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Automatic memory processes in normal ageing and Alzheimer's disease

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Abstract

This study examined the contribution of automatic and controlled uses of memory to stem completion in young, middle-aged and older adults, and compared these data with a study involving patients with Alzheimer's disease (AD) who performed the same task (Hudson and Robertson, 2007). In an inclusion task participants aimed to complete three-letter word stems with a previously studied word, in an exclusion task the aim was to avoid using studied words to complete stems. Performances under inclusion and exclusion conditions were contrasted to obtain estimates of controlled and automatic memory processes using process-dissociation calculations (Jacoby, 1991).

An age-related decline, evident from middle age was observed for the estimate of controlled processing, whereas the estimate of automatic processing remained invariant across the age groups. This pattern stands in contrast to what is observed in AD, where both controlled and automatic processes have been shown to be impaired. Therefore, the impairment in memory processing on stem completion that is found in AD is qualitatively different from that observed in normal ageing.

Studies of stem completion in the normal elderly and in individuals with Alzheimer's disease (AD) typically deploy task dissociation methods that assume explicit (e.g. cued recall) and implicit (e.g. word stem completion) memory tests are mediated by controlled and automatic retrieval processes respectively. In these paradigms patients with AD relative to elderly controls (Carlesimo et al., 1995; Partridge et al., 1990), and older adults relative to younger adults (Mitchell and Bruss, 2003; Ryan et al., 2001) show reliable deficits on cued recall tasks, which is assumed to reflect a normal age-related impairment in controlled retrieval processes that is exacerbated in AD. In contrast, the status of automatic retrieval processes in both groups is equivocal since intact (AD: Deweer et al., 1994; Partridge et al., 1990; normal aged: Clarys et al., 2000; Mitchell and Bruss, 2003) and impaired (AD: Carlesimo et al., 1995; Russo and Spinnler, 1994; normal aged: Davis et al., 1990; Hultsch et al., 1999) word stem completion rates have been reported.

In recent years, the validity of using implicit test performance as an index of automatic processing has been questioned (Reingold and Toth, 1996) on the basis that conscious uses of memory may be facilitative (Jacoby, 1991; Jennings and Jacoby, 1993; Toth et al., 1994). If conscious contamination occurs it is plausible that reduced stem completion rates observed in AD patients and in the normal elderly may not actually reflect reduced automatic memory processes per se, but arise from the greater capacity of control subjects to use intentional memory processes. Although attempts have been made to manipulate the degree of contamination on stem completion (Chiarello and Hoyer, 1988; Habib et al., 1996; Mitchell and Bruss, 2003), the process-dissociation procedure (Jacoby, 1991; Jacoby et al., 1993; Toth et al., 1994)¹ offers a direct method for obtaining

separate estimates of automatic and controlled processing within a task and is therefore useful for comparing the processing changes that occur through normal ageing with those associated with pathological ageing.

In the stem completion process-dissociation method (e.g. Jacoby et al., 1993; Toth et al., 1994) subjects are instructed to use stems as a cue to recall a studied word, and then either use that word (inclusion condition) or use an alternative word (exclusion condition) to complete the stem. Under inclusion conditions the probability of completing a stem with a studied word is due to the additive probabilities of controlled memory processing (C) plus automatic influences of memory (A) when conscious recollection fails ($1 - C$). Under exclusion conditions this probability is due to automatic processes (A) plus a failure of conscious recollection ($1 - C$). Estimates of controlled memory processes are derived from the difference in stem completion rates between inclusion and exclusion conditions; estimates of automatic uses of memory are computed by the calculation: $\text{exclusion}/(1 - C)$.

