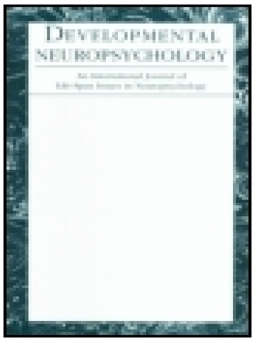

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Neuropsychological characteristics of normal aging

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Neuropsychological Characteristics of Normal Aging

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A basic neuropsychological battery was given to 346 normal adults. Participant characteristics were balanced according to: (a) age (55 to 60, 61 to 65, 66 to 70, 71 to 75, 76 or older), (b) sex, and (c) educational level (0 to 5 years, 6 to 12 years, more than 12 years of schooling). The items of the neuropsychological battery assessed language, memory, attention, abstraction, and constructional abilities, and also included a behavioral scale. Differences based on educational level were found for 28 of the 29 tests used, and age differences were found for 23, with better performance among younger and more highly educated participants. Sex differences were found for 10 tests, with better performance among males in 9 of these tasks. Few interactions were significant. A factor analysis was performed in which 43 factors were found to explain the total variance. However, a single factor explained 35.9% of the variance; this factor was related to visuospatial and visuomotor abilities. A second factor (6% of the variance) was related to verbal learning. A third factor (4.6% of the variance) was clearly related to speed, and a fourth factor (3.9% of the variance) to verbal semantic memory. Implications of these results are discussed.

Distinguishing normal and abnormal aging is a central problem in neuropsychological assessment. Several authors (e.g., Ardila & Rosselli, 1986; Lau et al., 1988) have emphasized the great difficulty in discriminating normal individuals from those with mild dementia. Routine neuropsychological tests usually do not include criteria for the elderly. Because cognitive

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changes during the initial stages of dementia are quite similar to cognitive changes observed during normal aging, it frequently becomes particularly difficult to perform a differential diagnosis between normal aging and the initiation of dementia. Some normal changes for a particular age-range could be indicative of dementia when observed in younger persons. Dementia, and specifically dementia of the Alzheimer type, has even been considered as an abnormally accelerated aging process (e.g., Berg, 1985; Constantinidis & Richard, 1985).

Different studies have approached the question of psychological abilities during aging. Plude and Hoyer (1986) studied the selectivity of visual information processing; they observed that some attentional deficits increased with aging. Park, Puglisi, and Smith (1986) observed that memory for meaningful pictures remains relatively intact with age. However, incidental but not prospective/intentional memory appears to be significantly influenced by age (Sinnott, 1986). Hertzog and Schaie (1986) demonstrated that individual differences in general intelligence tend to be highly stable over time. Several longitudinal studies have reported a decline in divergent thinking abilities with age (e.g., McCrae, Arenberg, & Costa, 1987).

In recent years, many attempts have been made to develop neuropsychological procedures for assessing aging and particularly dementia (e.g., Becker, Huff, Nebes, Holland, & Boller, 1988; Botwinick, Storandt, & Berg, 1986; Fillenbaum, Heyman, Wilkinson, & Haynes, 1987; Filley, Kelly, & Heaton, 1986; Folstein, Folstein, & McHugh, 1975). Erkinjuntti, Laaksonen, Sulkava, Syrjalainen, and Palo (1986) used a battery based on Luria's neuropsychological investigation method and observed a steady, but selective, cognitive impairment with increasing age in normal healthy people; the areas of cognition most sensitive to the effects of normal aging were mnesic and conceptual function and arithmetic skills; the age-related changes, however, could be clearly differentiated from changes found in patients with mild degrees of dementia. La Rue, D'Elia, Clark, Spar, and Jarvik (1986) compared dementia, depression, and healthy aging participants in the performance of three tests of learning and memory (the Benton Visual Retention Test, Inglis Paired Associate Learning Test, and the Fuld Object-Memory Evaluation); the major distinction among the groups was observed in the last test.

