CONTROLLED AND AUTOMATIC MEMORY PROCESS IN ALZHEIMER'S DISEASE

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ABSTRACT

The aim of this study was to examine the contribution of controlled (or conscious) and automatic (or unconscious) memory processes to the performance of a stem-completion recall task by persons with Alzheimer's disease and a matched group of healthy elderly individuals. The recall task made use of the process dissociation procedure of Jacoby (1991), which allows the separate estimation of conscious and unconscious influences on memory. Recollection was found to be severely impaired in the community dwelling demented patients. Further, the estimates of the automatic processing were also found to be reduced, although there was considerable overlap in the performance of the two groups on this parameter. It was found that the residual capacity of Alzheimer's patients to recall previously learned information was supported to a substantial degree by their automatic memory processes.

Key words: automatic memory, dementia

A defining characteristic of dementia of the Alzheimer's type (DAT) is a profound impairment on any direct or explicit tests of memory (e.g., Butters, 1984; Weingartner, Kaye, Smallberg et al., 1981). Thus, when demented patients are instructed to recall to consciousness previously studied information, their performance is almost invariably abnormal. Nonetheless, it is apparent that on some tasks DAT patients do show a degree of preserved capacity for learning. In particular, on tests measuring facilitation of performance by a previous learning episode, where the test is indirect and does not require conscious recall, DAT patients may show normal or near normal performance (e.g., Grosse, Wilson, Gabrieli et al., 1991; Keane, Gabrieli, Fennema et al., 1991; Monti, Gabrieli, Wilson et al., 1994). However, the dissociation between impaired direct memory and preserved indirect memory, which has been consistently demonstrated in persons with circumscribed amnesia, is not as clear cut in Alzheimer's disease. For example, on the widely used word-stem completion test of implicit memory function (Graf, Squire and Mandler, 1984), there are reports of both abnormal (e.g., Heindel, Salmon, Shults et al., 1989; Salmon, Shimamura, Butters et al., 1988; Shimamura, Salmon, Squire et al., 1987; Keane et al., 1991) and normal performance (e.g., Deweer, Ergis, Fossati et al., 1994; Grosse et al., 1991; Partridge, Knight and Feehan, 1990).

These inconsistencies in the literature on indirect memory performance in DAT are not easily resolved. In some circumstances they reflect important differences in the cognitive processes underlying the execution of the tasks used (Downes, Davis, Davies et al., 1996). In others, differences in methodology or

patient characteristics can account for discrepancies in the findings (e.g., Burke, Knight and Partridge, 1994; Ostergaard, 1994). Furthermore, differences in the psychometric characteristics of the tests of memory used in experimental studies can also be important. Where memory or priming tasks are contrasted that are not well matched for difficulty or reliability (Chapman and Chapman, 1973) or where priming effects are inferred from difference scores in an inappropriate manner (Chapman and Chapman, 1988; Knight, 1995), invalid conclusions about the integrity of implicit memory may be drawn.

Another more general difficulty in the interpretation of findings from studies of memory-impaired patients is the invalid identification of particular tasks with specific memory processes. This is relevant to lexical-semantic priming tasks, such as indirect tests of word-stem completion, which are often assumed to be measures of implicit memory processes. The performance of such tasks, however, is not necessarily process-pure and may well be contaminated by the use of intentional memory (Jacoby, 1991; Jacoby, Toth and Yonelinas, 1993; Roediger and McDermott, 1994; Yonelinas and Jacoby, 1995). Thus it may be that the preserved ability of healthy elderly subjects to use controlled retrieval strategies accounts for their superior performance on word-stem completion tests, relative to DAT patients (Randolph, 1991). Similarly, cued recall tasks may be performed by automatic rather than controlled memory procedures, rendering the interpretation of findings as a demonstration of a failure of explicit or implicit memory problematic.

