Patterns of Memory Performance in the Neurologically Impaired Aged

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SUMMARY: *The specific behavioral manifestation associated with the different disorders producing the syndrome of dementia have remained poorly investigated. We examined the memory performance of three distinct groups of patients with dementia secondary to Alzheimer's disease (AD) multiple-infarctions (MID) and vertebrobasilar insufficiency (VBI) on the ten subtests of the Wechsler Memory Scale (WMS). Statistical methods of analysis were used to maximize the differences between the groups. Univariate statistical procedures revealed that the AD group performed significantly and consistently lower than the two cerebrovascular groups. There were no significant differences between the two cerebrovascular disease groups, even though the MID group tended to perform consistently more poorly than the VBI group. For heuristic and conceptual purposes as well as to determine which combination of the ten WMS variables produced the "best" statistical model differentiating the groups the data was analyzed by multivariate techniques. A discriminate function analysis obtained a 100% valid positive hit rate in discriminating among the three groups. One hundred percent diagnostic accuracy was also obtained in discriminating between MID and AD as well as AD and VBI. The two cerebrovascular groups tended to overlap in their probability distributions with an 81% hit rate. Different predicitive statistical models were identified to differentiate the various diagnostic groups. It was possible to discriminate the three diagnostic groups by different patterns of memory performance.*

RÉSUMÉ: *Le comportement spécifique associé aux différents désordres produisant le syndrome de démence est encore peu connu. Nous avons étudié la mémoire chez trois groupes distincts de patients avec démence secondaire à la maladie d'Alzheimer (AD), à des infarctus cérébraux multiples (MID) et à l'insuffisance vertébro-basilaire (IVB) par 10 sous-tests de l'échelle de mémoire de Wechsler (WMS). Des méthodes statistiques d'analyse furent utilisées pour maximiser les différences entre les groupes. Celles-ci révélaient que le groupe AD s'exécutait à un niveau significativement et constamment plus bas que les deux groupes cérébro-vasculaires. Il n'y avait pas de différences significatives entre les deux groupes cérébro-vasculaires, même si le groupe MID tendait à une performance constamment plus basse que le groupe IVB. Une analyse de fonction permettait une discrimination à 100% positive entre les trois groupes. Un diagnostic sûr a 100% était aussi obtenu entre MID et AD et entre AD et IVB. Les deux groupes cérébro-vasculaires tendaient à se confondre partiellement (validité du diagnostic à 81%). Différents modèles statistiques de prédiction furent identifiés pour individualiser les groupes diagnostic.*

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INTRODUCTION

The most prominent psychological and behavioral deficits in organic dementias are of a cognitive nature involving intelligence and memory (Miller, 1973). DeJong (1973) states that clinically, dementia denotes a decline of the higher intellectual functions, including memory, judgment, reasoning, and the various perceptual, associative, and executive functions of the entire cerebrum. Heilman and Wilder (1971) define dementia as a neurologic deterioration which interferes with the intellectual processes used in environmental problem solving. Most authors agree that a consistent feature in dementia is overall neuropsyhcological deterioration. However, dementia as a syndrome of behavioral and cognitive reduction may be produced by a wide variety of etiologies, and the clinical and behavioral pattern may vary according to the nature of the cause, the localization of the etiologic process within the central nervous system, the rate of progression, the age of onset and various environmental factors (Karp, 1974).

Review of the clinical literature indicates few systematic, objective or quantitated investigative studies dealing with psychological and behavioral changes associated with different disorders producing dementia. Miller (1971; 1973) has shown that patients with Alzheimer's disease (AD) owe their memory disturbances to both an impairment in short-term memory and an additional difficulty in establishing new material in long-term memory storage. Perez et al (1975) found significant differences in cognitive and intellectual performance on the Wechsler Adult Intelligence Scale (WAIS) be-

tween patients with dementia secondary to vertebrobasilar insufficiency (VBI) or multi-infarct dementia (MID) versus neuronal atrophy of the Alzheimer's type. A discriminant function analysis classified 74% of the patients correctly based on the individual WAIS scores. The diagnosis was more easily made when tasks measuring visual motor coordination and abstract reasoning were included in the analysis. Pearce and Miller (1973) indicate that the pattern of intellectual decline in dementia is not identical with that occurring as a result of aging. Miller (1974) has also investigated the psychomotor performance of patients with AD and found that they perform more slowly on motor tasks than controls. Miller (1974) stated that the impaired execution of movements may be related to the extrapyramidal disturbances found in AD.