Some studies have analyzed the influence of level of schooling on neuropsychological evaluation (e.g., Ardila, Rosselli, & Rosas, 1989; Finlayson, Johnson, & Reitan, 1977; Lecours, Mehler, Parente, & Collaborators, 1987a, 1987b; Ostrosky et al., 1985, 1986); in general, these studies have shown that educational level is a tremendously important variable in performing neuropsychological assessment. Sometimes, performance in neuropsychological tests in low educational groups can be similar to that observed in cases of brain dysfunction and wrongly taken as indicative of such dysfunction. Cornelius and Caspi (1987) observed that educational level related substantially to performance on verbal meaning tests but was not systematically related to everyday problem solving. Craik, Byrd, and Swanson (1987) observed that differences in memory loss with aging were related to socioeconomic status.

Heaton, Grant, and Matthews (1986) compared performance on the Halstead–Reitan Neuropsychological Battery (Reitan & Davison, 1974) for three different educational levels (9, 13, and 17 years in average) and for three age-ranges (less than 40, 40 to 59, and greater than 60 years); they found significant educational effects on all tests; by the same token, the tests were strongly related to age; this was particularly true for psychomotor speed, conceptual ability, flexibility of thinking, and incidental memory subtests. The authors suggested that more highly educated individuals would show a smaller age-related decline in performance than would less educated groups. Bornstein and Suga (1988) studied neuropsychological test performance in groups of normal 55- to 70-year-olds stratified on the basis of educational level (5 to 10, 11 to 12, and 12 or more years of education); they found differences among educational groups in 6 of the 10 tests used; Bornstein and Suga suggested that more highly educated groups may be better able than less educated groups to compensate for the effects of the aging process; educational level would be more related to the timing at onset of decline than to the level of such decline.

In this research, we tried to analyze simultaneously the effects of age, educational level, and sex on neuropsychological test performance. We tapped a much lower educational distribution than that studied by Heaton et al. and Bornstein and Suga, because we included illiterate participants. Our age ranges were higher than those in Heaton et al.'s study (40 to 69) and Bornstein and Suga's (55 to 70). Furthermore, our participants belong to a different culture, providing an opportunity to make some cross-cultural comparisons.

METHOD

Participants

Participants were 346 normal adults who were divided into groups according to three variables: (a) age (55 to 60, 61 to 65, 66 to 70, 71 to 75, 76 or older), (b) educational level (0 to 5 years, 6 to 12 years, or 12 or more years of schooling), and (c) sex. The groups were balanced and a 5 × 3 × 2 design was obtained with 11 to 12 participants in each cell.

Participants were included in the study if they: (a) were not demented according to *DSM-III-R* (American Psychiatric Association, 1987) criteria; (b) had a score of 23 or higher on the Mini-Mental State (Folstein et al., 1975); (c) had no neurological or psychiatric background (cerebrovascular accidents, head trauma, epilepsy, or Parkinson's disease), as determined by a neurological and psychiatric screening; and (d) performed adequately in everyday life activities. All participants were Colombian, living in Bogota (population around 5,500,000 inhabitants), and native Spanish speakers.

Instrumentation

The neuropsychological battery we administered included items from the following tests:

1. A behavioral scale (Ardila, Duran, & Mosquera, 1988) intended to measure behavioral changes (changes in social relationships, sphere of interests, excessive concern with money, etc.), with a maximum score of 36 points. This scale was scored with the help of a person close to the participant.

From the Wechsler Memory Scale (Wechsler, 1945):

2. Orientation section,
3. Digits Forwards,
4. Digits Backwards,
5. Immediate Logical Memory,
6. Delayed Logical Memory (some 20 min later),
7. Immediate Nonverbal Memory, and
8. Delayed Nonverbal Memory (some 20 min later).

Verbal Learning Curve (Luria, 1966):

9. Verbal learning for 10 common bisyllabic nonrelated nouns: immediate recall after the first presentation,
10. Number of trials required to recall the 10 words, and
11. Delayed memory of the 10 words (some 20 min later).

12. Verbal Fluency: semantic (fruits and animals in 1 min).
13. Verbal Fluency: phonological (words beginning with *S* and *A* in 1 min; Benton & Hamsher, 1976).
14. 'A' Auditory Vigilance Test (Lezak, 1983).
15. Letter Cancellation test (Diller et al., 1974).

From the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974):

16. Porteus Mazes,
17. Similarities,
18. Digit Symbol,
19. Block Design subtests.

20. A shortened (15-item) Spanish version of the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983). Maximum score was 45 points.

