True and False Memory Priming of Perceptual Closure Problems in Healthy Older Adults and Older Adults with Alzheimer's Disease

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Abstract

Objectives

The current study set out to investigate whether false memories for pictures exhibit priming effects in older adult controls (OACs) and people with early onset Alzheimer's disease (AD). We conducted two studies to examine whether false memories for pictures had a priming effect on a perceptual closure task.

Method

In Experiment 1 older adult controls (OACs) and people with early onset Alzheimer's disease (AD) were presented with pictorial versions of the Deese/Rodiger-McDermott (DRM) lists and took part in a recognition task. This followed with a perceptual closure task (PCT), where both groups were shown degraded pictures that became clearer overtime and participants had to identify the picture as quickly as possible. In Experiment 2 we manipulated the modality – verbal vs pictorial in both the study phase and PCT phase.

Results

Experiment 1 results indicated false memories for pictures did not serve as effective primes in the PCT. Experiment 2 results revealed, pictorial false memories primed the PCT significantly slower than pictorial true memories in the visual PCT task, but the reverse finding was shown for the verbal PCT task. Finally, verbal false memories primed the verbal PCT reliably faster than true memories.

Conclusions

Our findings show when solving pictorial problems, for both older adults and people with AD false memories may not activate the appropriate representation in memory for solving a pictorial problems whereas actually presented items do.

Keywords: Alzheimer's disease, DRM paradigm, false memory, Perceptual closure Task

Key points

Question

Can false memories for picture be used as effective primes?

Findings

When solving pictorial problems, true memory items serve as more effective primes compared to false memory.

Importance

This work has practical implications for problems solving tasks and memory rehabilitation for people with Alzheimer's disease.

Next steps

Further work in the nature of false memories should be explored.

Introduction

It is widely accepted that memories are reconstructions and are susceptible to distortions and errors (e.g., Bartlett, 1932; Conway & Howe, 2022; Schacter, 1999). These errors are often referred to as false memories, the recall or recognition of events that never took place (e.g., Balota et al., 1999; Guyard & Piolino, 2006). The Deese/Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995) is the most commonly used paradigm to investigate false memories in a laboratory setting. In a typical DRM paradigm, 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 or recognize the CLs as having been presented on the list (Balota et al., 1999; McDermott, 1999).

The two dominant explanations of false memories are the activation-monitoring theory (see Roediger et al., 2001) and the fuzzy-trace theory (Cann et al., 2011; Reyna & Brainerd, 1995). The activation-monitoring theory suggests that false memories occur due to two distinct processes: an activation process and a source-monitoring process. For example, in the DRM paradigm, because the presentation of each of the lists of words automatically activates the related but unpresented critical lure, the critical lure 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, believing it was actually presented with the other list words (source-monitoring process). Thus, the production of the critical lure may result from its automatic activation and an erroneous attribution to an external source.

Fuzzy-trace theory, on the other hand, is based on parallel encoding of both a gist trace (semantic content) and an item-specific trace (verbatim or surface form on the item) during the encoding phase (Brainerd & Reyna, 2002). In fuzzy-trace theory, false memories are attributed to the gist extraction that occurs during the encoding phase while true memory is attributed to the item-specific trace (Brainerd & Reyna, 2002). While for presented items both item-specific and gist information are available, for critical lures, only gist information is available. Therefore, when participants rely solely on gist memory during recall or recognition tests, critical lures will be falsely remembered during this test phase (Colbert & McBride, 2007). The theory also assumes that because true memory relies on item-specific information – information that decays more rapidly than gist information – that false memories will last longer than true memories (Brainerd et al., 1995).

It is widely accepted that as we age, we are more susceptible to making more false memories e.g. (Devit & Schachter 2016; Norman & Schacter 1997). 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 et al., 2007; but see McCabe & Smith, 2002 and Thomas & Sommers, 2005, for contradictory results). There have been numerous suggestions as to why older adults have more false memories compared to younger adults (for a review, see Devit & Schacter, 2016). One suggestion is that they rely more on memory for the general features of the studied items, rather than on the specific item features (e.g., Balota et al., 1999; Gallo, 2006; Norman & Schacter, 1997; Schacter et al., 1997; Tun et al., 1998).

It's not just healthy young and older adults that produce false memories. People with Alzheimer's disease (AD) also exhibit false memories. AD is characterised by a progressive deterioration of cognitive functioning, and memory disorders are the earliest and the most serious clinical symptom of the disease. During the early stages of the disease, people with AD show impairments in episodic memory and rapidly forget newly learned information (Baudic et al., 2004). That said, a growing number of studies have shown that semantic memory impairment may occur relatively early in the course of the disease (Ober et al., 1986). These studies showed that people with AD retrieve fewer items from a given semantic or letter category on timed verbal fluency tasks, but also perform poorly on an object naming task and on low frequency items and less familiar items (Kirshner et al. 1984). More recent work by Wright, Marco & Venneri 2022, showed a significant loss of semantic advantage in verbal fluency tasks in people with early-stage AD, and this deficit remains during the course of the disease. Despite this evidence, there is much debate as to whether the semantic deficit stems from a loss of information in the semantic store (Chertkow et al., 1989), as opposed to the store being intact in people with AD and the deficit is related to a disturbance in a patient's ability to access and manipulate semantic information (Nebes 1989).

Previous research, has shown that people with early onset AD exhibit the same rate of false memories as older adult controls for verbal stimuli (Akhtar & Howe, 2019; Akhtar et al., 2018; Howe & Akhtar, 2020). However, other studies have shown the reverse effect, particularly with mild AD patients (e.g., Balota et al., 1999). In their study, they found that early onset AD people exhibited the same rate of false memories as older adult controls, however mild AD people, made reliably fewer false memories compared to older adult controls. Although this discrepancy exists in the literature, in the present study we were not concerned with examining this directly. We were 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.

