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Age-Related Cognitive Decline During Normal Aging: The Complex Effect of Education

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The purpose of this study was to further analyze the effects of education on cognitive decline during normal aging. An 806-subject sample was taken from five different Mexican regions. Participants ranged in age from 16 to 85 years. Subjects were grouped into four educational levels: illiterate, 1–4, 5–9, and 10 or more years of education, and four age ranges: 16–30, 31–50, 51–65, and 66–85 years. A brief neuropsychological test battery (NEUROPSI), standardized and normalized in Spanish, was administered. The NEUROPSI test battery includes assessment of orientation, attention, memory, language, visuoperceptual abilities, motor skills, and executive functions. In general, test scores were strongly associated with level of educational, and differences among age groups were smaller than differences among education groups. However, there was an interaction between age and education such as that among illiterate individuals scores of participants 31–50 years old were higher than scores of participants 16–30 years old for over 50% of the tests. Different patterns of interaction among educational groups were distinguished. It was concluded that: (a) The course of life-span changes in cognition are affected by education. Among individuals with a low level of education, best neuropsychological test performance is observed at an older age than among higher-educated subjects; and (b) there is not a single relationship between age-related cognitive decline and education, but different patterns may be found, depending upon the specific cognitive domain. © 2000 National Academy of Neuropsychology. Published by Elsevier Science Ltd

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Mortiner (1988) proposed that education provides protection against dementia. He argued that "psychosocial risk factors" (i.e., no or low education) reduce the margin of "intellectual reserve" to a level where a minor level of brain pathology results in a dementia. He further argued that this effect of low education will be most strongly associated with late onset dementia of the Alzheimer type (DAT).

During the last decade, several studies have, in general, albeit not always, supported this hypothesis. A positive association between DAT and low education has been observed in research studied carried out in quite different countries: Brazil (Caramelli et al., 1997), China (Hill et al., 1993; Liu et al., 1994; Yu et al., 1989), Finland (Sulkava et al., 1985), France (Dartigues et al., 1991), Italy (Bonaiuto, Rocca, & Lippi, 1990; Rocca et al., 1990), Israel (Korczyn, Kahana, & Galper, 1991), Sweden (Fratiglioni et al., 1991), and the United States (Stern et al., 1994). Negative results, however, have been also reported (Christensen & Henderson, 1991; Knoefel et al., 1991; O'Connor, Pollitt, & Treasure, 1991).

Capitani, Barbarotto, and Laicana (1996) approached the question from a somewhat different perspective. They proposed that three different patterns of association could be expected between age-related decline and education: (a) Parallelism: The age-related decline runs the same course in different educational groups, that is, no interaction is observed; (b) Protection: The age-related decline is attenuated in well-educated participants; and (c) Confluence: The initial advantage of well-educated groups in middle age is reduced in later life. Capitani et al. administered a test battery consisting of five tests to 307 Italian participants aged 40 to 85 years. Mean level of education for the low and high educated groups was about 6 and 13 years, respectively. They reported that for some tests (verbal fluency, spatial memory, and Raven's Progressive Matrices) parallelism was found; whereas for other tests (visual attention and verbal memory) protection was shown. Confluence was not observed for any of their five tests. They concluded that the protective effect of education is not always observed but depends upon the specific cognitive ability that is measured.

Several proposals have been presented to explain this protective effect of education frequently found for at least some tests of neuropsychological functioning. Mortiner and Graves (1993) proposed three different mechanisms: (a) exposure to risk factors is related to low education level and to socioeconomic status in adult life; (b) brain reserve capacity is determined by fetal or early-life exposure to factors associated with socioeconomic status of the family or origin; and (c) lifelong mental stimulation associated with education affects neuronal growth. The author concluded that there is an intercorrelation among these mechanisms, and low education or another correlate of socioeconomic status may be the most significant risk factor of DAT described to date. Katzman (1993) proposed that, "education (secondary school as compared to no education) increases brain reserve by increasing synaptic density in neocortical association cortex, leading to a delay of symptoms by 4 to 5 years in those with AD (and probably, other dementing disorders) hence halving the prevalence of dementia." (p. 17). Katzman (1993) supports his hypothesis pointing out that increased synaptic density is expected in high-educated people. This increase synaptic density represents sort of brain reserve, capable to delay the onset of dementia by some 4 to 5 years.

Even though the diagnosis of dementia requires not only a psychometric but also a functional criterion (American Psychiatric Association, 1994), most often psychometric procedures are used. This approach may result in a penalization for low-educated individuals. Psychometric tests tap abilities that are strongly school-dependent (Ardila, 1995). It should be emphasized that in general cognitive changes observed in the dementia of the Alzheimer's disease (AD) and normal aging are alike, but in AD they are pathologically accelerated (Cummings & Benson, 1992).

Illiterates and individuals with low levels of education have long been recognized to show low levels of performance on psychological tests. Educational attainment correlates to a high degree with scores on standard tests of intelligence. This correlation ranges from about 0.57 to 0.75 (Matarazzo, 1972; Matarazzo & Herman, 1984) (close to 50% of the variance). In consequence, it could be considered that test performance correlations with IQ are in fact correlations with educational level. Correlations with verbal intelligence subtests are usually higher (from about 0.66 to 0.75) than correlations with performance intelligence subtests (from about 0.57 to 0.61). It could be argued that psychometric measures of intelligence are strongly biased by our current schooling system. In consequence, not only psychometric, but also functional criteria of intelligence should always be taken into consideration (Pirozzolo, 1985).

Several studies have demonstrated a similarly strong association between educational level and performance on various neuropsychological measures (e.g., Ardila, Rosselli, & Ostrosky, 1992; Bornstein & Suga, 1988; Finlayson, Johnson, & Reitan, 1977; Heaton, Grant, & Mathews, 1986; Leckliter & Matarazzo, 1989; Ostrosky-Solis et al., 1985; Ostrosky, Quintanas, Canseco, & Meneses, 1986). However, some tests are notoriously more sensitive to educational variables (e.g., language tests) than others (e.g., the Wisconsin Card Sorting Test; Rosselli & Ardila, 1993). Extremely low scores in current neuropsychological tests are observed in illiterate people (Ardila, Rosselli, & Rosas, 1989; Rosselli, Ardila, & Rosas, 1990). Low scores in neuropsychological tests observed in illiterates can be partially due, not only to differences in learning opportunities of those abilities that the examiner considers relevant (although, evidently, they are not the really relevant abilities for illiterates' survival), and to the fact that, illiterates are not used to being tested (i.e., they have not learned how to behave in a testing situation), but also, that testing itself represents a nonsense (nonrelevant) situation (Ardila, 1995).