Disorders of memory are a characteristic and often prominent feature of dementia and may be one of the first indications, overt or subjective, that adverse changes in the mental processes are taking place. Karp (1974) considers memory loss as a logical focal point for the clinical analysis of disorders of mental functioning. Attempts have been made to elucidate the nature of the memory deficit in the dementias associated with neuronal atrophy in the presenile age group by Miller (1971, 1972) and Pearce and Miller (1973) and in the senile age group by Inglis (1966, 1970). Rivera and Meyer (1975) as well as Mathew and Meyer (1974) have emphasized and described the importance of the memory disorders associated with VBI.

Since the primary and early symptoms of organic dementia are usually psychological in nature, a comprehensive neuropsychological evaluation is an essential element of the initial clinical assessment. The neuropsychological approach to dementia can be described as having four distinct aspects. These include: 1) the measurement of intellectual, cognitive, memory, language and perceptual motor functioning of the patient; 2) the development of refined and precise psychological and behavioral measures which aim to differentiate and classify patients into the various diseases producing dementia; 3) the detailed description of the nature and natural course of the psychological disturbances associated with specific disease entities producing the various types of dementia; and, 4) to assess the effectiveness of medical and environmental therapeutic interventions.

The purpose of the present study is to investigate the performance of three groups of patients with distinct etiologies of dementia using the various subscales of the Wechsler Memory Scale (WMS) (Wechsler, 1945). The patients were carefully diagnosed as AD, MID, and VBI. The WMS is the most widely used of the individually administered tests designed to measure various aspects of memory functioning. The study also assesses the ability of the WMS in classifying the carefully diagnosed patients into one of the three groups.

METHODS

Patient Selection

Forty-two patients, 17 men and 25 women ranging in age from 45 to 85 with a mean age of 66 years, were admitted to the study. All were patients admitted to the Baylor-Methodist Center for Cerebrovascular Research, and the majority were followed for at least a year or more with numerous re-examinations.

One of the authors (Dr. V. Rivera, a neurologist) first classified the patients into the three diagnostic groups on the basis of personal examination and review of the entire diagnostic evaluation. This required careful inspection of the records of over 100 demented patients, and the 42 were admitted to the study since the diagnosis was objectively confirmed. Only patients with an uncomplicated diagnosis of VBI, rather than a mixed diagnosis of VBI and some other cerebral disorder, e.g., completed stroke or carotid disease, were included. In two cases the diagnosis of AD was confirmed by autopsy.

Clinical Diagnostic Classification

The following were the criteria used for establishing the diganosis and classifying the patients into the following three groups of dementias. In all cases, systemic disorders causing dementia were excluded by appropriate investigations.

Alzheimer's Disease (AD): These patients presented with a history of a chronic progressive dementing process without risk factors (Kannel et al., 1971) or evidence of cerebrovascular disease. The clinical course in these patients was not characterized by episodic worsening of mentation as typically occurs in patients with cerebrovascular disease. There was no history of transient cerebral ischemic attacks, but a steadily progressive deterioration of intellectual functions.

The general medical examination gave no evidence of arteriosclerosis elsewhere in the body. The neurological examination gave evidence primarily of frontal lobe and corticobulbar signs and evidence of parietal lobe disorders such as dyspraxia, dysphasia, visuo-spatial discrimination, and dyslexia. The signs of cerebral dysfunction were diffuse and bilateral. Grasp, sucking, and glabellar reflexes were usually prominent.

Cisternography and regional cerebral blood flow studies before and after cerebral spinal fluid removal (Mathew et al., 1974) were performed with Ytterbium ^{169} and excluded the diagnosis of normal pressure hydrocephalus. Aorto-cranial angiograms ruled out cerebrovascular disease, chronic subdural hematoma, or cerebral neoplasm. Pneumoencephalograms showed cortical atrophy predominantly in the frontal and parietal regions, and the thalamostriate vein configuration showed enlarged ventricles.