Traditionally, false memories have been seen as pejorative in nature, especially in the aging literature (e.g., Devit & Schacter, 2016: Malone et al., 2018). However, recent research has shown older adults and people with mild and moderate AD have used false memories in a positive way (Akhtar et al., 2018; Akhtar & Howe, 2019; Howe & Akhtar, 2020). Specifically, false memories can be used to prime responses to insight-based problem solving tasks using both a compound remote associative task (CRATs) and verbal proportional analogies (both tasks used frequently in intelligence tests, e. g., Stenberg & Rifkin 1979). CRAT problems, originally developed by Mednick (1962), involve the presentation of three words (e.g., *measuring, cake, tea*) and the task is to come up with a word (i.e., *cup*) which, when combined with each of the three original words, creates compound words or common phrases (i.e., *measuring cup, cupcake, teacup*). Verbal proportional analogies of the type '*a* is to *b* as *c* is to *d*' (e.g., *water* is to *boat* as *road* is to *car*) go beyond simple word associations. 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.

Akhtar et al. (2018) and Howe and Akhtar (2020, Experiment 1), presented older adult controls (OACs) and people with AD with DRM lists whose critical lures served as primes for half the CRAT problems that participants were later instructed to solve. They found that when participants falsely remembered the critical lures of the studied DRM lists, the corresponding CRATs were solved more frequently and faster than CRATs that had not been primed or in cases where DRM lists had been presented but critical lures were not falsely remembered. Akhtar and Howe (2019) and Howe and Akhtar (2020, Experiment 2), presented OACs and people with AD DRM lists whose critical lures served as primes for half the verbal proportional analogies that participants were later instructed to solve. Just like in Akhtar et al. (2018), these studies showed that when participants falsely remembered the critical lures of the studied DRM lists, the corresponding analogical problems were solved more frequently and faster than the analogical problems that had not been primed or in cases where DRM lists had been presented but critical lures were not falsely remembered. This same pattern of findings have been demonstrated in children and young adults (Howe et al., 2010; Howe et al., 2011; Howe et al., 2017). False memories, perhaps serve as better primes because according to the associative theories false memories are stronger than true memories because (1) they were activated more often as each list item is an associate of the CL whereas list items are only presented once and (2) they are self-generated (by the person viewing the list) whereas true memories are other-generated (by the experimenter) and we know that self-generated information is better remembered than other-generated (Akhtar et al., 2019).

Otgaar et al. (2015) used a similar paradigm, but instead of presenting CRAT or verbal analogical problems, they presented a perceptual closure task (PCT) to examine the effects of false memory priming. A perceptual closure task measures the ability to form a coherent mental picture of an object or a word with very little visual information. In Experiment 1 of their study, participants took part in a traditional DRM paradigm and a recognition task. Following this, participants were exposed to a PCT, such that they were presented with degraded images of presented words and critical lures. Their findings showed false memories for the critical lures primed the PCT faster than the presented words.

By way of summary, in all these priming studies outlined so far, false memories have been shown to be effective primes for verbal stimuli. Wang et al. (2018), in three experiments, examined whether false memories for pictures exhibit similar priming effects on a PCT in young adults. Specifically, their study was interested in investigating the conceptual versus perceptual nature of false memories. In all three experiments, they examined whether false memories for pictures had a priming effect on a PCT. In Experiment 1, participants were presented with pictorial versions of the DRM lists, followed by a recognition task. Participants were then presented with a pictorial version of the PCT and were instructed to identify as quickly as possible the degraded pictures of the studied items and critical lures. The findings showed that false memories for visual stimuli were reliably slower in priming the PCT compared to true memories for visual stimuli. In their Experiments 2 and 3, they manipulated modality (verbal stimuli vs visual stimuli) both in presentation of the DRM and the PCT. The results showed that false memories for picture stimuli primed the pictorial PCT reliably slower compared to true memories for pictures just like Experiment 1. Interestingly this was not the case, for the verbal PCT – here, false memories for picture stimuli primed the verbal PCT reliably faster compared to true memories for pictures. Finally, false memories for verbal stimuli primed the verbal PCT reliably faster, compared to true memories for verbal stimuli. They concluded that false memories for pictures are unlikely to contain perceptual information as they are more conceptual in nature and that the false-memory image may be more generic than the specific instance being tested in the PCT test. That is, when it comes to pictures, one would expect visual traces to be encoded for studied pictures and at the same time corresponding images are activated automatically in memory. Such activation of the list members might only spread along the conceptual network as the DRM list members are semantically related not perceptually related.

Present Study

The present study looked to replicate Wang et al. (2018) in people with early onset AD and OACs using both pictorial stimuli (Exp 1) and pictorial and word stimuli (Exp 2). We wondered whether the true and false memory priming reversal effects observed with younger adults extended to older healthy adults as well as those older people with AD. In particular, if people with AD had more false memories for pictures and words, would they also perform better on the PCT compared to the OACs? More specifically, we wanted to investigate (1) the replicability of our previous findings on false memory priming effects in verbal stimuli on a nonverbal problem-solving task (the PCT, Experiment 2) and (2) if Wang et al.'s findings of true memory for pictures could act as effective primes extends to both healthy older adults and people with AD.