This educational effect, nonetheless, is *not* a linear effect, but rather it is a negatively accelerated curve, tending to a plateau. Differences between 0 and 3 years of education are highly significant; differences between 3 and 6 years of education are lower; between 6 and 9 are even lower; and so forth. And virtually no differences are expected to be found between, for example, 12 and 15 years of education. The reason is simple: the ceiling in neuropsychological tests is usually low (Ardila, 1998).

Cornelious and Caspi (1987) found that educational level has a substantial relationship with performance on verbal meaning tests but was not systematically related to everyday problem solving (i.e., functional criterion of intelligence). Craik, Byrd, and Swanson (1987) observed that differences in memory loss during aging are related to socioeconomic status. Ardila and Rosselli (1989) reported that during normal aging the educational variable was even more influential on neuropsychological performance than the age variable. And, Albert and Heaton (1988) argue that, when education is controlled, there is not longer evidence of an age-related decline in verbal intelligence.

Frequently, studies analyzing the relationship between AD and education have included the Mini-Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975) (e.g., Yu et al., 1989). It has been pointed out, however, that the MMSE is educationally biased, particularly, when administered to illiterate people (Crum et al., 1993; Mungas et al., 1996; Murden et al., 1991). Cutoff points for normal illiterates have been set up as low as 13 points (Bertolucci et al., 1994). In this research study, the use of a more extensive neuropsychological test battery developed, standardized, and normalized in Mexico was preferred. The neuropsychological test battery known as NEUROPSI (Ostrosky-Solis, Ardila, & Rosselli, 1997; Ostrosky, Ardila, & Rosselli, 1999) was selected. NEUROPSI is a short neuropsychological test battery developed for Spanish speakers. However, it could be considered as an extended MMSE.

The purpose of this study was to validate and extend Capitani et al.'s (1996) observation that educational effect on age-dependent cognitive decline may be different depending upon the specific cognitive domain. It was hypothesized that not a single, but different patterns of association could be expected between age-related decline and education.

METHOD

Participants

All the participants were Mexican native Spanish speakers. The initial sample consisted of 883 nonpaid volunteers who were recruited from different community centers from five different states of the Mexican Republic (Mexico City, Colima, Toluca, Morelos, and Oaxaca) over a 4-year period (1993–1996). Sources of subjects included in the present analysis were as follows: regional medical facilities (medical and paramedical personal and spouses and/or relatives of the patients who attended for medical check-ups); nursing homes serving local residents; state agency list of home care recipients; senior center and housing; volunteers and self-referred; and high school and university students. Age ranged from 16 to 85 years. Education ranged from 0 to 24 years. Fifty-two percent of the sample were women. Ninety-five percent of the sample was right-handed.

The following inclusion criteria were used: (a) absence of dementia according to the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 1994); and (b) all participants were carefully screened for any history of neurological or psychiatric problems using a structured interview. Only sub-

TABLE 1
Distribution of the Sample (*N* = 806)

	Group 1	Group 2	Group 3	Group 4
Education	16–30 Years	31–50 Years	51–65 Years	66–85 Years
Illiterates				
n	30	28	34	24
Age				
M	21.32	39.67	58.88	71.2
SD	3.34	6.67	4.09	4.08
1–4 Years				
n	37	24	30	40
Age				
M	21.71	39.79	58.97	73.52
SD	3.80	5.48	3.97	6.21
Education				
M	2.94	2.70	2.27	2.47
SD	0.97	1.08	0.96	1.13
5–9 Years				
n	15	21	64	94
Age				
M	22.44	43.57	59.21	73.61
SD	4.95	4.24	3.72	5.43
Education				
M	8.60	7.66	7.55	7.32
SD	0.91	1.47	2.52	1.37
Over 10 years				
n	95	98	80	92
Age				
M	23.96	38.57	58.27	72.96
SD	3.81	6.04	3.85	4.81
Education				
M	14.52	15.75	16.21	13.53
SD	2.63	3.32	4.33	2.85

jects with no neurological or psychiatric history such as brain injury, cerebrovascular disease, epilepsy, Parkinson's disease, depression, substance abuse, psychiatric hospitalizations, and the like were included in the sample. All the subjects were active and functionally independent. Subjects with questionable health histories were excluded yielding a final sample of 806 subjects.

Participants were categorized into four age groups: (a) 16–30 years, (b) 31–50 years, (c) 51–65 years, and (d) 66–85 years. And four educational levels: (a) illiterates, (b) 1–4 years of education; (c) 5–9 years of education, and (d) over 10 years of education. Table 1 presents the general characteristics of the sample.

Instrument

The NEUROPSI, a short neuropsychological test battery for Spanish speakers (Ostrosky et al., 1997, 1999) was used in this research.

The NEUROPSI consists of simple and short items. Some test items were adapted from current neuropsychological instruments. Based on several pilot studies, tests such as the Rey-Osterrieth Complex Figure Test (Osterrieth, 1944) or the Token Test (De Renzi & Vignolo, 1962) were adapted and simplified to be able to evaluate the elderly and low-education populations. Both the language stimuli and the drawings included were previously standardized according to high, medium and low frequency of occurrence in the Spanish language (Aveleyra, Gomez, & Ostrosky-Solís, 1996). Drawings were adapted from the Snodgrass and Vanderwart (1980) drawing test. Parameters used to evaluate drawings included: name agreement, familiarity, and visual complexity. Eight stimuli with high, medium, and low frequency values according to the norms were selected. By design, NEUROPSI represents a rather basic and simple neuropsychological test battery. In order to assure standardized procedures a detailed "Instruction Manual" for both administration and scoring was developed.