Multi-Infarct Dementia (MID): The dementing process in these patients was associated with documented risk factors for cerebrovascular disease (Kannel et al., 1971), particularly a long-standing history of hypertension. The clinical course of the dementia was characterized by episodic strokes with cumulative worsening of mentation (Hachinski et al., 1974) plus associated transient

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TABLE 1

MEANS AND STANDARD DEVIATIONS OF AGE AND EDUCATION

	Age		Education	
	Mean	S.D.	Mean	S.D.
Multi-Infarct	69.25	11.428	10.250	4.024
Alzheimer's	62.20	11.429	13.700	3.529
VBI	65.31	8.404	10.062	4.040

cerebral ischemic episodes in either the carotid or vertebrobasilar arterial territories or both.

In the history and/or documentation of the general medical examination there was evidence of arteriosclerotic disease elsewhere in the body in every case. These included: angina, myocardial infarction, intermittent claudication, arterial bruits, abnormal electrocardiograms, etc. The neurological examination also showed multiple signs of diffusely represented cerebral deficits attributable to multiple vascular lesions such as hemiplegia, hemiparesis, alternating hemiparesis, dysphasia, hemianopia, cortical sensory loss confined to segmental zones of half the body.

Aorto-cranial arteriography confirmed the diagnosis by demonstrating arteriosclerotic plaques and/or occluded cerebral vessels.

Vertebrobasilar Arterial Insufficience with Dementia (VBI): The same criteria as for MID were present, but the clinical manifestations clearly arose from multiple episodes of infarcts and ischemia in the distribution of supply of the vertebrobasilar system. Typically, these patients suffered from: vertigo, dizziness, intermittent ataxia, drop attacks, episodes of transient global amnesia, nystagmus, hemianopia, photopsia, etc., plus a step-wise deterioration of memory and higher cortical functions.

Aorto-cranial arteriograms showed prominent lesions in the posterior circulation, such as stenosis of the cerebral arteries, plaques in the basilar artery and disease of the posterior cerebral arteries.

Neuropsychological Test Procedure

The WMS was administered individually to each patient as part of a comprehensive neuropsychological evaluation. The WMS consists of seven subtests. A detailed discussion of the WMS can be found in Wechsler's (1945) original paper. The following is a brief description of each subtest:

Test 1 — Personal and Current Information (INF): Comprises six simple questions (i.e., "How old are you? Who is the president of the U.S.?", etc).

Test 2 — Orientation (OR): Consists of five simple questions (i.e. "What year is this? Where are you now?", etc.) designed to test the patient's orientation to time and place.

Test 3 — Mental Control (MEN-CON): Consists of three sub-items. Counting backwards from 20 to 1, repeating the alphabet, and counting by threes. Designed to show defects which are not made evident by simple rote memory items.

Test 4 — Logical Memory (LOG-MEM): Consists of two prose passages read to the patient. The score is the average of the number of ideas produced correctly on both passages. Designed to measure immediate recall of verbal material.

Test 5 — Digit Span: Consists of recalling digits forward (DIGS-FWD) and digits backward (DIGS-BWD). Designed to measure rote memory for specific meaningless material.

Test 6 — Visual Reproduction (VIS-MEM): Requires the subject to draw from memory simple geometric figures exposed for a period of 10 seconds. Designed to measure recent visual memory.

Test 7 — Associate Learning: Consists of 10 paired associates, some easy (PA-AS-ES) and some hard (PA-AS-HD) which the subject is required to learn in three trials.

Each subtest produces a raw score. A Memory Quotient (MQ) corrected for age can be obtained from the performance of the patient on the seven subtests. The MQ is highly correlated with the individual intelligence quotient (IQ) on the WAIS. This is important because it makes possible the comparison of the patient's memory functioning