Recently, Hudson and Robertson (2007) deployed the process-dissociation procedure to examine the contribution of automatic and controlled uses of memory to a stem completion task in AD. The results showed deficient stem completion rates in AD, which was determined by a profound impairment in controlled memory processing together with a reduced level of automatic memory processing (see also Knight, 1998; Smith and Knight, 2002). The current study aimed to directly extend these findings by using the same materials and procedure to examine how the pattern of impairment in memory processing found in AD differs from normal age-related changes. Variations of process-dissociation have been used in a few ageing studies and normal ageing has been

found to reduce the contribution of controlled memory processes to source recognition (Jennings and Jacoby, 1993; Titov and Knight, 1997) and stem completion (Salthouse et al., 1997; Schmitter-Edgecombe, 1999; Zelazo et al., 2004), but in contrast to AD leave estimates of automatic processes invariant. However, comparisons between the processing changes in retrieval that occur with normal ageing and those found in AD have so far relied on drawing conclusions across studies that have used different procedures and different materials. Automatic processes are not constant but should be regarded as context-dependent (Neumann, 1984) and therefore determined by the parameters of the task (Jacoby, 1991). By using the same methods as Hudson and Robertson (2007), this study rules out between-study differences as a possible confound, and enables a direct comparison between normal ageing and AD to be made on the same stem completion task. In addition, in this study middle-aged adults were also included to see whether age-related changes in processing progress uniformly across the adult life span or whether there is a threshold effect.

Method

Subjects: Forty-eight adults participated in the study, 16 from each of three age bands (19-39; 40-59; 60-78); these consisted of undergraduate students, academic and non-academic university staff and people living in the Lincolnshire community. The mean age of each group was 26 years ($SD = 7.1$, 9 female, 7 male), 48 years ($SD = 4.4$, 10 female, 6 male) and 69 years ($SD = 3.8$, 10 female, 6 male) respectively. Based on the National Adult Reading Test (Nelson 1982) the average estimated FSIQ for each group was, 117.63 ($SD = 4.28$) for young subjects, 119.87 ($SD = 4.08$) for middle-aged subjects

and 116.81 (SD = 4.48) for older subjects. The older adults all obtained a score of 27 or above on the Mini Mental Status Examination (Folstein et al., 1975). The data of 16 AD patients reported by Hudson and Robertson (2007) were included in the study. This cohort met the clinical criteria for probable AD (McKhann et al., 1984; Morris et al., 1989), they had a mean age of 68 years (SD = 10.1, 8 female, 8 male) and a mean MMSE of 18.4 (SD = 3.3).

Stimuli: The stimuli and procedure were the same as those described by Hudson and Robertson (2007). In brief, the stimulus set consisted of four blocks of 12 words (5-7 letters in length); each word had a unique three-letter stem within the set. The blocks were rotated to allow each stem to correspond equally to a studied or unstudied word in inclusion and exclusion test conditions. All stimuli were printed on cards.

Procedure: Subjects were tested individually, first under inclusion conditions then under exclusion conditions. The basic study-test format for both conditions was identical. At study, subjects read aloud words from one block (plus 6 buffer words). At test, two blocks of word stems (one studied, one new) were presented in a pseudorandom order. Under inclusion conditions subjects tried to complete stems with a studied word, under exclusion conditions they tried to use an alternative word. Following the experiment, the NART was administered; older adults also completed the MMSE.

Results

The proportion of stems completed with target words were entered into separate

one-way ANOVA's (see Table 1). For the inclusion task, younger subjects produced more target completions than older subjects [$F(2, 45) = 8.56, p < .001$], the middle-aged group was intermediate and did not differ significantly. For the exclusion task, both younger and middle-aged subjects produced less target completions than older subjects [$F(2, 45) = 20.42, p < .0001$]. A 3×2 ANOVA which treated Group (young, middle-age, old) as a between-subjects factor and Condition (inclusion or exclusion) as a within-subjects factor showed that the proportion of base rate responses, and therefore response criterion did not vary between tasks or group (all F 's < 1).