Experiment 1

Method

Participants

The sample size was determined using G Power (Faul et al., 2007), we ran an a priori power analysis for an ANOVA: Repeated measures, between factors. We anticipated a medium effect size (d = 0.5) and power was estimated at 0.80. The number of groups was 2, and the number of measurements was 3. This power analysis showed 68 participants were needed (34 in each group). Thirty-five participants had a clinical diagnosis of probable or possible AD within a 16-month period prior to participation. All patients fulfilled international consensus criteria for AD (McKhann et al., 2011) and their clinical diagnoses were established by an independent clinician using neuropsychological examination, Mini-Mental State Examination (MMSE; Folstein et al., 1975), family interview, laboratory screening (i.e., 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 et al., 1975) that indicated they might have vascular component to their dementia were also excluded. Participation took place in the participant's home or at a local Day Centre to the participant. Consent was sought by the primary caregiver. Thirty-six participants made up the 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. Participation took place at in either their home or a local day centre. There were no significant differences between OACs and AD participants in terms of age, years of education, or performance on the National Adult Reading Test, but as shown in Table 1, both groups differed on most cognitive tests.

INSERT TABLE 1 HERE

Materials

The study consisted of three phases. **Study phase:** Six DRM wordlists were represented pictorially chosen from Peters et al. (2015, see Appendix A) and used in Wang et al (2018). Each DRM list consisted of eight semantically related words (e.g. thread, pin, eye, etc.) and these words were all associated to a non-presented target or 'critical lure' (needle). All pictorial representations were showing objects in the centre of the screen with a white background. The pictures were presented digitally for 2000ms, with 1500ms inter-stimulus interval using E-Prime 2.0 software. Pictures within each DRM list were presented in descending associative order.

Recognition test: Participants were presented with 48 pictures. This consisted of, 24 pictures presented in the study phase – these were made up from four pictures being randomly selected per list; 6 pictures were images of critical lures (e.g., image of cup); 6 pictures were not presented but were related pictures (e.g., image showing a straw) and 12 pictures were not presented and were unrelated pictures (e.g., pictures of flower, mop, etc). Each image was presented for 2000ms and there was a fixation cross on screen lasting 1500ms after each image.

Perceptual closure task: participants were presented with 72 images. These were made up of 48 studied pictures (24 were shown in the recognition test and 24 were not); 6 pictures of critical lures as shown in the recognition test; 6 were new images of the critical lures and 12 were unrelated images (6 from the recognition test and 6 were not, see Figure 1).

Each image was displayed with a distortion filter that enabled the pictures to become clearer over time. Nine gradual gradations of blur were presented for 1s and participants were instructed to respond within 10s. Both accuracy and latencies were measured for the identification of the pictures using E-Prime 2.0. The distorted pictures were created using GIMP 2.0.

Design and procedure

A 2 (Group: OACs vs AD) x 3 (Memory type: studied item, critical lure, unrelated) mixed design was used. To rule out any possible priming effect from the recognition test we did the following:

- Half of the studied pictures in the PCT were randomly presented in the recognition test and the other half were not shown during the recognition test.
- In terms of the critical lures in the PCT -we used two versions of pictures for the same critical lures; one version was presented in the recognition test and the other was not.
- This was the same for the unrelated pictures in the PCT - half of the unrelated pictures were included in the recognition test and the other half were only shown during the PCT.

Participants were tested individually and were randomly presented with 6 pictorial DRM lists and were instructed to memorise each picture and think about the concept of the picture when they saw it on the screen. Following this they played Bejewled for 5 minutes (filler task). After which, participants received a recognition test where pictures were presented on the screen and participants were instructed to answer ‘yes’ or ‘no’ in a pop-up window to indicate whether they had seen the picture before or not. Lastly, after playing Bejeweled for 5 minutes (filler task), participants took part in the perceptual closure task. They were instructed to press the space bar as soon as they recognized the blurred picture. After pressing the button, a window popped up and asked participants to type in what they thought represented the degraded picture. A pseudo-random order of degraded pictures were presented.

INSERT FIGURE 1 HERE

Figure 1. Diagram of the procedure for Experiment 1 (Note: CL refers to Critical Lures)

Transparency and Openness

We report how we determined our sample size, all data exclusions and all measures in the study. All data can be requested from the corresponding author. This study's design and its analysis were not pre-registered. All study materials for this study can be found https://osf.io/36hjw/?view_only=712931db9e2043a283bf7f4cc98669db

Results and discussion

Recognition task

The mean recognition rate for all studied pictures was 83.4% (*SD* = 2.47) compared to 21.5% (*SD* = 1.72) for critical lures (corrected false recognition rates). This is consistent with previous research using visual stimuli to induce false memories (Israel & Schacter, 1997; Wang et al., 2018).

INSERT TABLE 2 HERE

PCT

Before analysing the data from the perceptual closure task, we cleaned the data using the criteria found in Otgaar et al. (2015) and Wang et al. (2018):

1. Concerning studied pictures – To make sure participants had formed true memories only reaction times for correctly recognised pictures were included in the analysis.
2. Concerning critical lures – To make sure participants formed false memories for the critical lure pictures, only falsely recognised critical lures were included in the analysis.
3. Concerning 'no recognition presentation' as these pictures that were not included in the recognition task – criteria 1 and 2 did not apply here.
4. Pictures that were not identified correctly in the PCT were removed. This applied to all studied pictures, critical lures and unrelated items. For example, if a participant pressed the button indicating identification for a picture (cup) but then did not write an answer or filled in an incorrect response (e.g., dog), then this was removed from the analyses. However, synonyms of the answers were accepted.

