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Cognitive consequences of early phase of literacy

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Abstract

The effect of the degree of illiteracy (complete or incomplete) on phonological skills, verbal and visual memory and visuospatial skills is examined in 97 normal Brazilian adults who considered themselves illiterate, and 41 Brazilian school children aged 7 to 8 years, either nonreaders or beginning readers. Similar literacy effects were observed in children and in adults. Tasks involving phonological awareness and visual recognition memory of nonsense figures distinguish the best nonreaders and beginning readers. Children performed better than adults at oral repetition of short items and figure recall, and adults better than children at semantic verbal fluency, digit span, and word list recall. A principal component analysis of the correlations between tasks showed that phonological awareness/reading, phonological memory/oral repetition, and semantic verbal memory/fluency tasks, generated different components. The respective role of culturally based preschool activities and literacy on the cognitive functions that are explored in this study is discussed. (*JINS*, 2003, *9*, 771–782.)

Keywords: Literacy, Phonological awareness, Phonological memory, Visual memory

INTRODUCTION

Illiterates represent a substantial proportion of the world population[1], and they are clearly under-represented in psychological studies of human cognition (Morais & Kolinsky, 2000). As a consequence, the methodology of the cognitive study of the illiterate is underdeveloped. A comparison of illiterates with highly educated literates, for instance matched in age and using conventional testing methods, is expected to conclude that illiterates have lower cognitive performances in almost all areas of cognition (Ardila et al., 1989; Rosselli et al., 1990). However, such differences might be difficult to interpret, as they can be due not only to literacy but also to numerous other factors, such as schooling, general cognitive ability, or cultural and environmental differences.

In Brazil, the 1999 census statistics indicate an overall 13.3% incidence of adult illiteracy. In the region of the Federal District of Brasilia, which is populated by inhabitants originally from diverse areas of the country, the statistics show a 5.1% incidence of adult illiteracy (Instituto Brasileiro de Geografia e Estatística, 2000). There is converging evidence from studies comparing normal illiterate with normal literate subjects that neuropsychological test performance depends on literacy, even for tasks that do not directly involve reading and writing. Illiterates obtained lower scores than literates on measures of repetition of pseudowords, memory of pairs of phonologically related words, and generation of words according to a formal criterion (Reis & Castro-Caldas, 1997); naming, comprehension, verbal abstraction, orientation, and figure matching and recognition (Manly et al., 1999); naming line drawings (Reis et al., 1994); stick construction (Matute et al., 2000); and several components of calculation and number processing (Deloche et al., 1999). Other tasks, such as tests of verbal list delayed recall, non-verbal abstraction, and category fluency (Manly et al., 1999), or counting the elements of small sets (Deloche et al., 1999) were reported to be relatively unaffected by literacy status. This differential

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[1]In 1995, estimated illiteracy rates by gender and by region varied from 37% and 63% for males and females respectively in southern Asia, to 12% and 15% in Latin America and the Caribbean, and to 1% and 2% in developed countries (Unesco, 1997).

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effect of literacy according to the nature of the neuropsychological task is an argument against a unique general cognitive factor hypothesis, or the verbal nature of the task, which could explain all the observed differences between literates and illiterates. Other investigations in special populations of educated subjects tend to confirm this point. For instance, Chinese subjects who are educated but do not have alphabetic reading competence obtained low scores on tasks that specifically explore the segmental representation of oral language, such as deleting the initial consonant of a spoken pseudoword or making rhyme-judgments (De Gelder et al., 1993; Read et al., 1986).

Other studies, involving brain-damaged illiterates or using functional brain imagery in normal illiterates, reported that the functional organization of the brain itself depends on literacy. Right-stroke illiterates presented more word-finding difficulties, reduction in speech output and phonemic paraphasias than right-stroke literates, a fact taken to be an argument in favor of a more ambilateral cerebral representation of language in illiterates than in school educated subjects (Lecours et al., 1987). However, Lecours et al. (1987) data can stem from a premorbid literacy effect on the verbal tasks explored. A brain activation study using PET found that oral repetition of pseudowords involves neural structures that differ between literates and illiterates, which suggests that learning to read and write modifies the language network in the human brain (Castro-Caldas et al., 1998; Petersson et al., 2000).

The above evidence reveals the need for specific norms in the normal illiterate population for assessing neuropsychological functions in brain-damaged illiterates (Ardila, 2000; Ardila et al., 1989; Ostrosky-Solis et al., 1999; Rosselli et al., 1990). However, examining the cognitive abilities of the normal illiterate population carries a much broader interest, especially for issues related to the contextual factors affecting the acquisition and elaboration of mental functions during cognitive development.

Preschool oral language performances, for instance, can predict early (*vs.* delayed) reading acquisition both in normally developing and 'at risk' children (Badian, 1998; Burgess & Lonigan, 1998; Catts, 1993; Lewis et al., 2000; Menyuk et al., 1991). However, some preschoolers are exposed very early to print material in literate societies. Thus, it remains debatable whether many oral language 'predictors' of early reading acquisition, such as those involving phonological awareness, are real prerequisites of reading acquisition or, on the contrary, are a consequence of an early exposure to the alphabetic reading code (Lundberg, 1998; Morais et al., 1987; Rohl & Pratt, 1995). Studying the illiterates' performances on the same tasks as those used with preschoolers can demonstrate to what extent phonological tasks depend on exposure to print material.

