



Retrieval-induced forgetting in Alzheimer's disease

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Received 14 March 2001; accepted 15 August 2001

Abstract

It is claimed that Alzheimer's disease (AD) patients show reduced inhibitory processing and this has been put forward as a reason why AD patients make intrusion errors at recall. However, the evidence to date has been equivocal, because non-inhibitory mechanisms can account for the pattern of findings. Recently, however, a paradigm has been developed that is claimed to give a purer measure of inhibitory processing in episodic memory, the retrieval-induced forgetting (RIF) paradigm [Inhibitory Processes in Attention, Memory and Language, Academic Press, San Diego, 1994, p. 265; J. Exp. Psychol.: Learning, Memory Cognition 20 (1994) 1063; Psychol. Rev. 102 (1995) 68]. Thus, we were interested whether AD patients would show a deficit in inhibitory processing using this procedure. Participants studied lists of category cue—exemplar pairs (e.g. fruit—orange) then practised retrieval for a subset of items from a subset of categories before taking a final memory test for all studied items. As in previous work, inhibition was measured as the difference between final memory performance for unpractised items from practised categories, and unpractised items from unpractised categories. The results show that AD patients showed normal levels of inhibition with both tests of cued recall and category generation (CG). This suggests that a deficit in inhibitory processes during retrieval is not behind the high levels of intrusion errors made in recall in AD. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Retrieval inhibition; Dementia; Episodic memory; Intrusion errors

1. Introduction

Alzheimer's disease (AD) is a progressive dementia that is characterised by very low levels of recall on episodic memory tasks (e.g. [18]). However, not only are people with AD unlikely to recall much information, they are also prone to making intrusion errors; 'recalling' items that were never presented at study [16,22,27]. Clinical studies indicate that people with AD make many more intrusion errors than controls (e.g. [21]). A survey of 51 randomly selected AD patients who routinely attended the Memory Clinic at the Research Institute for the Care of the Elderly, St. Martin's Hospital, Bath considered intrusion errors on free recall of the CERAD word list [36].¹ There is also evidence to

suggest that intrusion errors are particularly diagnostic of AD. Fuld et al. [17] demonstrated a correlation between the number of intrusion errors and the biological features of the disease (senile plaque counts and levels of the enzyme choline acetyltransferase). Additionally, research has shown that even when matched for recall levels, AD patients make more intrusion errors than participants with a sub-cortical dementia, Huntington's disease [24].

There are two prominent accounts of intrusion errors in AD. First, because the intrusion errors in AD are predominantly for semantically related items, e.g. recalling *diamond* instead of *sapphire*, the propensity to make intrusions is thought to be reflective of a disruption in semantic memory processing [7]. Second, intrusion errors are proposed to be due to an inability to monitor output during retrieval [11]. Either account could stem from a deficit in inhibitory processes in AD. AD patients may fail to inhibit possible, but incorrect items at recall. That is AD patients may fail to inhibit other semantic activations during retrieval, or fail to inhibit output. In the present paper, we assess this novel hypothesis that intrusion errors result, to some degree, from

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¹ This showed that 43% of all patients made at least 1 intrusion error, and mean recall (standard deviation) of non-presented items made up 8% (11%) of all recall. The AD group had a mean (standard deviation) age of 77.47 (6.35) and a mean MMSE score of 19.29 (4.28).

a lack of inhibition during retrieval from memory. This hypothesis is consistent with reports of inhibition deficits seen in other cognitive tasks in AD.

Deficits in inhibitory processes are well documented in AD. For example, AD patients perform very poorly on the Stroop test [35], which has been claimed to be indicative of a deficit in inhibitory functioning (See [9,25,33], but also [26]). Faust et al. [14] used a sentence–word matching paradigm to test inhibitory function in AD. They presented participants with sentences followed by a word. The task was to say whether the word was consistent with the meaning of the sentence. The manipulation of interest was that the sentences contained either unambiguous terms with only a single meaning (e.g. shovel), or ambiguous ones, which had multiple meanings (e.g. spade, meaning both digging implement and a suit in a deck of playing cards). In the unambiguous sentences, the final word did not match any of the meanings of the sentence term: (e.g. “He dug with the shovel. ACE”), whereas in the ambiguous sentence, the final word matched the inappropriate meaning of the sentence term (e.g. “He dug with the spade. ACE”). The results indicated that both AD patients and older adult controls (OACs) were slower to reject the target in the presence of ambiguous sentences. However, the effect was markedly stronger for the AD patients, leading Faust et al. [14] to conclude:

“... the results are consistent with a growing number of studies demonstrating impairments in inhibitory control, with relative preservation of facilitatory processes, in DAT” (p. 225–6).

