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Memory Scanning Performance in Healthy Young Adults, Healthy Older Adults, and Individuals with Dementia of the Alzheimer Type*

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ABSTRACT

A memory scanning (Sternberg, 1966, 1975) task was administered to healthy young adults, older adults, and two groups of individuals with dementia of the Alzheimer's type (DAT) to determine age- and disease-related changes in the retrieval of information from short-term memory. Healthy older adults, in comparison to healthy young adults, displayed increases in both slopes and intercepts in memory scanning. Individuals at various stages of DAT (very mild, mild, moderate) displayed increases in both slopes and intercepts compared to nondemented age-matched control individuals. There was also some evidence that DAT individuals are more likely to engage in a self-terminating search instead of an exhaustive search of short-term memory.

One of the critical features of diagnosis of dementia of the Alzheimer type (DAT) is impaired memory performance (see Nebes, 1989, for a review). In addition, there is clear evidence of age-related changes in healthy adults (e.g., Craik, 1991). Of course, it is important to understand what components of memory break down in these populations. Memory researchers have identified a number of distinct memory types. These include: (a) short-term/long-term, (b) implicit/explicit, (c) primary/secondary, and (d) semantic/episodic, among others. The present study focuses primarily on issues related to short-term memory (STM) retrieval operations in healthy aged individuals and individuals with DAT.

The memory scanning task (Sternberg, 1966, 1975) was developed to directly address operations involved in STM retrieval. In this task participants receive a short list of items (e.g., numbers, letters) to retain in memory. After storing these items in memory a single probe item is presented. Participants must decide as quickly and as accurately as possible whether or not the probe item was a member of the original memory set. Because the list items are presumably stored in STM, response latency presumably reflects the time taken to retrieve an item from that memory system. The typical results from this paradigm indicate that as memory set size increases, reaction time (RT) to the probe item increases in a parallel fashion for both trials in which the probe is in the memory set (present trials) and trials in which the probe is not in the memory set (absent trials).

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To account for this pattern of results, Sternberg (1966, 1975) proposed a serial exhaustive scanning model in which the time taken to scan each additional memory set item requires a fixed amount of scanning time (e.g., 38 ms per item). Because this pattern holds for both *yes* (item present) and *no* (item absent) responses, Sternberg argued these results support the notion that participants compare the probe item to all items in the memory set prior to making a response. That is, regardless of ''where'' in the memory set the probe item occurs, participants continue to scan the entire memory set prior to responding. The serial-exhaustive scanning model can be contrasted with the more intuitively appealing serial self-terminating scanning model in which the participant would terminate the search process when a match is found. However, if this were the case, then one would expect that the slope values associated with yes responses would be one half the slope values associated with no responses because, on average, participants could respond based on half the number of comparisons when the item is in the set compared to when it is not in the set. Although the self-terminating model seems intuitively more plausible, the results from this paradigm consistently yield support for the serial-exhaustive model in both young and healthy older adults.

According to Sternberg's (1966) additive-factors logic, both the serial-exhaustive and serial self-terminating models can be envisioned to operate within an information processing system that includes the following discrete stages: (a) encoding (perception and encoding of the probe item), (b) comparison (serial and exhaustive scanning of the contents of STM), (c) decision (a binary decision as to whether or not the probe item was a member of the memory set), and (d) response execution (response selection and execution). There are also cascadic models of information processing and ''discrete'' is a simplifying assumption.

Presumably, the slope reflects cognitive operations occurring within the comparison stage (Stage 2) whereas the intercept reflects the cognitive operations occurring within the remaining three stages (Stages 1, 3, 4). Use of the memory scanning paradigm has several advantages over other paradigms regarding the investigation and identification of specific cognitive operations. First, as mentioned above, inferences based on slopes and intercepts can be used to isolate distinct information processing stages. Second, the resulting information processing model (serial-exhaustive) provides a relatively straightforward account of retrieval from STM (see Greene, 1992, for a review).

Memory scanning investigations involving healthy young and older adults have revealed qualitatively similar results to those obtained from college-aged young adults. Both age groups produce increases in RT with increases in set size. However, compared to young adults, elderly adults produce increases in both slopes and intercepts (e.g., Wickens, Braune, & Stokes, 1987). More importantly, healthy older adults also appear to engage in serial-exhaustive scanning.

