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MEMORY ABILITIES DURING NORMAL AGING

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One hundred and five normal subjects from 20 to 89 years old, and with a minimum of six years of formal education were selected. Subjects were divided into seven age ranges, with 15 subjects in each group. The following tests were individually administered: (1) Wechsler Memory Scale (WMS) (Wechsler, 1945); (2) Serial Verbal Learning (Ardila, Rosselli & Puente, 1994; Ardila & Ostrosky, 1991); (3) The Rey-Osterrieth Complex Figure (ROCF) (Osterrieth, 1944) (copy, immediate, and delayed reproduction); (4) Corsi's blocks (Milner, 1971) (forwards and backwards); and (5) Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 1985). This last test may be considered as a functional or ecological memory test. All test scores declined across ages between 4.1% and 76.6%. In all the tests, excepting Digits, standard deviations increased with age. It was observed that the youngest subjects could retain about three-fourths of the information presented, whereas the oldest retained around one-third of this information. About half of the test significantly correlated with the Rivermead Behavioral Memory Test. A factor analysis revealed four different factors accounting for 63.3% of the variance. A single nonverbal memory factor accounted for over 40% of the variance.

Keywords: Normal aging; memory decline; factor analysis; neuropsychological testing.

Normal aging is significantly associated with a decrease in memory and learning (Albert, 1988; Ardila & Rosselli, 1989). An increase in forgetfulness and a decrease in the capacity to store new information is observed. This decline develops at a slow rate during normal aging but is accelerated in abnormal aging (Cummings & Benson, 1992).

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Memory is not uniformly affected by age. Some aspects of memory are more impaired than others. Remote memory or tertiary memory remain relatively stable with age (Huppert, 1991; Kaszniak, Poone & Riege, 1986). Remote memory is particularly well preserved when the events have emotional content and require verbal-cultural knowledge (La Rue, 1992). Age changes in recent memory represent the most evident changes observed during normal aging. The decrease in secondary memory or long term memory, found in older people, may partially explain the recent memory defects (Miller, 1977). Secondary memory refers to acquisition, retention, and retrieval of information over intervals ranging from a few minutes to days or weeks (La Rue, 1992). The greatest differences between young and old groups have been reported in secondary memory (Albert, 1994). Primary memory or short-term memory, however, may show little changes with age.

Primary memory is limited in terms of the amount of information. When the information is to be retained for a substantial time, it must be transferred to secondary memory in order to be stored. This storage of new information is reduced with age. Although elders are able to encode (primary memory), difficulties in transferring it into long-term memory (secondary memory) are observed. These difficulties are true for verbal as well as nonverbal material (Crook et al., 1986), although they may be more pronounced for visuospatial memory (Eslinger et al., 1988). In the Rey-Osterrieth Complex Figure, for example, immediate recall scores decrease earlier in life and are more sensitive to aging effects than Rey-Osterrieth Complex Figure copy scores. A steady decline in the constructional/memory ratio (copy score/immediate recall score) has been observed since the 50's (Ardila & Rosselli, in press).

Age decrements are greater on recall than on recognition tasks (Craik, Byrd & Swanson, 1987), meaning that retrieval defects may contribute to secondary memory problems also. Cueing at retrieval and encoding improves the performance on memory tasks in the elderly (Cummings & Benson, 1992; Craik, Bird, & Swanson, 1987).

Aging is associated with a slowing in encoding (Cerella, Poon & Fozard, 1982) and in reaction time (Ardila & Rosselli, 1986). The rate of presentation of the to-be-retained information may affect memory performance in elderly individuals. Arenberg (1980) found significant differences in the performance of younger and older adults if the memory information is presented at a high rate. These differences disappeared when the rate of presentation slowed.

The impairment in recent memory has been associated with an age-dependent change in the use of metamemory strategies. Older people, for example, are less likely to use association strategies when learning a list of words (Albert, 1994), and therefore, require more trials than younger people to learn a list of words (Ardila & Rosselli, 1989).