[1]We conducted a 2 (Group: OACs vs AD) x 3 (Memory type: studied items, critical lures, unrelated) x 2 (Recognition: yes vs no) mixed measures ANOVA to examine the PCT reaction time in msec. There were no statistical interactions. There was a main effect of list type F (2, 264) = 265.36, $p < .001$, $\eta^2_p = .67$. Tukey's post-hoc test showed studied items (M = 4468.54 SE = 109.83; $p < .001$) produced faster identifications compared to critical lures (M = 6068.42 SE = 95.99; $p < .001$) and unrelated items (M = 5997.24 SE = 100.9; $p < .001$), where the latter two did not differ from each other (p = .179). As expected, there was a main effect of group, F (1, 132) = 170.151, $p < .001$, $\eta^2_p = .98$, with OACs (M = 4643.30 SE = 87.43) being significantly faster than people with AD (M = 6256.15 SE = 87.43). Finally,

[1] We controlled for the effects of the differences on the cognitive tests statistically for Exp 1. In all of our analysis, we ran analysis of covariance (ANCOVA) with these demographic variables as covariates. For all ANCOVAS, the pattern of the findings for main effects and interactions were unchanged from the analysis with ANOVA. For simplicity the ANOVAs are reported here.

there was a main effect of recognition presentation, $F(1, 132) = 22.31$, $p < .001$, $\eta^2_p = .15$, with recognised items being statistically faster ($M = 5157.71$ $SE = 88.74$) than non-recognised items ($M = 5741.74$ $SE = 87.43$) (see Figure 2.)

INSERT FIGURE 2 HERE

Figure 2. Mean reaction times for OACs and people with AD for the different memory type and recognition presentation.

Just like in Wang et al. (2018, Experiment 1), we found that false memories for pictorial lists did not serve as effective primes for the PCT, but true memories (studied pictures) did for both people with AD and OACs. Moreover, there was no difference between critical lures and unrelated pictures. One can argue that the fact that participants saw true items on two presentations (once in the study phase and then in the recognition task) that this might account for why true memories served as more effective primes compared to critical lures and unrelated items. To rule this out, we compared studied items that were only shown in the study phase (1 presentation) to critical lures that were only shown in the recognition task (1 presentation). We still found that studied items served as better primes compared to critical lures, $F(1, 132) = 143.36$, $p < .001$, $\eta^2_p = .58$ (see Figure 2). In addition, we compared studied items in the study phase (1 presentation) to studied items in the study phase and in the recognition task (2 presentations) and found no difference, $p > .856$.

So, what is it about visual/pictorial false memories that makes them less effective as memory primes? It seems that although people with AD and OACs falsely recognised critical lures in the recognition task, false memory activation did not provide any facilitation on the PCT. However, the reverse was observed for studied pictures, where memory activation improved the speed in the identification of studied pictures. Wang et al. (2018) proposed that the difference has to do with the perceptual versus conceptual nature of false memories. They argued that false memories for pictures are unlikely to contain perceptual information and are most likely conceptual in nature. However, there is no agreement as to whether verbal false memories are conceptual or perceptual in nature.

This experiment was limited in that it **only** used visual stimuli at study and in the PCT. To this end, like Wang et al. (2018), we conducted a second experiment where we manipulated the picture-word modality in the study phase and the PCT. The rationale for this was to determine whether visual false memories are conceptual in nature.

Experiment 2

The rational for Experiment 2 was to compare priming effects of true and false memories for both verbal and visual stimuli in people with AD and OACs.

Method

Participants

The sample size was determined using G Power (Faul et al., 2007) we ran an a priori power analysis for an ANOVA: Repeated measures, interaction effect. We anticipated an effect size (d = 0.7) and power was estimated at 0.80. The number of groups was 8, and the number of measurements was 3. This power analysis, showed 152 participants were needed in total – that is 38 participants (19 OACs and 19 people with AD) in each group, there were four groups in total.

Seventy-eight different participants had a clinical diagnosis of probable or possible AD (McKhann et al., 2011). Participation took place in the participant's home or at a local Day Centre to the participant. Eighty-seven participants made up the 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. Those OACs that had Participation took place either in their home or in a local day centre. There were no significant differences between OACs and AD participants in terms of age, years of education, or performance on the National Adult Reading Test, but as shown in Table 3, both groups differed on most cognitive tests.

INSERT TABLE 3 HERE

Materials

Study phase. Six pictorial and six verbal DRM lists from Experiment 1 were used.

Recognition test. The recognition task consisted of both a picture (like Experiment 1) and verbal versions of the DRM lists. For example, in the verbal version, each word corresponded to a picture in the pictorial version.

Perceptual closure task. The perceptual closure task (PCT) also contained a word and pictorial version. Both versions contained the same items – but with a different presentation modality (pictures or words). The level of degrading for words were the same as the filters for the pictures as in Experiment 1. The word version of the PCT included:
66 words of these images, 48 were studied (24 were shown in the recognition test and 24 were not), 6 were of critical lures, 6 were related words and 6 were unrelated words. The picture version of the PCT included: 66 images - 48 were studied (24 were shown in the recognition test and 24 were not), 6 were of critical lures from the recognition test, 6 were new images of the critical lures and 6 were unrelated pictures.

Design and procedure

A 2 (Group: OACs vs AD) x 2 (DRM Modality: pictures vs words) x 2 (PCT modality: pictures vs words) x 3 (Memory type: studied item, critical lures, unrelated) design was used.

Participants were tested individually. We manipulated stimulus modality, pictures versus words. Experiment 2 had four conditions, see Table 4.

INSERT TABLE 4 HERE

Results

Recognition test

INSERT TABLE 5 HERE

The mean recognition rates for people with AD and OACs across the different conditions are presented in Table 5. The table shows that when the DRM lists were presented verbally, corrected false recognition rates for critical lures were higher compared to when they were presented pictorially.

The same filtering process was conducted on the PCT data as in Experiment 1 prior to analysing the data.[2] A 2 (Group: AD vs OACs) by 4 (Condition: picture-picture, picture word, word picture, word-word) x 3 (Memory: studied item, critical lures, unrelated items) mixed measures ANOVA was conducted on the PCT reaction time. Missing data >3% were replaced by the average values.