Jacoby (1991) described a method for separating conscious from unconscious (or automatic) processes in memory that allows the estimation of controlled memory performance without contamination by unconscious or automatic influences, which he termed the process dissociation procedure. One advantage of this method is that it allows the examination of differences in the processes impaired and nonimpaired individuals use to recall or recognize previously studied information. In the present instance, it permits the investigation of how cued recall tasks are performed by demented and nondemented elderly persons. Jacoby's method involves the use of an oppositional procedure to measure recollection. This is achieved by instructing participants to complete word stems during the test phase with words that were presented during the study phase in one part of the experiment (the *inclusion* condition), and to complete word stems with words different from those they had studied earlier in the other (the *exclusion* condition). Results from these two conditions are then combined to give a measure of controlled memory processing or recollection (R). Those individuals capable of accurate recollection will have a high probability of completing stems with studied words in the inclusion condition and a low probability of completing stems with studied words in the exclusion condition. In contrast, the demented person, with little capacity for controlled recollection, will be as likely to respond with a studied word in the exclusion condition as in the inclusion condition. The process dissociation procedure has been used to examine recollection in amnesia by Mayes et al. (1995) and Verfaellie and Treadwell (1993). In both studies it was found that amnesic patients showed impaired recollection in the presence of a preserved capacity to recognize previously exposed stimuli as familiar.

Jacoby et al. (1993) presented equations that allow the separate calculation of conscious recollection and the automatic influences on recollection (A), from the probability of producing a studied word in the inclusion condition (I) and the probability of a studied word being produced in the exclusion condition (E). R, the probability of conscious recollection, is defined as the difference between I and E. The contribution of automatic processes to recall (A) is given by $E/(I-R)$. During the course of the experiment, participants are also asked to complete word stems from a list of unprimed new words and the number of words from this list that participants give in response to these stems provides an estimate of the probability of guessing a primed response. The estimate of A can subsequently be corrected for guessing by subtracting the baseline probability of completing a stem by chance with a predesignated word from the initial estimate of A. Different procedures for estimating A and R have been developed that take better account of false alarm rates (e.g., Buchner, Erdfelder and Vaterrodt-Plünnecke, 1995; Mayes, Van Eijk and Isaac, 1995; Roediger and McDermott, 1994), which are of particular value for process dissociation procedures that require participants to recognize which of two lists words belong to (e.g., Yonelinas, 1994). However, in the present study, which uses a cued recall paradigm based on the procedures used by Jacoby et al. (1993), the methods of estimating R and A given in that paper are appropriate, provided that the baseline guessing rates of the two groups are equivalent.

Jacoby's (1991) process dissociation model requires a number of assumptions, one of the most important being that for the estimate of A to be valid, controlled and automatic memory processes must be independent. Different estimates of A would emerge if all the items produced by controlled recollection were also accessible via automatic processes (the redundancy model of Joordens and Meikle, 1993) or if the automatic and the controlled memory processes were entirely separate and had no overlap (the exclusivity model of Jones, 1987). Cowan and Stadler (1995) have examined the general set of models where the amount of overlap between automatic and controlled processes is fixed (which includes the redundancy and exclusivity models as extreme cases) and compared such fixed-ratio models with Jacoby's independence model (which assumes that the amount of overlap is proportional to the amount of automatic memory processing). By considering the effect on estimates of A of increasing the proportion of overlap in controlled and automatic processing from 0 to 1 under either fixed-ratio or independence assumptions, they showed that the set of fixed-ratio models produced implausible results for the data from studies of the impact of reduced attention allocation on memory (Debnar and Jacoby, 1994; Jacoby et al., 1993). They concluded that at the present time, for the conditions under which it has been tested, Jacoby's independence model provides a more parsimonious explanation of experimental findings than alternative models.