TABLE 2

RESULTS OF ANALYSIS OF COVARIANCE

Variables	Multi-Infarct		Alzheimer's		VBI		F-Value
	Mean	SE	Mean	SE	Mean	SE	
Memory Quotient (MQ)	82.81	4.32	55.82	5.69	96.81	4.29	15.886**
Information (INF)	3.47	0.51	1.93	0.67	4.89	0.51	6.090*
Orientation (OR)	3.25	0.39	1.38	0.51	4.20	0.38	9.417**
Mental Control (MEN-CON)	4.57	0.57	1.21	0.75	5.18	0.57	9.103**
Logical Memory (LOG-MEM)	3.87	0.68	1.19	0.90	4.89	0.68	5.229*
Digits Forward (DIGS-FWD)	4.99	0.38	4.46	0.51	5.72	0.38	2.067^{NS}
Digits Backward (DIGS-BWD)	3.45	0.42	1.77	0.55	3.38	0.42	3.265^{NS}
Visual Memory (VIS-MEM)	3.34	0.66	—0.06	0.87	5.07	0.65	10.724**
Pair Associates [Easy] (PA-AS-ES)	5.62	0.69	1.60	0.91	6.94	0.69	10.685**
Pair Associates [Hard] (PA-AS-HD)	1.85	0.55	—0.65	0.72	3.68	0.54	11.235**

** = $p < 0.001$ (d.f. 2,37)

* = $p < 0.01$ (d.f. 2,37)

Mean values and standard error adjusted for covariates age and education.

TABLE 3

RESULTS OF SCHEFFÉ TEST TO DETERMINE SIGNIFICANCE BETWEEN SPECIFIC GROUPS

Variables	Multi-Infarct vs Alzheimer's	Multi-Infarct vs VBI	Alzheimer's vs VBI
Memory Quotient (MQ)	$p < 0.01$	$p > 0.05$*	$p < 0.01$
Information (INF)	$p > 0.05$*	$p > 0.05$*	$p < 0.01$
Orientation (OR)	$p < 0.05$	$p > 0.05$*	$p < 0.01$
Mental Control (MEN-CON)	$p < 0.01$	$p > 0.05$*	$p < 0.01$
Logical Memory (LOG-MEM)	$p > 0.05$*	$p > 0.05$*	$p < 0.05$
Visual Memory (VIS-MEM)	$p < 0.05$	$p > 0.05$*	$p < 0.01$
Pair Associates [Easy] (PA-AS-ES)	$p < 0.01$	$p > 0.05$*	$p < 0.01$
Pair Associates [Hard] (PA-AS-HD)	$p < 0.05$	$p > 0.05$*	$p < 0.01$

* = Not Significant

with his other intellectual and cognitive functions.

RESULTS

Analysis of Covariance and The Scheffé Test

In order to control for such factors as possible effects of age and education (see Table 1) on the performance tested among the three diagnostic categories an analysis of covariance was performed. The AD group tended to be younger than the other two groups. The mean education level for the VBI and the MID group was not different, but the AD group showed a significantly higher level of education, having on the average three years additional education. Table 2 shows the results of the analysis of covariance for each of the WMS subtests. Significant differences were found among the groups for each of the variables except for DIGS-FWD and DIGS-BWD where no statistically significant differences were found.

A Scheffé Test for ad hoc comparisons was performed in order to determine any specific differences between the groups for each of the variables examined. The results are shown in Table 3. No significant differences were found between the MID and VBI groups on any of the variables tested. The AD and the VBI groups were significantly different for all the subtests included at the $p < .01$ level of significance except for LOG-MEM where the level of significance was $p < .05$. Likewise, the MID and the AD groups showed significant difference ($p < .01$ — $p < .05$) for all the variables with the exception of INF and LOG-MEM where there were no significant differences.

Discriminant Function Analysis and Maximum R-Square Improvement Stepwise Regression

In the present section we were concerned with analyzing the multiple measurements of the WMS obtained for each patient in the three diagnostic categories. The Statistical

TABLE 4

MAXIMUM R-SQUARE IMPROVEMENT STEPWISE REGRESSION FOR ALL GROUPS

Number in Model	Variables in Model	R^2	F-Value for Increment	p	d.f.
1	PA-AS-HD	0.1205			
			1.9252	NS	1,39
2	MQ; DIGS-BWD	0.1616			
			1.9569	NS	1,38
3	MQ; INF; DIGS-BWD	0.2025			
			1.3173	NS	1,37
4	MQ; INF; MEN-CON; DIGS-BWD	0.2299			
			1.8423	NS	1,36
5	OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM	0.2673			
			0.8284	NS	1,35
6	OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.2843			
			0.4086	NS	1,34
7	OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.2928			
			0.2065	NS	1,33
8	INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.2972			
			0.4259	NS	1,32
9	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-ES-ES	0.3064			
			0.4000	NS	1,31
10	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-ES; PA-AS-HD	0.3151			