The following sections are included in the NEUROPSI neuropsychological test battery:

1. Orientation. Time (day, month, and year), Space (city and specific place), and Person (How old are you? or, When were you born?). Maximum score = 6 points.
2. Attention and concentration (Maximum score = 27).
2.1. Digits backwards, up to six digits. Maximum score = 6 points.
2.2. Visual detection. In a sheet that includes 16 different figures, each one repeated 16 times, the subjects are requested to cross-out those figures equal to the one presented as a model. The 16 matching figures are equally distributed at the right and at the left visual fields. The test is suspended after 1 minute. Two scores are obtained: number of correct responses (maximum score = 16), and number of errors.
2.3. 20 minus 3, five consecutive times (Maximum score = 5).
3. Coding (Maximum score = 18).
3.1. Verbal memory. Six common nouns corresponding to three different semantic categories (animals, fruits, and body parts), are presented three times. After each presentation, the subject repeats those words that he or she remembers. The score is the average number of words repeated in the three trials (maximum score = 6). In addition, intrusions, perseverations, recency and primacy effects are noted.
3.2. Copy of a semi-complex figure. A figure similar to the Rey-Osterrieth Complex Figure, but substantially simpler is presented to the subject. The subjects are instructed to copy the figure as well as they can. A special scoring system is used, with a maximum score of 12 points.
4. Language (Maximum score = 26).

4.1. Naming. Eight different line drawing figures are presented to be named. They correspond to animals, musical instruments, body parts, and objects. The names used are different from those names included in the Verbal Memory section. If the subject presents visual difficulties, an alternative procedure is used: the patient is required to name small objects placed in the hand, and body-parts. Maximum score = 8.

4.2. Repetition. The subject is asked to repeat one monosyllabic word, one three-syllabic word, one phrase with three words, and one seven word sentence. Successful repetition in each one is scored 1. Maximum score = 4.

4.3. Comprehension. On a sheet of paper, two circles (small and large) and two squares (small and large) are drawn. Six consecutive commands, similar to those used in the Token Test are given to the subject. The easiest one is "point to the small square," and the hardest one is "in addition to the circles, point to the small square." Maximum score = 6.

4.4. Verbal fluency.

4.4.1. Semantic verbal fluency (animals). Two scoring systems were used: (a) the total number of correct words; and (b) A 4-point scale was used. One point was given to 0–5 words; two points to 6–8 words; three points to 9–14 words; and four points to 15 or more words in a minute. Intrusions and perseverations are noted. For the current analysis, the first scoring system was used.

4.4.2. Phonological verbal fluency (words beginning with the letter F). Two scoring systems were used: (a) the total number of correct words; and (b) a 4-point scale was developed. One point was given to 0–3 words; two points to 4–6 words; three points to 7–9 words; and four points to 10 or more words in a minute. Intrusions and perseverations are noted. For the current analysis, the first scoring system was used.

5. Reading. The subjects are asked to read aloud a short paragraph (109 words). Next, three questions about the paragraph are orally presented. The correct answer to each question is scored 1. Maximum score = 3. Paralexias are noted.

6. Writing. The subjects are asked to write under dictation a six word sentence; and to write by copy a different six word sentence. Maximum score = 2. Paragraphias are noted.

7. Conceptual functions (maximum score = 10)

7.1. Similarities. Subjects are presented three pairs of words (e.g., orange-pear) and asked to find the similarity. An example is provided. Each one is scored as 0 (physical similarity: both are round), 1 (functional similarity: both can be eaten), or 2 (the answer corresponds to the supra-ordinate word: fruits). Maximum score = 6.

7.2. Calculation abilities. Three simple arithmetical problems are presented for subjects o solve. Maximum score = 3.

7.3. Sequences. The subject is asked to continue a sequence of figures drawn on a paper (What figure continues?). Maximum score = 1.

8. Motor functions (maximum score = 8).

8.1. Changing the position of the hand. Subject is asked to reproduce three positions with the hand (right and left). The model is presented by the examiner up to three times. A maximum score of 2 is used for the left and for the right hand. Maximum score = 4.

8.2. Alternating the movements of the hands. Subject is asked to alternate the position of the hands (right hand close, left hand open, and to switch). Maximum score = 2.

8.3. Opposite reactions. If the examiner shows the finger, the subject must show the fist; if the examiner shows the fist, the subject must show the finger. Maximum score = 2.

9. Recall (maximum score = 30).

9.1. Recall of verbal information.

TABLE 2
Means and Standard Deviations Found in the Different Neuropsychological Tests According to the Age in the Illiterate Subjects

	16–30 Years		31–50 Years		51–65 Years		66–85 Years	
Test	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Orientation								
Time	2.0	(0.9)	2.6	(0.6)	2.6	(0.5)	2.0	(0.9)
Space	2.0	(0.2)	1.9	(0.2)	1.9	(0.3)	1.9	(0.3)
Person	0.9	(0.2)	1.0	(0.0)	1.0	(0.0)	0.9	(0.2)
Attention								
Digits Backwards	2.2	(1.1)	2.8	(1.1)	2.9	(1.0)	2.7	(0.9)
Visual Detection	11.4	(3.5)	11.1	(3.6)	9.9	(4.3)	7.5	(5.6)
20 minus 3	2.2	(1.5)	3.8	(1.5)	3.1	(1.8)	2.9	(1.8)
Coding								
Verbal Memory	4.3	(0.6)	4.6	(0.7)	4.6	(0.8)	3.9	(0.9)
Copy of a Figure	8.1	(2.1)	7.9	(1.8)	7.6	(2.2)	7.2	(2.7)
Language								
Naming	7.3	(0.9)	7.4	(0.9)	7.2	(0.8)	7.4	(0.5)
Repetition	3.7	(0.4)	3.8	(0.3)	3.9	(0.2)	3.9	(0.2)
Comprehension	3.7	(1.1)	3.8	(1.2)	3.7	(1.3)	3.5	(1.4)
Verbal Fluency								
Semantic	13.2	(3.7)	13.7	(4.5)	12.7	(5.0)	13.1	(7.1)
Phonologic	3.5	(3.8)	3.4	(3.1)	3.6	(4.0)	3.3	(4.6)
Conceptual Functions								
Similarities	2.2	(2.3)	3.2	(2.3)	2.4	(2.3)	2.5	(2.2)
Calculation	0.9	(1.1)	1.4	(1.0)	1.6	(1.1)	0.9	(1.1)
Sequences	0.2	(0.4)	0.1	(0.3)	0.2	(0.4)	0.1	(0.2)
Motor Functions								
Left-Hand	1.1	(0.7)	1.4	(0.6)	1.4	(0.6)	1.4	(0.6)
Right-Hand	1.0	(0.7)	1.1	(0.6)	1.1	(0.6)	1.4	(0.6)
Alternating	1.7	(0.7)	0.8	(0.7)	0.8	(0.6)	1.1	(0.8)
Opposite Reaction	1.9	(0.2)	1.7	(0.6)	1.7	(0.5)	1.6	(0.5)
Recall								
Words	4.3	(1.6)	3.6	(2.2)	2.4	(2.4)	2.1	(2.3)
Cueing	4.7	(1.2)	4.5	(1.4)	4.6	(1.4)	3.7	(1.9)
Recognition	5.5	(1.1)	5.7	(0.7)	5.7	(1.1)	5.7	(0.6)
Semi-Complex Figure	7.5	(2.2)	6.6	(1.7)	6.9	(2.1)	6.4	(3.1)