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Memory defects represent a common complaint in people over 60, and particularly in individuals over 70. In elders, memory impairment represents a significant factor partially responsible for their limitations in everyday activities. The external validity of laboratory neuropsychological memory tests, however, is not well defined yet (Lezak, 1995).

Besides the purely memory defects, elders' underperformance in laboratory memory tests may be under the influence of a whole array of extra-memory factors, such as, lack of motivation, absence of familiarity with the testing procedures, sensory defects, depression, etc.

The purposes of the present study were:

1. To analyze memory decline across ages reflected in different neuropsychological memory tests.
2. To correlate the capability of neuropsychological memory tests to predict functional memory performance. For this purpose, in addition to neuropsychological laboratory tests, a test of functional memory was also included.
3. To perform a factor analysis of the test scores, in order to find out memory factors, and analyze the effects of aging on these different memory factors.

METHOD

Subjects

One hundred and five normal subjects (44 men, 61 women) from 20 to 89 years old, and with a minimum of six years of formal education were selected. Subjects were divided into seven age ranges, with 15 subjects in each group. All the subjects belonged to a middle socioeconomic status, were living in Mexico City, and were native Spanish speakers. All subjects were initially interviewed to determine eligibility. A neurological and psychiatric screening questionnaire was used to rule out previous neurological and psychiatric conditions. A handedness questionnaire was also administered. All subjects were nonpaid volunteers.

The following inclusion criteria were used: (1) Absence of dementia according to the DSM-IV (American Psychiatric Association, 1994); (2) A score of 24 or over in the Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975); and (3) No neurological or psychiatric history such as: brain injury, cerebrovascular disease, epilepsy, Parkinson's disease, depression, psychiatric hospitalizations, and the like. Table I presents the general characteristics of the sample.

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TABLE I General Characteristics of the Sample

	Range	*Mean*	*SD*	*Men*	*Women*
Group 1	20–29	24.4	2.9	11	4
Group 2	30–39	32.8	2.8	5	10
Group 3	40–49	44.6	3.1	6	9
Group 4	50–59	54.2	2.1	4	11
Group 5	60–69	63.3	2.8	8	7
Group 6	70–79	74.8	2.0	6	9
Group 7	80–89	83.4	3.1	4	11
Total				44	61

Instruments

The following tests were individually given to each subject:

1. Wechsler Memory Scale (WMS) (Wechsler, 1945), including the following subtests:
   1.1. Information
   1.2. Orientation
   1.3. Mental Control
   1.4. Logical Memory
   1.5. Digits Forward
   1.6. Digits Backwards
   1.7. Visual Reproduction
   1.8. Associative Learning
   1.9. Total score

In addition to the standard application, delayed recall for the Logical Memory, Visual Reproduction, and Associative Learning subtests were also included.

2. Serial verbal learning (SVL) (Ardila, Rosselli & Puente, 1994; Ardila & Ostrosky, 1991). To recall 10 common words sequentially presented. The 10-word list was read by the examiner, and the subject repeated as many as possible, regardless of the order. The list was read up to maximum of five times. Two different scores were used:
   2.1. First trial: Number of words recalled after the first presentation.
   2.2. Delayed recall after 20 minutes.

3. The Rey-Osterrieth Complex Figure (ROCF) (Osterrieth, 1944). Three conditions were used:
   3.1. Copy. Subjects were required to copy the figure placed in front of them on a plain piece of paper. There was no time limit. Both the copy and the

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memory designs were scored considering 18 units separately (Lezak, 1995; Taylor, 1959). Maximum score was 36.

3.2. Immediate memory. When the subject finished copying the figure, both the design and the subject's copy were removed and the subject was asked to draw the figure from memory.

3.3. Delayed recall of the figure after 20 minutes.

4. Corsi's blocks (Milner, 1971). Two conditions were used:
   4.1. Forwards.
   4.2. Backwards.

5. Rivermead Behavioural Memory Test (RBMT) (Wilson et al., 1985, 1989). The subject has to recall, to carry out daily activities, or to memorize some type of information required for an everyday performance. The battery includes tests such as recognition of unfamiliar faces, recalling a prose passage, retracing a route around the room, remembering to take and deliver messages, remembering to ask for a hidden object, and remembering to take an appointment. It may be considered as a measure of ecological or functional memory.