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TABLE 5

DISCRIMINANT FUNCTION CLASSIFICATION FOR ALL GROUPS

From Group	MID	AD	VBI
MID	16	0	0
AD	0	10	0
VBI	0	0	16

Analysis System Computer program for multi-variate analysis developed at the University of North Carolina was used. In a multi-variate analysis the multiple variables are considered in combination as a system of measurement (Cooley and Lohnes, 1971). The results are presented first for the analysis performed on the three diagnostic groups and then for every pair of diagnostic combinations.

1. — MID, AD and VBI:

A discriminant function analysis (Cooley and Lohnes, 1971) was performed on the 10 predictor variables of the WMS and the three diagnostic groups. The multiple discriminant analysis produced a set of coefficients or weights for the various dependent measures which best separate or discriminate the three different diagnostic categories. The between group variance is maximized relative to the within group variance. A composite discriminant predictor score was then computed for each patient based on his or her raw scores and the optimal lambda weightings (λ) for each variable. Based on this composite score, each patient was then classified into one of the three diagnostic categories.

A Chi-Square (X^2) test was then performed in order to measure the degree of separation of the probability distributions of the three diagnostic groups. The X^2 was significant ($X^2 = 169.36$, d.f. $= 110$, $p < .05$) thus the within covariance matrices were used in performing the discriminant function analysis. Table 5 presents the assignment of patients to each diagnostic group based on the 10 predictor variables. Examination of Table 5 reveals that the hit rate of the discriminant function analysis in classifying patients as VBI, MID or AD by the various subtests of the WMS alone was 100%.

In order to determine which combination of the 10 WMS variables produced the "best" statistical model that discriminated among the three diagnostic groups a Maximum R-Square (R^2) improvement stepwise regression was performed. This technique was applied in order to find which variables of a collection of independent variables should most likely be included in a regression model. It finds first the one-variable model producing the highest R^2 statistic. R^2 is the square of the multiple correlation coefficient and is equal to the proportion of the dependent variable's total variance which is accounted for by the model. Then another variable, the one which would yield the greatest increase in R^2, is added. Once this two-variable model is obtained, each of the variables in the model is compared to each variable not in the model. For each comparison, the procedure determines if removing the variable in the model and replacing it with the presently excluded variable would increase R^2. After all the possible comparisons have been made, the switch which produces

TABLE 6

MAXIMUM R-SQUARE IMPROVEMENT STEPWISE REGRESSION FOR MID AND AD

Number in Model	Variables in Model	R^2	F-Value for Increment	p	d.f.
1	MQ	0.2039			
			3.3920	NS	1,23
2	MQ; INF	0.3060			
			3.0797	NS	1,22
3	MQ; INF; DIGS-BWD	0.3910			
			1.1418	NS	1,21
4	MQ; INF; DIGS-BWD; VIS-MEM	0.4224			
			0.8122	NS	1,20
5	MQ; INF; DIGS-FWD; DIGS-BWD; VIS-MEM	0.4449			
			0.4666	NS	1,19
6	MQ; INF; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEN	0.4582			
			0.1342	NS	1,18
7	MQ; INF; OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM	0.4622			
			0.0666	NS	1,17
8	MQ; INF; OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.4644			
			0.0209	NS	1,16
9	MQ; INF; OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-ES; PA-AS-HD	0.4650			
			0.0028	NS	1,15
10	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-ES; PA-AS-HD	0.4650			

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TABLE 7

DISCRIMINANT FUNCTION CLASSIFICATION FOR MID AND AD

From Group	MID	AD
MID	16	0
AD	0	10

the largest increase in R^2 is made. Comparisons are made again, and the process continues until the procedure finds that no switch could increase R^2. The two-variable model thus settled on is considered the "best" two-variable model the technique can find. The technique then adds a third variable to the model, according to the criteria used in adding the second variable. The comparing-and-switching process is repeated and the "best" three-variable model is discovered, and so forth. Variables are added one by one to the model until all variables are included. Any two models can be compared for predictive accuracy by testing the difference between their R^2's with F tests.