In the present study, a variation of the Jacoby et al. (1993) method of obtaining estimates of I and E was employed. The procedure used was adopted after an initial study had been completed to develop a task suitable for use with the demented elderly. In this pilot study it was found that the procedure used by Jacoby et al. (1993) in Experiment 1, whereby stems in the inclusion and

exclusion conditions were randomly distributed in the test phase of the experiment, was not appropriate for either the elderly controls or the demented patients. The majority of subjects in both groups were unable to switch between conditions on a trial-by-trial basis. Accordingly, the inclusion and exclusion conditions were administered as separate blocks (as in Jacoby et al., 1993; Experiment 4). A list-length of 12 items was chosen on the basis of the experience gained in the pilot study, where it was found that DAT patients were able to attend and respond meaningfully to a word list of that magnitude.

The aim of the present study was to examine the independent effects of controlled and automatic processing on the performance of a word-stem completion recall task by persons with dementia. It was hypothesized that the demented persons would have significantly lower *R* estimates than the controls. Further, on the basis of the findings that implicit memory may be impaired in dementia (e.g., Salmon et al., 1988; Shimamura et al., 1987), it was hypothesized that automatic memory processes would be impaired in dementia relative to the performance of the comparison group.

MATERIALS AND METHODS

Subjects

The Alzheimer patients were 10 (4 male, 6 female) community-dwelling persons attending the psychogeriatric assessment unit at Wakari Hospital, Dunedin, as outpatients. They averaged 69.20 years ($SD = 7.09$, range = 58-78) in age and had an average of 8.78 years ($SD = 1.48$) of formal education. Their average estimated premorbid IQ score, based on the National Adult Reading Test (NART; Nelson, 1982), was 111.15 ($SD = 3.73$). All patients met the criteria for DAT of McKhann, Drachmann, Folstein et al. (1984) and had no history of other major psychiatric or neurological disorder. As an aid to excluding patients with multi-infarct dementia, the Hachinski Ischemic score (Hachinski et al., 1975) was completed after a review of the patient's medical notes and consultation with medical staff. All participants had an Ischemic score of less than 5. On the Mini Mental Status Examination (MMSE; Folstein, Folstein and McHugh, 1975) the DAT patients had an average score of 21.60 (range 18 to 24), placing them in the mild to moderate range of impairment.

The Normal Control (NC) subjects were 10 elderly persons (7 female, 3 male) with no evidence of dementia and no history of major psychiatric or neurological disorder. They had an average age of 68.00 years ($SD = 6.78$, range = 58-77), an average of 9.11 years ($SD = 2.37$) of formal education, and an average NART estimated FSIQ of 113.89 ($SD = 4.90$). They were recruited from amongst the relatives of patients or community volunteers at the hospital. All scored 29 or 30 on the MMSE. There were no significant differences in age, years of education, or estimated premorbid IQ between the two groups.

Stimuli

The experimental stimuli comprised three lists of 12 5- or 6-letter words taken from the priming word-lists used by Shimamura and colleagues (e.g., Salmon et al., 1985). The lists were constituted such that no word in any one list had the first two letters in common. Each was chosen such that the 3-letter stem could be completed by at least 10 English words. The experiment involved two conditions, the inclusion condition and the exclusion condition. For each subject, one list of words was assigned in counterbalanced order to each condition, and the third list was designated as new words. Six new words were added to the inclusion condition and six to the exclusion condition. The study words were printed in 12 mm uppercase black letters on 10 × 15 cm white cards. The word stems in the

exclusion condition comprised the first three letters of the words from the study list and the six new words, printed in identical uppercase letters on a 1.5×5 cm white rectangle, mounted on 10×15 cm red cards. The 18 word stems for the inclusion condition were presented in an identical manner but on green cards.