Moreover, nonword repetition has been considered both a behavioral marker for inherited language impairment, following evidence from a twin study (Bishop et al., 1996), and an especially difficult task for illiterates (see above), presumed to be without inherited language impairment. Oral repetition of nonwords is a phonological working memory test, in which the involvement of subvocal rehearsal is questionable (Gathercole, 1995; Gathercole et al., 1994). Subvocal rehearsal is the second component of the phonological loop model; the other is the phonological short-term store (e.g., Baddeley, 1986). It is possible that literacy influences one or the other component of the phonological loop. Young preschool children, for instance, would not use subvocal rehearsal spontaneously, even if they were able to do so upon request (Bjorklund & Douglas, 1997; Cowan, 1997). Thus, it is uncertain whether subvocal rehearsal depends mainly on chronological age, (pre)school training, culturally-related training (Whitehurst & Lonigan, 1998), and/or acquisition of literacy. The study of phonological working memory in normal adult illiterates, using tasks in which subvocal rehearsal is mandatory and others in which it is not, may shed new light on this point.

There is great variation of the degree of literacy within literates, which could permit an approach to the cognitive correlates of literacy without having to compare the performance of literate individuals with that of illiterate individuals (Stanovitch, 1993; Stanovitch & Cunningham, 1992). These authors reported that differential exposure to print within the literates, measured using a variety of questionnaire and recognition methods, was related to vocabulary, cultural knowledge, spelling ability, and phonological verbal fluency. Likewise, within illiterates, there may be important variations of the degree of illiteracy, which could allow for a study of the cognitive correlates of (il)literacy by comparing the performance of illiterates with that of semiliterates.

Many authors have emphasized the difficulty of distinguishing the specific influence of literacy from that, more general, of schooling, in the interpretation of the cognitive differences between literates and illiterates. For example, is literacy the critical factor explaining the specific difficulties of the illiterate in naming line drawings (Chandra et al., 1998; Reis & Castro-Caldas, 1997) or in visual retention tasks (Manly et al., 1999)? Other factors either related to schooling, such as knowing how to use a pencil and actually using it for drawing, or related to other cultural features, may be more critical. A possible methodology that could be used to address this problem may be to compare performance of illiterates on these specific tasks to that of preschool and school children before and after acquisition of reading. An example of such methodology is Kolinsky et al. (1987) study, where both illiterate and ex-illiterate groups and pre-school and schoolchildren were compared on a task of finding parts within figures. Schematically, a task involving cognitive processes which depend on reading acquisition should present the following characteristics: (1) the task should be successfully performed by literates and impossible or almost impossible to execute by illiterates; (2) children should present a dramatic increase of performance during the period of reading acquisition, contrary to other tasks (e.g., age-dependent, or dependent on activities other than reading) which would show only a slight and

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smooth improvement of performance, during the same period. The combined evidence from the illiterate-semiliterate adults and from children could provide strong arguments in favor of or against the specific role of early phase of literacy in a given cognitive ability.

The present study examines the effect of the degree of illiteracy (complete or incomplete) on neuropsychological test performance and especially on phonological skills, verbal and visual memory and visuospatial skills, both in adults and children. It is expected that results will contribute to clarifying which specific cognitive processes, and especially those that known to be related to reading acquisition in children, are in fact reading acquisition dependent.

The neuropsychological battery used included (1) simple reading tasks which permit the verification of the degree of illiteracy; (2) oral language tasks, with emphasis on phonological skills: repetition of short and long nonwords compared to repetition of words; tasks examining auditory perception of speech; phonological verbal fluency compared to semantic (category) verbal fluency; metaphonological tasks; (3) verbal and nonverbal memory tasks; and (4) tasks involving visuospatial skills. Most subtests of this battery were previously used in France in a longitudinal investigation of motor and cognitive development in normally developing pre-school and school children (Curt et al., 1995; De Agostini & Dellatolas, 2001; Dellatolas et al., 1997, 1998).

METHODS

Research Participants

Adults

The group of participants was comprised of 97 normal adults (51 men and 46 women) between 20 and 67 years of age (*M*: 42.9 years; *SD* = 11.6 years), from the region of Brasilia, Brazil. All subjects considered themselves illiterate. Forty-one subjects never attended school; 39 subjects attended school for only a few months; 7 subjects never attended school but attended a literacy program for adults; 10 subjects attended school for more than 1 year but considered themselves illiterate. The participants were recruited from urban work centers and from jobs in public cleaning and maintenance, domestic employment (maids, etc.), construction, and agricultural work, as well as from among the companions and family members of patients hospitalized at the SARAH Hospital. The participants' occupations[2] were classified into four categories: General Cleaning Services (67%), Construction Workers (16.5%), Domestic Services (10.3%) and Agricultural Services (6.2%).

Children

Forty-one Brazilian school children without any known pathology, 22 girls and 19 boys, aged from 7 to 8 years, were examined individually in their schools by a psychologist. The study was performed at the beginning of the Brazilian school year. Twenty children were in grade 1 and 21 in grade 2. All children were from public schools. Among the Grade 1 children, 10 had a preschool experience during the past year and 10 had no such experience. Among the 21 children of Grade 2, 10 were in a school situated in an area of low SES (a satellite city near Brasilia) and 11 were in a school at the center of Brasilia (median or high SES). The children were previously identified through school records and invited to participate in the study. They were sent a letter, addressed to parents, explaining the objectives of this research. No other criteria was used to select a child. The interviews were conducted by a trained psychologist at the library of each school during the school day.