There was a significant interaction between Memory and Condition, F (6, 155) = 153.53, $p < .001$, $\eta^2_p = .755$; Memory and Group, F (2, 155) = 4.96, $p < .001$, $\eta^2_p = .03$; and Group and Condition, F (3, 155) = 8.24, $p < .001$, $\eta^2_p = .13$ (see Figure 3). Simple main effect analysis revealed people with AD, were significantly slower in each modality, compared to OAC's (pic-pic F(1,155) = 115.88, $p < .001$, $\eta^2_p = .43$; pic-word F(1,155) = 168.2, $p < .001$, $\eta^2_p = .52$; word-pic F(1,155) = 45.18, $p < .001$, $\eta^2_p = .23$; word-word F(1,155) = 56.88, $p < .001$, $\eta^2_p = .27$). There was a main effect of Group, F (1,155) = 365.54, $p < .001$, $\eta^2_p = .7$, with OACs (M = 4160.73 SE = 52.42) recognising items in the PCT significantly faster than people with AD (M = 5589.86, SE = 54.04; $p < .001$, $\eta^2_p = .44$). There was a main effect of

[2] We controlled for the effects of the differences on the cognitive tests statistically for Exp 2. In all of our analysis, we ran analysis of covariance (ANCOVA) with these demographic variables as covariates. For all ANCOVAS, the pattern of the findings for main effects and interactions were unchanged from the analysis with ANOVA. For simplicity the ANOVAs are reported here.

Memory, *F* (1, 155) = 673.33, $p < .001$, $\eta^2_p = .8$, and a main effect of Condition, *F* (3, 155) = 67.01, $p < .001$, $\eta^2_p = .7$ (see Figure 3).

Simple main effect analyses revealed the following:

1 For the **picture-picture group**, studied items (*M* = 4182, *SE* = 93.42, $p < .001$, $\eta^2_p = .56$) primed the PCT more quickly than the critical lures (*M* = 5759, *SE* = 78.46) and unrelated items (*M* = 5762, *SE* = 84.28) and the latter two did not differ significantly, $p > .05$. This pattern of results also emerged for each group such that the OACs and people with AD showed this same pattern, a finding that replicates Experiment 1 - (see Figure 3).

2 For the **picture-word group**, critical lures (*M* = 4473, *SE* = 78.46, $p < .001$, $\eta^2_p = .61$) primed the PCT more quickly than the studied items (*M* = 5703, *SE* = 93.42) and both were significantly faster than the unrelated items (*M* = 6493 *SE* = 84.27; *p*s < .001). This same pattern of results emerged for the OACs and people with AD (see Figure 3).

3 For the **word-picture group**, critical lures (*M* = 3989, *SE* = 78.46) and studied items (*M* = 4153, *SE* = 93.54) did not differ from each other and both were significantly faster than the unrelated items (*M* = 5054, *SE* = 84.28; *p*s < .001). Again, the OACs and people with AD followed the same pattern (see Figure 3).

4 For the **word-word group**, critical lures (*M* = 3565 *SE* = 79.51, $p < .001$, $\eta^2_p = .8$) primed the PCT quicker than the studied items (*M* = 4239, *SE* = 94.67) and both were significantly faster than the unrelated items (*M* = 5124, *SE* = 85.41; *p*s < .001). Again, the OACs and people with AD followed the same pattern - (see Figure 3).

INSERT FIGURE 3 HERE

Experiment 2 replicated Experiment 1 inasmuch as false memories elicited from pictures were not as effective primes in the PCT compared to true memories. Furthermore, there were no reliable differences between false memories priming the PCT and unrelated pictures priming the PCT. These findings are also consistent with those reported by Wang et al. (2018). Interestingly, Experiment 2 replicated Otgaar et al.'s (2015) Experiment 1 and Wang et al.'s (2018) Experiment 2, inasmuch as verbal false memories elicited from verbal DRM lists served as superior primes, compared to verbal true memories.

Importantly, Experiment 2 also showed that in the Picture-Word condition where false and true memories were elicited from pictorial DRM lists, they both served as effective primes for the verbal PCT. For both people with AD and OACs, the magnitude of false memory priming was larger than that for true memories. A similar pattern was observed in the word-word condition, where verbal DRM lists were presented, and participants completed a verbal PCT. This suggests that regardless of the modality of the DRM lists (picture vs words), false memories will act as effective primes for verbal PCT. This is not true however, for picture PCT.

These findings can be explained as follows (also see Wang et al., 2018). When pictures of the DRM items were presented, concepts of these items were activated and spread to nearby nodes (i.e., critical lures) in a semantic network in a manner similar to when word DRM items were presented. The activation of critical lure concepts later facilitated the identification of critical lure words. If DRM pictures created visual false memories (i.e., vivid imagery representations of critical lure pictures), then visual false memories should have a priming effect in the pictorial PCT, which was not found.

Finally, in the word-picture condition (DRM word presentation followed by pictorial PCT) both critical lures and true memories served as effective primes. This was an expected finding – if we consider false memories as conceptual in nature. When the verbal DRM lists were presented, conceptual nodes for studied items and critical lures are spread across the semantic network, and encoded verbally and which are both activated during study. As such we would not expect these to prime a pictorial version of the PCT. This was also observed by Wang et al (2018).

General discussion

Our experiments focused on one positive aspect of false memories, namely their ability to prime solutions to perceptual closure problems. Here, participants are shown degraded representations of pictures of objects or words and tried to identify them as quickly as possible. In other problem-solving tasks (i.e., CRATs and analogies) both older adults and people with Alzheimer's disease benefit from having formed a false memory in a prior list-learning task when the false memory is also the solution to the problem (Akhtar & Howe, 2019; Akhtar et al., 2018; Howe & Akhtar, 2020). In fact, false memories tend to serve as better primes than true memories in these tasks (e.g., see Howe et al., 2013).