The aim of the experiment presented here was to assess whether this inhibitory deficit might influence the pattern of recall in AD. We are aware of one study of relevance to episodic memory that has indirectly examined inhibitory mechanisms in AD, but it is not a compelling test of the above hypothesis. A version of a directed forgetting paradigm was used by Manning et al. [28] in which they presented lists of items, with an additional item the participant is told to forget. In an immediate recall test, people with AD tended to retrieve this item, demonstrating that they had failed to inhibit it. Whilst this study is suggestive of an inhibitory deficit in AD, it is not convincing, because the results could be due to a failure to remember the instructions, rather than a failure to inhibit the undesired item. Alternatively, it may be evidence of source forgetting, with AD patients forgetting which item is to be recalled and which is not.

In this paper, we present results from a paradigm that is ideal for assessing inhibition in episodic memory: the retrieval-induced forgetting (RIF) paradigm. Anderson et al. [3] introduced this paradigm as a demonstration of the role of inhibition in memory retrieval. The task has three phases: initial learning of a list of category–exemplar pairs, repeated ‘practice’ of recalling a subset of the exemplars from some categories and a cued recall phase for all exemplars. For example, participants study a set of pairs that include fruits (orange, lemon, banana, pineapple) and hobbies (gardening,

biking, drawing, ceramics). During retrieval practice, half of the exemplars from half of the categories are practised using a word stem completion task (e.g. fruit: Or_). At the final recall test, there are three kinds of items: (1) practised items from practised categories (RP⁺ items), (2) unpractised items from practised categories (RP⁻ items) and (3) unpractised items from unpractised categories (U).

Anderson and Bjork [2] showed that repeated practice of a subset of exemplars leads to superior memory for those items, compared to exemplars from the unpractised category. However, this was accompanied by inferior memory for the unpractised members of the practised category relative to control items from unpractised categories. That is, with the above example, orange was more likely to be recalled, and pineapple less likely to be recalled than the equivalent items for categories not practised (ceramics, biking) (for a full account of the phenomenon, see [2]). We aim to use this paradigm to explore retrieval processes in AD. Anderson and Bjork [2] present an indication of the suitability of this paradigm to assess inhibition in episodic memory:

“... if retrieval inhibition results from a decreased ability to apply attentional mechanisms we might expect less impairment for special populations whose deficits supposedly arise from a decreased ability to apply attentional inhibition ...” (p. 305).

One major advantage of using this paradigm to assess inhibition is that it requires no instruction to forget. The inhibition that arises from the RIF procedure is argued to be due to an attentional mechanism that is a natural consequence of the retrieval practice phase. Because of this, it is possible to test memory with different tasks. The experiment presented here uses cued recall (the standard test used to elicit the retrieval-induced forgetting effect) and also category generation (CG) as an implicit test. The addition of this CG test was largely a pragmatic one. We were aware that AD patients often perform poorly on explicit tests of retention, whereas implicit tests tend to show that some memory representation for the item exists (e.g. [23]). Thus, CG should be less subject to floor effects, which may confound the ability to observe inhibition.

To summarise, we expected that given the documented intrusion errors made in AD, and the strong evidence in favour of an inhibitory deficit in AD, the AD group would fail to show any suppression of recall for the RP⁻ items relative to the recall of U items. Because the RIF paradigm affects the accessibility of an individual item [4], we expected this to be the case both for explicit recall and category generation.

2. Method

2.1. Participants

In all, 12 AD patients and 18 OAC participants took part in this study. AD participants were recruited from the Memory Clinic at the Research Institute for Care of the Elderly,

St. Martin's Hospital, Bath. Patients were diagnosed by an independent clinician as being demented with the DSM III-R [1] criteria and as having AD by the NINCDS–ADRDA criteria [29]. The AD participants had a mean mini-mental state examination (MMSE [15]) score of 21.1 (2.5), a mean age of 77.2 (4.9) years and a mean education level of 11.5 (2.5) years formal education.

