. Patients with a Hachinski score (Hachinski, Zilhka, du

Boulay, McAllister, Marshall, Ross, Russell, & Symon, 1975) that indicated they might have vascular component to their dementia were also excluded. 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 (n = 18), or were recruited from Age Concern London (n = 12). All OAC participants had recently been screened for dementia using the MMSE, all scoring above the standard cut-off of 26/30.

As noted, the demographic characteristics of the participants are shown in Table 2. One-way analyses of variance (ANOVAs) were used to analyze these demographic variables. These analyses showed that there were no significant differences between groups in mean age, $F < 1$. There was a significant difference in the National Adult Reading Test (NART) predicted IQ scores (Nelson, 1982) for the groups, $F(1, 58) = 18.56$, $p < .001$, with the AD group scoring reliably lower than the OACs. There was also a significant difference in the mean number of years of formal education between groups, $F(1, 58) = 12.01$, $p <. 001$, with the OACs having reliably more years of formal education. For Mini Mental State Examination Score (MMSE; Folstein, Folstein, & McHugh, 1975), as expected, there was also a significant difference between groups, $F(1,58) = 56.21$, $p < .001$, with the people with AD performing reliably lower that the OACs. In addition, people with AD were also tested on the word list memory test from the Consortium to Establish a Registry for Alzheimer's Disease CERAD neuropsychology battery (Morris, Edland, Clark, Galasko, Koss, Mohs, & Heyman, 1993; Welsh, Butters, Hughes, Mohs, & Heyman, 1991). For delayed recall, they recalled an average of 0.8 (SD = 1.92) words. This level of performance on this particular task is in keeping with other reports for people with AD in the literature (e.g., Akhtar, Moulin, & Bowie, 2006; Moulin, James, Freeman, & Jones, 2004), where mean performance is typically less than one for people with AD. Mean normal performance is around six items (Moulin et al., 2004).

Older healthy adults gave their written informed consent. For people with AD, written informed consent was given either by them or their primary caregivers. The OACs were community dwelling and people with AD were recruited from two day-care centres in London. All participants were fluent in English.

INSERT TABLE 2 HERE

Design, Materials, and Procedure. A 2 (Group: AD vs. OAC) x 2 (Priming: primed vs. unprimed) mixed design was used, where the first factor was between-participants and the second was a within-participant factor. For purposes of the analyses, primed items were further divided according to whether participants falsely remembered the critical lure (designated “primed/FM”) or did not falsely remember the critical lure (designated “primed/no-FM”). This resulted in a 2 (Group) x 3 (Priming) design. We followed the same procedure as Howe et al. (2010, 2011) such that each participant was primed on half the subsequent CRAT problems with preceding DRM lists whose critical lures were also the solution to those CRAT problems. The order of both the DRM lists and CRAT problems was carefully counterbalanced to eliminate order effects.

Ten CRAT problems were selected from the normative data in Experiment 1 (see Appendix). Their nonprimed solution rates ranged between 30% and 80% in order to insure that they were neither too easy nor too hard. In addition, 10 DRM lists whose CLs were the corresponding solutions to these CRATs were selected. Each list contained 10 word associates of the critical lure and were taken from Roediger et al. (2001) norms. Lists were randomly divided into two groups of five with participants being primed using one of these sets. In order to prevent differences in false memory rates, the two sets of five DRM lists were equated on backward associative strength (BAS) (List Set 1 BAS = 0.777, List Set 2 BAS = 0.725).

Participants were given one set of the five DRM lists in a randomized order. Each list was presented verbally, followed by a distractor task (counting backward by four from a 3-digit number for 30s). This was followed by a recognition test similar to that in Howe, Wilkinson, Garner, and Ball (2016) whereby participants were verbally presented with the 5 critical lure words from the studied DRM lists, 5 unstudied and unrelated critical lures, 32 true items from the studied DRM lists, 32 foils unrelated to studied DRM lists, and 8 filler items. 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. Following completion of the DRM lists, all 10 CRAT problems were completed. The same procedure used for the CRAT pilot study was used for the main experiment and solution rates and solution times were collected for correctly solved CRAT problems.