21. Written description of the Cookie Theft (Card 1; Goodglass & Kaplan, 1972). Maximum score = 3.

22. Abstraction: A shortened version of a concept formation test (Ardila & Rosselli, 1986; Bruner, Goodnow, & Austin, 1956). Maximum score = 3.

23. Recognition of unfamiliar faces (Lezak, 1983). Maximum score = 6.

24. Test of ideomotor and ideational apraxia (Geschwind & Damasio, 1985; Poeck, 1986). Maximum score was 8 points.

25. Finger-tapping test (Reitan & Davison, 1974) with the preferred hand.

26. Finger-tapping test with the nonpreferred hand.

27. Calculation Ability Test (Rosselli & Ardila, 1989). Four simple arithmetical tasks. Maximum score = 4.

28. Rey-Osterrieth Complex Figure (copy; Lezak, 1983; Osterrieth, 1944). Taylor's (1959) quantitative system was used. Maximum score = 36.

29. Rey-Osterrieth Complex Figure (immediate recall).

The total testing time was about 90 min.

RESULTS

Analysis of Variance

1. *Behavioral scale.* There were statistically significant differences between age, $F(4, 345) = 6.042$, $p < .0001$, and educational groups, $F(2, 345) = 7.246$, $p < .001$. Extreme scores were observed in lower age ranges and university education ($M = 32.16$) and higher age ranges with primary education ($M = 26.59$).

2. *Orientation.* Differences occurred for age, $F(4, 345) = 8.181$, $p < .0001$, and educational level, $F(2, 345) = 46.082$, $p < .0001$. No interaction was significant.

3. *Digits Forwards.* There were no significant differences among age

groups, $F(4, 345) = 2.475$, ns; statistically significant differences were observed among schooling groups, $F(2, 345) = 45.872, p < .0001$.

4. *Digits Backwards.* Only the level of education was a statistically significant variable, $F(2, 345) = 27.737, p < .001$.

5. *Immediate Logical Memory.* Age, $F(4, 345) = 5.215, p < .0001$, and educational level, $F(2, 345) = 15.768, p < .0001$, were significant variables.

6. *Delayed Logical Memory.* Both age, $F(4, 345) = 7.900, p < .0001$, and educational level, $F(2, 345) = 15.612, p < .0001$, appeared as statistically significant variables. Table 1 presents the means for immediate and delayed memory of a text (number of ideas out of 21).

7. *Immediate Nonverbal Recall (Wechsler Memory Scale).* Age, $F(4, 345) = 4.632, p < .001$, schooling, $F(2, 345) = 18.450, p < .0001$, and sex, $F(1, 345) = 17.313, p < .0001$, were significant variables.

8. *Delayed Nonverbal Memory.* Statistically significant differences were found for age, $F(4, 345) = 4.898, p < .001$, and schooling, $F(2, 345) = 13.090, p < .0001$.

9. *Immediate Recall of 10 words.* Age, $F(4, 345) = 8.904, p < .0001$, and schooling, $F(2, 345) = 16.396, p < .0001$, were statistically significant. The Age × Sex interaction was also significant, $F(4, 344) = 3.477, p < .008$.

10. *Number of trials required to recall 10 words.* Only schooling was a statistically significant variable, $F(2, 345) = 13.760, p < .0001$. Table 2 presents the results obtained for different groups.

11. *Delayed recall of words.* Age, $F(3, 345) = 9.573, p < .0001$, schooling, $F(2, 345) = 10.214, p < .001$, and sex, $F(1, 345) = 8.622, p < .004$, showed significant effects.

12. *Verbal Fluency: semantic.* Age, $F(4, 345) = 12.005, p < .0001$, as

TABLE 1
Logical Memory: Immediate and Delayed

Schooling (Years)	*Time of Test*	*Age (Years)*				
		55 to 60	*61 to 65*	*66 to 70*	*71 to 75*	*> 75*
0 to 5	Immediate	12.43	11.29	11.05	10.75	9.32
	Delayed	11.11	10.67	10.21	8.79	7.55
6 to 12	Immediate	13.96	13.46	12.22	12.09	10.91
	Delayed	12.50	12.00	11.46	10.23	8.74
> 12	Immediate	14.94	14.87	13.63	12.82	12.52
	Delayed	13.71	12.90	11.85	11.20	10.67

Note. Mean number of ideas out of 21.