There have also been some investigations using the memory scanning paradigm in participants who possess greater slowing in response latencies and also memory deficits. For example, individuals with multiple sclerosis reveal deficits in both slopes and intercepts compared to healthy age-matched controls (Rao, Aubin-Faubert, & Leo, 1989). Similar slope/intercept deficits have also been observed in individuals with Korsakoff's amnesia (Naus, Cermak, & DeLuca, 1977). Elderly depressed individuals reveal greater intercepts compared to healthy controls, but are virtually identical to controls in scanning rate (Hart & Kwentus, 1987). Developmentally disabled individuals typically reveal greater slopes than control individuals, although intercept differences tend to vary across studies (see Silverman & Harris, 1982, for a review of this area). There is also evidence from the Parkinson's disease (PD) literature that in comparison to healthy controls, nondemented PD individuals produce larger intercepts but display no difference in slopes (e.g., Poewe, Berger, Beuke, & Schelosky, 1991).

There are only two reports (Boaz & Denney, 1993; deToledo-Morrell et al., 1991) examining memory scanning performance in individuals with DAT. DeToledo-Morrell et al. (1991) were concerned with P-300 amplitude in probable

DAT and healthy control individuals. In addition to P-300 latency, these authors also recorded RT in a variant of the memory scanning paradigm. The results from this study produced the predicted group by set size interaction, which occurred for both RTs and error rates. Unfortunately, the error rates of the DAT patients surpassed 20% or more. Furthermore, these authors did not perform analyses examining yes and no responses separately. Thus it is difficult to specify the characteristics of the search process (i.e., serial exhaustive vs. self-terminating) from this study.

Boaz and Denny (1993) attempted to address the shortcomings observed in the deToledo-Morrell et al. (1991) study. In comparison to healthy young and nondemented elderly controls, the Alzheimer's Disease (AD) individuals in Boaz and Denny's study (1993) produced deficits in both scanning rate and intercepts. These authors argued that their AD participants were employing a different memory search strategy than that of the nondemented control participants.

Specifically, this strategy involved AD participants first checking if the probe item was the last item of the memory set. If a match occurred, a response was made. If, however, no match occurred, participants would then proceed to scan the entire memory set. Unfortunately the results of this study are somewhat difficult to interpret because some aspects did not replicate results typically obtained with normal healthy elderly adults. That is, their healthy nondemented elderly adults did not show greater slopes and intercepts than did their healthy young adults. As noted, an increase in slopes and intercepts has been reported by a number of investigators (Anders, Fozard, & Lillyquist, 1972; Eriksen, Hamlin, & Daye, 1973; Salthouse & Somberg, 1982; Strayer, Wickens, & Braune, 1987; Wickens et al., 1987). There is one other aspect of this report that bears discussion. Specifically, a rather large memory set size was used (2, 3, 4, or 5 items). Memory span sizes greater than 4 items may be particularly difficult for mildly and moderately demented individuals to process (Storandt, Botwinick, Danziger, Berg, & Hughes, 1984). This observation is particularly relevant because Boaz and Denney (1993) displayed each set size for the same amount of time (2 s). The use of this constant exposure duration for each set size may have encouraged a differential scanning strategy similar to that described above.

The present experiment was designed to further address the nature of STM retrieval in DAT patients compared to that in healthy young and older adults. The present study provides four methodological refinements that should provide further evidence regarding STM retrieval operations in DAT. First, the inclusion of two separable stages of DAT progression (very mild and mild DAT) across individuals allowed for a more precise identification of when deficits associated with memory retrieval materialize in the course of the disease. There was no such separation based on dementia severity in previous studies. Second, the present experiment employed memory set sizes (2, 3, and 4) that are clearly within the memory span capabilities of mild and moderately demented individuals (Storandt et al., 1984). Third, we allowed all groups to examine the various set sizes for a time period proportional to the exact set size. Fourth, we included a relatively large sample size to provide stable estimates across groups. We also included healthy young adult participants to insure that we replicate the standard increase in set size and slope that has been observed in the healthy aging literature. As noted above, because the Boaz and Denny (1993) study did not replicate the standard aging pattern, the inferences that can be drawn from that work are somewhat limited.

On a more practical level, studying memory scanning in DAT is important from an applied perspective. For instance, Duchek, Hunt, Ball, Buckles and Morris (1998) have shown that visual search error rates and RTs were the best predictors of driving performance in DAT individuals. Furthermore, in the DAT population, measures of selective attention (which is related to visual search processes) may serve to better distinguish safe versus unsafe drivers. Older drivers are more at risk for automobile accidents and this risk could stem from deficits related to visual search processes. Thus, a task such as memory scanning could be used as part of a

larger cognitive screening battery to identify such at-risk drivers. Efficient scanning performance is critical for older drivers because they need to scan and react to relevant information (children, stop signs, other cars) while at the same time inhibiting irrelevant information.