Results

We controlled for the effects of educational level and NART statistically. In all of our analyses, we ran an analysis of covariance (ANCOVA) with these demographic variables as covariates. For all ANCOVAs, the pattern of findings for the main effect of group and interactions with group were unchanged from the analysis with ANOVAs. For simplicity, therefore, the ANOVAs are reported here.

False memories were comparable to previous studies (Roediger, Balota, & Watson, 2001; Waldie & Kwong-See, 2003). 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 61% (M = 3.05, SD = 1.31) of the time and the OAC group 60% (M = 3.01, SD = .91) of the time. There were no reliable differences.

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, $F(3, 58) = 6.51$, $p < .001$. Pairwise comparisons revealed greater recognition in list items (80%) compared to foil items (66.7%) ($M = 25.63$, $SD = 2.51$ vs $M = 21.34$, $SD = 3.3$) and greater recognition of CL words (60.6%) compared to unrelated CL words (40.4%) ($M = 3.03$, $SD = .80$ vs $M = 2.02$, $SD = 1.08$) . There was no main effect for group ($F < 1$) and no interaction ($F < 1$).

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 detection theory (SDT) measures, 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. The Snodgrass and Corwin correction was conducted for SDT measures for all list items. For discriminability (*d*'), larger values indicate better memory performance, and for criterion value (*C*), values greater than 0 represent a conservative response bias and less than 0 represents a liberal response bias. The values of *d'* and *C* are shown in Table 3. The calculation of *d'* and *C* for used the false alarm rate for unrelated foils. Signal detection measures for hits and critical lures were analyzed using separate independent t-tests. The analysis of *d'* for hits and critical lures revealed no reliable differences ($t < 1$). Analysis of the criterion C, revealed no reliable differences for hits or critical lures ($t < 1$).

INSERT TABLE 3 HERE

The mean CRAT solution rates (proportions) and the mean CRAT solution times (in seconds) were calculated for each participant and analyzed separately in a series of 2 (Group: AD vs. OAC) x 3 (Priming: primed/FM vs. primed/no-FM vs. unprimed)

ANOVAs. For primed CRAT problems, solution rates and solution times were conditionalized on whether participants 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 factors were solution type (unprimed, primed/no-FM, or primed/FM) and group. The data are shown in Table 4.

Concerning solution times, there was a main effect for priming $F(2, 58) = 15.26$, $p < .001$, $\eta^2_p = .244$, where post hoc tests (Tukey's LSD) showed that solution times were faster for primed/FM problems (*M* = 21.49) compared to primed/No-FM problems (*M* = 38.12, $p < .01$) and unprimed CRAT problems (*M* = 38.50, *p* = < .01), and the latter two conditions did not differ. Furthermore, solution time results showed no significant difference across participant groups, with OAC's average problem solving time being 31.39s (SE = 1.132) and AD's being 34.09s (SE = 1.519). There was no interaction.

INSERT TABLE 4 HERE

Concerning solution rates, there was a main effect for priming $F(2, 58) = 15.26$, $p < .001$, $\eta^2_p = .248$, where post hoc tests (Tukey's LSD) showed that solution rates were higher for primed/FM CRAT problems (M = 0.52) than for primed/no-FM (*M* = 0.23) and when participants were unprimed (*M* = 0.26), and the latter two did not differ. There was no main effect for group, where OACs (*M* = 0.42) and AD (*M* = 0.39) solved similar numbers of CRAT problems and no interaction.

Discussion

The present study set out to investigate whether false memories can have a positive consequence on human cognition with older healthy adults and those with AD, as has been shown in children and young adults (Howe et al., 2010, 2011). To investigate this, participants were asked to solve CRAT problems, half of which had been preceded by the presentation of DRM lists whose critical lures were also the solutions to those problems. Consistent with previous research, our study showed no reliable differences in the number of false memories produced in the recognition task (Roediger, Balota, & Watson, 2001; Waldie & Kwong-See, 2003). This finding can be explained by the fact that 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 (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 essentially act similarly to true memories when it comes to priming subsequent task performance (McDermott, 1997). Furthermore, 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 = below threshold activation and recognition = above threshold activation. 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 to no effect on memory strength of the critical lure because, as already mentioned, false memories arise during the encoding not retrieval process (see Howe et al., 2016, 2017).