Procedure

The participants were contacted individually and invited to participate in the study. The same psychologist trained in the data collection process conducted individual interviews at each participant's workplace or school.

The Neuropsychological Battery

The neuropsychological battery, originally in French, was translated into Portuguese by a professional with fluency in both languages. Based on this translation, adaptations of the items were made in such a way as to maintain the evaluation parameters established in the original version: number of syllables in words and nonwords and frequency of the words in Portuguese.

The neuropsychological battery comprises the following 20 subtests:

1. *Repetition of words and nonwords (four subtests):* The subject was asked to repeat the following: (1) 16 short (mono- and bi-syllabic) words: *porta* (door), *flor* (rose), *tarde* (evening), *olho* (eye), *noite* (night), *amor* (love), *musgo* (moss), *derme* (skin), *laivo* (spot), *fenda* (slit), *cerne* (pith), *gleba* (soil), *halo* (halo), *casa* (home), *mastro* (mast), *bule* (pot); (2) 16 short (mono- and bi-syllabic) nonwords: *log*, *belu*, *zal*, *pab*, *dongue*, *raf*, *mup*, *goce*, *peli*, *tec*, *suda*, *mav*, *fir*, *pafal*, *sot*, *gara*; (3) 16 long (three- to six-syllable) words: *passarinho* (canary), *cinema* (movies), *balanço* (balance), *jardinagem* (gardening), *bicicleta* (bicycle), *margarida* (daffodil), *esperança* (hope), *apartamento* (apartment), *aniversário* (birthday), *capacidade* (capacity), *fotografia* (photography), *americano* (American), *umidade* (humidity), *automóvel* (automobile), *respiração* (respiration), *redondeza* (surroundings); (4) 16 long (three- to six-syllable) nonwords: *tocapebo*, *bacota*, *veliguri*, *mecipedazi*, *sila-*

[2] BRASIL. Ministério do Trabalho e Emprego. CBO : Classificação Brasileira de Ocupações. Available at: ⟨http//www.mtb.gov.br⟩. Acesso em: 03 jan. 2001.

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dongue, mofalipelu, ritojuce, pefumogua, cavope, framedocalelo, linevafo, rocacami, bopelano, valimefage, jufrarito, rebagaloke. The precise instruction for words was, "I will say a word and you will have to repeat this word. You have to say the same thing that I said" and for nonwords, "Now I will say one word that means nothing. You have to say the same thing that I said." The score was the number of items correctly produced (max = 16 for each subtest).

2. *Semantic verbal fluency*: The subject was asked to produce as many words as possible belonging to the category *animals* within 1 minute, and then to the category *clothing*. The precise instruction was, "Do you know name of animals/clothes? You will say to me all the names of animals/clothes that you know, as rapidly as possible." The score was the total number of correct corresponding words produced.

3. *Visual recognition memory of nonsense figures*: Twenty-four nonsense figures were presented at the rate of one every 5 s. Every previously seen figure was subsequently presented in a multiple choice paradigm with three previously unseen nonsense figures (Figure 1). The subject had to recognize the target figure. The position of the target was random. The precise instruction was, "I will show you figures which mean nothing, one by one. You have to look at each figure very carefully, because after that you will have to remember them. You have to try to keep the figure in your head." After presentation the instruction was, "Now I show you four figures and you have to show me the figure that you have already seen. Among the four figures, there is only one that you have already seen." The subject was asked to remain silent during this task. The score (max = 24) corresponds to the number of correct recognitions (Signoret, 1991).

4. *Rhyme identification*: After oral presentation of the target word (eight items), three words were orally presented and the subject had to recognize the word that rhymes with the target (e.g., *esperança/desenho, criança, bambu*). The position of the correct word was random. The precise instruction was, "We say that two words rhyme when their ends are the same. For instance: *Batatinha quando nasce, esparrama pelo chão. A menina quando dorme, põe a mão no coração*. Chão, mão and coração end the same. You have the same thing with *nariz, chafariz, feliz, imperatriz*, which end the same." Before the task two examples were given, with corrections of the subject's answer when necessary. The score corresponds to the number of correct answers (max = 8).

5. *Phonological fluency*: The subject was asked to produce as many words as possible beginning with the sound /p/ within 1 min, then with the sound /f/, then with the sound /m/. The precise instruction was, "We will try to find words which begin with the same sound (noise). First, we will try together to find words whose first sound