[INSERT TABLE 1 ABOUT HERE]

Estimates derived from the process-dissociation calculations revealed an age-related decline in controlled processing [$F(2, 45) = 26.72, p < .0001$]; younger adults displayed greater control than middle-aged adults ($p < .01$), who in turn displayed greater control than older adults ($p < .0001$). In contrast, age did not impair automatic memory processes [$F(2, 45) < 1$]. Relative to data from AD patients, the normal aged produced more target completions under inclusion [$t(30) = 5.88, p < .0001$] and less under exclusion conditions [$t(30) = 2.04, p < .05$]. Patients with AD were impaired in both controlled [$t(30) = 6.55, p < .0001$] and automatic memory processes [$t(30) = 3.22, p < .003$].

Discussion

This study used the process-dissociation procedure to measure controlled and automatic retrieval processes in young, middle-aged and older adults, and compared these estimates with existing data from patients with AD, to examine whether changes in

memory processing due to pathological ageing are qualitatively different to normal age-related changes. Relative to younger and middle-aged adults, older adults completed less stems with target words under inclusion conditions, but produced more target completions under exclusion conditions. This pattern parallels the performance of AD patients relative to age-matched controls (Hudson and Robertson, 2007; Knight, 1998; Koivisto et al., 1998), and as indicated by the NART scores did not arise from a decline in verbal competence. The estimates derived from the process-dissociation calculations confirmed that the reduction in cued recall with age was entirely attributable to an age-related deficit in controlled memory processing which was detectable from middle-age. The availability of automatic processes remained invariant between age groups (Schmitter-Edgecombe, 1999; Zelazo et al., 2004). Importantly, these estimates are not likely to be due to a differential response bias since the proportion of base rate completions did not differ between groups or across inclusion and exclusion conditions.

To date, very few studies have used process-dissociation methods to examine controlled and automatic processing in middle-aged adults. However, the study of this group and indeed additional age cohorts is important for understanding the relationship between adult age and memory processing across the life span. Data from the middle-aged group reported here concurs with Titov and Knight (1997), indicating that impairments in controlled retrieval processes in older adults do not have a sudden onset but occur in a continuous manner across the adult life span. The finding that the contribution of controlled memory processes to stem completion declines with normal ageing and is further exacerbated in AD, whereas automatic memory processes are unaffected by normal ageing but decline in AD³, has also been shown through the

combined findings of Schmitter-Edgecombe (1999), Zelazo et al., (2004) and Knight (1998). This pattern is also consistent with task dissociation studies which have shown that manipulations which reduce the potential for conscious contamination decrease the difference between completion rates of older and younger adults (Chiarello and Hoyer, 1988; Habib et al., 1996; Mitchell and Bruss, 2003), but do not effect the difference in completion rates between patients with AD and healthy older adults (Meiran and Jelicic, 1995). But notably, these conclusions are drawn from different studies that have used different materials and test characteristics. However, memory processes are specific to elements of the task (Neumann, 1984) and can fluctuate according to experimental demands (Jacoby, 1991). An important contribution of the present study is that any potential between-task confounds have been eliminated because both pathological and healthy participants were administered the same task.

The dissociation between AD patients and elderly controls in automatic processing indicates that the nature of the stem completion impairment found in AD is qualitatively different to that observed in normal ageing. If a dimensional model of AD is accepted (e.g. Huppert, 1994), automatic memory processing may be a discriminating entity on a continuum from normal ageing through to AD. Further, the status of automatic processes may help discriminate between patients with AD from other memory impaired groups in which automatic memory processes are intact. These include individuals with depression (Jermann et al., 2005), or with non-dementing forms of amnesia (Cermak et al., 1992).