Because much of this prior research has focused on verbal stimuli (word lists and word problems) we wondered whether false memory priming benefits also extended to pictorial stimuli (picture lists and pictorial problems). In order to examine this, we used a perceptual closure task that can involve picture-based problems and presented DRM lists that are known to induce false memories but used pictures rather than words to represent the concepts on the lists. In previous research with young adults that have used these tasks, a reversal of the usual priming effect has been found. That is, Wang et al. (2018) found that when the perceptual closure task involved pictorial materials, priming effects were stronger with true memories than with false memories. We wondered whether this same reversal would occur with older adults and adults with Alzheimer's disease.

In the two experiments presented here we have shown that false memories elicited from pictorial DRM lists do not serve as effective primes in a pictorial version of the perceptual closure task. That is, for older healthy adults and older adults with Alzheimer's disease, true memories served as better primes for solving pictorial closure problems. However, like Wang et al. (2018), when verbal stimuli and verbal closure problems were used, false memories served as better primes than true memories. It would seem that when solving pictorial problems, false memories may not activate the appropriate representation in memory for solving a pictorial problems whereas actually presented items do. As Wang et al. (2018) explained, if true memories for pictures contain imaginal representations whereas false memories do not (i.e., they are purely conceptual), then true memories should prime identification of pictorial problems more quickly than false memories.

Interestingly, older adults with Alzheimer's disease not only evince true and false memories, ones that aid in priming problem solution, but they also tend to take longer to solve these problems than healthy older adults. Although both groups show a similar qualitative pattern when it comes to priming solutions on problem-solving tasks, there are quantitative differences in the speed of problem solving. Because this same pattern has been shown previously with verbal problem-solving tasks (e.g., CRATs and analogies; see Howe & Akhtar, 2020), it would seem that associative activation of information in semantic networks is still intact in people with Alzheimer's disease, activation times are slower than in healthy older people. Thus, a major contributor to differences between these groups is not the ability to access and utilize semantic networks, but the speed with which this access and spreading associative activation takes place.

In summary, we have extended the false memory priming paradigm to include pictorial stimuli and pictorial problems and discovered some limiting conditions on the false memory priming effect. These limitations have been found previously with young adults and we have now determined that these limitations also extend to perceptual closure tasks with older healthy adults and older adults with Alzheimer's disease. These findings add to the growing body of evidence suggesting that there are many similarities in true and false memory processing in aging, not just with healthy older adults but also those with Alzheimer's disease.

Appendix A: DRM lists

Pen	**Bread**	**Chair**	**Cup**	**Fruit**	**Car**
Pencil	Butter	Table	Mug	Apple	Truck
Fountain	Sandwich	Legs	Saucer	Vegetable	Bus
Leak	Rye	Seat	Tea	Orange	Train
Quill	Jam	Couch	Coaster	Kiwi	Jeep
Marker	Milk	Desk	Handle	Citrus	Ford
Bic	Flour	Recliner	Coffee	Pear	Keys
Scribble	Dough	Sofa	Straw	Banana	Garage
Crayon	Crust	Wood	Goblet	Berry	Tyre

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Table 1. Means (and Standard Error) Demographic Characteristics of Participants for Experiment 1.

	Mild AD N = 35	OAC N = 36	P Value
Age	70.25 (4.23)	72.24 (5.6)	NS
Education (years)	11.9	12.1	NS
NART estimated IQ	116.77 (5.2)	114.2 (5.3)	NS
MMSE (out of 30)	24.3 (2.2)	29.8 (0.5)	<0.0001*
MoCA (out of 30)	24.29 (1.8)	28.66 (1.7)	<0.0001*
CERAD			
Immediate (max = 30)	13.3 (2.33)	17.3 (2.44)	<0.0001*
Delayed (out of 10)	1.8 (1.37)	6.7 (3.22)	<0.0001*
Recognition (out of 10)	5.3 (1.18)	9.2 (3.25)	<0.0001*
Digit span (out of 10)			
FWD	5.5 (1.3)	7.1 (1.87)	<0.0001*
BCK	3.1 (1.18)	5.9 (1.22)	<0.0001*

NART – National Adult Reading Test
MMSE – Mini Mental State Examination
MoCA – Montreal Cognitive Assessment
CERAD – CERAD word list
*Significant difference between OAC and AD
NS, difference not significant

Table 2. Percentages and standard deviations of the recognition task for Experiment 1.

	Study Items	FMs	Unrelated
OAC	85.8% (1.76)	17.4%(1.2)	7% (.95)
AD	77.3% (2.2)	25.6% (1.72)	18.4% (1.22)
	F = 34.94**	F = 40.94**	F = 29.41**

**p <.001

Table 3. Means (and Standard Error) Demographic Characteristics of Participants for Experiment 2.

	Mild AD N = 78	OAC N = 87	P Value
Age	73.42 (7.2)	72.24 (7.4)	NS
Education (years)	11.2	11.8	NS
NART estimated IQ	116.14 (6.7)	115.2 (7.6)	NS
MMSE (out of 30)	24.3 (2.2)	29.6 (0.6)	<0.0001*
MoCA (out of 30)	24.22 (1.7)	28.66 (1.2)	<0.0001*
CERAD			
Immediate (max = 30)	12.99 (2.22)	17.4 (3.93)	<0.0001*
Delayed (out of 10)	1.7 (1.29)	6.7 (3.22)	<0.0001*
Recognition (out of 10)	5.6 (3.2)	9.1 (2.3)	<0.0001*
Digit span (out of 10)			
FWD	5.6 (1.2)	7.2 (1.78)	<0.0001*
BCK	2.29 (2.3)	5.8 (1.18)	<0.0001*

NART – National Adult Reading Test
MMSE – Mini Mental State Examination
MoCA – Montreal Cognitive Assessment
CERAD – CERAD word list
*Significant difference between OAC and AD
NS, difference not significant

Table 4. Percentages and standard deviations of the recognition task for Experiment 2.