Table 4 presents the maximum R^2 improvement stepwise regression for all groups. Inspection of Table 4 reveals that the "best" model discriminating between the three groups was the one variable model which included PA-AS-HD accounting for 12% of the variance. Addition of any other variable to the model did not increase R^2 significantly. The ten variable model accounted for 31% of the variance. No significant difference in R^2 was found between the one variable model and the ten variable model ($F = 0.9818$, d.f. $= 9, 31$).

2. — MID and AD:

The X^2 test performed in order to measure the degree of separation of the probability distributions of AD and MID was significant ($X^2 = 93.43$, d.f. $= 55$, $p < .05$) thus the within covariance matrices were used in performing the discriminant function analysis. The two groups were found to be discrete. Table 7 presents the assignment of patients to each diagnostic group. The discriminatory accurance was again 100%.

Table 6 presents the maximum R^2 improvement stepwise regression for MID and AD groups. The "best" model discriminating between AD and MID was the one variable model which included MQ accounting for 20% of the variance. Addition of any other variable to the model did not increase R^2 significantly. Forty-six percent of the variance was accounted by the ten variable model. No significant difference in R^2 was found between the one variable model and the ten variable model ($F = 0.8156$, d.f. $= 9,15$).

TABLE 9

DISCRIMINANT FUNCTION CLASSIFICATION FOR AD AND VBI

From Group	AD	VBI
AD	10	0
VBI	0	16

3. — AD and VBI:

The X^2 test was significant ($X^2 = 87.29$, d.f. $= 55$, $p < .05$) thus the within covariance matrices were used in performing the discriminant function analysis. Table 9 presents the assignment of patients to each

TABLE 8

MAXIMUM R-SQUARE IMPROVEMENT STEPWISE REGRESSION FOR AD AND VBI

Number in Model	Variables in Model	R^2	F-Value for Increment	p	d.f.
1	MQ	0.4281			
			4.9705	0.05	1,23
2	MQ; MEN-CON	0.5296			
			6.4424	< 0.01	1,22
3	MQ; OR; MEN-CON	0.6359			
			3.5408	NS	1,21
4	MQ; OR; MEN-CON; DIGS-BWD	0.6883			
				NS	1,20
5	MQ; OR; MEN-CON; LOG-MEN; DIGS-BWD	0.7122	1.6783		
6	MQ; INF; OR; MEN-CON; DIGS-BWD; PA-AS-ES	0.7401	2.0500	NS	1,19
7	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-BWD; PA-AS-ES	0.7509	0.7826	NS	1,18
8	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-BWD; PA-AS-ES; PA-AS-HD	0.7536	0.1875	NS	1,17
9	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-BWD; VIS-MEM; PA-AS-ES; PA-AS-ES; PA-AS-HD	0.7537	0.0065	NS	1,16
10	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-ES; PA-AS-HD	0.7537	0.0060	NS	1,15

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diagnostic group. The discriminatory accuracy obtained was 100%.

The maximum R^2 improvement stepwise regression for AD and VBI is presented in Table 8. The "best" model was the three variable model including MQ; OR and MEN-CON which accounted for 64% of the variance. Addition of any other variable to the model did not increase R^2 significantly. The ten variable model accounted for 75% of the variance. No significant difference in R^2 was found between the three variable model and the ten variable model ($F = 1.0243$; d.f. $= 7,15$).

4. — MID and VBI

The X^2 test was not significant (X^2 72.81, d.f. $= 55$, $p < .05$) thus the pooled covariance matrix was used in the discriminant function analysis. The two groups tended to overlap in their probability distribution. Table 11 presents the discriminant function classification. The valid positive classification was 81% and the false positive 19%.

Table 10 presents the maximum R^2 improvement stepwise regression. The "best" model found by the technique was the one variable model which included INF accounting for 17% of the variance. No other variable added to the model increased R^2 significantly. The ten variable model accounted for 44% of the variance. No significant difference in R^2 was found between the one variable model and the ten variable model ($F = 1.1231$; d.f. $= 9,21$).