Procedure

The nature and purpose of the study was explained by the experimenter to each participant, who signed a form signifying their consent to participate. The designated next-of-kin or legal guardian of each DAT patient was also informed of the nature of the study and agreed that the patient participate. The experimental procedures were conducted in a suitable testing room at the hospital clinic where the participants were recruited. At the testing session they were first asked for relevant background information, and then to complete the MMSE and NART. They were next introduced to the general experimental procedure and told that they would be asked to read aloud a list of 12 words and to remember the words they had read. Half of the participants completed the inclusion condition first and half the exclusion condition. In the inclusion condition, participants read aloud the 12 words from the designated list, presented on the white cards by the experimenter, in a different random order for each person. The study list was administered to each participant twice. Participants were then immediately administered the 18 3-letter stems on the green cards, in a different random order. They were instructed to respond to each stem by giving the word from the study list that began with the three letters of the stem. They were told that if they could not recall the word on the study list, they should respond by giving the first word that came to mind. In the exclusion condition, participants again twice read aloud the words from the randomly-ordered study list. They then responded to the 18 word stems on the red cards following instructions to give a word beginning with the stem that had not been on the study list. They were reminded of these instructions frequently throughout the administration of this condition. There was a 10 minute interval between the two conditions.

RESULTS

Means and standard deviations of the task variables for both groups are presented in Table I. As is apparent, the DAT group had a higher mean E score and a lower mean I score than the NC group. The data were analyzed to determine the effects of group and order of presentation on I, E, and New Word scores. The Order factor was included to check whether there was any carry over from one condition to the other. It was possible, for example, that the participants in the DAT group were unable to switch from the inclusion instructions to the exclusion instructions when the condition changed. This would have been reflected in a significant Order main effect or Group $\times$ Order interaction for the E scores. A two factor, Group $\times$ Order, ANOVA revealed a Group effect for both I, $F(1, 96) = 50.84$, $p < .000$, and E, $F(1, 16) = 11.36$, $p < .003$. Neither the Order effect nor the interactions were significant, implying that both the demented and control groups were able to adopt the differing instructions required for the two conditions. There was no significant effect for the New Words meaning that baseline guessing rates were comparable for the two groups; accordingly estimates of R and A were not corrected for the probability false alarms.

Estimates of the probability of R and A for each group, computed following the method of Yonelinas (1994) and Jacoby et al. (1993), are also presented in

TABLE I
*Proportion of Items from the Study List Recalled in Each Condition and Parameter Estimates
 for both Groups*

Condition/Parameter	DAT		NC	
	M	SD	M	SD
Condition				
Inclusion	.47	.15	.86	.10
Exclusion	.28	.12	.13	.06
New words	.01	.01	.01	.01
Parameter				
Recollection	.19	.19	.73	.09
Automatic	.35	.12	.52	.25

DAT = Dementia of the Alzheimer type; NC = Normal Control.

Table I. Using one-tailed tests of the hypotheses that the DAT group would have lower R and A estimates, it was found that there was a significant difference both for R, $t(18) = 7.98$, $p < .0001$, and for A $t(18) = 1.94$, $p < .03$.

DISCUSSION

In the present study, the importance of automatic memory processes in the performance of cued recall tasks by persons with Alzheimer's disease was investigated using the process dissociation procedure of Jacoby (1991) and colleagues. The results of the study provide an understanding of the manner in which DAT patients perform stem completion tasks used as direct tests of cued recall. As was apparent from their performance of the inclusion condition, the mildly to moderately demented Alzheimer patients were severely impaired on a traditional cued recall task, although their performance was still substantially greater than chance. The scores of the DAT patients in the exclusion condition revealed that their inclusion performance was strongly supported by automatic memory processes. Thus the ability of Alzheimer patients to make use of controlled memory processes is overestimated using traditional cued recall tests, and when the effects of automatic or fluent processes are removed, estimates of their probability of recollection tend towards zero. Indeed, the test of recollection used in the present study was found to be highly sensitive to the effects of dementia, there being no overlap in R scores between the DAT group ($-.17$ to $.50$) and the NC group ($.67$ to $.92$). A significant finding in the present study was that the estimates of the amount of automatic processing employed by the control group were greater than those of the DAT patients. To date automatic processing has been found to be resistant to factors that influence R, such as aging (Jennings and Jacoby, 1993) and divided attention (Jacoby et al., 1993). It appears therefore that dementia has a pervasive effect on memory processing and that the process-dissociation procedure is sensitive to the decline in the unconscious influences on memory. However, the overlap in estimates of A for the two groups was substantial, suggesting that automatic processes are less susceptible to impairment in the early stages of dementia than conscious recollection.

