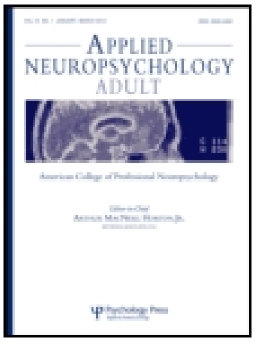

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ARTICLES

A Sociodemographic and Neuropsychological Characterization of an Illiterate Population

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The objectives of this article are to characterize the performance and to discuss the performance differences between literate and illiterate participants in a well-defined study population. We describe the participant-selection procedure used to investigate this population. Three groups with similar sociocultural backgrounds living in a relatively homogeneous fishing community in southern Portugal were characterized in terms of socioeconomic and sociocultural background variables and compared on a simple neuropsychological test battery; specifically, a literate group with more than 4 years of education (n = 9), a literate group with 4 years of education (n = 26), and an illiterate group (n = 31) were included in this study. We compare and discuss our results with other similar studies on the effects of literacy and illiteracy. The results indicate that naming and identification of real objects, verbal fluency using ecologically relevant semantic criteria, verbal memory, and orientation are not affected by literacy or level of formal education. In contrast, verbal working memory assessed with digit span, verbal abstraction, long-term semantic memory, and calculation (i.e., multiplication) are significantly affected by the level of literacy. We indicate that it is possible, with proper participant-selection procedures, to exclude general cognitive impairment and to control important sociocultural factors that potentially could introduce bias when studying the specific effects of literacy and level of formal education on cognitive brain function.

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Key words: literacy, illiteracy, educational level, formal schooling, alphabetic orthographic knowledge, neuropsychological assessment

In a recent review of the influence of formal schooling on intelligence and its cognitive components, Ceci (1990) suggested that the level of formal schooling correlates with performance on IQ tests, reflecting an influence of education on the cognitive processes supporting task performance on these tests. Ceci implied that this influence can be conceptualized in two ways: students acquire general knowledge and processing strategies important for task performance, and formal education provides students with attitudes, values, and motivation that are important in testing situations. It has also been suggested that literate people acquire skills to organize and process information in less idiosyncratic and more efficient ways compared with illiterate people (see e.g., Luria, 1976; Manly et al., 1999). Thus, educated literate people have, in addition to basic literacy (the skills of reading and writing, i.e. orthographic knowledge), acquired cognitive skills and strategies for efficient processing of information. Among other things, this entails that literacy and level of education can influence the outcome on specific psychological and neuropsychological tests. Consistent with this suggestion, several behavioral studies have demonstrated that literacy level influences the performance on tests commonly used in neuropsychological assessment (Ardila, Rosselli, & Rosas, 1989; Lecours et al., 1987; Manly et al., 1999; Ostrosky-Solís, Ardila, & Rosselli, 1999; Rosselli, Ardila, & Rosas, 1990), including visuospatial (Ardila et al., 1989; Matute, Leal, Zarabozo, Robles, & Cedillo, 2000; Ostrosky, Efron, & Yund, 1991; Reis, Guerreiro, & Castro-Caldas, 1994; Reis, Petersson, Castro-Caldas, & Ingvar, 2001), arithmetic (Deloche, Souza, Braga, & Dellatolas, 1999) and language tasks (Adrian, 1993; Castro-Caldas, Petersson, Reis, Stone-Elander, & Ingvar, 1998; Morais, Cary, Alegria, & Bertelson, 1979; Reis & Castro-Caldas, 1997). Taken together, this shows that literacy and formal education provide cognitive skills in addition to mastery of reading and writing.

The Naturally Occurring Illiteracy of Southern Portugal

For social reasons, illiteracy occurs naturally in Portugal. Forty to fifty years ago, it was common for older daughters of a family to be engaged at home in the daily household workings. Therefore, they did not enter school and later may have started to work outside the family. In larger families, the older daughters typically helped with the younger siblings; the younger children were generally sent to school when they reached the age of 6 or 7.

The fishing village Olhão of Algarve in southern Portugal, where most of our studies have been conducted, is socioculturally homogeneous, and the majority of the population has lived most of their lives in the community. Mobility within the region has been limited, and the main source of income is related to the sea and fishing or agriculture. Literate and illiterate people live intermixed and participate actively on similar terms in this community. Illiteracy is not perceived as a functional handicap, and the same sociocultural environment influences both literate and illiterate people on similar terms. Some of the literate and illiterate participants in our studies are from the same family, thereby increasing the homogeneity in background variables. In addition, most of the literate participants taking part in our studies are not highly educated.

The objective of this article is to characterize a population of southern Portugal in greater detail than previously reported. In this article, we present and discuss the performance of our study population on a neuropsychological test battery. We discuss the relevance of performance differences between literacy groups and indicate that the selection procedure used ensures, with reasonable confidence, that the illiterate participants are cognitively normal; that their lack of formal education results from specific sociocultural reasons and not low intelligence, learning disability, or brain pathology; and that these illiterate participants are comparable with the literate participants included in our studies of this population.