The OAC group was recruited from a group of healthy volunteers. They had a mean MMSE score of 27.88 (2.1), a mean age of 73.4 (3.44) and a mean education level of 12.9 (3.7) years. The OAC group was significantly younger than the patients, $F(1, 28) = 6.38$, $MSE = 16.80$, $P < 0.05$, and had, as expected, a higher MMSE score, $F(1, 28) = 40.12$, $MSE = 8.31$, $P < 0.001$. There were no significant differences in education between the groups, $F(1, 27) = 1.32$, $MSE = 10.89$.

2.2. Materials

The stimuli were selected from Battig and Montague's [5] category generation norms. There were 12 items in the to-be-remembered list, consisting of four exemplars from each of three categories. At the encoding phase, all 12 items were presented to participants as pairs in category–exemplar form. At the retrieval practice phase, two exemplars were practised from two of the presented categories. No items were practised from the remaining category. Thus, there were four RP⁺, four RP⁻ and four U exemplars. Materials were counterbalanced: each word appeared equally as an RP⁺, RP⁻ or U item.

2.3. Procedure

Participants were tested individually in a quiet testing room. They were informed that they would be participating in a test of memory, and they were shown an example of the test category–exemplar pairs (e.g. fruit—melon). Participants were instructed to learn the pairs for an upcoming test. At presentation, word pairs were presented in a random order, on a computer screen, one pair at a time for 8 s (AD participants) or 4 s (OAC participants). The differences in study time were carried out in order to reduce the possibility of floor effects in the AD group.

After the 12 to-be-remembered words had been presented, participants were introduced to the practice phase. They were instructed that they would practice a subset of items from the whole list. The RP⁺ pairs were presented on the computer screen with only the first letter of the exemplar pair visible, e.g. (fruit—M.). Participants were asked to try to remember the word. If they could not remember it, they were shown an additional letter until they correctly recalled the item. There was no time limit given, but participants were told to ask for the next letter if they felt they could not recall the item. This procedure was sufficient to ensure that the correct item was generated during practice. Practice of the four items occurred in a random order within one block;

the block was presented three times. Thus, each RP⁺ item was practised three times.

Immediately after the practise phase, participants completed the final memory tests. First, they were instructed to verbally recall as many of the exemplars as they could remember from each category. They were cued for all three categories using the category name: *remember all the fruits that you studied on the original list*, for example. Recall from the categories was in a counterbalanced order, thus, across participants there were equal numbers recalling from an unpractised or practised category first.

Immediately after the recall phase, and for the same categories in the same order, participants were given the category generation test. Participants were told that their task was to say out loud the first eight exemplars that they could think of for each category they were given. There was no explicit instruction—participants were neither told to include or exclude previously presented words, or words they had produced on the recall phase. The experimenter then gave an example unrelated to the test materials to ensure understanding. For each test category, participants were given 1 min in which to generate category members.

3. Results

The focus of this experiment was inhibitory processes in memory. The extent to which inhibition is present is indicated by the reduction in performance for RP⁻ items compared to U items. If the AD group was inhibiting items at retrieval, we would expect a significant difference between RP⁻ and U items in both recall and category generation. The effects of practice, reflected in performance on the RP⁺ items are not of interest, and are, therefore, not included in any of the analyses reported here. However, performance on RP⁺ items is reported for completeness. The number of target exemplars correctly recalled (explicit memory) and generated (implicit memory) is shown in Fig. 1.

For cued recall, there were main effects of group, with the AD recalling fewer items than the control group, $F(1, 28) = 26.94$, $MSE = 0.09$, $P < 0.001$; and item, with superior recall for U than RP⁻ items, $F(1, 28) = 11.42$, $MSE = 0.05$, $P < 0.01$. However, there was not a significant interaction, $F < 1$. This indicates that despite large differences in recall, both groups display the standard inhibitory effect, with lower recall for RP⁻ than U items. The lack of a significant interaction suggests that there is no difference in the groups inhibition of RP⁻ items. Thus, the cued recall results do not support the hypothesis that there is deficient inhibitory processing in episodic memory performance in AD. For category generation, we find the identical pattern. The older adult control group correctly generated more targets overall, $F(1, 28) = 7.44$, $MSE = 0.11$, $P < 0.05$; there were more targets generated for U than RP⁻ items, $F(1, 28) = 23.66$, $MSE = 0.02$, $P < 0.001$ and there was not a significant interaction, $F < 1$. Therefore, with the category genera-