Condition	Modality	
1	picture-picture (like Exp. 1)	DRM lists are presented in a pictorial form in the study phase and degraded pictures in the PCT
2	picture-word	DRM lists are presented in a pictorial form in the study phase but degraded words for these in the PCT
3	word-word	DRM word lists are presented in the study phase and degraded words in the PCT
4	word-picture	DRM word lists are presented in the study phase and degraded pictures of the words in the PCT

Modality of the recognition test was the same as the study phase.

Table 5. Mean recognition rates in different groups of participants for studied items, critical lures and unrelated items for Experiment 2.

	picture-picture			picture-word			word-picture			word-word		
	OAC	AD	F	OAC	AD	F	OAC	AD	F	OAC	AD	F
	(N =21)	(N =20)		(N =21)	(N =20)		(N =21)	(N =20)		(N =21)	(N =19)	
Studied items	87.50%	76.46%	22.41**	87.60%	75.72%	23.1**	83.81%	73.96%	15.13**	84.12%	73.58%	13.64**
False Memories	18%	29.13%	4.24*	17.73%	29.80%	7.24*	49.25%	58.23%	6.88**	45.23%	63.23%	7.21**
Unrelated items	8.10%	18.30%	4.87*	8.6%%	20%	14.69**	6.30%	15%	7.3*	5.41%	6.30%	6.79*

** significant at p < .001
* p significant at < .05

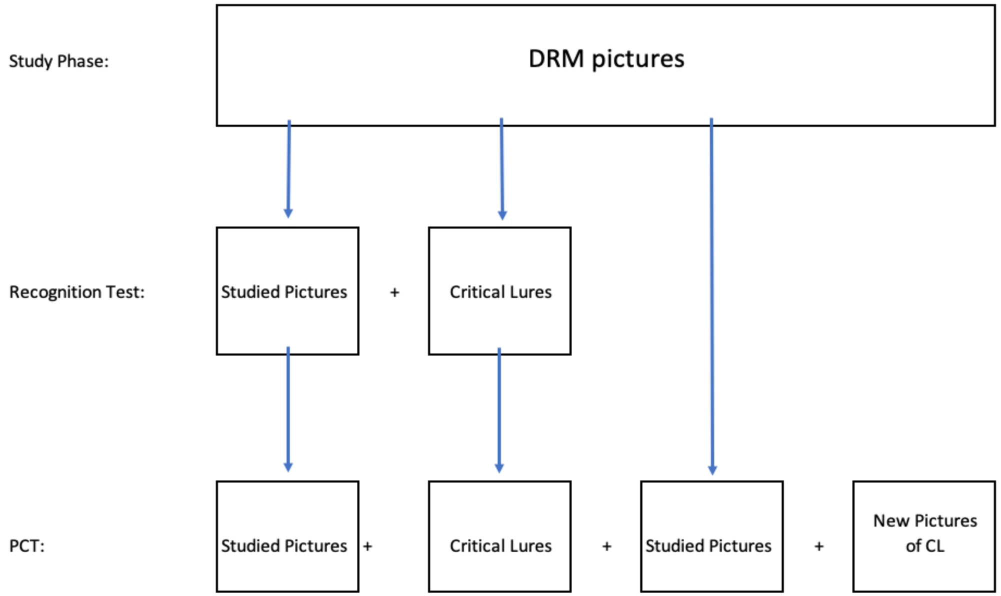

Figure 1. Diagram of the procedure for Experiment 1 (Note: CL refers to Critical Lures)