METHOD

Participants

There was a total of 85 participants. Twenty-four (*M* age = 20 years) were healthy college-aged undergraduates recruited through the Washington University Psychology Department. The remaining 61 participants were recruited from the Washington University Alzheimer's Disease Research Center (ADRC). All ADRC participants were initially screened for reversible dementias, depression, severe hypertension, and other disorders known to affect cognitive functioning. Criteria for inclusion and exclusion regarding senile DAT followed those of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA; McKhann et al., 1986). For the ADRC participants, severity of dementia was staged according to the Washington University Clinical Dementia Rating (CDR) scale (Berg, 1988; Hughes, Berg, Danziger, Coben, & Martin, 1982). This scale stages dementia in the following manner: CDR = 0 designates no dementia, CDR = .5 designates very mild dementia, CDR = 1.0 designates mild dementia, and CDR = 2.0 designates moderate dementia.

The CDR is the result of an initial 90-minute interview which includes questions pertaining to cognitive ability in relationship to memory, judgment, and problem solving, orientation, personal care, community affairs, and hobbies. The patients and their collateral sources (e.g., spouse, child) participate in this interview, which is conducted by one of eight board-certified physicians (4 neurologists, 4 psychiatrists). The interview is videotaped for subsequent review for reliability by a second physician. Both the reliability of the CDR and the validation of the diagnosis (based on autopsy) by the research team have been excellent (93% diagnostic accuracy) and well documented (Berg et al., 1998; Berg & Morris, 1994; Burke et al., 1988; Morris et al., 1988).

Of the 61 ADRC participants, 22 (*M* age = 75 years, *M* education = 14.7 years) had no dementia, 23 (*M* age = 74 years, *M* education = 14.5 years), had very mild dementia, and 16 (*M* age = 75 years, *M* education = 13.8 years) had mild or moderate dementia. These differences in education level did not reach significance ($F < 2.0$). In the present study the CDR = 0 (no dementia) category was the equivalent of a control condition in comparison to the other categories (CDR = .5, 1.0, 2.0). Thus, the CDR = 0 individuals in the present experiment volunteered to participate in this longitudinal project and, based on the results of extensive screening, were classified as normal (no dementia). It is important to note here that earlier work on a different sample of patients by Rubin, Morris, Grant, and Vendegna (1989) has revealed that 11/16 (69%) of the patients originally diagnosed with very mild dementia progressed to a more severe stage of dementia or had AD confirmed at autopsy. This pattern suggests that the very mild classification is, in fact, a very early stage in the progression of the disease.

Psychometric Test Performance

All ADRC participants received a 2-hour battery of psychometric tests which are designed to assess psychological functioning including language, memory, psychomotor ability, and intelligence. In the present experiment, memory performance was assessed via the following: Wechsler Memory Scale (WMS; paired-associate learning; Wechsler & Stone, 1973), WMS Logical Memory (surface-level story memory), WMS forward and backward digit span, and Benton Visual Retention Test (picture memory, Benton, 1963). Visual Perceptual-Motor performance was assessed via the Benton Copy Test and Trail-Making Form A. In the Benton Copy Test, participants are required to copy a geometric figure; in Trail-Making Form A, participants connect a series of numerically ordered dots that eventually form a specific pattern (Armitage, 1946). Adult intelligence was assessed using the following subtests of the Wechsler Adult Intelligence Scale (WAIS): Information, Block Design, Comprehension, and Digit Symbol (Wechsler, 1955). Additionally, ADRC participants received the WMS Mental Control and the Word Fluency Test. The WMS Mental Control test evaluates the ability to quickly produce a well-rehearsed letter or digit sequence (i.e., the alphabet) in a specified time period. The Word Fluency Test (Thurstone & Thurstone, 1949) is concerned with processes associated with lexical retrieval. Participants must quickly generate as many words orally as they can beginning with a specified letter (P or S) in an allotted time period (60 s/letter). For the most part, test performance declined as dementia severity

increased. One notable exception, at least in the context of the present experiment, concerns the measure of digit span (forward + backward). Although the demented individuals did have slightly lower digit spans in comparison to the other groups, this difference was not reliable. Storandt et al. (1984) revealed that demented individuals show deficits on digit spans of 5 or more digits. Results of these various psychometric tests appear in Table 1.