9.2.1. Spontaneous recall. Maximum score = 6.
9.2.2. Cueing recall: Recall of words presented by categories (animals, fruits, and body-parts). Maximum score = 6.
9.2.3. Recognition. The examiner reads 14 different words, and the subject must tell which ones were previously presented. Maximum score = 6.
9.2. Recall of the semi-complex figure. Maximum score = 12.

In total, 26 different scores are obtained. Maximum total score is 130. In this study, NEUROPSI Reading and Writing sections were not included. In consequence, only 24 different test scores were analyzed.

Procedure

General demographic information was first collected, followed by psychiatric and neurologic screening. NEUROPSI neuropsychological battery was administered by trained psychologists under the supervision of a professor. Examiners were aware that this information would be used for normalization purposes, but were blind to the hy-

TABLE 3
Means and Standard Deviations Found in the Different Neuropsychological Tests According to the Age in the Subjects with 1–4 Years of Education

Test	16–30 Years *M*	*(SD)*	31–50 Years *M*	*(SD)*	51–65 Years *M*	*(SD)*	66–85 Years *M*	*(SD)*
Orientation								
Time	2.1	(1.1)	2.6	(0.5)	2.8	(0.4)	2.8	(0.4)
Space	1.9	(0.2)	2.0	(0.0)	1.9	(0.1)	2.0	(0.0)
Person	1.0	(0.0)	0.9	(0.2)	0.9	(0.3)	1.0	(0.0)
Attention								
Digits Backwards	2.6	(1.0)	2.7	(0.7)	2.9	(0.9)	2.8	(0.8)
Visual Detection	13.7	(2.5)	12.3	(2.7)	9.6	(3.4)	8.8	(3.7)
20 minus 3	3.5	(1.6)	3.5	(1.4)	4.3	(1.3)	4.4	(0.9)
Coding								
Verbal Memory	4.3	(0.8)	4.6	(0.7)	4.5	(0.7)	4.1	(0.7)
Copy of a Figure	9.5	(2.0)	9.2	(2.6)	9.4	(1.7)	9.1	(2.5)
Language								
Naming	7.3	(1.0)	7.7	(0.5)	7.5	(0.7)	7.7	(0.8)
Repetition	3.8	(0.3)	3.8	(0.4)	3.9	(0.4)	3.9	(0.3)
Comprehension	4.5	(0.9)	4.8	(0.9)	4.6	(1.0)	4.7	(0.9)
Verbal Fluency								
Semantic	15.2	(5.6)	14.0	(4.3)	15.4	(3.9)	14.6	(4.1)
Phonologic	6.5	(4.3)	6.9	(3.5)	7.4	(4.2)	7.3	(3.7)
Conceptual Functions								
Similarities	3.5	(1.8)	4.6	(1.7)	3.8	(1.7)	3.2	(1.9)
Calculation Abilities	1.1	(1.1)	1.5	(1.1)	1.6	(1.1)	2.0	(0.9)
Sequences	0.4	(0.5)	0.3	(0.5)	0.3	(0.5)	0.2	(0.4)
Motor Functions								
Left-Hand Position	1.3	(0.7)	1.4	(0.6)	1.2	(0.8)	1.2	(0.8)
Right-Hand Position	1.1	(0.7)	1.2	(0.6)	1.1	(0.8)	1.3	(0.7)
Alternating Movements	1.3	(0.7)	1.2	(0.7)	1.9	(0.6)	1.1	(0.8)
Opposite Reactions	1.9	(0.3)	1.8	(0.4)	1.7	(0.5)	1.3	(0.6)
Recall								
Words	3.8	(2.1)	1.3	(1.8)	2.6	(1.0)	2.3	(1.8)
Cueing	4.8	(1.3)	5.1	(1.3)	4.1	(1.5)	3.1	(1.6)
Recognition	5.6	(0.7)	5.7	(0.6)	5.3	(0.7)	5.1	(0.9)
Semi-Complex Figure	8.6	(2.2)	8.2	(2.7)	7.3	(2.2)	6.7	(2.9)

potheses regarding the association between cognitive decline and education. All testing was performed in a single 30-minute session. The test-retest reliability with a 3-month interval, administered and scored by the same examiner for the total NEUROPSI score was 0.89 (Ostrosky et al., 1999). Interrater agreement was substantial; correlation coefficients for the NEUROPSI scales ranged from 0.93 (Copy and recall of Complex figure) to 1.0 (total NEUROPSI score and all other scales). These high interrater reliability coefficients indicate that standardized instruction assures that scoring of the test is consistent across examiners. The NEUROPSI is currently also under testing in various clinical groups including dementia, depression, schizophrenia, lupus, closed head injury, and focalized left and right hemisphere lesions. Results are not yet available for presentation, but preliminary results appear encouraging.