TABLE 2
Mean Number of Trials Required to Recall 10 Words

Schooling (Years)	Age (Years)				
	55 to 60	*61 to 65*	*66 to 70*	*71 to 75*	*> 75*
0 to 5	8.39	9.05	9.75	9.90	10.14
6 to 12	7.62	7.75	7.89	8.45	9.00
> 12	7.24	7.65	7.72	7.86	7.97

well as educational level, $F(2, 345) = 12.869$, $p < .0001$, were statistically significant. Word generation varied between 18.91 and 32.20 for extreme groups on average.

13. *Verbal Fluency: phonological.* Age, $F(4, 345) = 9.204$, $p < .0001$, and educational level, $F(2, 345) = 23.713$, $p < .0001$, were significant. Table 3 shows the results for verbal fluency tests in the different age and educational groups.

14. *'A' Auditory Vigilance Test.* Statistically significant differences were found only for educational level, $F(2, 345) = 8.963$, $p < .0001$.

15. *Cancellation task.* Differences appeared for age, $F(4, 345) = 5.212$, $p < .0001$, and schooling, $F(2, 345) = 11.562$, $p < .0001$.

16. *Porteus Mazes.* Age, $F(4, 345) = 13.350$, $p < .0001$, schooling, $F(2, 345) = 27.898$, $p < .0001$, and sex, $F(1, 345) = 12.328$, $p < .001$, were statistically significant. No interaction was found significant.

17. *Similarities.* Age, $F(4, 345) = 9.486$, $p < .0001$, and educational level, $F(2, 345) = 20.754$, $p < .0001$, were statistically significant.

18. *Digit Symbol.* Age, $F(4, 345) = 21.028$, $p < .0001$, and schooling, $F(2, 345) = 76.796$, $p < .0001$, effects were found. Age and education interacted, $F(8, 344) = 2.688$, $p < .007$. Scores varied between 9.75 on

TABLE 3
Verbal Fluency: Semantic and Phonological

Schooling (Years)	Test Type	Age (Years)				
		55 to 60	*61 to 65*	*66 to 70*	*71 to 75*	*> 75*
0 to 5	Semantic	25.65	24.43	22.42	22.55	18.91
	Phonological	18.83	16.81	14.58	14.55	14.05
6 to 12	Semantic	32.00	31.87	26.78	25.41	21.91
	Phonological	24.59	24.21	19.85	18.68	14.43
> 12	Semantic	32.20	32.30	31.63	27.55	23.44
	Phonological	26.72	25.85	25.09	24.86	18.17

average for the older group with lower education, and 41.24 for the younger group with higher education.

19. *Block Design.* This test was highly sensitive to age, $F(4, 345) = 7.976$, $p < .0001$, and educational level, $F(1, 345) = 42.304$, $p < .0001$. Table 4 shows the scores in different age and educational groups.

20. *Naming test.* The three studied variables turned out to be significant: age, $F(4, 345) = 9.573$, $p < .0001$; schooling, $F(2, 345) = 28.814$, $p < .0001$; and sex, $F(1, 345) = 12.846$, $p < .0001$. No interaction was significant.

21. *Written description of a picture.* Age, $F(4, 345) = 5.065$, $p < .001$, and schooling, $F(2, 345) = 15.237$, $p < .0001$, were statistically significant.

22. *Abstraction.* Age, $F(4, 345) = 6.871$, $p < .0001$, and educational level, $F(2, 345) = 37.190$, $p < .0001$, were statistically significant.

23. *Recognition of unfamiliar faces.* The only significant effect was for schooling, $F(2, 345) = 6.774$, $p < .001$. None of the interactions was statistically significant.

24. *Ideomotor and ideational praxis.* None of the differences or interactions was statistically significant.

25. *Finger tapping (preferred hand).* Differences were significant for all three variables: age, $F(4, 345) = 19.477$, $p < .0001$; schooling, $F(2, 345) = 10.902$, $p < .0001$; and sex, $F(1, 345) = 28.920$, $p < .0001$.

26. *Finger tapping (nonpreferred hand).* Differences were significant for all three variables: age, $F(4, 345) = 17.366$, $p < .0001$; schooling, $F(2, 345) = 11.521$, $p < .0001$; and sex, $F(1, 345) = 26.920$, $p < .0001$. Table 5 shows the results in the tapping test for different groups.