Apparatus

Testing was conducted with an Apple IIe microcomputer that was interfaced with a Mountain Hardware clock which recorded response latencies to the nearest millisecond. A response keypad connected to the microcomputer was used for yes and no responses.

Procedure

Participants were tested individually and sat approximately 30 cm from the monitor. Participants rested their left-hand index finger on the left keypad (labeled YES) and their right-hand index finger on the right keypad (labeled NO). They were orally instructed that a row of single-digit numbers (memory set) would appear in the upper half of the monitor, above the plus sign. This row contained either 2, 3, or 4 digits randomly chosen from the digits 1-9, and was presented for a duration equal to 300 ms per digit. Thus, a 2-digit memory set was displayed for 600 ms, and a 4-digit memory set was displayed for 1200 ms. The memory set was then removed and was followed by a fixation stimulus (a plus sign, +), which appeared in the middle of the monitor for 1000 ms. The fixation stimulus was then removed and was followed by a single digit (probe) which appeared in the bottom half of the monitor until participants responded. They were instructed to make a quick and accurate response as to whether or not the probe digit was contained within the memory set for that particular trial. One practice block preceded the 4 experimental blocks, and a rest break occurred between blocks, at which time the instructions were reread to each participant. Each block contained 36 trials (18 yes, 18 no). Across the experiment (and for yes and no responses) each participant received the following number of trials per condition: 16 trials of Set Size 2; 24 trials of Set Size 3; and 32 trials of Set Size 4. Thus, there was a total of 144 trials (72 yes, 72 no). The increase in the number of trials as a function of set size was used in order to obtain ''stable'' estimates of response latency at the more error-prone larger set size. Across yes responses at each set size, the probe digit occurred equally often at each serial position within the memory set. The entire experiment lasted 20 to 25 minutes.

Table 1. Mean (and Standard Deviation) Psychometric Test Performance for Each Participant Group.

	Healthy aged (n = 22)		Very mild (n = 23)		Mild/moderate DAT (n = 16)		
Psychometric test	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*F* Value
Logical Memory	9.95	(2.85)	5.04	(2.50)	2.43	(1.65)	44.0****
Trails Form A	42.22	(16.31)	55.57	(28.96)	67.86	(23.57)	5.18**
WAIS Information	21.59	(4.41)	17.00	(5.54)	12.43	(5.56)	13.81****
WAIS Block Design	30.41	(9.23)	23.78	(10.68)	18.21	(7.57)	7.35**
WAIS Digit Symbol	46.18	(12.82)	34.83	(10.03)	30.43	(8.63)	10.58***
Benton Delay (# correct)	6.09	(1.69)	4.61	(1.90)	2.93	(1.90)	13.00****
Benton Copy (# correct)	9.73	(.63)	9.17	(1.37)	8.93	(1.59)	2.13
Boston Naming Test	56.09	(3.69)	49.30	(10.49)	41.64	(14.92)	9.02***
Mental Control	7.36	(2.08)	6.13	(2.62)	5.71	(2.52)	2.43
Associate Recall	13.14	(4.00)	10.04	(3.71)	6.14	(2.77)	15.92****
Benton Recall (errors)	6.64	(3.03)	11.17	(5.31)	14.57	(4.64)	14.55****
Benton Copy (errors)	.27	(.63)	.83	(1.37)	1.07	(1.82)	1.90
Word Fluency (letters S + P)	31.55	(12.62)	25.57	(9.72)	19.29	(9.06)	5.64**
Digit Span (F + B)	11.55	(2.91)	10.57	(2.06)	10.21	(1.63)	1.66

Note. DAT = dementia of the Alzheimer type, WAIS = Wechsler Adult Intelligence Scale; F = forward; B = backward. *F* value is from group main effect and the degrees of freedom associated with this value are 2 and 56. * $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

Design

The design was a 4 (Group: young adult, nondemented healthy elderly adult, very mild DAT, mild/moderate DAT) × 3 (Set Size: 2, 3, 4 digits) × 2 (Decision: yes, no) mixed-factor design, with Group as the only between-subjects factor.

RESULTS

Reaction Time Analysis

Unless otherwise stated, all analyses of RTs are based on log transformed scores as a means of dealing with the variance differences across groups. Table 2 displays the mean of the median RTs and percentage of correct responses as a function of Group, Set Size, and Response Type.