Methods

Participant Selection and the Demographic Characteristics of the Sample

All participants volunteered without receiving any form of compensation. In this on-going project, so far we have tested 85 healthy female participants recruited with the help of local authorities and doctors, already recruited participants, word-of-mouth (Sample 1), and several day-centers (Sample 2). As a prerequisite for further participation in our studies, participants are characterized with a structured sociocultural and medical-health interview as well as a short neuropsychological test battery (Garcia, 1984; Garcia & Guerreiro, 1983). The sociocultural interview assesses occupational history, parent's literacy level, and participants' acquired level of literacy or, in the case of illiteracy, the reasons for illiteracy. The medical-health interview assesses medical variables and health history to estimate and exclude the likelihood of neurological, psychiatric, or other diseases potentially involving the brain. The neuropsychological test battery for mental state assessment is used to exclude significant cognitive dysfunction. Based on these interviews and self-reports, it was estimated that the participants included in this and other studies of ours are active, independent, and fully functional in daily life. There were no significant age differences in either Sample 1 (illiterate: 66 ± 5; literate with 4 years of schooling: 62 ± 7; literate with more than 4 years of schooling: 64 ± 4; median test $\chi^2 = 2.01$, $p = .4$) or Sample 2 (illiterate: 73 ± 4; literate with 4 years of schooling: 73 ± 6; literate with more than 4 years of schooling: 78 ± 2; median test $\chi^2 = 2.9$, $p = .3$). However, Sample 2 was significantly older than Sample 1 in each literacy group. In the following sections and in the appendix we describe the exclusion criteria, subdivision of the samples into educational groups, the sociocultural and medical-health interviews, the socioprofessional status of the sample, and, finally, the neuropsychological test battery in detail.

Exclusion Criteria

In our illiteracy studies, including this one, participants were excluded from further investigations based on the following criteria: (a) significant histories of neurological, psychiatric, or other diseases affecting the brain; (b) functional employment or daily life problems; (c) problems acquiring reading and writing skills; or (d) results two standard deviarions below normative values (Garcia, 1984; Garcia & Guerreiro, 1983) on verbal fluency, verbal memory with interference, and orientation test (Table 1). In addition, illiterate participants were excluded if they were able to identify the letters in the screening test; literate participants were excluded if they were unable to read a newspaper text fluently, were unable to answer six simple comprehension questions correctly, or made spelling errors on a simple dictation task. Participants who had started school or an educational program but not finished or who had or were presently engaged in literacy training for adults were excluded.

Sociocultural Interview

Illiterate participants were asked (a) whether they had received any formal education or entered school at any time and the reasons for not continuing school, (b) about their profession and any job-related difficulties and whether there had been any difficulties in keeping any of their occupations or whether there had been any other performance-related problems, (c) about the level of education of their parents. In addition, participants were tested on a letter identification task (sequences of letters representing the Portuguese public TV station, the Portuguese mail service, the Portuguese telephone company, the word *hospital*, and a random letter sequence). Participants were asked whether they could write their name (writing their own name was not an exclusion criterion because most illiterate people have learned to write their names by copying to sign different sorts of documents they encounter in ordinary life, for example, social security forms, documents at the post office). In addition, the literate participants were asked about their educational level and assessed on a simple reading comprehension test (a short newspaper text followed by six comprehension questions) and asked to

Table 1. *Normative Data Used to Scored the Mental Status of the Volunteers According to the Age and Educational Group*

	Education and Age					
	Illiterate		≤4 years		>4 years	
	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years
Verbal fluency	10.3 ± 2.3	12.4 ± 3.93	16.2 ± 2.92	14.6 ± 3.42	17.3 ± 2.87	16.0 ± 2.66
Verbal memory with interference	10.9 ± 1.8	11.2 ± 1.8	11.4 ± 1.62	10.2 ± 2.86	11.8 ± 2.33	10.9 ± 1.38
Orientation (total)	13.3 ± 1	13.2 ± 1.54	14.9 ± .29	14.6 ± .67	14.8 ± .39	14.9 ± .29

write nine verbally presented simple words (five monosyllabic and four disyllabic: *sol, gema, irmão, sal, figo, sela/cela, mãe, ovo, mão*).

Medical-Health Interview

All participants were questioned concerning (a) any past or present history of neurological and nonneurological disease, including cerebrovascular disease, epilepsy, traumatic head injuries with loss of consciousness, neoplastic disease, and diabetes; (b) any past or present history of psychiatric disease and use of psychoactive medication.

Neuropsychological Test Battery for Mental State Assessment

The neuropsychological test battery included the following tasks (for further details see the Appendix):

1. Language tests: visual naming, visual identification, verbal and oral language comprehension, word and sentence repetition, word and sentence reading, and word writing
2. Praxis abilities
3. Verbal fluency
4. Verbal abstraction
5. Memory: digits span, verbal memory with interference, basic information
6. Orientation
7. Mental calculation
8. Cancellation task

Altogether, 66 participants from the original participant pool of 85 participants (48 from Sample 1; 18 from Sample 2) were included for further investigations (Table 2). The reasons for exclusion were as follows: indications of mental state impairment (nine illiterate participants and three literate participants with 4 years of schooling), a psychiatric history (two illiterate participants and one literate participant with 4 years of schooling), a neurological history (one illiterate participant and one literate participant with 4 years of schooling), a history of learning disability (one illiterate participant), and one drop out from the illiterate group. However, it should be noted that the results of the statistical analysis discussed later did not change when the excluded participants were included in the analysis.

The participants were divided into three literacy groups: completely illiterate (G1), literate with 4 years of schooling (G2), and literate with more than 4 years of schooling (G3). The inclusion of the literate group with 4 years of schooling (G2) allowed us to characterize the effects of acquiring alphabetic orthographic knowledge relatively independent or unaffected by other effects of formal schooling, whereas the literate group with more than 4 years of schooling (G3) allowed us to assess the effects of a more extensive educational background.