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Procedure

All subjects were initially interviewed to determine eligibility. Further, the directed interview and testing were presented. Testing took about 60 minutes, and was administered by graduate neuropsychology students.

RESULTS

Table II presents the mean scores and standard deviations in the different tests. It is observed that test scores decline across ages. Decline in scores ranged between 4.1% and 76.6%. Score decline depended upon the specific test. For some tests, differences between the first and the last age range were small. In other tests, differences were notoriously larger. The best preserved scores across age ranges were observed in the Orientation subtest of the WMS, and the worst preserved scores were found in the Delayed condition of the Visual reproduction subtest of the WMS. The scores found in the last age range (80–89 years) with regard to the scores observed in the first range (20–29 years), corresponded to the following percentages:

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TABLE II General results in the memory tests for the different age ranges

	20–29	*30–39*	*40–49*	*50–59*	*60–69*	*70–79*	*80–89*
WMS: Information	5.4 (0.5)	5.2 (0.8)	5.3 (0.6)	5.4 (0.5)	5.1 (0.9)	5.0 (0.7)	4.7 (1.0)
Orientation	4.9 (0.2)	5.0 (0.0)	5.0 (0.0)	5.0 (0.0)	4.9 (0.6)	4.8 (0.4)	4.7 (0.6)
Mental Control	7.5 (1.5)	7.5 (1.1)	7.5 (1.9)	6.9 (1.4)	6.5 (2.0)	6.0 (2.2)	5.8 (1.9)
Logical Memory	9.2 (2.6)	7.8 (1.8)	7.6 (2.9)	7.7 (2.9)	8.1 (3.0)	7.4 (2.6)	6.7 (2.5)
Digits Forwards	6.1 (1.2)	5.4 (0.5)	5.2 (1.0)	5.0 (1.0)	5.0 (1.3)	5.0 (1.0)	4.9 (0.8)
Digits Backwads	4.5 (1.0)	4.0 (1.0)	3.4 (1.3)	3.2 (0.9)	3.4 (1.0)	3.4 (0.9)	2.9 (0.6)
Visual Reprod	14.1 (1.2)	13.4 (1.9)	13.1 (2.6)	13.5 (2.3)	10.0 (3.3)	7.3 (3.3)	6.2 (2.1)
Associat Learning	19.0 (1.4)	16.3 (3.1)	16.4 (3.4)	14.6 (3.1)	12.5 (4.9)	12.5 (3.4)	9.3 (3.7)
Total Score	70.7 (6.5)	65.0 (5.5)	63.7 (8.6)	61.3 (5.6)	56.3 (11.7)	53.6 (5.2)	45.4 (6.3)
Del. Log Memory	7.9 (2.9)	7.6 (1.7)	7.1 (2.8)	6.9 (1.4)	5.4 (2.5)	4.8 (0.7)	4.0 (1.8)
Del. Vis Reprod	12.8 (2.3)	11.9 (1.7)	9.6 (3.4)	9.2 (3.3)	7.8 (3.0)	4.1 (1.8)	3.0 (1.8)
Del. Assoc Learn	9.9 (0.2)	9.1 (1.4)	9.1 (1.0)	8.0 (1.5)	7.8 (1.3)	7.0 (1.2)	6.1 (1.5)
SVL: First trial	9.4 (0.9)	8.7 (1.2)	8.5 (1.4)	8.4 (1.4)	7.8 (1.7)	6.5 (1.6)	6.0 (1.8)
Delayed recall	8.9 (1.6)	8.1 (1.2)	7.1 (1.6)	6.4 (1.2)	6.6 (2.1)	6.3 (1.5)	4.2 (2.4)
ROCF: Copy	35.1 (1.3)	35.0 (1.1)	34.6 (1.6)	34.2 (1.5)	30.3 (5.8)	29.4 (1.1)	29.2 (5.0)
Immediate memory	25.8 (4.9)	24.1 (4.7)	19.9 (4.8)	19.2 (4.5)	13.4 (7.4)	12.2 (4.7)	8.9 (4.3)
Delayed recall	24.1 (6.8)	24.6 (4.4)	20.4 (5.6)	16.8 (6.9)	15.8 (8.7)	10.8 (4.8)	10.0 (3.9)
Corsi's blocks: Forwds	6.2 (0.9)	5.8 (0.9)	5.3 (1.0)	4.7 (0.9)	4.9 (1.0)	5.0 (0.8)	4.4 (0.8)
Backwds	5.4 (1.2)	5.2 (1.1)	4.5 (1.2)	4.0 (0.9)	4.1 (0.9)	4.4 (0.8)	3.7 (1.2)
RBMT	11.0 (1.0)	10.9 (1.3)	10.2 (1.5)	9.7 (1.2)	10.2 (1.5)	9.4 (0.7)	7.8 (2.4)