Error trials were removed prior to RT analysis. In addition, all trials below 200 ms and above 2000 ms were removed and treated as outliers. This resulted in removing less than 2% of trials across groups. Young adults were included as a means of replicating standard age effects in memory scanning performance.

There are five observations to be made from Figure 1. First, as one can see, all groups produced increases in response latency as set size increased. Second, as expected, there was an overall slowing of response latency across groups. Third, there is an increasing *difference* between yes and no responses across groups. Fourth, there is an increase in set size across groups. Finally, there is some evidence that the increase in set size is greater for the no responses than the yes responses across groups.

The above observations were supported by a 4 (Group) × 3 (Set Size) × 2 (Decision) mixed-factor analysis of variance (ANOVA). This analysis yielded main effects of Group, $F(3, 81) = 27.62$, $p < .001$; Set Size, $F(2, 162) = 150.37$, $p < .001$; and Decision, $F(1, 81) = 41.61$, $p < .001$. The Group × Decision interaction was significant, $F(3, 81) = 3.61$, $p < .02$. All groups were faster on yes trials than on no trials, and the magnitude of this difference increased across groups: young, 21 ms, $F(1, 23) = 6.67$, $p < .02$; old, 59 ms, $F(1, 21) = 10.25$, $p < .01$; very mild, 86 ms, $F(1, 22) = 7.63$, $p < .02$; mild, 124 ms, $F(1, 15) = 21.98$, $p < .001$. Newman-Keuls analysis revealed that the mild difference was greater than the young ($p < .01$), the old ($p < .01$), and the very mild difference ($p < .05$). The very mild difference was greater than the young ($p < .01$) and the old difference was greater than the young ($p < .05$). The very mild and old difference was not significant ($p > .05$).

The Group × Set Size interaction was also significant, $F(6, 162) = 3.97$, $p < .01$. As shown in Table 2, the effect of Set Size increased from young adults to the mildly demented individuals. The Decision × Set Size interaction was not significant ($F < 1.0$). The three-way interaction of Group × Set Size × Decision approached significance, $F(6, 162) = 1.87$, $p < .09$.

Percentage Correct Analysis

With regard to mean percentage correct, there are three observations to make from Table 2. First, it is noteworthy that in contrast to Boaz and Denny (1993), even the very mild and mild/moderate dementia groups produced a relatively high accuracy rate (94% and 92%, respectively). Second, no responses were more accurate than yes responses, and this pattern appears to hold across the various subject groups. Third, the Set Size manipulation did not appear to exert much of an influence on accuracy.

The above observations were generally confirmed with a mixed-factor ANOVA performed on the error rates. The ANOVA revealed significant main effects for Group, $F(3, 81) = 7.64$, $p < .001$; and Decision, $F(1, 81) = 45.28$, $p < .001$; but not Set Size, $F(2, 162) = .81$, $p > .44$. The Group × Decision interaction was marginally significant, $F(3, 81) = 2.64$, $p = .0551$. The Group × Set Size interaction was not significant ($F < 1.0$), although the Decision × Set Size interaction was significant, $F(2, 162) = 3.49$, $p < .02$. The three-way interaction of Group, Decision and Set Size again approached significance, $F(6, 162) = 2.00$, $p < .07$.

Slope and Intercept Analyses

In order to obtain estimates of (a) memory scanning rate (slope) and (b) speed of cognitive operations occurring during the encoding, decision, and response execution stages (intercept) outlined previously, separate analyses were performed on the slope and intercept values. These

Table 2. Mean of Median Response Latencies (in milliseconds), Standard Deviations, and Percentage Correct as a Function of Participant Group and Set Size for Yes and No Responses.

		Response					
		Yes			No		
		Set Size					
Participant group		2	3	4	2	3	4
Young adult	*M*	498	544	593	527	567	603
	SD	95	102	119	100	105	119
	%C	96	93	93	96	97	98
Healthy aged	*M*	738	816	933	808	899	955
	SD	114	124	151	138	167	169
	%C	95	96	94	98	97	99
Very mild DAT	*M*	781	854	934	833	951	1041
	SD	185	207	188	229	276	307
	%C	90	91	90	97	96	96
Mild/moderate DAT	*M*	904	1009	1077	1015	1133	1215
	SD	262	303	305	282	263	320
	%C	93	90	88	91	93	94

Note. DAT = dementia of the Alzheimer type; %C = percentage correct.