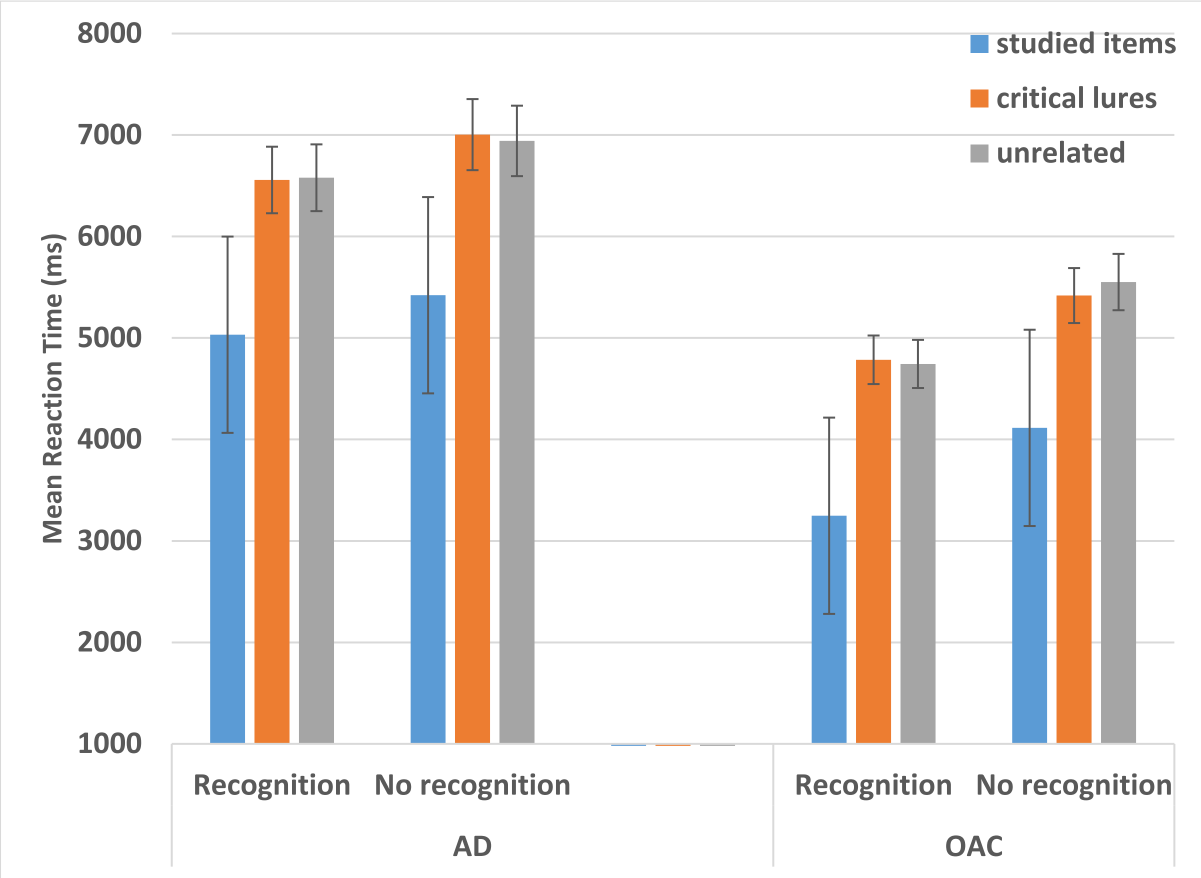

Figure 2. Mean reaction times for OACs and people with AD (error bars represent 95% CI) for the different memory type and recognition presentation for Experiment 1.

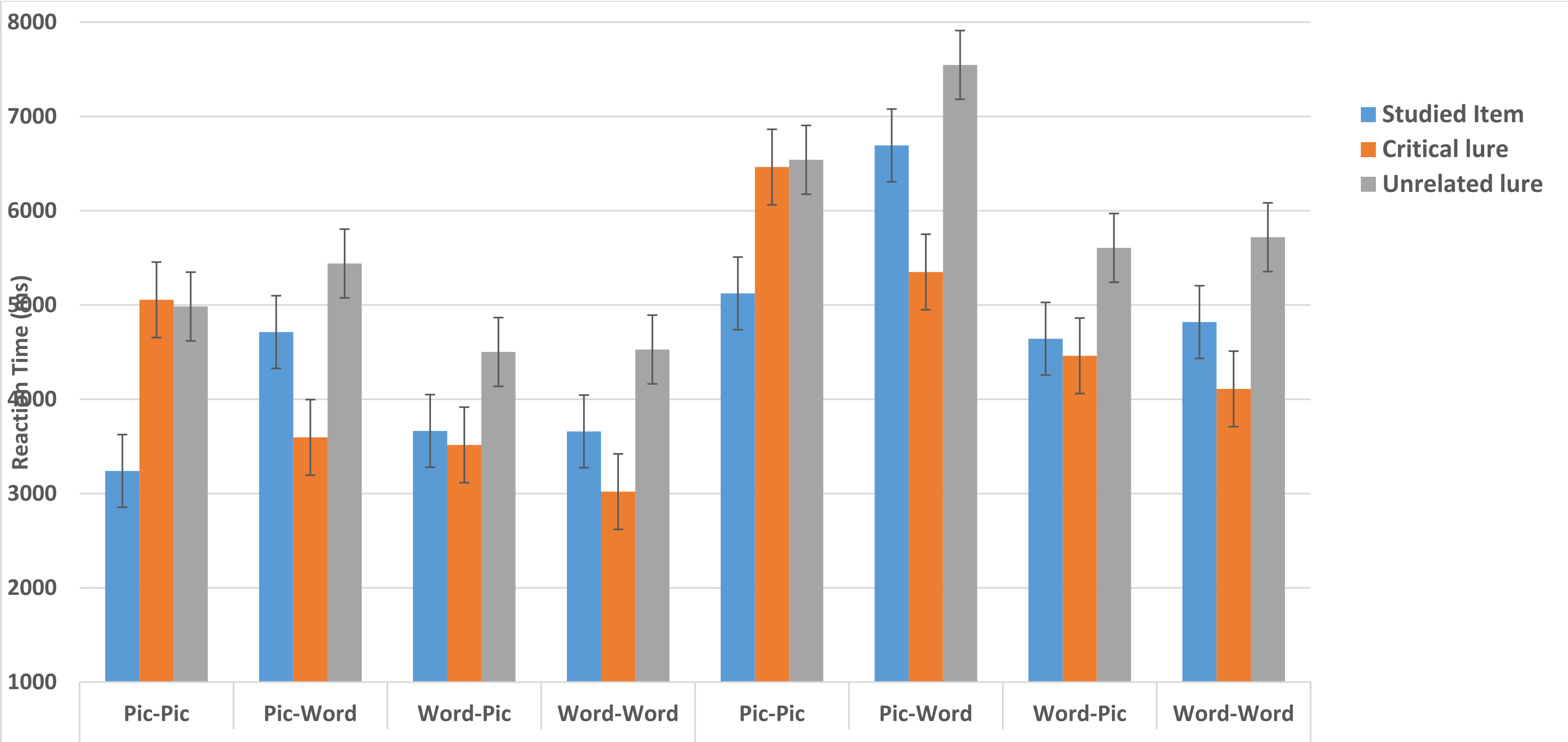

Figure 3. Mean reaction times to studied items, critical lures and unrelated items (error bars represent 95% CI) in the different conditions for people with OAC and AD for Experiment 2.