DISCUSSION

The memory disorder is a most prominent behavioral deficit occurring in patients with dementia. The purpose of the present study was to investigate the performance of three groups of patients with distinct etiologies of dementia on the various subtests of the WMS. A major attempt was made to utilize statistical methods of analysis that would maximize the differences between the groups.

The data was first analyzed by univariate statistical procedures.

TABLE 11

DISCRIMINANT FUNCTION CLASSIFICATION FOR MID AND VBI

From Group	MID	VBI
MID	13	3
VBI	3	13

The results indicate that there are significant differences in specific memory performance between patients with dementia due to VBI and MID versus neuronal atrophy of the Alzheimer's type. Table 2 presents the mean and standard error for each variable in each diagnostic category. Inspection of this table reveals that the group with AD performed significantly and consistently lower on all measures even though they tended to be younger and to have significantly more years of formal education (Table 1). There were no significant differences between the two cerebrovascular disease groups, even though the MID group tended to perform consistently more poorly than the VBI group. The three

TABLE 10

MAXIMUM R-SQUARE IMPROVEMENT STEPWISE REGRESSION FOR MID AND VBI

Number in Model	Variables in Model	R^2	F-Value for Increment	p	d.f.
1	INF	0.1655			
			2.8500	NS	1,29
2	MQ; DIGS-BWD	0.2408			
			2.4297	NS	1,28
3	MQ; OR; DIGS-BWD	0.3013			
			1.9626	NS	1,27
4	MQ; OR; MEN-CON; DIGS-BWD	0.3487			
5	MQ; OR; MEN-CON; DIGS-FWD; DIGS-BWD	0.3931	1.9955	NS	1,26
6	MQ; OR; MEN-CON; DIGS;FWD; DIGS-BWD; VIS-MEM	0.4094	0.6864	NS	1,25
7	MQ; OR; MEN-CON; DIGS-FWD; DIGS-BWD; VIS-MEM	0.4309	0.9198	NS	1,24
8	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.4349	0.1591	NS	1,23
9	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-HD	0.4362	0.0546	NS	1,22
10	MQ; INF; OR; MEN-CON; LOG-MEM; DIGS-FWD; DIGS-BWD; VIS-MEM; PA-AS-ES;PA-AS-HD	0.4365	0.0118	NS	1,21

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groups differed in the degree of impairment even though the MID and VBI did not differ significantly by univariate statistical procedures. The present findings are consistent with the previous results of Perez et al (1975) in which the three diagnostic groups differed similarly in the degree of intellectual and cognitive impairment on the WAIS.

Table 2 presents the results of the analysis of covariance performed among the three diagnostic categories. It is important to note that the DIGS-FWD and DIGS-BWD subtests of the WMS did not differ significantly among the groups. Cohen (1959) in a factor analytic study of the Wechsler Intelligence Scale for children identified the Digit Span subtests as a Freedom-from-Distractability factor. These subtests appear to require concentration and attention. The three groups appear to be equally impaired on this factor.

Table 3 presents the findings of the analyses performed in order to determine specific differences between the groups on each WMS variable found to differ significantly by the analysis of covariance. Close inspection of this table reveals that MID and AD did not differ significantly on the INF and LOG-MEM subtests. It seems that these groups show a similar impairment of recent verbal memory as well as in the ability to provide personal and current political information from memory storage.

The results of the discriminant function analysis performed on the 10 predictor variables and the three diagnostic groups as well as for every pair of diagnostic combinations are encouraging (see Tables 5, 7, 9 and 11). One hundred percent valid positive hit rate was obtained in discriminating among the three diagnostic groups. The MID and AD as well as the AD and VBI groups were found to be discrete. One hundred percent diagnostic accuracy was obtained in discriminating between these groups. It is interesting to note that when comparing the two cerebrovascular disease groups they tended to overlap in their probability distributions. The valid positive rate for discriminating the MID and VBI was 81%. Each cerebrovascular dementia group differed significantly from the neuronal atrophy dementia group but were less homogeneous when comparing their individual patient samples.