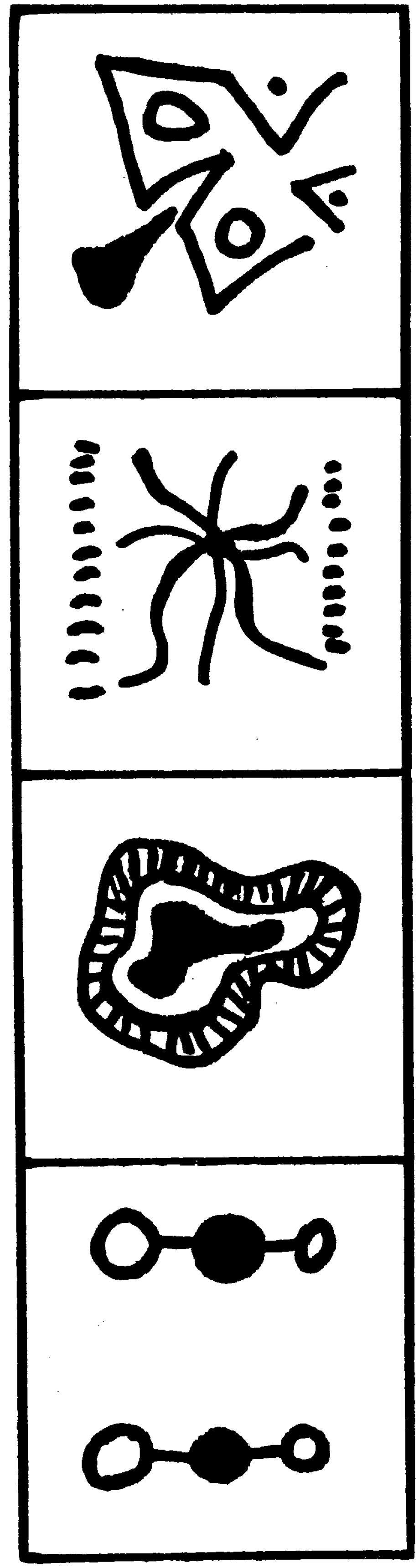

Fig. 1. Visual recognition of nonsense figures. Example: Signoret (1991).

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is /ʃ/: we can say *chapéu*, *chocolate*, *chato*, *choro*. Now we try to find together words whose first sound is /d/: for instance, *dado*, *dia*. Also, we can find words which begin with the sound /t/, such as *tatu*, *telefone*. Now you have to do the same thing, with the sound /p/, as in *pedra*, *piolho* and *pai*." Also, three examples were given with the sounds /f/ and /m/. The score was the total number of correct words produced.

6. *Minimal pairs phonetic discrimination*: Twenty pairs of words were orally presented, 10 identical and 10 with a minimal phonological difference (e.g., *vila/fila*, *passo/pato*, etc.). There were 17 disyllabic pairs with the difference evenly distributed between the two positions and 3 trisyllabic pairs. Subject had to say *identical* or *different*. The precise instruction was, "I will say two words and you have to say if they are the same or not. You have only to listen to the words and not to repeat them. For instance: *rato–rato* is the same; *rato–ralo* is different." The score (max = 20) corresponds to the number of correct answers.

7. *Initial phoneme deletion*: In this 12-item task the subject was asked to delete a phoneme from real words. The sound sequence remaining after initial phoneme deletion was a word. The items were: *nave/ave*, *molho/olho*, *luva/uva*, *cidade/idade*, *régua/égua*, *cobra/obra*, *prato/rato*, *globo/lobo*, *manta/anta*, *clima/lima*, *prenda/renda*, *flama/lama*. The precise instruction was, "Now we will play another game. You will try to find the word hidden in the word I say to you. To find this hidden word, you have to delete in your head the first sound of the word you have heard. For instance, I say *pilha*; if you delete in your head the sound that you have heard at the beginning, you obtain *ilha*. From *pilha*, if you delete the first sound, you obtain *ilha*. The word which is hidden in *pilha* is *ilha*. Now repeat these words. Another example: I say *casa*; if you delete the first sound that you heard at the beginning, you have *asa*; repeat these words (*casa/asa*). Is this OK? Now it is up to you to find the hidden word. Listen carefully to the word that I say, then delete in your head the first sound of this word and say to me the word which is hidden." The score ranged from zero to 12.

8. *Digit span*: The subject had to reproduce an increasing number of digits (presentation rate: 1/s). The examiner pronounces a series of two, then three, etc. digits and the subject has to repeat them. There were two items for each number of digits. The task stops after two consecutive errors. The precise instruction was, "Listen carefully to what I say. When I make a sign, repeat what I have said." The score represented the number of digits produced in the correct sequence.

9. *Span for familiar monosyllabic words*: As in digit span, with monosyllabic familiar words instead of digits. Score represented number of words produced in the correct sequence.

10. *Span for monosyllabic nonwords*: As in the previous task, with monosyllabic nonwords instead of monosyllabic words. Score represented number of nonwords produced in the correct sequence.

11. *Figure recall*: One geometric figure was presented for 1 min. Then the figure was hidden and the subject asked immediately to reproduce it. The precise instruction was, "Look carefully at this drawing. You have to try to remember it. You can look at it for a certain time, then I will hide the drawing and you will try to do the same drawing as well as you can, with all the details. You do not have to speak, just look." The subject's effort was scored, according to the instructions in the Signoret battery, from zero to 12 (Signoret, 1991).

12. *Embedded figures*: In this five-item task, the subject was asked to show the target geometric figure (at the top of the sheet) embedded in a more complex geometric figure (at the bottom of the sheet), using a pencil (Dellatolas et al., 1998; Gottschaldt, 1926, 1929; see also Kolinsky et al., 1987). Two examples are given before the tasks. The precise instruction was, "I am showing you drawings. Look carefully at this one (at the top). Now look at this one (at the bottom). Now try to find the first drawing which is hidden into this one."