Socioprofessional Status of the Overall Sample and Reasons for Illiteracy

To characterize the socioprofessional background of the participants, we used a subscale of the European Brain Injury Scale (Brooks & Truelle, 1994). The distribution of socioprofessional status is shown in Table 3; there were no significant differences between groups (Wilcoxon matched paired test). This was also the case when Sample 1 was analyzed separately.

The main reasons for illiteracy (i.e., not entering a school program) in our illiterate sample were, as indicated in the introduction, household work (including taking care of younger siblings), inconvenient school location (i.e., long distance to the nearest school), cultural reasons (i.e., it was not viewed as necessary for a girl to acquire an education outside home), or economic factors.

Table 2. *The distribution of Educational Years and Source of Recruitment (Sample 1 and 2) of the Overall Sample of Female Volunteers*

	Sample 1[a]			Sample 2[b]			
Literacy Level	Age	*n*	Education	Age	*n*	Education	*N*
G1-illiterates	66.2 ± 4.9, [57–76]	23	0	73.1 ± 3.6, [70–79]	8	0	31
G2-literates	61.9 ± 7.0, [51–76]	18	4	73.0 ± 6.1, [65–83]	8	4	26
G3-literates	63.6 ± 4.2, [56–69]	7	10 ± 4.0, [6–12]	78.0 ± 1.4, [77–79]	2	7 ± 3.0, [5–9]	9

Note: Means, standard deviation, minimum and maximum for each literacy group are provided: G1 = illiterate subjects; G2 = literate subjects with 4 years of schooling; G3 = literate subjects with more than 4 years of schooling. $N = 66$.
[a]$n = 48$. [b]$n = 18$.

Table 3. *Professional Status of the Overall Sample (Number of Respondents in Sample 1/Sample 2)*

Professional Status	Illiterates[a]	4 Years[b]	>4 Years[c]
0. Professional, executive, manager	—	—	—
1. Intermediate, head clerk, businessman, large farmer	—	—	22% (2/0)
2. Skilled occupations, small farmer, office worker, foreman, shop keeper	—	16% (2/2)	22% (1/1)
3. Semi-skilled occupations, lower office workers	68% (19/3)	48% (11/2)	11% (1/0)
4. Unskilled occupations	13% (2/2)	4% (1/0)	—
5. Other (housewife)	19% (3/3)	32% (4/4)	44% (3/1)

Note: The sub-scale is composed of seven items. Only Six of the Seven items were used; the sixth item excluded assessed whether the subject was a student or still at school.
[a]$n = 31$. [b]$n = 26$. [c]$n = 9$.

Statistical Analysis

The data from Sample 1 and Sample 2 were analyzed in two ways: a separate analysis of Sample 1 only and then an overall analysis including both Sample 1 and 2. The data from Sample 1 ($n = 48$) used nonparametric statistics (cf. following) for each neuropsychological test according to the three literacy levels. In the second analysis, the data from Sample 1 and 2 were pooled ($n = 66$) and analyzed using an analysis of variance (ANOVA) model with two factors (literacy level and age). Overall, the two different analyses yielded similar results.

Results

First, we analyzed whether there were any participants who scored more than two standard deviations below the normative data [Table 1, (Garcia, 1984; Garcia & Guerreiro, 1983)] in two or more of the following tests: verbal fluency, verbal memory with interference, and orientation (Tables 4a and b). None of the participants scored more than one standard deviation below the norm on more than one task. Scoring below the norm on one task only is considered a random effect without significance, and these participants were thus included in the study (participants scoring below the norm: verbal memory with interference: one G1 participant and one G2 participant; verbal fluency: two G2 participants and two G3 participants; orientation: six G2 participants).

Sample 1

Table 5 shows the means and the standard deviations for each test and literacy group, as well as the minimum and maximum scores. There were literacy effects on several of the tasks, including word and sentence repetition ($p = .03$), verbal abstraction ($p = .01$), digit span ($p = .0003$), basic information ($p < .0001$), orientation ($p = .005$), and mental calculation ($p < .0001$). In contrast, there were no significant differences on visual naming, visual identification, oral comprehension, praxis, verbal fluency, verbal memory with interference, orientation in place, and the cancellation task. In addition, there were no significant differences between the two literate groups on reading comprehension and writing.

Samples 1 and 2 Pooled

After pooling Sample 1 and Sample 2, the overall sample included 31 G1-illiterate (age = 68 ± 6 years), 26 G2-literate (age = 65 ± 8; 4 years of education), and 9 G3-literate participants (age = 67 ± 7; 9 ± 2 years of education). Before pooling the samples, we tested whether there were any significant differences between the corresponding literacy groups separately because Sample 2, recruited from the day centers, was significantly older than Sample 1 in each literacy group (cf. Table 2; G1 Sample 1 vs. Sample 2, $p = .0002$; G2 Sample 1 vs. Sample 2, $p = .002$, and G3 Sample 1 vs. Sample 2, $p = .04$). The group comparisons showed significant differences only for the G1 and G2 groups: G1: oral comprehension ($p = .002$) and digit span ($p = .0008$); G2: temporal orientation ($p = .03$) and calculation ($p = .007$). It is likely that the age difference between the two samples explains (at least in part) these differences. Therefore, we analyzed the overall data set, including the age factor in the analysis. First, the pooled sample was split according to two age cohorts: 50–64 years and more than 65 years. We analyzed the data using an ANOVA model with two factors (literacy G1, G2, G3, and age cohort). We excluded visual naming, visual identification, reading comprehension, writing and praxis tasks, and the reading and writing tasks from