RESULTS

General Results

Tables 2, 3, 4 and 5 present the means and standard deviations for each neuropsychological test by age and educational group. In general, scores increase with education and

TABLE 4
Means and Standard Deviations Found in the Different Neuropsychological Tests According to the Age in the Subjects with 5–9 Years of Education

	16–30 Years		31–50 Years		51–65 Years		66–85 Years	
Test	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Orientation								
Time	3.0	(0.0)	2.9	(0.3)	2.9	(0.2)	2.8	(0.5)
Space	2.0	(0.0)	2.0	(0.0)	2.0	(0.0)	1.9	(0.1)
Person	1.0	(0.0)	1.0	(0.0)	1.0	(0.0)	0.9	(0.1)
Attention								
Digits Backwards	3.4	(0.7)	3.4	(1.2)	3.6	(0.8)	3.4	(0.8)
Visual Detection	15.0	(1.2)	13.9	(2.2)	10.2	(3.8)	9.4	(3.1)
20 minus 3	4.3	(1.3)	4.6	(0.6)	4.4	(1.9)	4.6	(0.2)
Coding								
Verbal Memory	4.8	(0.7)	5.1	(0.6)	5.0	(0.7)	4.5	(0.8)
Copy of a Figure	11.6	(0.8)	11.1	(0.9)	10.9	(1.0)	10.8	(1.5)
Language								
Naming	7.7	(0.5)	7.9	(0.3)	7.9	(0.4)	7.7	(0.7)
Repetition	4.0	(0.0)	4.0	(0.0)	3.9	(0.1)	3.9	(0.1)
Comprehension	5.9	(0.3)	5.7	(0.4)	5.5	(0.7)	5.3	(0.9)
Verbal Fluency								
Semantic	19.9	(5.7)	19.6	(6.1)	17.5	(3.6)	16.6	(4.4)
Phonologic	13.4	(4.5)	10.4	(4.4)	10.6	(3.8)	9.4	(4.2)
Conceptual Functions								
Similarities	5.1	(1.2)	5.2	(1.0)	5.0	(1.1)	4.7	(1.4)
Calculation	2.3	(0.8)	2.4	(0.7)	2.5	(0.7)	2.3	(0.8)
Sequences	0.7	(0.4)	0.8	(0.4)	0.9	(0.3)	0.8	(0.4)
Motor Functions								
Left-Hand Position	1.5	(0.7)	1.6	(0.7)	1.6	(0.5)	1.6	(0.7)
Right-Hand Position	1.5	(0.7)	1.6	(0.7)	1.6	(0.6)	1.5	(0.6)
Alternating Movements	1.5	(0.8)	1.5	(0.7)	1.4	(0.6)	1.5	(0.6)
Opposite Reactions	1.8	(0.4)	1.4	(0.7)	1.6	(0.5)	1.6	(0.5)
Recall								
Words	4.8	(1.1)	4.5	(1.3)	4.4	(1.6)	3.6	(1.9)
Cueing	4.7	(1.7)	5.0	(1.0)	4.9	(1.4)	4.1	(1.6)
Recognition	5.7	(0.6)	5.5	(0.7)	5.8	(0.4)	5.3	(1.2)
Semi-Complex Figure	10.4	(1.9)	9.9	(1.9)	9.5	(1.8)	7.9	(2.6)

decrease with age. Scores in Group 1 and Group 2 are quite similar. By the same token, scores in Group 3 and Group 4 are rather similar. It is important to note that in subjects with low education, particularly illiterates, highest scores in many tests were observed in the second (31–50 years) and not in the first (16–30 years) age range. This pattern was found in 15 out of 24 test scores: Orientation (time and person), Attention (Digits backwards and 20 minus 3), Coding (Verbal memory), Language (Naming, Repetition, Comprehension, and Semantic Verbal fluency), Conceptual functions (Similarities and Calculation abilities), Motor functions (Changing left-hand and right hand position), and Recall (Words and Recognition). This pattern was also observed in the group with over 10 years of education in four test scores: Orientation (Space), Attention (Digits backwards and Visual Detection), and Phonologic Verbal fluency.

Analysis of Variance

Table 6 presents the analysis of variance for education and age variables. All the tests, excepting Recall-Recognition condition were sensitive to the educational level. The highest *F*-values were observed in Digits Backwards, Copy of a Figure, Language

TABLE 5
Means and Standard Deviations Found in the Different Neuropsychological Tests According to the Age in the Subjects with over 10 Years of Education

Test	16–30 Years *M*	*(SD)*	31–50 Years *M*	*(SD)*	51–65 Years *M*	*(SD)*	66–85 Years *M*	*(SD)*
Orientation								
Time	2.9	(0.2)	2.9	(0.2)	2.9	(0.1)	2.8	(0.4)
Space	1.9	(0.1)	2.0	(0.0)	2.0	(0.0)	1.9	(0.2)
Person	1.0	(0.0)	1.0	(0.0)	1.0	(0.0)	0.9	(0.1)
Attention								
Digits Backwards	4.3	(1.0)	4.4	(1.0)	4.0	(1.0)	3.9	(1.1)
Visual Detection	14.0	(2.5)	14.3	(2.6)	12.9	(2.7)	10.9	(2.9)
20 minus 3	4.7	(0.8)	4.7	(0.7)	4.9	(0.4)	4.8	(0.6)
Coding								
Verbal Memory	5.0	(1.0)	5.0	(0.7)	5.3	(0.7)	4.7	(0.9)
Copy of a Figure	11.8	(0.5)	11.7	(0.5)	11.3	(1.2)	10.9	(1.4)
Language								
Naming	7.9	(0.3)	7.9	(0.2)	7.9	(0.6)	7.8	(0.4)
Repetition	4.0	(0.0)	3.9	(0.1)	3.9	(0.1)	3.9	(0.2)
Comprehension	5.9	(0.2)	5.9	(0.3)	5.8	(0.4)	5.7	(1.1)
Verbal Fluency								
Semantic	21.6	(5.4)	22.3	(5.0)	20.1	(5.1)	18.4	(4.8)
Phonologic	13.4	(4.3)	14.4	(4.2)	13.4	(3.9)	11.9	(4.1)
Conceptual Functions								
Similarities	5.7	(0.7)	5.5	(1.0)	5.2	(0.9)	5.1	(1.2)
Calculation	2.6	(0.7)	2.6	(0.8)	2.7	(0.6)	2.5	(0.8)
Sequences	0.9	(0.2)	0.9	(0.3)	0.9	(0.2)	0.8	(0.4)
Motor Functions								
Left-Hand Position	1.7	(0.5)	1.6	(0.6)	1.7	(0.6)	1.6	(0.6)
Right-Hand Position	1.8	(0.5)	1.6	(0.6)	1.5	(0.6)	1.4	(0.6)
Alternating Movements	1.9	(0.3)	1.8	(0.4)	1.8	(0.5)	1.6	(0.6)
Opposite Reactions	1.9	(0.3)	1.8	(0.4)	1.7	(0.4)	1.6	(0.5)
Recall								
Words	5.3	(0.9)	4.9	(1.2)	4.6	(1.5)	3.7	(1.8)
Cueing	5.5	(0.9)	5.1	(1.2)	5.1	(1.3)	4.3	(1.5)
Recognition	5.6	(0.6)	5.5	(0.8)	5.7	(0.6)	5.3	(1.1)
Semi-Complex Figure	10.9	(1.2)	10.5	(1.6)	10.2	(1.9)	8.8	(2.6)

Comprehension, Phonological Verbal Fluency, Similarities, Calculation, and Sequences. In these tests, *F*-values were over 100. It should be noted that in order to control the statistical error of multiple analyses the Bonferroni correction was applied.