Our findings are the first to show that false memories can successfully prime insight-based problem solving in both AD and OACs. Just like in Howe et al. (2011) we propose when problem solutions were primed by the prior presentation of DRM lists whose critical lures were falsely remembered and were solutions to those problems, critically both the probability of such problems being solved and the speed with which they were solved improved significantly. This was true regardless of whether the problem solvers were people with AD or OACs. These findings strongly suggest that false memories do not “fade” more rapidly for people with AD than for OACs and they are capable of priming and facilitating performance on a subsequent problem-solving task. What is important to consider here, is the DRM lists can prime and facilitate performance on problem-solving tasks both in terms of the rate and the speed which they are solved. However, one can only make this conclusion when the critical lure is falsely recognised. Such facilitation is not found when the false CL has not been remembered. Interestingly, priming with no recognition of the CL resulted in problem-solving rates and times identical to conditions in which there was no priming. This adds to the growing view that false memories, like true memories, can successfully prime higher cognitive processes, at least in terms of problems involving insight-based solutions (Diliberto-Macaluso, 2005; Howe et al., 2010, 2011, 2016).

Our research is the first to demonstrate that false memory priming effects occur regardless of cognitive abilities. In the present study, priming effects were equally robust in OACs and people with AD. This cognitive invariance has important theoretical implications. We suggest intact semantic networks exist in both these groups of older adults. To add strength to this argument, we compared our findings to previous research with younger adults (e.g., Howe et al., 2011, 2016). What this comparison shows is that rates of priming for younger adults in those studies is similar to those same rates for the older adults in the present study. Specifically, regardless of differences in materials and overall false memory rates, when young adults remembered the CL, their priming power for solving subsequent CRAT problems was similar to the rate for when older adults got the CL in the present research. That is, average solution times for young adults (19.22) was similar to that for older adults (21.20) as were the average solution rates for younger adults (0.76) and older adults (0.6).

Thus, what our study shows is that semantic networks are relatively well preserved in people with AD and OACs, at least when compared to those same rates for younger adults in earlier research.

From all of this research it is clear that false memories generated from the DRM word lists and CRAT problem solutions arise from the nonconscious and automatic spreading of activation among semantic concepts (Balota et al., 1999; Roediger et al., 2001). Therefore, as a result of priming occurring in both of the populations studied here, spreading of activation between nodes in the semantic networks must be intact. In the extant literature, decline in performance on tasks such as verbal fluency have been attributed to the breakdown in semantic networks, particularly for people with AD (Balota et al., 1999; Watson et al., 2001). What our findings suggest is that these breakdowns are not due to the deterioration of semantic networks but rather, due to possible failures in source monitoring. Although further research is needed to confirm this hypothesis, what our study shows is that there was no decline in spreading activation within semantic networks; false memories were as frequent in people with AD as in those without AD (our OACs) and they served as equally powerful primes for both groups when solving CRAT problems.

Another hypothesis worth considering could be that CRAT problems were solved via insight-like (perhaps automatic, nonconscious) strategy or via a more analytic (perhaps deliberate) strategy (e.g., Konious 2006; Knonious & Beeman 2009). These studies show that distinct brain mechanisms are involved for the two types of solutions. Although in the present study there were no differences between OACs and people with AD in using primes for solving CRAT problems, the mechanisms through which the two groups of participants reached the solution could have differed. Of course, this hypothesis would require additional research.

Previous research has shown the positive consequences that false memories have on problem-solving tasks in both children and adults, yet this has not been fully examined in individuals with associated cognitive decline (Howe et al., 2010). The results from the current study demonstrate for the first time the priming effects false memories have on complex insight-based problem solving tasks such as CRATs on OACs and people with AD. Additionally, our findings add to the recent literature on the positive consequences that false memories have on human cognition, particularly in the way they facilitate performance on higher-order cognitive tasks such as the CRAT. Given that these significant results were found in both older adults and people with AD, our findings strongly suggest that significant differences that may arise in memory functioning are not the result of deterioration in spreading activating in semantic networks, at least not in the DRM/CRAT tasks.