values were derived from each subject for both yes and no responses for each of the three set sizes and are presented in Table 3. Slope values were derived for each individual subject by regressing yes and no RT over Set Size. The slope value represents the amount of change on the ordinate (RT) per unit change on the abscissa (Set Size). Thus, a slope value of 38 ms would indicate that 38 ms of processing time is added each time the set size is increased by each additional item. (It is noteworthy that the slope estimates for young adults, 38 ms and 48 ms, shown in Table 3, are quite consistent with the extant literature on young adults; see Sternberg, 1966). The point at which the regression line intersects the y-axis is the estimated intercept value. This value results by extending the regression line to the y-axis. Thus, the intercept value provides an estimate of how long it takes to encode a stimulus, make a binary decision, and organize a response. These values also appear in Table 3.

The absolute difference between yes and no slope estimates can be used to provide insights into the nature of the STM scanning process. As noted earlier, the tendency for no slopes to be greater than yes slopes provides some support for a shift from exhaustive scanning to self-terminating scanning. Interestingly, the ratio of no/yes slopes did in fact increase with increasing age and dementia severity (i.e., ratio = .79, .73, 1.36, and 1.18 for young, healthy elderly adults, very mild DAT individuals, and mild DAT individuals, respectively). This pattern supports the notion that dementia severity may modulate *how* items are scanned in STM. As noted, this pattern suggests that normal aging produces a serial-exhaustive search process while dementia severity is more likely to produce a serial self-terminating search process. The slope analysis was a 4 (Group) × 2 (Decision) mixed-factor ANOVA performed on the untransformed slope values. There was a main effect of Group, $F(3, 81) = 4.90$, $p < .01$, but not of Decision, $F < 1.00$. More importantly, however, there was a reliable Group × Decision interaction, $F(3, 81) = 3.30$, $p < .03$, indicating that there was more of a relative increase in ''absent'' slopes across groups than ''present'' slopes. Newman-Keuls analysis revealed that the very mild ratio (slope of no trials divided by

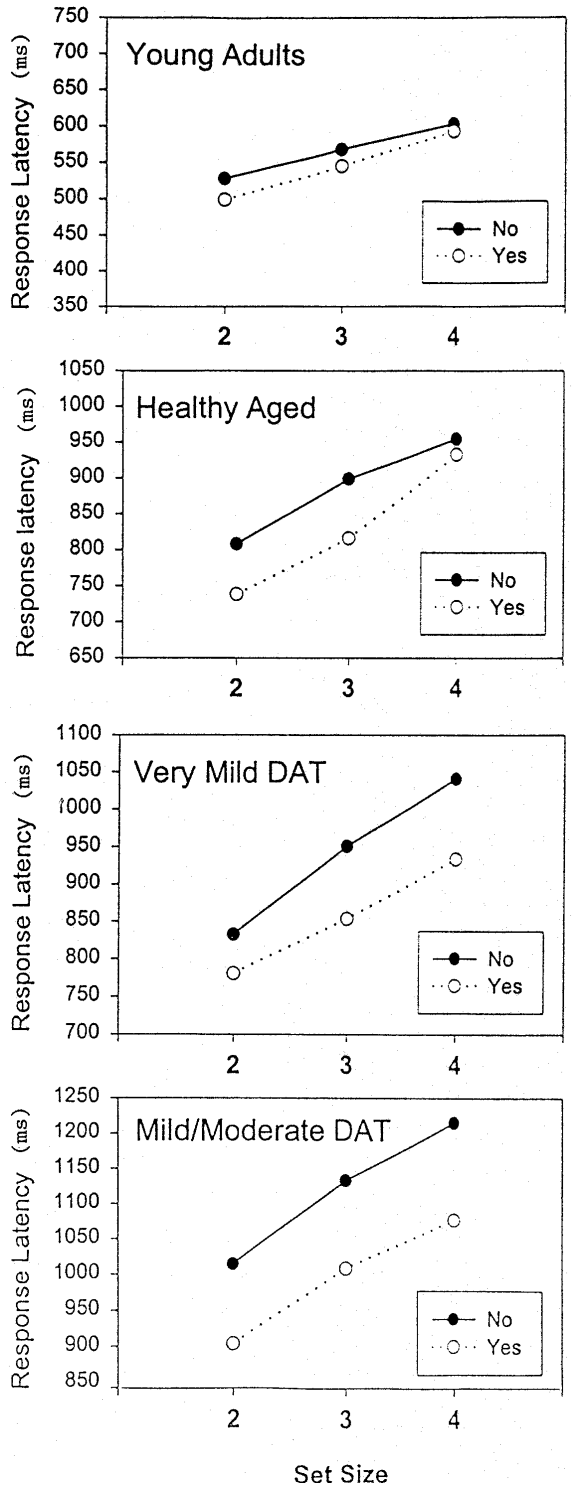

Fig. 1. Mean of median response latencies as a function of Response (yes vs. no), Set Size, and Group. DAT = dementia of the Alzheimer type.