Differences among age groups were smaller than differences among education groups, but many of them reached a .01 statistical level of significance: Orientation in Time, Attention, (Visual Detection and 20 minus 3), Coding (Verbal Memory and Copy of a Figure), Semantic Verbal Fluency, Conceptual functions (Similarities, Calculation, and Sequences), Motor functions (Opposite Reaction), and Recall (Words, Cueing and Semi-Complex Figure). Education interacted with age in the following tests: Orientation (Time and Person), Attention (20 minus 3), Coding (Verbal memory), Language (Repetition), and Conceptual functions (Calculation).

Patterns of Decline

The patterns of decline were analyzed in the different educational groups. In order to maximize the effects of the educational variable on the age-related cognitive changes, only the two extreme groups (illiterates and 10 or over years of education) were com-

TABLE 6
Analysis of Variance

	Education			Age			Education × Age		
Test	*F*	*p*	Power	*F*	*p*	Power	*F*	*p*	Power
Orientation									
Time	50.20	.000	1.000	8.22	.000	0.992	6.84	.000	1.000
Space	4.61	.003	0.890	0.58	.629	0.171	0.68	.631	0.340
Person	2.25	.081	0.569	1.96	.119	0.506	3.39	.000	0.987
Attention									
Digits Backwards	110.30	.000	1.000	2.12	.096	0.542	1.95	.042	0.848
Visual Detection	24.44	.000	1.000	46.88	.000	1.000	4.94	.045	0.843
20 minus 3	61.04	.000	1.000	4.76	.003	0.900	2.72	.004	0.955
Coding									
Verbal Memory	27.00	.000	1.000	16.34	.000	1.000	0.68	.728	0.341
Copy of a Figure	199.53	.000	1.000	8.66	.000	0.955	0.53	.857	0.263
Language									
Naming	28.80	.000	1.000	1.82	.147	0.473	1.56	.122	0.741
Repetition	14.89	.000	1.000	0.81	.489	0.226	2.52	.008	0.938
Comprehension	215.67	.000	1.000	2.87	.036	0.687	1.01	.432	0.509
Fluency									
Semantic	91.78	.000	1.000	10.79	.000	0.999	1.65	.098	0.768
Phonological	200.94	.000	1.000	5.61	.001	0.945	1.87	.054	0.829
Conceptual Functions									
Similarities	125.34	.000	1.000	6.91	.000	0.979	1.60	.112	0.752
Calculation	93.69	.000	1.000	3.00	.030	0.708	2.60	.006	0.945
Sequences	169.82	.000	1.000	4.21	.006	0.858	0.49	.882	0.245
Motor Functions									
Left-Hand	22.60	.000	1.000	0.68	.566	0.194	1.89	.051	0.833
Right-Hand	15.70	.000	1.000	0.90	.442	0.242	1.11	.355	0.556
Alternating	70.86	.000	1.000	4.76	.003	0.901	1.38	.191	0.676
Opposite	8.53	.003	0.994	15.77	.000	1.000	1.81	.063	0.814
Recall									
Words	33.85	.000	1.000	37.12	.000	1.000	1.96	.041	0.851
Cueing	14.89	.000	1.000	30.69	.000	1.000	1.68	.090	0.777
Recognition	1.30	.274	0.347	7.75	.000	0.989	1.40	.183	0.683
Semi-Complex Figures	80.24	.000	1.000	33.99	.000	1.000	1.02	.419	0.526

pared (see Table 2 and Table 5). Different patterns of cognitive decline were observed. The following patterns were identified:

Parallelism. Test scores change in a parallel way in the different educational groups. Sometimes, scores remain relatively stable across age ranges. Sometimes, they decrease in a parallel way in the different educational groups. Table 7 illustrates an example of parallelism observed in the Copy of a Semi-Complex Figure task: Across-age percentages of changes are roughly the same in the two extreme educational groups.

Protection. The higher educational groups present a slower decline in test scores than the individuals with a lower educational level. Table 7 illustrates protection observed in the Recall of Words score. In the higher educational group, performance at the age of 66–85 years was 70% of performance observed at 16–30 years, whereas in the illiterate group it was only 49%.

Confluence upwards. Scores in the two groups approach across ages, due to an increase in the low-education group scores. The example of the Digit Backwards task is presented in Table 7. Scores increase in illiterates across ages; whereas in the high-education group scores mildly decrease.

TABLE 7
Examples of Different Patterns of Cognitive Decline Across Age Ranges

	Age			
	16–30 Years	31–50 Years	51–65 Years	66–85 Years
Parallelism: Copy of a Figure				
Over 10 years	11.8	11.7	11.3	10.9
	100%	99%	95%	92%
Illiterates	8.1	7.9	7.6	7.2
	100%	97%	94%	89%
Protection: Recall of Words				
Over 10 years	5.3	4.9	4.6	3.7
	100%	92%	87%	70%
Illiterates	4.3	3.6	2.4	2.1
	100%	84%	56%	49%
Confluence Upwards: Digits Backwards				
Over 10 years	4.3	4.4	4.0	3.9
	100%	102%	93%	90%
Illiterates	2.2	2.8	2.9	2.7
	100%	127%	132%	123%
Confluence Downwards: Semantic Verbal Fluency				
Over 10 years	21.6	22.3	20.1	18.4
	100%	103%	93%	85%
Illiterates	13.2	13.7	12.7	13.1
	100%	104%	96%	99%

Note. In each case, performance at the 16–30 years is taken as 100%.