The finding that automatic memory processes are impaired in AD but intact in normal ageing on the stem completion task used here, is not necessarily a pattern that

would generalize to other tasks. Although there are no reports of impaired automatic processing in normal ageing (but see La Voie and Light, 1994; Light et al., 2000) numerous reports of normal implicit memory performance on a range of tasks contends that under certain conditions automatic memory processes are available to AD patients (see Fleischman and Gabrieli, 1998). Hypotheses regarding the specificity of automatic processing in AD and normal ageing do need to be directly tested. Indeed, not all process-dissociation studies involving patients with AD have reported impaired automatic processing. Both Koivisto et al. (1998) and more recently Adam et al. (2005) found that patients with AD had deficits in controlled memory processes but preserved automatic memory processes, which would suggest that the processing impairment in AD only differs quantitatively to normal age-related changes. There are however, two caveats that question this conclusion. First, in Koivisto et al. (1998) the validity of the automatic estimates is uncertain as there was variance in the base rate completions between inclusion and exclusion conditions. In Hudson and Robertson (2007) base rate completions were comparable. Second, in Adam et al. (2005) a highly significant negative correlation between automatic memory processes and dementia severity was found, indicating that automatic memory processes may be preserved in the earlier stages but are susceptible to the progression of AD. This finding may account for the inconsistency between that study and Hudson and Robertson (2007) where the MMSE means for the AD sample were 21.6 (mild) and 18.4 (moderate $\sim 70\% < 21$) respectively.

In sum, the findings from this study and Hudson and Robertson (2007) show that the stem completion deficit in AD is qualitatively different to that observed in healthy older adults relative to younger adults. Whereas normal ageing produces impairments in

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controlled uses of memory which are notable in middle-age, in AD both controlled and automatic processing is impaired. In addition to being theoretically relevant, the status of automatic processing in AD may have clinical relevance and help differentiate between normal age-related and pathological memory impairment.

Footnotes

¹ The validity of the process-dissociation estimates depends on the assumption that controlled and automatic memory processes are independent. This assumption and other issues of contention relating to the procedure have been debated elsewhere and will not be discussed in detail here (see Curran and Hintzman, 1995; Graf and Komatsu, 1994; Jacoby, 1998; Reingold and Toth, 1996; Richardson-Klavehn et al., 1996).

² The finding that AD reduces automatic uses of memory may explain why the stem completion rates by patients with AD tend to be lower than other amnesic patients who have more circumscribed lesions (Gabrieli et al., 1994) and do not exhibit an impairment in automatic memory processing (Cermak et al., 1992).

³ Evidence from PET studies may help to explain the neural basis for this pattern. Deploying controlled memory processes has been shown to robustly increase activation of the frontal cortex (Schacter et al., 1996), and marked pathological changes to the frontal lobes occur through normal ageing (Albert and Killinay, 2001; Fuster, 1989), and still more extensively in AD (DeKosky and Scheff, 1990). In contrast, word stem completion has been associated with reductions in occipital activation, which purportedly reflects the less effortful and more automatic reprocessing of studied stimuli (Squire et al., 1992; Schacter et al., 1996). This particular property has been observed in healthy older adults (Bäckman et al., 1997) but is abnormal in AD (Bäckman et al., 2000).

Table 1. Proportion of stems completed with target words and estimates of controlled and automatic influences of memory derived from the process dissociation procedure for all groups.

	Young		Middle-aged		Old		AD*	
	Studied	New	Studied	New	Studied	New	Studied	New
<u>Condition</u>								
Inclusion								
<i>M</i>	0.82	0.18	0.77	0.19	0.69	0.18	0.42	0.21
SD	0.07	0.07	0.07	0.07	0.13	0.07	0.14	0.07
Exclusion								
<i>M</i>	0.21	0.19	0.26	0.19	0.34	0.19	0.42	0.22
SD	0.04	0.08	0.06	0.08	0.07	0.06	0.13	0.08
<u>Estimate</u>								
Controlled								
<i>M</i>	0.62		0.51		0.35		0.00	
SD	0.09		0.07		0.14		0.16	
Automatic								
<i>M</i>	0.56		0.53		0.54		0.42	
SD	0.12		0.11		0.11		0.10	

* From Hudson and Robertson (2007)

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