13. *Counting dots*: Three cards, with 8, 10, and 18 dots, pseudo-randomly displayed, were used. The subject was asked to count aloud the number of dots on each card, a first time without pointing, and a second time with simultaneous pointing at each dot. The first card was used for training. The precise instruction was, "I am showing you some dots. Look at them and count them silently without touching them (mental counting). Now you will count touching the dots one by one." Performance on the last two cards only was considered for the computation of the score (i.e., number of correct results, max = 4; Dellatolas et al., 1998).

14. *Counting backwards*: The subject was asked to count from 22 to 1. The precise instruction was, "Are you able to count backwards? Listen, I will explain it to you. I will count forwards 1, 2, 3, 4, 5 and now I will count backwards 5, 4, 3, 2, 1. Now repeat, 5 . . . now you try to count backwards from 22 to 1." The examiner stops the task at 15. The score was zero for failure, and 1 for success.

15. *Word list recall:* Twelve words were presented orally, 1/s, and the subject had to recall them after each presentation. There were three trials. The precise instruction was, "I will say a series of words and you will remain silent. When I finish, try to say the same words back to me, in the order you remember them." The score (max = 12) was the mean number of words of the two best recalls (Signoret, 1991).

16. *Reading words (mono- or bisyllabic)*: Sixteen short words, the same as those used for the repetition task,

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written in capital letters on one sheet were presented to the subject, who was asked to try to read them. The precise instruction was, "Now I will present some written words and you will try to read what is written." The score ranged from zero to 16.

17. *Identification of capital letters and Identification of the 10 digits (this task was proposed in adults only):* The subject was asked to name 10 capital letters (*E*, *B*, *C*, *A*, *D*, *P*, *I*, *M*, *U*, *O*) and 10 digits (*2*, *6*, *3*, *9*, *5*, *4*, *0*, *8*, *7*, *1*). The time to complete the entire examination varied between 50 and 122 min ($M = 72.1$ min, $SD = 13.3$).

RESULTS

The degree of illiteracy at word-level reading was assessed first by the subtest of reading 16 words. In adults, 68 subjects (70.1%) were completely unable to read even one word (Group 1: *adult nonreaders*, $n = 68$), and 29 were able to read at least one word (Group 2 = adult beginning readers, who will be labeled in the following as *adult readers*, $n = 29$). In Group 2, performance at word-level reading varied from 1 to 16. Similarly, the children were divided into two groups, according to their performance at the same task: those who were unable to read even one word (Group 3, *child nonreaders*, $n = 13$), and those who were able to read at least one word (Group 4, *child readers*, $n = 38$). In Group 4, the reading score varied from 3 to 16.

Table 1 shows the age, sex and school-attendance distributions of the four groups. In adults, only school attendance was different, as expected, between the two groups. In group 1, 50% have attended school (even if only for a few months) and 50% have not; the corresponding proportions in adult readers (Group 2) were 75% and 25% [$\chi^2(1) = 5.6$, $p = .02$]. In children, mean age of Group 3 (i.e., nonreaders) was about 5 months younger than that of Group 4 (readers; $t = 5.2$, $p < .001$) and males were underrepresented in Group 3 compared to Group 4 [$\chi^2(1) = 4.1$, $p = .04$]. Also, all children of Group 3 were in Grade 1, but 25% of Group 4 were in Grade 1 and 75% in Grade 2 [$\chi^2(1) = 20$, $p < .001$].

Table 1. Description of the samples

	Adults		Children	
Variable	Nonreaders $N = 68$	Readers $N = 29$	Nonreaders $N = 13$	Readers $N = 28$
Age: mean (SD)	42.9 (11.8)	43.0 (11.3)	7.3 (0.2)	7.7 (0.2)
Sex: % males	48%	62%	23%	57%
History of Schooling:				
No school	50%	24%		
Some schooling	50%	76%		
School grade				
Grade 1			100%	25%
Grade 2			0%	75%

In a first analysis within adult groups (Groups 1 and 2), the effect of both literacy group and school-attendance group on the score at each task was examined. The school-attendance effect, when literacy was taken into account, was significant for only one task, phonological fluency ($p < .001$). For all the other tasks, the effect of school attendance was not significant when literacy was partialed out. Furthermore, there was no change of the effect of literacy when school-attendance was or was not taken into account. Similarly, an analysis within the children groups (Groups 3 and 4) showed that the pattern of the effects of literacy did not present a noteworthy change when age and sex were partialed out. For three tasks the level of significance of literacy was between $p = .01$ and $p = .05$ in univariate analysis, and it was no more significant after adjustment for age and sex. However, when the univariate level of significance of reading group was equal to or less than .01 (this concerned six tasks), the literacy effect remained significant when age and sex were partialed out. Given the above results, only age-group (adults *vs.* children) and reading performance (either reading group: readers *vs.* nonreaders, or reading score: from zero to 16) were retained for subsequent analysis.