Table 3. Slope and Intercept Values (both in ms) as a Function of Group and Response Type.

	Group			
	Young adult	Healthy aged	Very mild DAT	Mild/moderate DAT
Slope/yes	48	98	77	87
Slope/no	38	72	105	103
Intercept/yes	403	536	627	738
Intercept/no	453	667	629	813

Note. DAT = dementia of the Alzheimer type.

slope of yes trials) was greater than the young ($p < .01$), old ($p < .01$), and mild/moderate ($p < .05$) ratios. The mild/moderate ratio was greater than the young and old ratios ($ps < .01$). The young and old ratios were not significantly different ($p > .05$).

Although the mild/moderate ratio of no slopes to yes slopes was greater than the young and old ratios, one must be somewhat cautious in interpreting this pattern. Specifically, as shown in Table 2, there does appear to be some evidence of a speed accuracy trade-off in the mild/moderate DAT individuals. Specifically, there is a small 3% *increase* in accuracy across set size for the no responses for the mild/moderate individuals. Although this is a potential problem with the mild/moderate DAT individuals, this does not compromise the interpretation of the very mild DAT individuals in which there is no evidence of a speed accuracy trade-off. Finally, one should also note here that overall RTs tended to increase with error rates and the correlation between these two measures was positive but did not reach significance ($r = +.33, p < .12$).

Turning to the intercept estimates, as expected there were substantial Group differences, reflecting the fact that the young adults produced lower intercepts (i.e., were faster) compared to the healthy older adults, who in turn produced lower intercepts compared to the demented individuals. Likewise, yes responses produced lower intercepts than no responses. The intercept analysis yielded main effects for Group, $F(3, 81) = 10.41, p < .001$, and Decision, $F(1, 81) = 10.79, p < .01$. The Group × Decision interaction was not significant, $F(3, 81) = 2.01, p < .12$.

Correlations between Psychometric Test Function and Slope Estimates

We also correlated psychometric test performance with the slope values for yes and no responses for each group (no DAT, very mild DAT, mild/moderate DAT) to gain further insights into the nature of the underlying processes that might produce the differing pattern of slope estimates across groups. These correlations are presented in Table 4. One can see that the correlations are, in general, in the predicted direction, that is, better psychometric performance on a given task was negatively related to the size of the slopes. Interestingly, there was little relationship to the standard long-term episodic memory measures such as Logical Memory and Associate Recall, and semantic memory measures tapped by the WAIS information test. This pattern is consistent with the notion that the memory scanning task reflects a more active STM system. Interestingly, the psychometric tasks which tap into spatial/visual memory processing (Benton Copy and Benton Recall) are more consistently related to scanning performance, which may reflect the visual nature of the stimuli presentation in the Memory Scanning task.

Table 4. Pearson-Product Moment Correlations for each Group as a Function of Psychometric Test Performance and Reaction Time/Set Size Slope Values for Yes and No Responses.

		Group		
Test	Response	Healthy aged	Very mild DAT	Mild/moderate DAT
Logical Memory	Yes	.05	.31	–.17
	No	–.20	.00	.18
Trails Form A	Yes	.28	.01	.30
	No	.49*	.38	–.06
WAIS Information	Yes	.21	.23	–.38
	No	.28	.01	.01
WAIS Block Design	Yes	–.09	–.17	–.68**
	No	–.24	–.58**	–.36
WAIS Digit Symbol	Yes	–.23	–.09	–.33
	No	–.12	–.29	–.20
Benton Delay (# Correct)	Yes	–.53**	–.19	–.42
	No	–.39	–.51*	–.05
Benton Copy (# Correct)	Yes	–.37	–.33	–.60*
	No	–.29	–.54*	–.08
Boston Naming Test	Yes	–.28	.06	–.33
	No	–.46*	.00	.00
Mental Control	Yes	–.52*	.15	–.65*
	No	–.28	–.18	–.32
Associate Recall	Yes	–.09	.30	–.30
	No	–.02	.10	.13
Benton Recall (Errors)	Yes	.43*	.14	.41
	No	.30	.60**	.03
Benton Copy (Errors)	Yes	.37	.33	.57*
	No	.29	.54**	.10
Word Fluency (letters S + P)	Yes	–.07	–.20	–.44
	No	–.40	–.40	.03
Digit Span	Yes	–.35	.07	–.23
(Forward + Backward)	No	–.45*	.01	–.76**

Note. DAT = dementia of the Alzheimer type. Significance of correlations changes due to different sample sizes across groups.
* $p < .05$. ** $p < .01$.