Table 4a. *The Scores of the Overall Sample (Sample 1 + 2), According to Age Group (Age Group 50–64 Years and Age Group 65–79 Years)*

	Education and Age					
	Illiterate		4 Years		>4 Years	
	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years
n	7	24	12	14	4	5
Verbal fluency	16.7 ± 1.9	15.1 ± 2.8	16.8 ± 2.6	13.4 ± 3.8	13.5 ± 2.5	15.6 ± 1.8
Verbal memory with interference	12.6 ± 0.8	10.7 ± 2.2	11.4 ± 1.7	10.8 ± 1.5	11.8 ± 1.0	11.6 ± 1.5
Orientation (total)	13.9 ± 0.7	13.8 ± 1.2	14.5 ± 0.7	14.3 ±0 .7	15.0 ± 0	15.0 ± 0

Table 4b. *The Scores of the Overall Sample 1, According to Age Group (Age Group 50–64 Years and Age Group 65–79 Years)*

	Education and Age					
	Illiterate		4 Years		>4 Years	
	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years	Aged 50–64 Years	Aged 65–79 Years
n	7	16	12	6	4	3
Verbal fluency	16.7 ± 1.9	15.0 ± 2.9	16.8 ± 2.6	12.8 ± 3.1	13.5 ± 2.5	15.3 ± 1.5
Verbal memory with interference	12.6 ± 0.8	10.9 ± 1.9	11.4 ± 1.7	11.0 ± 1.8	11.8 ± 1	12.3 ± 1.5
Orientation (total)	13.9 ± 0.7	13.7 ± 1.3	14.5 ± 0.7	14.5 ± 0 .8	15.0 ± 0	15.0 ± 0

Table 5. *Mental State Assessment of Sample 1*

Neuropsychological Test	Illiterates (G1)[a]	4 Years (G2)[b]	>4 Years (G3)[c]	*p*
Visual Naming	10.0 ± 0	10.0 ± 0	10.0 ± 0	ns
Visual Identification	10.0 ± 0	10.0 ± 0	10.0 ± 0	ns
Oral Comprehension	7.0 ± 0	7.0 ± 0	7.0 ± 0	ns
Word and Sentence Repetition	10.7 ± 0.5	10.9 ± 0.2	11.0 ± 0	.03
Reading	—	2.0 ± 0	2.0 ± 0	ns
Reading Comprehension	—	5.9 ± 0.2	6.0 ± 0	ns
Writing	—	2.0 ± 0	2.0 ± 0	ns
Praxis	4.0 ± 0	4.0 ± 0	4.0 ± 0	ns
Verbal Fluency	15.5 ± 2.7	15.5 ± 3.3	14.3 ± 2.2	ns
Verbal Abstraction	4.0 ± 1.3	4.7 ± 1.1	5.6 ± 0.5	.01
Digit Span	4.1 ± 0.9	5.2 ± 1.4	7.0 ± 1.8	.0003
Verbal Memory With Interference	11.4 ± 1.8	11.3 ± 1.7	12.0 ± 1.2	ns
Information	8.8 ± 0.9	9.8 ± 0.5	10.0 ± 0	<.0001
Orientation (total)	13.7 ± 1.1	14.5 ± 0.7	15.0 ± 0	.005
Personal	4.6 ± 0.5	5.0 ± 0	5.0 ± 0	.003
Spatial	2.9 ± 0.3	3.0 ± 0	3.0 ± 0	ns
Temporal	6.2 ± 0.9	6.6 ± 0.7	7.0 ± 0	.04
Calculation	3.0 ± 0.9	4.0 ± 0	4.0 ± 0	<.0001

this analysis because the performance did not show sufficient variability (almost all participants performed very well on these tasks).

The same literacy effects observed in the analysis of the Sample 1 data were replicated in the pooled sample (Table 6). The age factor affected the performance significantly on the digit span task and (a trend) on the verbal memory task. Both digit span and episodic memory are known to be sensitive to age (Salthouse, 1991), and digit span is known to be sensitive to educational level (Ardila et al., 1989; Castro-Caldas, Reis, & Guerreiro, 1997; Garcia &

Table 6. *F and p Values for Age (Two Groups) and Literacy (Three groups) Factors for Each Test Related to the Two Factor ANOVA Model*

	Age Factor		Literacy Factor		Age × Literacy	
Neuropsychological Tests	***F***	***p***	***F***	***p***	**F**	***p***
Oral Comprehension	0.83	.40	0.22	.81	0.22	.81
Word and Sentence Repetition	1.20	.28	3.40	.04	0.67	.51
Verbal Fluency	1.30	.26	0.86	.43	3.10	.05
Verbal Abstraction	0.93	.34	5.01	.01	4.30	.02
Digit Span	4.70	.04	10.20	.0002	0.70	.50
Verbal Memory With Interference	2.90	.09	0.63	.54	1.10	.34
Basic Information	0.92	.34	10.00	.0002	0.58	.57
Orientation (total)	0.09	.76	5.90	.005	0.09	.92
Personal	0.21	.65	7.80	.001	0.28	.76
Spatial	0.29	.60	0.38	.69	0.38	.69
Temporal	0.51	.49	3.60	.04	0.35	.71
Calculation	0.04	.85	11.70	.00005	1.30	.28

Guerreiro, 1983; Reis, Guerreiro, Garcia, & Castro-Caldas, 1995). Only two literacy × age interactions were significant. For verbal fluency, the interaction was related to the younger G3-literate participants, with an inferior performance compared with the older G3-literate participants and to both younger and older illiterate participants. A Scheffe test for the verbal abstraction task showed that the older illiterate group performed inferior compared with the equivalent age groups of literate participants. These results indicate that, for all practical purposes, formal schooling and age represent two independent factors in the influence on neuropsychological test performance, consistent with previous findings (Ostrosky-Solís, Ardila, Rosselli, Lopez-Arango, & Uriel-Mendonza, 1998).