Confluence downwards. The scores in the two groups approach across age-ranges as a result of a decrease in scores in the high-education group. Indeed, this effect implies kind of "protection effect of illiteracy": Scores are low in young people and they remain low across ages. In high educated people, scores are initially high but they decrease across age-ranges. In Table 7, this effect is illustrated with the Semantic Verbal Fluency Test.

As a matter of fact, these four patterns represent extreme situations observable in only some selected cases. For the many of the test scores, however, no particular neat enough pattern was apparent.

Finally, the percentage of the variance accounted for by the educational variable in the different test scores was calculated (Table 8). It was found that in some tests, education accounted for over one third of the test variance (Phonological Verbal Fluency and Language Comprehension). In 10 test scores, primarily the constructional and conceptual tests, education accounted for over 20% of the variance. For the Orientation in place and person scores, education accounted for less than 1% of the variance.

DISCUSSION

Capitani et al.'s (1996) proposal regarding the existence of different patterns of association between age-related decline and education was supported. It was observed that, depending upon the specific cognitive domain, different age-dependent patterns can be found. Four different patterns were identified in this study, but for several measures of cognitive functioning no specific pattern was discernable.We consider that the present research extends previous word on the relation of education to age-related decline in the following ways: (a) It cross-validates Capitani et al.'s results using a different population

TABLE 8
Percentage of the Variance Accounted by the Educational Variable in the Different Subtests

Test	Percentage of the Variance
Verbal Fluency: Phonologic	38.5
Language Comprehension	35.3
Copy of a Figure	32.9
Sequences	32.9
Digits Backwards	29.5
Similarities	27.3
Verbal Fluency: Semantic	23.6
Calculation	22.6
Recall of a Figure	21.1
Alternating Movements	20.6
20 minus 3	19.0
Visual Detection	17.1
Orientation: Time	12.0
Recall: Words	10.3
Coding: Verbal Memory	9.7
Recall: Cuing	8.5
Language: Naming	7.9
Opposite Reactions	7.2
Language: Repetition	7.0
Motor Functions: Right-Hand	6.9
Motor Functions: Left-Hand	5.7
Recall: Recognition	1.5
Orientation: Person	0.7
Orientation: Space	0.6

and a broader range of education; (b) it extends Capitani et al.'s results, describing a larger number of associations between education and age-dependent cognitive changes; and (c) it considers not only the association between education and cognitive decline, but also the association between education and cognitive development.

Current results point to a rather complex relationship between cognitive decline and educational level. Two main findings were obtained in this study: (a) In people with low education, particularly in illiterates, maximum scores more often were observed not in the youngest group (young adults: 16–30 years) but in the second age range (middle-aged adults: 31–50 years); and (b) Not a single, but several different types of relationships between education and cognitive decline during normal aging were found, depending on aspect of cognitive functioning.

The first result is not totally unexpected. This observation has been already mentioned in the literature (Ardila et al., 1989; Rosselli et al., 1990). It may be hypothesized that a lower level of cognitive stimulation results in a slower cognitive development. Strictly speaking, people attending school are highly stimulated in those tasks usually included in psychological and neuropsychological tests. It is not surprising to find that highest scores in cognitive tests are obtained at an earlier age.

It has to be noted that the cohort effect may have a confounding variable in this study. It is not just age effects that produce differences in performance, but cohort effects (unique experiences including cohort specific educational experiences, of a group of people born at the same time or interval of time) and time effects (historical events that impact on developmental abilities, and may include changes in educational policy or technique of education) play important roles as well. People born and living through the same period of history share many common experiences and differences between people born at different times may reflect different influences operating on different such cohort rather than age differences (Baltes & Schaie, 1974; Shaie, 1994; Shaie & Baltes, 1977). Longitudinal studies do not support significant age cognitive decline usually reported in cross-sectional studies (Horn & Horn, 1997). Age-dependent cognitive changes using longitudinal studies generally are found to be inflated. Our cross-sectional results, in consequence, must be taken with caution. Nonetheless, cross-sectional and longitudinal results may be similar when the comparable measures are used in the two kinds of studies (Shaie, 1994). Our study must be taken as a cross-sectional research, with its inherent methodological limitations.

The education level was an important influence on neuropsychological test performance. The educational effect, however, was rather different depending upon the cognitive domain. For some tests, education accounted for over one third of the variance. In others, it has observed to be below 1%. In almost half of the test scores, education accounted for over 20% of the score variance. It may be proposed that the effect of education is not homogeneous in different cognitive domains. Even though in 23 out of 24 test scores statistically significant differences were observed, the level of these differences was quite different. Some of the differences were very robust, whereas some others were marginal.

The very low scores observed in neuropsychological tests in illiterates can be partially due to differences in learning opportunities of those abilities that the examiner considers most relevant, although, they are not the really relevant abilities for illiterates' survival. They can be also due to the fact that, illiterates are not used to being tested. Furthermore, testing itself represents a nonsense situation that illiterate people may find surprising and absurd. This lack of familiarity with testing situations represents a confounding variable when testing individuals with limited education.

The possibility of some intervening variables, that is, factors associated with illiteracy should be taken into consideration. Illiteracy is most frequently associated with poverty and low socioeconomic status (SES). An association between nervous system disorders and low SES has been pointed out (e.g., Alvarez, 1983). Some research studies have shown that low SES subjects receive quantitatively and qualitatively less stimulation at home in comparison with the high SES subjects. This differential stimulation contributes to the development of different behavioral styles (Cravioto & Arrieta, 1982). The results of these research studies indicate that development in an impoverished social environment may result in insufficient stimulation, which in turn may alter the development of the central nervous system. It has been well-established that some nervous system pathologies, for example, epilepsy, are significantly more frequent in developing countries and in low SES subjects than in industrialized countries and high SES individuals (e.g., Gómez, Arciniegas, & Torres, 1978; Gracia, Bayard, & Triana, 1988).

The pattern of decline in different abilities turned out to be particularly complex. In some cognitive domains a very rapid age-dependent cognitive decline was found. Nonetheless, age differences were not obtained on several measures: Orientation (space and person), Digits Backwards, Language Repetition, Phonological Verbal Fluency, Changing the Position of the Left and Right Hand, and Alternating Movements with the Hands. These are obviously the cognitive abilities most resistant to the effects of aging. For some of them, an interaction with the educational level was observed.