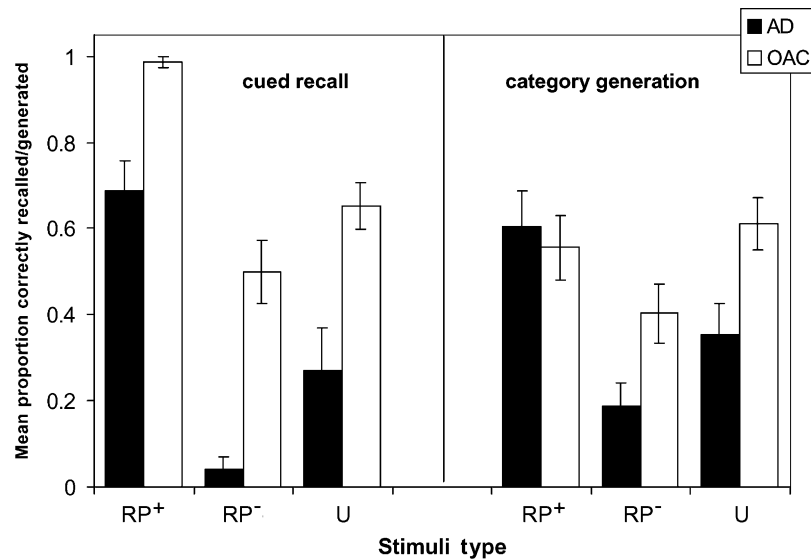


Fig. 1. Mean proportion of items recalled and generated to cues. Error bars = 1 standard error.

tion task, there is still evidence that both groups produced the standard inhibitory effect. Neither final test, cued recall or category generation, suggests that there is an inhibitory deficit in the recall of people with AD.

We were interested in the tendency to produce intrusion errors in AD. In the present study, there are clear differences in the levels of intrusions between the groups. As a proportion of all items recalled, AD patients made a mean (standard deviation) of 0.27 (0.15) intrusion errors compared to 0.03 (0.06) in the control group. This difference was statistically significant, $F(1, 28) = 39.72$, $MSE = 0.01$, $P < 0.001$. Moreover, only one AD patient made zero intrusion errors. For comparison, the mean recall of RP⁻ items as a proportion of total recall was 0.01 (0.03) in the AD group and 0.05 (0.03) in the control group.

4. Discussion

Previous researchers have found that there is an inhibitory deficit in AD, which results in the processing of items in memory that should be suppressed. We hypothesised that the inhibitory deficit found by previous researchers would extend to processes used in recall. We tested this hypothesis using the retrieval-induced forgetting paradigm. Both with an explicit and implicit test of memory, we demonstrated that inhibition of items in episodic memory was equivalent in older adults with and without AD. On the basis of this evidence, it appears that inhibition of competitor items during retrieval is intact in AD.

First, we address the differences between previous research and this study. The fact that we did not find a RIF deficit in AD suggests that the inhibitory process that is dysfunctional in previous reports is not at work in the suppression of RP⁻ items in the paradigm used here. The inhibition

necessary for RIF effects appears intact in AD, whereas the inhibition that suppresses unwanted word meanings (i.e. Faust et al. [14]) is impaired. Clearly, this suggests the need for a multi-faceted construct of inhibition, rather than a central inhibitory resource that affects different processes and different materials. This receives support from research that has shown that whereas some inhibitory processes are impaired in older adults relative to young controls, others are not [10,20,26]. Further evidence that there is not a unitary inhibitory mechanism, even for recall comes from individual differences research that has shown that performance on different inhibitory tasks (RIF and directed forgetting) does not correlate [34]. The exciting possibility exists that AD could be used as a tool to help cognitive psychologists examine different forms of inhibition.