An important assumption of Jacoby's process dissociation model is that estimates of A and R are independent. As noted previously, Cowan and Stadler (1995) have demonstrated that for studies of the effects of attentional resources on memory this assumption is more plausible than alternative models. This is of significance in the present context because on any memory test that a DAT group can perform meaningfully, the control group will tend to score close to ceiling levels. Indeed, the experience of Cermak et al. (1995) with amnesic patients suggests that designing a test where demented and control groups have equivalent R estimates would be difficult to achieve. Nonetheless, it is likely that as the probability of recollection tends towards 1, estimates of A will become less reliable. Although no participant in the present study had an I score of 1 or 0, it could be suggested that the estimate of A for the control subjects was an underestimation because of the high I and low E scores for that group. When considering this issue, however, it is important to note that high I scores do not constrain the magnitude of the E scores. This was apparent in the pilot study conducted for the present experiment where I and E trials were randomly presented; in this case, the control subjects scored highly on I but also tended to have high E scores, while the DAT patient group had lower but nearly equivalent scores on both I and E.

There are also some findings from other research that give an indication of what would happen if a healthy elderly group was tested on a more difficult task using the process dissociation methodology, which produced lower values of R. Experiment 2 of Jennings and Jacoby (1993) employed a process dissociation task in which I and E scores were obtained for the probability of the correct recognition of words participants had either read, heard, or seen as anagrams. Their study included a group healthy elderly persons with an average age of 70, who obtained I, E, R, and A values of .60, .53, .07, and .57 respectively for words they had read. Similarly, Titov and Knight (1997) tested a group of healthy older volunteers with an average age 68 on a process dissociation task modeled on the procedure used by Yonelinas (1994), in which participants were required to recognise which of two lists a series of target words came from. This study produced estimates of I, E, R, and A of .65, .38, .27, and .57. Combining these findings with those of the present study, it can be seen that in three experiments in which healthy elderly participants with an average age of about 70 were tested using a process dissociation task in which they were required to recollect words they had read, the estimates of A were comparable (about .55) despite a range of I, E, and R scores. Furthermore, in both Jennings and Jacoby (1993) and Titov and Knight (1997), the estimates of A were comparable for younger and older individuals despite significantly lower values of R for the older groups. This suggests that the significantly different estimates of A for the DAT and NC groups were not a necessary consequence of the substantial differences in R between the two groups.

At a theoretical level, the process dissociation procedure offers the opportunity to explore forms of memory failure in a manner not previously possible. For example, Verfaillie and Treadwell (1993) discuss the relevance of the procedure for explaining the finding in some studies (e.g., Hirst, Johnson, Phelps et al., 1988) of a disproportionate preservation of memory in recognition

versus free recall tasks in severely amnesic patients. At the practical clinical level, results from process dissociation tasks demonstrate that when controlled processing is impaired by old age (e.g., Davis et al., 1990), amnesia (Verfaillie and Treadwell, 1993), or even dementia, automatic processes may continue to function at a normal or near normal level. This may be significant in planning effective learning contexts in the development of rehabilitation strategies. Further, as an assessment tool in the practice of clinical neuropsychology, the process dissociation procedure shows considerable promise. The application of Jacoby's model allows the calculation of an estimate of controlled memory uncontaminated by automatic processes, thereby enhancing the precision of measurement of memory dysfunction in amnesic or demented clients. As with the selective reminding procedure of Buschke and Fuld (1974), the computation of memory-related parameters, in this case A and R, does not depend on a particular testing format, and therefore task parameters (e.g., delay, exposure time, list length etc.) can be varied to suit the clinician's individualized requirements.

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