Different patterns of cognitive decline were observed when comparing subjects with low and high education: Parallelism, protection, confluence upwards, and confluence downwards. However, it is not easy to fit the different test scores in these four patterns. In only some cases, these patterns were evident enough. In most cases, a clear enough pattern was not observed.

It should be emphasized, however, that the baseline point (highest scores in neuropsychological tests) is quite different in low and high educational groups. In consequence, a minor cognitive decline in illiterates may be extremely deleterious from the psychometric point of view, whereas a similar raw decline in high educated subjects may be virtually unnoticed. This is an unavoidable artifact due to the fact that psychometric criteria of dementia measure school-dependent abilities. Cognitive abilities included in usual neuropsychological tests (e.g., to name objects, to draw a figure, to perform calculation tasks, etc.) are at least partially learned and strongly trained at school.

The diagnosis of dementia using psychometric procedures necessarily penalize low-educated individuals. The use of psychometric instruments may inflate the measures of the severity of the cognitive decline, and hence, estimates of the prevalence of DAT. The direct clinical observation of illiterates and low-educated populations does not seem to confirm the hypothesis that DAT is significantly higher in individuals with low education. Thus, as an example, in neurological settings in developing countries, dementia seldom represents a reason for consultation in low-educated people. Of course, this can result from the interpretation that aging is associated with cognitive decline, and cognitive decline is not a disease but a normal process. Nonetheless, everyday observation suggests that most low-educated and illiterate individuals continue to be functionally active during their 60s, 70s, and even their 80s and 90s. As an illustration, in rural areas in developing countries, where most people have a very limited level of education, it is extremely unusual to find that somebody, regardless of the age, cannot participate to some extent in working and productive activities. This observation, however, obviously has to be documented.

Katzman (1993) have pointed out that, "when the very mild cognitive changes of normal aging are superimposed on lifelong cognitive impairment in some subjects with no or low education, an erroneous diagnosis of dementia could occur." (p. 15). Even though we certainly agree with his basic idea (mild cognitive changes in low educated people may result in the erroneous diagnosis of dementia), we cannot share his departing point: low-educated people present a lifelong cognitive impairment. This assumption supposes that what is normal is to be educated; no or low educated is kind of abnormality ("impairment"). It should be kept in mind that most of the world population have low levels of education, and even nowadays, about one third of the world people are illiterate (UNICEF, 1995). One or two centuries ago, most of the world population was illiterate. Ten or 20 centuries ago perhaps some 99% of the world population was illiterate. Low education or illiteracy obviously is not an abnormality, at least from the statistical point of view. We are afraid that Katzman is taking as "normal" what indeed is "abnormal" (or at least, "unusual"); and as "abnormal" what really is the norm. Further, we do not think that people with low levels of education are understimulated; rather, we prefer to think that highly educated people are overstimulated from the point of view of some specific cognitive tasks. This may be just a matter of language use, but it may be crucial in perceiving and interpreting pathology. When dealing with individuals with low levels of education, functional scales, as Katzman (1993) points out, obviously become crucial (Loewenstein et al., 1992). However, functional scales have also to be adapted to the low-educated people conditions.

We are afraid that a significant misunderstanding may frequently exist with regard to the education effects. School attendance does not mean that educated people simply possess certain abilities that less educated individuals are lacking. It does not mean that highly educated people have the same abilities that less educated individuals have, plus something else. If comparing two children, one with 10 years of formal education, and the other one with zero schooling, it also means that the zero-education child was performing for 10 years certain activities (working or whatever) that the 10-year education child was not performing. The child with no formal education was obviously obtaining certain learnings that the child with 10 years of education was not. Nonetheless, formal cognitive testing evaluates those abilities that the educated child was trained in, and is not surprising that he or she will outperform the child with no formal education. It must be emphasize that educational level has a substantial relationship with performance on some cognitive tests but is not systematically related to everyday problem solving (functional criterion of intelligence) (Cornelious & Caspi, 1987). It is not totally accurate to assume that people with low levels of education are somehow “deprived.” It may be more accurate to assume that they have developed different types of learnings. It tests were based on the knowledge and skills of those with low levels of formal education, highly educated people might be in disadvantage.

There is another important observation with regard to the diagnosis of dementia in individuals with low levels of education. In the DAT procedural memory (how to do things) is usually much better preserved than declarative memory (to be aware of memories) (Cummings & Benson, 1992). Quite often, low education is associated with manual activities (e.g., farming, handcrafting, manual labor, etc.). Conversely, high education is strongly correlated with intellectual activities. Minor intellectual defects may be fatal for highly educated people. Nonetheless, people with low levels of education may continue working in a roughly normal way, despite minor or moderate cognitive defects. As an example, in some rural areas in Colombia it has been observed that individuals with very significant cognitive defects (“dementia”), can continue working as coffee collectors in a relatively normal way. The patient simply is taken to the coffee plantation (he cannot go by himself due to the spatial orientation defects), but once at the coffee plantation, he can perform the activity of collecting coffee in a roughly normal way. Obviously, this patient is significantly more impaired from the point of view of the neurologist/ neuropsychologist examiner than from the point of view of his own social group.

This observation raises an additional question: When assessing DAT in manual laborers, procedural memory testing should be included. Or, at least, behavioral scales should emphasize the ability to perform lifelong procedural working activities.

In brief, it can be concluded that, using a rather different population and a broader range of age and education, Capitani et al.’s (1996) results were supported in this study. While Capitani et al. used an Italian group, apparently urban people, we selected a Mexican sample including not only urban but also rural people. This cross-validation may suggest some generalizability of the results to other populations. As a matter of fact, our sample was quite large (over 800 participants), but differences were highly significant. It can be conjectured that using smaller samples, similar results can be found. A larger number of patterns of association between education and age-dependent cognitive changes were disclosed. Furthermore, it was observed that not only cognitive decline but also cognitive development was associated with education: in low-educated people, maximum test scores more often were observed not in the youngest group (young adults: 16–30 years), but in the second age range (middle-aged adults: 31–50 years). Evidently much more research in this area is required before considering that this question has been settled.

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