The results were similar (the only exception was a significant age effect on oral comprehension) using a multiple-step regression analysis in a case-wise model, in which age was included as a continuous variable, to investigate the relation between literacy and age effects on test performance.

Discussion

To investigate the influence of formal education on the cognitive system of the human brain, we conducted a series of behavioral and functional neuroimaging studies (for a recent review see Petersson, Reis, & Ingvar, 2001) on an illiterate population and matched literate controls living in the southern Portugal (cf. the introduction section). Controls were matched with respect to several relevant variables (e.g., age, sex, general health, sociocultural background, and level of everyday functionality). These differences suggest that formal education and learning an alphabetic written language can influence the human cognitive system in a nontrivial way and provide support for the hypothesis that the functional architecture of the brain is modulated by literacy. In these types of studies, it is important to ensure that the illiterate participants are equal in all relevant respects except for the direct consequences of not acquiring orthographic knowledge and receiving a formal education. In this article, we have characterized our study population in greater detail than previously reported, and we have described the performance of this population on a neuropsychological test battery. We will now discuss the relevance of the observed performance differences between the literacy groups and argue that the selection procedure we have used ensures, with a reasonable degree of confidence; that the illiterate participants are cognitively normal; that they did not receive formal education for specific sociocultural reasons, as described; and that they are not illiterate because of low intelligence, learning disability, or brain pathology. Furthermore, we argue that the illiterate participants are comparable with the literate participants included in our studies except for the lack of formal education and the absence of orthographic knowledge.

Visual Naming, Visual Identification, Oral Comprehension, and Praxis Abilities

There were no significant differences between the literacy groups on visual naming, visual identification, oral comprehension, or praxis ability tasks (Table 5).

Also, when the two literate groups (G2, G3) were compared, there were no significant differences on the reading and writing tasks. We have previously reported that, in contrast to naming two-dimensional representations, there is no effect of literacy when real objects are named (Reis et al., 1994; Reis et al., 2001). Other studies have indicated that the level of literacy influences the performance when participants are asked to name two-dimensional pictorial representations of three-dimensional objects (e.g., Kremin et al., 1991; Lecours et al., 1987; Manly et al., 1999; Ostrosky-Solís et al., 1998; Rosselli et al., 1990).

The oral comprehension task used in this study was simple, and performance was high; therefore, ceiling effects are difficult to exclude. Other studies have indicated that there may be differences between educational groups when more sensitive comprehension tasks are used (Manly et al., 1999; Ostrosky-Solís et al., 1999). However, Manly et al. (1999) did not observe any significant difference between illiterate participants and literate participants without formal education. Furthermore, the oral comprehension result reported by Ostrosky-Solís et al. (1999) is complicated by the fact that their task required processing of geometric concepts and two-dimensional representations. We have previously shown that illiterate people find it more difficult to process two-dimensional representations compared with real three-dimensional objects (Reis et al., 1994; Reis et al., 2001).

Similar remarks can be made with respect to the praxis task. We did not observe any significant effects of literacy, although others have reported literacy effects on more complex tasks (Rosselli et al., 1990). In general, these differences may be related to participant-selection procedures, task difficulty, or ecological validity (i.e., to what extent the task draws on a shared cultural background). In particular, some of the oral commands used by Rosselli et al. (1990) may have been perceived as less natural by the illiterate participants or perhaps the illiterate group did not fully appreciate the significance of the specific testing procedure.

Word and Sentence Repetition

There was a small but significant overall group difference on the immediate word and sentence repetition task. The reason the illiterate group scored slightly lower than the literate group is entirely related to the performance on the long sentence. The long sentence contains a shift in subject number (singular/plural) between the first and second part of the sentence. The illiterate participants systematically repeated the sentence, transforming the subject of the first part of the sentence into the plural. At least two explanations are possible. Perhaps illiterate people are not fully aware (explicitly) of the grammatical structure of complex sentences and that the dominant processing bias is toward pragmatic or global aspects of sentence semantics. Alternatively, and particularly related to the material used in this study (*Ele vendeu a casa e ambos foram para a quinta*—He sold the house, and both went to the farm), it may be the case that it is less natural for an illiterate participant with the particular cultural background of our study population, that decisions are made unilaterally by a single member of a couple. However, consistent with previous results (Reis & Castro-Caldas, 1997), the present repetition results indicate that the illiterate group does not have a general problem with word repetition.

Verbal Fluency and Digit Span

In the verbal fluency task, the participants were asked to name as many different things as possible in 1 min that one can buy at the supermarket. Compared with several other criteria used in semantic fluency (e.g., animals/furniture), in our case, this appears to more properly reflect a shared cultural background between literacy groups because most people, both literate and illiterate, in our study population do a significant part of their shopping at supermarkets and to a similar degree (most participants were housewives). Based on this, we predicted that there would be no significant effect of literacy, which was confirmed in that there were no significant differences between the three literacy groups using this criterion. However, on both semantic and phonological verbal fluency tasks, we (Reis & Castro-Caldas, 1997) and others (Ostrosky-Solís et al., 1998; Ostrosky-Solís et al., 1999) have reported literacy effects. We suggest that a likely explanation for these differences in results reported relates to our particular choice of semantic category as suggested. In contrast, clear and consistent differences between literacy groups have been shown on phonological verbal fluency (e.g., Manly et al., 1999; Ostrosky-Solís et al., 1998; Ostrosky-Solís et al., 1999; Reis & Castro-Caldas, 1997) in line with previous reports of differences in phonological processing between literate and illiterate people (Morais, 1993; Petersson, Reis, Askelof, Castro-Caldas, & Ingvar, 2000; Reis & Castro-Caldas, 1997).