Previous research indicates that AD patients have difficulties with inhibitory tasks that involve response selection, e.g. Stroop test [35] or processing ambiguous sentences [14]. However, this paper suggests that the automatic suppression of competitor (RP⁻) items is intact in AD. It is conceivable that automatic suppression is intact, whereas deliberate inhibition in tasks such as the Stroop test, is impaired in AD. If intrusion errors reflect the failure to suppress related but incorrect responses, then the present data show AD patients simultaneously inhibiting RP⁻ items, whilst failing to inhibit other potential but inappropriate answers. In fact, they suppress the ones that they want to recall and do not suppress those items that they do not want to recall. Clearly, a unitary account of inhibition in retrieval is hard to sustain.

Secondly, we turn to an explanation of intrusion errors in recall in AD. We expected that an examination of the inhibition of competitor items might illuminate our understanding of intrusion errors in AD. However, the present work suggests that AD patients do not suffer from a lack of inhibition during retrieval from episodic memory. Despite this, there

are clear problems with the unintentional recall of items that were not presented at study. Although this is typical of the memory impairment in AD, it is conceivable that the category cue procedure used here inflates the level of intrusion errors compared to free recall. What is behind these intrusion errors in this task, given that inhibitory function seems intact as measured by the suppression of RP^- items?

One possibility is that the inhibitory process captured in the RIF procedure is not the deficient inhibitory process that is leading to intrusion of a competitor item at study (for a discussion of the inhibitory nature of various retrieval inhibition tasks see [2]). Given that there is little correspondence between inhibition on one memory task and another (as discussed above), this is clearly a major consideration. Therefore, it is possible that the low-level attentional process that inhibits RP^- items is intact in AD, but the conscious control of items retrieved from memory is impaired. It is possible that the RIF procedure automatically stops items coming to mind during retrieval, but that an intrusion error occurs when an item is brought to mind during retrieval, but is not *consciously* rejected. This possibility should be assessed using paradigms where conscious control of memory is used (e.g. the directed forgetting procedure [6]).

We should also consider that a methodological artefact may have produced intact inhibition in the AD sample in our study. Although there were significant age differences between groups, it is unlikely that this is responsible for the pattern of results found here. If anything, we would expect older participants to show less of an inhibitory effect [19]. However, in the work presented here, there are no group differences in the RIF effect even though the AD group is significantly cognitively impaired and older. Floor effects seem unlikely to account for the intact effect in the AD group, since we have demonstrated the RIF effect with category generation also, where performance was superior to cued recall.

Another possibility is that our sample of AD patients is a group of high-performing individuals who are not sufficiently cognitively impaired to show an inhibitory deficit. The clear differences between patients and controls in overall recall and MMSE score speak against this. Further, to check whether inhibitory processes may be related to disease severity, we split the AD group into those who showed the effect (an arithmetic difference such that $RP^- < U$, $n = 5$), and those who did not ($n = 7$). When comparing these groups, there was no difference in recall (RP^+ items) or general level of cognitive functioning (MMSE), both $F < 1$.

Finally, it should be acknowledged that the intrusion errors are not necessarily a failure of inhibition. One interpretation of these errors is that they are made on the basis of gist, or a failure to recall the source of a to-be-remembered item. In recognition paradigms, AD patients have been shown to be susceptible to distortions of memory: they make false alarms due to the over application of semantic gist [8]. Previous research has also shown that AD participants make more source errors than controls [31], and they confuse performed

actions for perceived ones [12,13]. Feasibly, this indicates that in AD once an item comes to mind there is a degree of confusion as to whether or not it was studied earlier. AD patients are also more likely to guess in recall tests [32], although people with AD are appropriately aware of when they are guessing in tests of recognition [30]. Thus, future work could assess the role of guessing, gist and source errors in the intrusion errors of recall.

In summary, Anderson et al.'s [3] interpretation of the retrieval inhibition effect is that retrieval of the items during practice actively inhibits the recall of associated items. Thus, the work presented here indicates that the recall of people with AD features the same ability to inhibit competitor items at retrieval found in normal populations. On the basis of this evidence, it seems unlikely that the propensity to make intrusion errors in episodic memory tasks in AD is as a result of deficient inhibitory mechanisms that automatically suppress competitor items at retrieval.

Acknowledgements

This work was supported by a grant from the Economic and Social Research Council (R000222681). We are grateful for the co-operation of patients and staff of the Research Institute for the Care of the Elderly, St. Martin's Hospital, Bath and the helpful comments Pilar Andres made on a version of this manuscript.

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