27. *Calculation.* Age, $F(4, 345) = 7.923$, $p < .0001$, schooling, $F(2, 345) = 41.306$, $p < .0001$, and sex, $F(1, 345) = 23.263$, $p < .0001$, were significant effects.

28. *Rey-Osterrieth Complex Figure (copy).* Age, $F(4, 345) = 21.898$, $p < .0001$, schooling, $F(2, 345) = 29.377$, $p < .0001$, and sex, $F(1, 345) = 6.529$, $p < .01$, were statistically significant. No interaction was significant.

29. *Rey-Osterrieth Complex Figure (immediate recall).* All main variables were statistically significant: age, $F(4, 345) = 18.403$, $p < .0001$;

TABLE 4
Mean Scores on Block Design Test

Schooling (Years)	*Age (Years)*				
	55 to 60	*61 to 65*	*66 to 70*	*71 to 75*	*> 75*
0 to 5	5.42	4.82	4.74	4.26	2.90
6 to 12	8.79	8.74	6.96	6.64	4.78
> 12	9.24	8.92	8.65	8.15	6.71

Note. Maximum score = 12.

TABLE 5
Finger-Tapping Test

Schooling (Years)	*Hand*	*Age (Years)* 55 to 60	61 to 65	66 to 70	71 to 75	> 75
0 to 5	Preferred	40.89	39.71	32.68	32.37	26.15
	Nonpreferred	37.21	36.24	31.63	29.68	26.60
6 to 12	Preferred	44.42	43.25	39.83	36.20	30.00
	Nonpreferred	39.21	39.92	37.04	35.23	27.65
> 12	Preferred	48.08	41.67	40.04	39.40	33.52
	Nonpreferred	46.29	39.57	37.54	35.95	31.29

schooling, $F(2, 345) = 20.913$, $p < .0001$; and sex, $F(1, 345) = 22.41$, $p < .0001$. No interaction was significant.

Factor Analysis

A factor analysis of the battery was performed. It was observed that 43 factors explained 100% of the variance. However, one single factor explained 35.9% of the variance. Factor 2 explained only 6% of the variance. Factor 5 and those following each explained less than 3% of the total variance. This means that there is one main factor and a whole array of secondary factors. Table 6 presents the first four factors, their eigenvalues, percentages of variance, cumulative variances, the tests that best measure these factors, and their corresponding correlations.

Factor 1 includes essentially the following items: Rey–Osterrieth Complex Figure (copy), Block Design, Digit Symbol, and Porteus Mazes. These are basically nonverbal visuospatial and visuomotor tasks. Factor 2 is basically measured by number of trials required to memorize 10 words and the number of words recalled in the first (immediate) and second trial. It seems to be a Verbal Learning factor and explains 6% of the total variance. Factor 3 (4.6% of the variance) is measured by Verbal Fluency (semantic) and finger tapping. This is a Generation factor, related to speed in generating words and movements. Factor 4 (3.9% of the variance) includes immediate and Delayed Logical Memory (memory of a text); therefore, it is a Verbal Semantic Memory factor. The rest of the factors are less important, each explaining less than 3% of the variance.

DISCUSSION

There are several points in the results obtained that should be emphasized. Socioeducational level appears to be an even more important variable

TABLE 6
Factor Analysis of Test Battery: First Four Factors

Factor	*Eigenvalue*	*Percentage of Variance*	*Cumulative Variance Percentage*	*Test*	*Correlation*
1	15.47606	35.9	35.9	Rey-Osterrieth (copy)	.81
				Block Design	.76
				Digit Symbol	.73
				Mazes	.71
2	2.58252	6.0	41.9	Delayed recall (2nd trial) of words	.57
				Number of trials to memorize words	.56
				Immediate recall of words	.45
3	1.95732	4.6	46.5	Fluency (semantic)	.39
				Finger tapping	.34
4	1.69290	3.9	50.4	Delayed recall of text	.38
				Immediate recall of text	.36