Average scores are presented for each test. Standard deviations are shown in parenthesis.

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WMS: Orientation: 95.9%
WMS: Information: 87.0%
ROCF: Copy: 83.2%
WMS: Digits Forwards: 80.3%
WMS: Mental Control: 77.3%
WMS: Logical Memory: 72.8%
Corsi's blocks: Forwards: 71.0%
Rivermead Behavioral Memory Test: 70.9%
Corsi's blocks: Backwards: 68.5%
WMS: Digits Backwards: 64.4%
WMS: Total Score: 64.2%
Serial Verbal Learning: First trial: 63.8%
WMS: Delayed Associative Learning: 61.6%
WMS: Delayed Logical Memory: 50.6%
WMS: Associative Learning: 48.9%
Serial Verbal Learning: Delayed recall: 47.2%
WMS: Visual Reproduction: 43.9%
ROCF: Delayed recall: 41.5%
ROCF: Immediate memory: 34.5%
WMS: Delayed Visual Reproduction: 23.4%

WMS Orientation subtest, and ROCF copy condition are not usually regarded as memory tests. The memory tests least sensitive to the effects of aging were in consequence WMS Information subtest, Digits Forward subtest of the WMS, and the WMS Logical Memory subtest. The tests most sensitive to the effects of aging were, Visual Reproduction subtest of the WMS both delayed, and immediate condition; and the ROCF both immediate and delayed recall. That is, nonverbal memory tests of recently acquired information.

It is important to emphasize that not only mean scores decreased, but also standard deviations increased with age. Comparing the first (20–29 years) and last age (80–89 years) ranges, the ratio between the mean and the standard deviation (mean/standard deviation), it was observed that in all the tests, excepting Digits, dispersions increased between the first and the last age ranges. This means that with advancing age, the age groups became more heterogeneous with regard to the scores in the different memory tests. For the delayed condition of the WMS Associative Learning subtest the dispersion in the last age range was over 12 times larger than the dispersion found in the first age range. This subtest was also the most sensitive test to aging effects. For most of the memory tests, score dispersions increased about two-three times between the 20s and the 80s. Table III shows these changes in the dispersions of the scores across age ranges.

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TABLE III Changes in dispersion. Comparison between the youngest (20–29 years) and the oldest (80–89 years) groups

	R1: Mean/SD*	*R2**: Mean/SD*	*R1/R2****
WMS: Information	10.8	4.7	2.29
Orientation	24.5	7.8	3.14
Mental Control	5.0	3.0	1.67
Logical Memory	3.5	2.6	1.32
Digits Forwards	5.1	6.1	0.83
Digits Backwads	4.5	4.8	0.93
Visual Reprod	11.7	2.9	4.03
Associat Learning	13.5	2.5	5.40
Total Score	10.8	7.2	1.50
Del. Log Memory	2.7	2.2	1.22
Del. Vis Reprod	5.5	1.6	3.43
Del. Assoc Learn	49.5	4.0	12.37
SVL: First trial	10.4	1.7	6.11
Delayed recall	5.5	1.7	3.22
ROCF: Copy	27.0	5.8	4.65
Immediate memory	5.2	2.1	2.47
Delayed recall	3.5	2.5	1.40
Corsi's blocks: Forwds	6.8	5.5	1.23
Backwds	4.5	3.1	1.45
RBMT	11.0	3.2	3.43