DISCUSSION

The present results appear relatively clear. Healthy nondemented individuals responded more slowly and also scanned the items more slowly compared to healthy young adults. These results are consistent with previous findings (e.g., Anders et al., 1972; Eriksen et al., 1973; Salthouse & Somberg, 1982; Strayer et al, 1987; Wickens et al., 1987), and suggest that normal healthy aging affects all components of information processing, including the encoding, comparison, decision, and response stages.

Individuals with DAT also produced an increase in both intercepts and slopes compared to the healthy age-matched controls. More interesting, however, is the finding that there was evidence of a difference in the ''quality'' of memory scanning in DAT individuals. Specifically, there was a greater separation between positive and negative slopes in the DAT individuals compared to the nondemented control individuals. (This pattern is quite clear in the very mild DAT individuals; however, as noted earlier this pattern is somewhat compromised in the mild/moderate DAT individuals by some trade-off in accuracy). The relative increase in slopes for the

absent trials in early stage DAT individuals suggests that on some trials these individuals may engage in a self-terminating search. Possibly this change in the nature of the retrieval process reflects the considerable slowing in the scanning process exhibited by these individuals. That is, it may be more efficient to engage in a self-terminating search process if the scanning process is relatively slow. Interestingly, one of the appeals of a serial exhaustive process is the relative fast scanning process. If this scanning is sufficiently slowed down, it is quite possible that the efficiency of such a retrieval process is diminished. Alternatively, it is possible that early stage DAT individuals are likely to engage in a self-terminating search because of an increased cautiousness that is due to their overall cognitive decline. In either case, the present results indicate that there may be a change in the nature of a relatively simple memory mechanism, retrieval from STM, in the early stages of DAT.

Interestingly, in the only other study of DAT individuals that we are aware of that has separated yes and no slopes, Boaz and Denny (1993) also found a larger difference between negative and positive slopes in their DAT individuals than in their control individuals. Specifically, they found the slopes of no responses to be 44 ms greater than yes responses in their DAT individuals, whereas the healthy older adults and the young adults only produced 5 ms and 0 ms differences in yes and no slopes, respectively. However, these authors were unable to detect a reliable interaction which, as noted earlier, may be due to the relatively low power in this study (9 DAT, 10 healthy old, and 10 young adults) compared to the present study. Thus, although the interaction was not reliable in the Boaz and Denny data, the pattern was clearly in the same direction as the present results, and therefore increases our confidence that the slope of no responses will be greater than the slope of yes responses in early stage DAT compared to age-matched controls.

It is also noteworthy that the present results occurred despite relatively minimal memory span (forward plus backward) differences across the demented groups (Storandt et al., 1984), suggesting that the type of search strategy employed is more critical than the amount of information to be searched. Clearly, additional research is needed to clarify this finding. The present results suggest, however, that how individuals search for information in their environment is associated with normal aging as well as their underlying cognitive status.

The present qualitative difference in memory scanning in DAT individuals converges with recent work producing qualitatively distinct patterns of cognitive performance in other domains. For example, evidence from semantic priming and implicit memory studies suggest that there is relatively little breakdown in these processes in early stages of DAT unless attention is engaged (e.g., Balota & Duchek, 1991; Balota & Ferraro, 1996; Nebes, 1989; Ober & Shenaut, 1995; Park et al., 1998). On the other hand, it appears that tasks which engage attentional control/inhibition systems do appear to produce exaggerated breakdowns (e.g., Balota & Ferraro, 1993; Ferraro, Balota, & Connor, 1993; Nissen & Bullemer, 1987; Speiler, Balota, & Faust, 1996; see Parasuraman & Haxby, 1993, for a review). Thus, these results provide further evidence that DAT is not simply a global deterioration in cognitive functioning, but that particular substrates of cognition are differentially disrupted in early stages of the disease process, yielding qualitatively distinct patterns of cognitive performance.

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