than age in neuropsychological testing. Statistically significant differences for age groups were found in 23 of the tests used; statistically significant differences among schooling groups were found in 28 of our tests. For Recognition of Unfamiliar Faces, Digit Span (forwards and backwards), number of trials to recall 10 words, and 'A' Auditory Vigilance Test, differences were found among educational groups, but not among age groups. Only ideomotor and ideational praxis was not sensitive either to age or educational level. Immediate nonverbal recall, delayed recall of 10 words, Porteus Mazes, Digit Symbol, naming test, tapping test (preferred and nonpreferred hand), Calculation, and Rey-Osterrieth Complex Figure (copy and immediate recall) were sensitive to sex of participants, with better performance by males or all these tests, excepting delayed recall of 10 words. Consequently, when enough different educational groups are distinguished, level of education becomes even more important as a variable than age in performing neuropsychological tests.

Some tests appeared particularly sensitive to the effects of aging (such as Block Design and Rey-Osterrieth Complex Figure). For others, aging effects were minimally observed or not disclosed at all (e.g., digit span and ideomotor praxis). Digit span has been repeatedly reported as a task low in sensitivity to aging (Talland, 1965). Consequently, these particular nonsensitive tests (e.g., digit span and praxis) are especially useful when diagnosing pathological aging (dementia), taking into account that they are minimally sensitive to the effects of normal aging.

Verbal abilities had been considered only partially sensitive to age, and its decline is observed usually after age 70 (Albert, 1988). Confrontation naming declines mildly with age (LaBarge, Edwards, & Knesevich, 1986). Our results show a slow but significant decline in naming ability, particularly in the older groups. Verbal fluency had been observed to diminish with age (Obler & Albert, 1981). In our research, semantic as well as phonological fluency significantly decreased with age, particularly in the oldest group. However, although both semantic and phonological verbal-fluency tasks were sensitive to age and schooling variables, it seems that semantic search is more sensitive to age effects and phonological fluency to educational effects. Verbal Logical Memory has been observed to decline even at the age of 50 (Albert, Duffy, & Naeser, 1987). In our results, this early decline was observed only in the lowest educational groups; for the other two educational groups, evident differences are found only after 65. Albert and Heaton (1988), Craik et al. (1987), and Bornstein and Suga (1988) also observed that some cognitive changes in aging are dependent on the person's educational level.

The ability to perform visuospatial tasks shows a substantial decline with age (Albert, 1988). Waugh and Barr (1980) gave the Block Design and Assembly Design subtests to young and old participants and found that the low performance on these subtests by the older group was related to the slowing of response time; however, Doppelt and Wallace (1955) found significant differences between the scores of elderly participants on the timed and untimed version of the Block Design test; older participants benefited more than younger ones with additional time. Nevertheless, even after eliminating the time restriction, differences between young and old groups remained. This means that the older group's low performance on these subtests is only partially related to time dependency. Performance on figure-drawing tasks has been shown to be affected by age. Plude, Milberg, and Cerella (1986) showed that a cube drawing significantly differed between young and old participants when instructed to draw from memory but not when instructed to copy using some landmarks.

Factor analysis disclosed that a single factor is saturating virtually all the tests used. This General factor (a kind of "Factor G" for aging) would be best measured with tests such as Rey-Osterrieth Complex Figure, Block Design, Digit Symbol, and Porteus Mazes—that is, with constructional and visuomotor tasks. It has to be noted, however, that Block Design and Digit Symbol are two tests that are time dependent. Much less important factors are related to Verbal Learning (memorizing a 10-word list), Fluency (verbal and motor), and Verbal Semantic Memory (immediate and delayed logical memory). However, those tests are also highly saturated by the first General factor. Fluency (Factor 3) is also a time-dependent factor (finding names according to a particular category in 1 min; tapping during 10 sec). It has been repeatedly indicated in the literature that there is a positive correlation between age and increased reaction time (Underwood, 1949). Stern, Oster, and Newport (1980) reported that the increase in reaction time was particularly evident in older groups when additional active processing of the information is required, showing that there is also a slowing in the decision-making process associated with age. This increase in latency time may account in part for the low scores of our older groups in the time-related subtests.

In conclusion, different neuropsychological tests are differentially sensitive to aging. Educational level is frequency as important a factor as age. There is a fundamental factor underlying aging, measured by visuospatial and visuomotor ability tests; it is highly dependent on speed to respond. Memory difficulties were found to relate particularly to serial verbal learning and semantic verbal learning.

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