Finally, our findings have a number of important theoretical and practical implications. First, we propose that OACs and people with AD have intact semantic networks. Second, although there are clear differences between true and false memories (Roediger & McDermott, 1995) our findings add to the growing literature suggesting that false memories can work in a very similar way to those observed for true memories (Diliberto-Macaluso, 2005). Third, our findings add to an emerging consensus that false memories, just like false beliefs (Howe & Derbish, 2010), can have beneficial effects in human cognition and not simply the negative consequences we are all familiar with (see Howe & Knott, 2015). We are aware some may interpret false memories as negative regardless of their benefits as outlined in this paper, we believe that this by-product of a powerful reconstructive memory system is positive (see Howe et al., 2010). Our findings have taken us a step closer to realizing at least one beneficial aspect of false recollection in that it helps to 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 OACs, people with AD, children, and adults (Howe et al., 2011).

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Table 1 CRAT Problems: Solution Rates and Times

CRAT Problem	CRAT Solution	% Solved	Solution Time (s)
Heart/potato/tooth	Sweet	18.8	30.2 (12.24)
Over/deep/Walk	Sleep	21.9	23.7 (17.45)
Skin/ball/tissue	Soft	25	13.5 (10.02)
Bike/top/goat	Mountain	34.4	20.1 (17.68)
Base/tank/territorial	Army	40.6	21.3 (18.03)
Cut/sore/war	Cold	43.8	21.9 (18.86)
Hold/print/stool	Foot	43.8	18.6 (13.62)
List/death/Bone	Wish	46.9	19.2 (13.84)
Polo/flannel/vest	Shirt	46.9	24.5 (20.69)
Bow/Haul/jump	Long	53.2	18.6 (16.09)
Bowl/Juice/Salad	Fruit	53.2	11.6 (9.73)
Measuring/cake/tea	Cup	59.4	18.5 (13.97)
Pal/tip/knife	Pen	62.5	14.3 (12.50)
Bite/vein/web	Spider	68.8	17.1 (13.63)
Jack/magic/board	Black	75	13.5 (12.48)
Crumbs/dough/Knife	Bread	81.3	13.4 (12.54)
Care/spa/mental	Health	87	10.2 (7.73)
Knitting/stick/pine	Needle	87.5	16.2 (14.52)
Sill/frame/cleaner	Window	87.6	11.8 (14.09)
School/Chair/Heels	High	90.6	12.8 (13.63)
Rocking/wheel/high	Chair	93.7	9.8 (11.71)

Note: Standard deviation is in parenthesis and solution times are presented

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

	AD	OAC
MMSE	19.54 (.55)	27.39(.58)
NART	106.54 (1.79)	116.78(.95)
Education	10.02 (.27)	12.32 (.42)
Age	76.43 (1.13)	77.32 (.84)

Note. MMSE = Mini Mental State Examination Score

Predicted IQ from the National Adult Reading Tests

Education = Years of formal education.

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

	OAC		AD	
	d'	*C*	*d'*	*C*
Hits	1.42 (.48)	0.23 (.2)	1.13 (.39)	0.18 (.1)
CL	0.93 (.78)	0.22 (.39)	0.84 (.53)	0.18 (.32)

Note. CL – critical lures

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

Participant	Priming		
	Unprimed	Priming/FM	Priming/NO-FM
Solution times (seconds)			
Older Adults	36.97 (1.92)	21.20 (1.27)	37.24 (1.61)
Alzheimer's Patients	44.06 (2.58)	21.98 (1.72)	39.70 (2.16)
Solution rates (proportion)			
Older Adults	0.38 (0.24)	0.59 (0.39)	0.23 (0.15)
Alzheimer's Patients	0.32 (0.31)	0.57 (0.51)	0.24 (0.31)

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

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