R1 refers to the ratio mean/standard deviation in the youngest group (20–29 years). R2 refers to the ratio mean/standard deviation in the oldest group (80–89). A R1/R2 value over 1.00 means that the dispersion is larger in the oldest than in the youngest group.

Table IV compares the percentage of information loss in immediate and delayed recall conditions. Only in four tests was this type of comparison calculated: ROCF, SVL, Logical Memory (WMS), and Visual Reproduction (WMS). It is observed that the lowest loss of information found was the immediate recall of the SVL. As a matter of fact, this test condition could be considered a measure of immediate verbal memory. And the highest loss of information was observed

TABLE IV Percentage of information loss in different testing conditions

	20–29	*30–39*	*40–49*	*50–59*	*60–69*	*70–79*	*80–89*
ROCF: Immediate memory	28.7	32.9	44.8	46.6	62.7	66.1	75.1
Delayed recall	32.9	31.6	43.3	53.1	56.1	69.8	72.2
SVL: First trial	5.3	12.6	14.6	16.0	21.3	34.6	39.3
Delayed recall	10.6	18.6	26.6	35.3	33.3	35.3	58.0
WMS: Imm Log Memory	60.0	66.0	66.6	71.0	64.6	67.8	71.0
Delayed Log Mem	65.5	71.3	68.9	76.2	69.8	79.1	82.6
WMS: Imm Visual Reprod	6.2	10.2	12.4	9.7	33.3	51.1	58.6
Delayed Vis Rep	14.6	20.4	36.0	38.6	47.5	72.8	80.0
Average: Immediate	25.0	30.4	34.6	35.8	45.4	54.9	61.0
Delayed	27.2	35.4	43.7	50.8	51.6	64.2	73.2

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in the delayed condition of the WMS Logical Memory subtest. In the first age range, the difference between the immediate and delayed conditions was minor, whereas in older subjects this difference was notoriously stronger. Younger people lose on average about one-fourth of the information included in these memory tasks (i.e., they can retain about three-fourths of the information that is presented), whereas loss of older people was on average about two-thirds of this information (i.e., they retain about one third of the to-be-memorized information).

Correlations between different memory test scores and the Rivermead Behavioral Memory Test (functional memory) scores were calculated. The Rivermead Behavioral Memory Test may be considered as a measure of functional memory. In consequence, these correlations could be pointing to the capability of these neuropsychology memory tests to predict functional or ecological memory. Only nine out of 19 test correlations turned out to be statistically significant. Highest correlations were found with the Serial Verbal Learning -Delayed recall ($r = .55$), and with Delayed Associative Learning subtest of the WMS ($r = .54$). It might be assumed that these two test scores best predict functional memory. All significant correlations were about .40–.50 and, in consequence, they can be regarded just as moderate correlations.

A factor analysis with varimax rotation of the memory test battery scores was performed. Four different factors with an eigenvalue higher than 1.00 were disclosed. These factors accounted for about 63.3% of the total variance. Table VI presents the general results of the factor analysis.

Factor I was measured by ROCF immediate and delayed conditions, and WMS Visual reproduction subtest, immediate and delayed conditions. The first factor, accounting for 42.3% of the total variance, was obviously a nonverbal memory factor. The three following factors were notoriously weaker. Factor II was measured by the three Digits scores used (total, forwards, and backwards). It may be interpreted as an immediate verbal memory factor. Factor III, accounting for 6.7%

TABLE V Correlations between different memory test scores and the Rivermead Behavioral Memory Test (functional memory) score. Only those correlations over 0.40 ($p < .01$) are presented

Test	*Correlation*
Serial Verbal Learning: Delayed recall	0.55
WMS: Delayed Associative Learning	0.54
Serial Verbal Learning: First trial	0.52
WMS: Total Score	0.52
Rey-Osterrieht Complex Figure: Immediate memory	0.51
WMS: Delayed Visual Reproduction	0.48
WMS: Delayed Logical Memory	0.47
Rey-Osterrieht Complex Figure: Delayed recall	0.42
Corsi's blocks: Backwards	0.41

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TABLE VI Factor analysis of the memory test battery.