Table 2 shows results of a two-way ANOVA with age-group (adults *vs.* children) and reading group (nonreaders *vs.* readers) as explanatory variables and all the cognitive scores as dependent variables. The age-group effect was significant for 7 of the 18 scores. Children succeeded better than adults at oral repetition of short words and nonwords and figure reproduction. On the contrary, adults succeeded better than children at semantic fluency, digit span, counting dots and word list recall. Readers showed better performance than nonreaders for all tasks except four (i.e., oral repetition of short and long words and short nonwords, and digit span). The age by reading group interaction was never significant (i.e., the literacy effect for the adults and for the children were not significantly different), except for counting backwards, which all children of Group 3 failed. However, inspection of the means in Table 2 shows that, for some tasks, the significance of a main effect (i.e., age, reading group) was due mainly or exclusively to one of the subgroups, despite the absence of significant interaction (e.g., repetition of short nonwords, semantic fluency, figure reproduction). Reading group had a particularly strong effect on two tasks: phonological fluency and initial phoneme deletion. For initial phoneme deletion, performance was higher for the 7 simple onset items (CV. . .), such as *nave*/*ave* (mean percent correct, total sample: 38%) than for the 5 cluster onset items (CCV. . .), such as *prato*/*rato* (mean percent correct, total sample: 16%) and this was observed in all the four groups.

As already mentioned, among adult and children readers (i.e., Groups 2 and 4), word-level reading performance varied dramatically. However, the results remained practically the same in linear regression models (using the procedure General Linear Models of the SAS software, which allows the explanatory variables to be either categorical or continuous), with the cognitive scores as dependent variables and

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Table 2. Effects of age group and literacy status on the cognitive tasks, with means and standard deviations

Task	max	Adults: Nonreaders group 1 $n = 68$	Adults: Readers group 2 $n = 29$	Children: Nonreaders group 3 $n = 13$	Children: Readers group 4 $n = 28$	F values: Age group $DF = 1,134$	F values: Reading group $DF = 1,134$	F values: Interaction $DF = 1,134$
Oral repetition								
Short words	16	13.6 (1.9)	13.4 (1.8)	15.1 (1.0)	15.3 (1.0)	24.4***	0.01	0.3
Short nonwords	16	14.2 (1.8)	14.1 (2.4)	14.5 (1.3)	15.4 (0.8)	7.7**	0.2	1.9
Long words	16	15.1 (1.6)	15.6 (0.7)	15.3 (0.9)	15.6 (0.7)	0.2	2.2	0.07
Long nonwords	16	8.8 (2.6)	10.7 (2.5)	9.3 (3.0)	11.3 (3.0)	1.0	13.0***	0
Semantic fluency		15.9 (5.2)	18.1 (4.9)	10.9 (3.6)	15.9 (4.4)	14.0***	13.6***	1.9
Visual Recognition	24	11.9 (4.3)	15.2 (3.6)	13.3 (2.5)	16.3 (4.2)	2.3	15.1***	0.05
Rhyme identification	8	5.3 (2.0)	6.9 (1.4)	4.8 (2.2)	6.1 (2.0)	3.0	15.4***	0.15
Phonological fluency		5.8 (4.5)	16.6 (7.4)	4.3 (4.0)	13.8 (6.4)	3.6	80.9***	0.37
Minimal pairs	20	16.1 (3.1)	17.5 (2.4)	15.9 (4.0)	18.5 (2.4)	0.5	10.9***	1.1
Initial phoneme deletion	12	1.8 (1.9)	5.8 (3.2)	1.5 (1.8)	5.9 (3.3)	0.04	67.1***	0.15
Digit span		4.8 (1.2)	5.0 (1.4)	3.7 (0.6)	3.9 (0.8)	23.4***	0.7	0
Span for words		3.4 (0.9)	4.0 (0.8)	3.4 (0.6)	3.9 (0.9)	0.07	9.4**	0.13
Span for nonwords		2.1 (0.9)	2.6 (0.7)	2.1 (0.3)	2.3 (0.7)	1.1	5.0*	0.8
Figure reproduction	12	5.0 (2.3)	5.8 (2.7)	5.6 (2.1)	7.6 (1.9)	7.0**	9.5**	1.7
Embedded figures	5	2.2 (1.4)	3.2 (1.5)	1.7 (1.2)	2.7 (1.5)	3.3	12.8***	0
Counting dots	4	3.1 (1.1)	3.6 (0.6)	2.5 (1.0)	3.3 (0.8)	5.3*	11.2***	0.3
Counting backwards	1	0.35 (0.48)	0.48 (0.51)	0	0.68 (0.48)	0.4	18.7***	8.6**
Word list recall	12	6.3 (1.6)	7.7 (1.7)	5.5 (1.4)	6.2 (1.6)	11.7**	10.4**	1.2

Note. Asterisks denote significant levels as follows: *$p < .05$, **$p < .01$, ***$p < .001$.

age-group and reading score (from zero to 16, instead of the dichotomous 0/1 reading group) as explanatory variables. The latter analyses showed the same results as Table 2, with only one difference: three additional tasks showed significant age-group effects, rhyme judgment ($p = .03$), phonological fluency ($p = .003$) and embedded figures ($p = .03$), with better performance in adults (note that these three tasks have F-values equal or greater than 3 in Table 2).

Table 3 shows the final result of regression analyses with backwards selection procedure, with dependent variable either the reading score (Table 3A, linear regression) or the reading group (Table 3B, logistic regression), and initial explanatory variables all the cognitive scores. In the linear regression, six cognitive scores were selected. It is noteworthy that the coefficient of two of the scores, digit span and word list recall, is with opposite sign than the coefficient of the remaining four. In the logistic regression, only four of the above six scores were selected: phonological fluency, initial phoneme deletion, visual recognition, and (with opposite sign) digit span. On the basis of these four scores, 86.8% of the subjects can be classified correctly as readers or nonreaders.