In accordance with previously reported results (Ardila et al., 1989; Castro-Caldas et al., 1997; Garcia

& Guerreiro, 1983; Reis et al., 1995), we observed a significant literacy effect on the digit span task; literate participants performed significantly better than illiterate participants. In addition, the G2 versus G3 effect was significant (Mann–Whitney U Test; $U = 17$; $p = .03$). Thus, it appears that the number of years of formal education is a factor that influences digit span performance. Furthermore, we have previously observed a significant effect of the magnitude component of digit representations. In other words, the performance of illiterate participants was significantly lower for digits greater than five compared with digits less than five, although this was not the case for literate participants (Reis et al., 1995).

Digit span has been related to verbal working memory (Baddeley, 1992; Baddeley & Hitch, 1974). We have previously suggested that there are differences between literate and illiterate people related to the phonological loop, the phonological component of working memory (Petersson et al., 2001). Taken together, we suggest that these findings may consistently be interpreted as indicating that phonological aspects of verbal working memory processing are different in literate and illiterate people.

Verbal Abstraction

Verbal abstraction is one of the cognitive domains in which formal education has a strong influence. The ability to process information in an abstract way is a cognitive skill acquired and progressively developed during formal schooling and, in particular, after the first few years of education. Ceci (1990) considered this to be an indirect influence of formal education. Consistently, we observed a significant difference between the literacy groups. However, even so, the illiterate group performed at an intermediate level on the abstraction task. Similar results have been reported by others using other types of conceptual tasks taxing similar cognitive abilities (Manly et al., 1999; Ostrosky-Solís et al., 1999). Importantly, Manly et al. (1999) assessed nonverbal reasoning showing no difference between literacy groups. This indicates that the reasoning skills of illiterate people are not necessarily inferior to literate people, which is to be expected when considering illiteracy for specific sociocultural reasons as outlined previously.

Verbal Memory With Interference

In the verbal-memory-with-interference task, there was no significant difference between literacy groups in total score, free recall, cued recall, or recognition. This is consistent with Portuguese normative data (Garcia, 1984; Garcia & Guerreiro, 1983) and findings from similar memory tasks reported by others (Manly et al., 1999; Ostrosky-Solís et al., 1999). These results are consistent with a recent positron emission tomography study indicating that illiterate people show normal patterns of activation during both episodic encoding of word pairs and cued recall (Petersson, Reis, Castro-Caldas, & Ingvar, 1999). However, Ostrosky-Solís et al. (1999) reported a difference between the illiterate or low-education group (i.e., participants with 1–4 years of schooling) and the high-education groups (4–9 and ≥10 years) on a free recall task, although there were no significant differences between groups on the recognition task. This indicates that formal education beyond 4 years may facilitate free recall performance, perhaps related to more effective memory (encoding or retrieval) strategies or richer semantic associations.

Basic Information

Formal education is likely to provide knowledge that may help answer the 10 general knowledge questions included in the basic information task. Even though there were significant group differences, the minimum illiterate score was seven. The illiterate participant systematically failed on two of the questions: "How many seasons are there in a year?" and "How many *scuds* are there in 1,000 *reis*?" It therefore appears that these particular questions are dependent on general knowledge acquired at school. Although the illiterate participants know the four seasons and are oriented in terms of season, it is also likely that the familiarity of the illiterate people with calendars and time-managers are limited compared with literate people. The second question deals with an abstract aspect of counting money and with the use of a large magnitude of the quantity involved, the latter known to be relatively more difficult for illiterate people compared with literate people (Reis et al., 1995).

Orientation and Mental Calculation

There were no significant group differences on the place orientation task. However, the illiterate participants showed a systematic error pattern related to the questions: "When were you born?" (personal orientation); "What is the name of the Portuguese prime minister?" and "What is the name of the Portuguese president?" (temporal orientation). This is naturally related to the fact that illiterate people have little opportunity to read and write the exact date (Manly et al., 1999). However, the latter two questions should perhaps be viewed as general knowledge questions. In line with this suggestion, the G2-literacy group (4 years of education) also frequently failed on these questions. Nonetheless, almost all participants were able to produce relevant semantic information about the prime minister and the president. A plausible alternative explanation for these differences are related to the fact that these political offices have changed relatively often recently in conjunction with the fact that literate people have access to written media and therefore may be better informed about recent events in society. Consistent with these suggestions, when we excluded the data related to these questions, there were no significant group differences in personal, temporal, or total orientation scores. The conclusion then is that there is little difference between the literacy groups on the different orientation tasks.

Finally, there was a small difference between literacy groups on the mental calculation task. The illiterate sample performed well on all tasks, except multiplication, using their fingers to count. Similar results have been reported in a Brazilian sample (Deloche et al., 1999).