Factor	*Pct. of Var*	*Cum. Pct.*	*Scores*	*r*
I	42.3	42.3	ROCF (immediate)	0.88
			ROCF (delayed)	0.85
			Visual reprod (imm)	0.77
			Visual reprod (del)	0.72
II	9.0	51.3	Digits (total)	0.92
			Digits (forward)	0.87
			Digits (backwards)	0.64
III	6.7	58.0	Information	0.78
IV	5.3	63.3	Logical memory (imm)	0.84
			Logical memory (del)	0.83

of the variance, was almost exclusively measured by the Information score of the WMS. Factor III may be interpreted as long-term memory factor. The last factor accounting for 5.3% of the total variance was measured with the two Logical memory scores (immediate and delayed conditions). It may be considered in consequence as a verbal memory factor.

DISCUSSION

Three major points in our results deserve further analysis: (1) the changes in dispersions (standard deviations) found across age ranges; (2) the correlations between functional memory tests and psychometric memory tests; and finally (3) the four-factor structure of our memory test battery.

The increase in the score dispersions across age ranges is not totally unexpected (Albert, 1988, 1994; Ardila & Rosselli, 1992; Huppert, 1991; Kaszniak, Poone & Riege, 1986). This increase in test score dispersion may represent a major and fundamental factor during normal aging. Individual differences are significant, and whereas some subjects may maintain a relatively steady good cognitive performance ("successful aging") other individuals may present a premature and relatively rapid cognitive decline. This premature cognitive decline sometimes may be observed from the 40's, and eventually may lead to a dementia of the Alzheimer type. In this research study standard deviations in all tests scored, excepting Digits, increased with age. Interestingly, Digits is a test quite resistant to the effects of aging (Ardila & Rosselli, 1989; Albert, 1988, 1994). The increase in the standard deviations was over 10 times in WMS Associative learning, delayed condition.

The correlations between functional memory ((RBMT) and psychometric memory tests were moderate in general. Higher correlations were observed between functional memory and verbal memory tests than between functional

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memory and nonverbal memory tests. Only SVL, WMS Associative learning, WMS Visual reproduction, WMS Logical memory, ROCF and Corsi's blocks were significantly correlated with RBMT. Highest correlations were observed with the delayed condition of two verbal memory tests, SVL and WMS Associative learning. The single test best predicting RBMT scores was the SVL, and the worst was Digits.

RBMT scores were relatively stable across age groups. Performance in the oldest age group was about 70% of the performance observed in the youngest subjects. This means, RBMT scores were not so stable as Digits, but notoriously more stable than WMS Visual reproduction subtest (both conditions) and ROCF (both conditions). Decline in RBMT scores was similar to the decline in scores observed in the WMS Logical Memory subtest. It may be assumed that decline in functional memory is just moderate, and in general slower than the decline observed in laboratory psychometric memory test scores. Some significant decline was observed only during the 80s (see Table II).

The four factors observed in the factor analysis are not completely unexpected: Nonverbal memory, immediate memory, long-term memory, and verbal memory factors. What was quite unexpected, was the particularly strong significance of the first factor. Factor I accounted for over 40% of the total variance, whereas the other factors were notoriously weaker and minor factors. Nonverbal memory defects, and in general, nonverbal memory impairments may be considered as core cognitive deficits associated with aging (Albert, 1988; Ardila & Rosselli, 1989; Hupper, 1991).

The analysis of different types memory abilities across age range can notoriously increase our understanding not only about normal, but also abnormal aging.

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