Letter and digit knowledge were examined in adults only. In Group 2 ($n = 29$), all subjects were able to name the 10 digits, 75% of them named correctly the 10 letters, and the remaining 25% made only 1 or 2 errors. In Group 1 ($n = 69$), degree of letter knowledge varied from zero (1 subject) to 10 (21 subjects, 30.9%), of digit knowledge from zero (3 subjects) to 10 (46 subjects, 67.7%) and overall, digits were better known than letters (paired t test = 4.7, $p < .001$) Only two tasks were significantly related to letter naming in Group 1: phonological fluency (Pearson $r = .44$, $p = .002$; Spearman $R = .49$, $p < .001$) and initial phoneme deletion (Pearson $r = .33$, $p = .007$; Spearman $R = .34$, $p = .005$). It is worth noting that the correlation coefficient between degree of letter knowledge and repetition of long nonwords or span for short nonwords was very close to zero ($r = .003$, $p = .98$; $r = -.05$, $p = .68$ respectively).

Table 3. Stepwise regression analyses

Task	b	SE(b)	F value	p
A. Linear Regression. Dependent variable: reading score				
Oral repetition long nonwords	.29	.14	4.4	.04
Visual Recognition	.20	.08	5.8	.02
Phonological fluency	.35	.06	30.3	<.001
Initial phoneme deletion	.61	.15	16.6	<.001
Digit span	−.88	.29	9.3	.003
Word list recall	−.48	.22	4.7	.03
B. Logistic Regression.Dependent variable: reading group (0 or 1)				
Visual Recognition	−.24	.07	10	.001
Phonological fluency	−.25	.07	14.8	.0001
Initial phoneme deletion	−.41	.13	10.6	.001
Digit span	.50	.24	4.5	.03

Note. Stepwise regression procedures with backwards selection of the explanatory variables (initial step: all 18 cognitive scores). b: coefficient; SE(b): standard error of the coefficient; F-value and significance level.

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Finally, trying to give a global view of the 171 correlations between the 19 scores (including reading), a principal component analysis was performed in the total sample ($N = 138$). Five factors were automatically retained (i.e., with eigenvalues greater than 1) and Table 4 shows them after varimax rotation. Factor 1 is a "reading" factor, generated by the reading score and the two strongly reading-dependent tasks, phonological fluency and initial phoneme deletion. Factors 3 and 4 are clearly verbal. Factor 3 is "phonological verbal," including all the oral repetition tasks and span for nonwords. Factor 4 is "semantic verbal," generated mainly by digit span, with relatively high loadings of semantic verbal fluency, span for words and word list recall. Factor 5 includes the two counting tasks, but rhyme judgment and embedded figures also had relatively high loadings on this factor. Factor 2 includes the two visual memory tasks (i.e., visual recognition and figure reproduction), however its meaning is less clear, as minimal pairs phonetic discrimination and word list recall also load on it.

DISCUSSION

Delimitation of the Groups

A comparison between illiterates and semiliterates, all from the same region of Brazil, guarantees a degree of constancy in the sociocultural background for all participants. A limitation of many previous studies in illiterates is that illiteracy was not measured directly, but rather its definition was based either on self-report or on the (quasi)-absence of schooling. Manly et al. (1999) for instance, recruit illiterates on self-report first, and try to propose a better definition of their illiterate group using the result of a phonological fluency task second (i.e., the true illiterates would be those for whom the phonological fluency task is impossible). In the present study we used a simple reading task of 16 short words presented in upper-case letters to differentiate, among the self-referred illiterates, the complete illiterates from the other subjects. Results were not substantially different when reading performance was considered as a dichotomous variable (i.e., zero *vs.* 1 or more words read) or as a continuous variable (i.e., from zero to 16). In the latter analysis *p*-values for reading performance and age-group were lower than in the first, however the pattern of the results was the same. This is not astonishing given the important proportion of subjects who were unable to read even one word.

In adults, there was a significant but rather weak association between literacy and school attendance (completely absent or not). Presence of school attendance had no significant effect on cognitive performances (after adjusting for literacy), except for one subtest (phonological fluency). This finding may be related to the uncertainty of the teaching content during a short school attendance period. It could be argued that subjects who remained completely illiterate despite some school attendance are different from those who read one or more words despite complete absence of school attendance (e.g., the first less intelligent, the latter more intelligent). However, the data do not support this hypothesis, as no significant interaction was observed between schooling and literacy.

All children were between 7 and 8 years of age, but a detailed analysis showed that nonreaders were closer to 7 years and readers closer to 8 years. This age difference may contribute to increasing the differences in performance between readers and nonreaders. However, when age was partialed out, the reading group effect in children remained significant for most tasks.