General Discussion

One approach to study the interaction between (neuro-)biological and cultural factors and its influence on cognitive development and the functional organization of the human brain is to take advantage of particular forms of naturally occurring illiteracy. We have used this strategy to investigate the influence of formal education on the cognitive system of the human brain in a series of behavioral and functional neuroimaging studies (Petersson et al., 2001) of an illiterate population with matched literate controls living in the southern Portugal. The study of people, who, for specific (e.g., as described previously) sociocultural reasons, did not have the opportunity to acquire basic reading and writing skills, can serve as a model to study the influence of alphabetic orthography on auditory-verbal language (Castro-Caldas et al., 1998; Petersson et al., 2000; Reis & Castro-Caldas, 1997). Several studies have indicated that the lack of alphabetic orthographic knowledge affects aspects of auditory-verbal language processing and that formal schooling has further consequences, including the opportunity to acquire a broader knowledge base of general information as well as strategies for more systematic, abstract, and efficient processing of information (for reviews see Ardila, Ostrosky, & Mendonza, 2000; Ceci & Williams, 1997; Petersson et al., 2001).

Ideally, when investigating and comparing literate and illiterate people, the different literacy groups should be similar in all relevant respects except for the direct consequences of illiteracy or lack of formal education. This emphasizes the importance of excluding or controlling for other, potentially confounding, factors, such as learning disabilities, different types of cognitive dysfunction, differences in relevant sociocultural background factors, and other factors important for normal cognitive development. These are important issues to address when conducting literacy studies investigating the influence of literacy and formal schooling on cognition. However, the use of standard intelligence or neuropsychological test batteries (e.g., the WAIS battery) to select and match different study populations is difficult. For example, most standard intelligence tests are associated with educational attainment (Ceci, 1990) and may tax more fundamental cognitive abilities to a limited degree (Ardila, 1999). Similarly, the performance on many neuropsychological tests is likely to be affected by at least some of the factors mentioned previously (Petersson et al., 2001). Instead, alternative approaches need to be sought. For example, Ardila (1999) suggested that current intelligence scales should be replaced with neuropsychological instruments sensitive to more fundamental cognitive abilities and relatively independent of educational level. Even in our relatively small sample of people, many previously reported results (e.g., Manly et al., 1999; Ostrosky-Solís et al., 1999; Petersson et al., 2001; Reis & Castro-Caldas, 1997) were replicated. This consistency over different populations indicates that it is feasible to develop neuropsychological test instruments relatively independent of and robust to differences in level of education. Alternatively, the detailed characterization of the influence of these factors allows for strategies based on statistical discounting and effective equalizing of background factors. To tax relevant cognitive abilities, it appears necessary to develop instruments or construct normative data to compare groups on more neutral terms. Such an enterprise is of importance because neuropsychological test instruments that are relatively free of educational influence and at the same time tax cognitive functions of interest is of value for both clinical as well as for research purposes. This requires a careful choice and development of tasks of ecologically validity reflecting important aspects of shared background factors. In this study, for example, naming and identifying the real objects, verbal fluency using an ecologically relevant semantic criterion, verbal memory, and orientation were not affected by the level of literacy. In addition, oral comprehension and praxis abilities were free from both literacy and educational influence. However, these two tasks were simple and need further investigation because we cannot exclude ceiling effects. In contrast, several other cognitive abilities, for example, working memory (digit span), verbal abstraction, long-term semantic memory, and multiplications, are affected by the level of literacy. Although the performance of the illiterate group was lower compared with the literate group on these tasks, on closer analysis, it appears that it is possible to discount, that is, to provide a natural explanation for, the influence of literacy on some of these tasks. In addition, we indicated that some apparent literacy effects could disappear if more ecologically appropriate tasks or procedures are used.

Conclusion

We and others (c.f. Morais & Kolinsky, 2000; Petersson et al., 2001), have indicated that the level of literacy and formal education influence cognition beyond the skills of reading and writing, and we have argued for the importance of developing neuropsychological instruments for the assessment of fundamental cognitive abilities relatively independent of literacy and educational level both for clinical and research purposes. Alternative approaches are to develop normative databases or to use appropriate procedures for statistical discounting of covariates of no-interest for the study populations of interest. These strategies are dependent on valid ways to declare the different populations of interest equal in all other relevant respects than those being investigated. We also have indicated that it is possible, using careful and adequate participant-selection procedures, to exclude learning disabilities and behavioral and cognitive impairment, as well as to control important sociocultural factors that potentially may bias the effects of literacy and education on cognitive brain functions. It should be noted that in our studies, the single reason for illiteracy, described previously, related to well-defined and sociocultural specific reasons. In other words, the detailed results presented here, together with normal everyday level of functioning, indicate that our illiterate participants were cognitively normal and had the same capacity to learn, adapt, and survive in their environment as literate participants.

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Appendix
The Neuropsychological Test Battery for Mental State Assessment

1. Language tests

1.1. Visual naming (maximum score = 10). Five real objects: key *chave*, coin *moeda*, watch *relógio*, button *botão*, pen *caneta*; Two body parts: nose *nariz*, hair *cabelo*; Three colors: red *vermelho*, yellow *amarelo*; green *verde*

1.2. Visual identification (maximum score = 10). Five real objects: key *chave*, coin *moeda*, watch *relógio*, button *botão*, pen *caneta*; Two body parts: nose *nariz*, hair *cabelo*; Three colors: red *vermelho*, yellow *amarelo*, green *verde*

1.3. Oral language comprehension (maximum score = 7). Close your eyes. *Feche os olhos.* Open your mouth. *Abra a boca.* Stretch out your tongue. *Deite a língua de fora.* Put the coin on the watch. *Ponha a moeda em cima do relógio*. Put the watch near the pen. *Ponha o relógio ao lado da caneta*. Lift up your left/right hand. *Levante a mão esquerda/direita*. Put your right hand/left on your left/right ear. *Ponha a mão direita/esquerda na orelha esquerda/direita*.