For heuristic and conceptual as well as practical purposes it is important to detect possible patterns of memory performance for the three diagnostic groups on the multiple measurements obtained. In order to determine which combination of the 10 WMS variables produced the "best" statistical model that discriminated the three diagnostic groups a series of maximum R^2 improvement stepwise regression analyses were performed. This powerful multivariate analysis of regression technique supplements concepts of statistical significance with additional information concerning the relative efficiency of a particular model (i.e., proportion of variance accounted for by model) in discriminating the groups. This analytic technique, in addition to finding the "least square weights" for the predictor variables in each model, also generates the coefficient of determination (R^2) for each model. The task is to trim away useless predictor information (i.e., insignificant sources of variance) and arrive at the simplest representation of the data without reducing the discriminatory accuracy. According to Ward and Jennings (1973), if a simple model and a less simple model can estimate sample means equally well, the estimates of the simpler model will, on the average, be closer to the parameter means than those produced by the less simple one. The first step was to identify the "best" (i.e. simplest) statistical model discriminating among the three groups (see Table 4). The one variable model including PA-AS-HD was found to be the "best" model. This model accounted for 12% of the variance. Addition of the remaining nine WMS variables increased the accounted variance by only 19%. This increment was not significant. The present finding identified the ability to learn new difficult verbal pair associates as the "best" single variable of the WMS in discriminating the three diagnostic groups.

Having identified the "best" statistical model discriminating among the three groups, the next step was to identify the "best" model for each pair of diagnostic combinations (see Tables 6, 8, and 10). When the MID and AD groups were compared, the "best" model was the one variable model including MQ. This model accounted for 20% of the variance. Addition of the remaining nine variables increased the accounted variance by 26%. This increment was not significant. The overall level of memory functioning as reflected in the MQ was the simplest model in differentiating MID and AD.

Comparison of AD and VBI revealed that the "best" model was the three variable model including MQ;OR and MEN-CON. This model accounted for 64% of the variance. Addition of the remaining six variables increased the accounted variance by only 12%. This increment was not significant. The results indicate that the VBI and AD groups were more easily differentiated when not only overall level of memory functioning (MQ) was analyzed but also when measures of orientation to time and place (OR) as well as concentration and attention in operating on highly overlearned sequences such as the number system and the alphabet (MEN-CON) were included in the model.

The "best" model differentiating the two cerebrovascular groups (MID and VBI) was the one variable model including INF accounting for 16% of the variance. Addition of the remaining nine variables increased the accounted variance by 27%. This increment was not significant. These two groups were more simply discriminated by a task measuring personal information (age and date of birth) as well as current political information.

There are important implications resulting from the present findings. First of all, different predictive statistical models were identified to differentiate the various diagnostic groups. If we assume that the higher the proportion of variance ac-

counted for by a model the better is the model then we can state that the "best" overall model was the three variable model discriminating between AD and VBI. However, all models identified produced excellent diagnostic accuracy. The MQ found to be a significant factor in discriminating the two cerebrovascular dementia groups from the neuronal atrophy dementia group. Some of the variables identified as good predictors such as PA-AS-HD, INF, OR and MEN-CON can be easily included in the standard clinical evaluation of the dementias. With these variables, combined with those previously found by Perez et al (1975) from the WAIS, it might be possible to develop an "early warning screening system" in order to detect a dementing process at its onset and possibly institute remediable or preventive measures.

Some limitations of the present findings particularly those pertaining to the multivariate analysis should be pointed out. The results provide primarily a heuristic and conceptual framework for additional practical application. According to Cooley and Lohnes (1971) the investigator who wants his statistical model of linear components taken seriously must either 1) base them on large and representative samples or 2) demonstrate their validity on replication samples. We are currently collecting large samples of neuropsychological data for various diagnostic classifications producing dementia including a group of matched normal controls. Future replication studies on large samples should further evaluate the discriminatory accuracy of neuropsychological procedures. It is not until then that practical applications should be considered. Some of these potentially useful practical applications include the identification and prevention as well as treatment evaluation of various diseases producing the behavioral deficits associated with dementia by comprehensive neuropsychological procedures. This is particularly important since dementia is a growing public health problem of our aging population.

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