1.4. Word and sentence repetition (maximum score = 11). Three disyllabic words: pencil *lápis*; fork *garfo*; button *botão*; Three trisyllabic words: cigarette *cigarro*; window *janela*; scissors *tesoura*; Three polysyllabic words: automobile *automóvel*; large rat *ratazana*; orange- tree *laranjeira*; Two sentences: a short sentence (The car is not good. *O carro não está bom.*) and a long sentence (He sold the house, and both went to the farm. *Ele vendeu a casa e ambos foram para a quinta.*)

1.5. Word and sentence reading (maximum score = 2). One word (hospital *hospital*) and one short sentence (John went to the beach. *O João foi para a praia*.)

1.6. Writing (maximum score = 2). One word (key *chave*) and the name of the subject.

2. Praxis abilities (maximum score = 4)

Two buccofacial: to suck *chupar*; to blow *soprar*; One symbolic: to say good-bye with your hand *fazer adeus com a mão*; One limb ideomotor gesture: to feign that you hold a glass and drink water *fingir que pega num copo e bebe água*

3. Verbal fluency

The subject was instructed to name as many items to eat as possible that can be purchased at a supermarket, during 1 min.

4. Verbal abstraction (max. score = 6)

Interpretation of two proverbs: (1) When the sun rises, it is for everyone. *O sol quando nasce é para todos*. (2) Whoever has glass ceilings should not throw rocks at his neighbors' home. *Quem tem telhados de vidro não deve atirar pedras ao do vizinho.*

5. Memory

5.1. Digits span (Wechsler Memory Scale—translation of the French Version—the forward series (i.e., the same numbers and lengths; maximum score = 9). (See Table 7.)

5.2. Verbal memory with interference: Five words [free recall (3 points), cued (2 points), recognition (1 point); maximum score =15: Cat *gato,* apple *maçã,* blouse *blusa*, knife *faca*, carantion *cravo.* Interference during 1 minute. (See Table 8.)

5.3. Basic information. Ten general knowledge questions of similar design as in the WAIS information test (maximum score = 10):

What is the capital city of Portugal? *Qual é a capital de Portugal?*

How many seasons are there in a year? *Quantas estações tem o ano?*

Which are the colors in the Portuguese flag? *Quais as cores da bandeira Portuguesa?*

How many items are there in a dozen? *Quantas coisa tem uma dúzia?*

Where do you buy a packet of sugar? *Onde se compra o açúcar?*

How many *escudos* are there in a *conto de reis*? *Quantos escudos há num conto de reis?*

How many months are there in a year? *Quantos meses tem o ano?*

How many items are there in a pair of objects? *Um par de objectos quantos são?*

Which day is Christmas day? *Em que dia do ano é o Natal?*

Which country has a border with Portugal? *Qual é o país que faz fronteira (que pega) com Portugal?*

6. Orientation task with the items from the Mental Status Questionnaire

6.1. Personal orientation (maximum score = 5).

What is you full name? *Diga-me o seu nome todo?*

How old are you? *Quantos anos tem?*

Which year were you born? *Em que ano nasceu?*

Which month? *E em que mês?*

Which day of the month? *E em que dia do mês?*

6.2. Orientation in place (maximum score = 3).

Where do you live (in which city)? *Qual é a sua morada (em que terra vive)?*

Table 7. *Digits Span*

Series	Trial I	Trial II
3	5–8–2	6–9–4
4	6–4–3–9	7–2–8–6
5	4–2–7–3–1	7–5–8–3–6
6	6–1–9–4–7–3	3– 9–2–4–8–7
7	5–9–1–7–4–2–8	4–1–7–9–3–8–6
8	5–8–1–9–2–6–4–7	3–8–2–9–5–1–7–4
9	2–7–5–8–6–2–5–8–4	7–1–3–9–4 –2–5–6–8

Table 8. *Verbal Memory With Interference*

Free Recall	Cued Recall	Recognition
Cat *"Gato"* (3)	Animal *"Animal"* (2)	Cat/dog *"Gato/cão"* (1)
Apple *"Maçã"* (3)	Fruit *"Fruta"* (2)	Pear/apple *"Pera/maçã"* (1)
Blouse *"Blusa"* (3)	Clothing *"Vestuário"* (2)	Blouse/waistcoat *"Blusa/colete"* (1)
Knife *"Faca"* (3)	Object to cut *"Obj. cortante"* (2)	Axe/knife *"Machado/faca"* (1)
Carnation *"Cravo"* (3)	Flower *"Flôr"* (2)	Carnation/rose *"Cravo/rosa"* (1)

What do you call the place (house) where we are now? *Como se chama este sítio (esta casa) onde estamos?*

In which city are we now? *Em que terra (cidade) é que estamos?*

6.3. Temporal orientation (maximum score = 7) .

Which day of the week is it today? *Que dia da semana é hoje?*

Which year are we in? *Em que ano estamos?*

Which month is it? *Em que mês estamos?*

Which day of the month? *E em que dia do mês estamos?*

Which season of the year is it? *Em que estação do ano estamos?*

Who is the president of Portugal? *Quem é o Presidente da Républica?*

Who is the prime minister? *Quem é o 1° Ministro?*

7. Mental calculation (maximum score = 4)

Two additions: 4 + 2, 12 + 5

One subtraction: 18 – 6

One multiplication: 3 × 4

8. Cancellation task

A line bisection task consisting of 21 lines (3.5 cm each) randomly distributed.