Table 4. Principal Component Analysis (varimax rotation) of the correlation matrix of the 19 tasks

Task	F1	F2	F3	F4	F5
Oral repetition					
Short words	−0.07	0.32	*0.75*	−0.22	0.10
Short nonwords	0.07	0	*0.78*	−0.11	0.02
Long words	0.10	0.42	*0.46*	0.14	−0.32
Long nonwords	0.36	0.20	*0.64*	0.26	0.14
Semantic fluency	0.20	0.37	−0.01	*0.45*	0.02
Visual Recognition	0.19	*0.65*	0.08	0.01	0.11
Rhyme identification	0.35	0.19	0	0.30	*0.49*
Phonological fluency	*0.82*	0.19	0.04	0.14	0.08
Minimal pairs	0.09	*0.63*	0.13	−0.01	0.16
Initial phoneme deletion	*0.81*	0.21	0.10	0.13	0.16
Digit span	−0.09	−0.10	0.01	*0.83*	0.19
Span for words	*0.51*	−0.03	0.27	*0.49*	0.01
Span for nonwords	0.21	−0.07	*0.57*	0.34	0.13
Figure reproduction	0.16	*0.66*	0.18	−0.09	0.17
Embedded figures	0.11	0.41	0.01	0.20	*0.48*
Counting dots	−0.01	0.04	0.22	0.09	*0.73*
Counting backwards	0.30	0.27	−0.04	−0.03	*0.61*
Word list recall	0.13	*0.49*	−0.17	*0.43*	0.06
Reading	*0.81*	0.23	0.19	−0.18	0.16

Note. Five factors : 58.1% of the variance.

Literacy Effect in Children and Adults

Literacy effect was remarkably similar in adults and in children. The only exception (i.e., significant Age-Group × Literacy Group interaction) was the counting backwards task, where the effect of literacy was stronger in children than in adults, due to complete failure at this task by nonreading children.

Age Group Effects

Children succeeded better than adults at the two first tasks of the battery, namely, oral repetition of short words and nonwords. For short nonwords this was due mainly to the higher performance of children of Group 4. However, this age-group difference disappeared for the two following tasks which also involved oral repetition (of long items). To explain this, an adaptation effect can be hypothesized. The situation of cognitive testing and especially the request for

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oral repetition is probably perceived as more strange and unusual in unschooled adults than in school children. Also, the higher performance of children compared to adults for figure reproduction was mainly due to the higher performance of children of Group 4, most of them in Grade 2. The opposite pattern, adults better than children, was observed for semantic verbal fluency, list recall, counting dots and digit span. This suggests that early schooling is probably not a major factor for good performance on these tasks.

Phonetic Discrimination, Phonological Segmentation and Phonological Memory

Nonreaders made more errors than readers at minimal pairs phonetic discrimination, however this task was succeeded at 80% correct in nonreaders. The good performance of illiterates on phonetic discrimination of minimal pairs is in accordance with previous investigations (Adrian et al., 1995; Scliar-Cabral et al., 1997). Adrian et al. (1995), for instance, observed a mean percentage of correct responses greater than 95% in 15 illiterates using 16 pairs of CV syllables with the critical difference always on initial *C*. The high level of success of illiterates on phonetic discrimination tests, together with the absence of any reading group effect for oral repetition of short words and nonwords, suggest that illiterates do not present difficulties at the perceptual level.

The two tasks involving speech segmentation abilities, that is, phonological fluency (in accordance with Manly et al., 1999) and initial phoneme deletion, were clearly the best discriminators between readers and nonreaders. The performance was very poor in nonreaders at these tasks, despite the long instructions and multiple examples (see methods). At initial phoneme deletion, items with cluster onset (CCV. . .) were particularly difficult: for instance, only 1 subject of Group 1 and none of Group 3 succeeded *prato*/*rato* (*vs.* 14% and 32% in Group 2 and 4, respectively). This finding is in accordance with previous reports (Morais et al., 1986, 1987, 1988; Read et al., 1986; Reis & Castro-Caldas, 1997). Morais et al. (1986) for instance, showed that illiterates, compared to ex-illiterate adults, displayed inability to delete the initial consonant of an utterance and to deal with phonetic segments in a detection task; their performance was better in a task of rhyme detection, as in the present study (see also Duncan et al., 1997; Muter et al., 1998).

Repetition of long nonwords and span for nonwords are generally considered as phonological memory tasks involving the phonological loop (Baddeley, 1986). In accordance with several previous reports (Bishop et al., 1996; Content et al., 1986b; Kamhi & Catts, 1986) phonological segmentation ability and phonological memory appear as distinct cognitive processes in the present study: they loaded on different factors in principal component analysis, and also, in adult nonreaders, letter knowledge was correlated with phonological segmentation but not with phonological memory.

Scores in all groups decrease when subjects are asked to repeat long nonwords, instead of long words, or long nonwords instead of short nonwords; also their span for meaningless syllables (presentation at a rate of 1 syllable/s) is much lower than their span for words. Higher digit than word span is observed in adults only. Among oral repetition tasks, only repetition of long nonwords was significantly associated to literacy. This latter observation is in accordance with a previous brain activation study (oral repetition of three-syllable words and nonwords) using PET, showing that nonword repetition was less successful in illiterates than literates and activated different brain regions in the two groups of subjects (Castro-Caldas et al., 1998; Petersson et al., 2000). Also, brain activation was similar for words and nonwords in literates but not in illiterates. These findings could be interpreted as being in favor of a more automatic processing of nonword repetition in literates (e.g., subcortical activations, which were not observed in illiterates) than in illiterates (e.g., prefrontal activations, which were not observed in literates).

It might be worth considering that the cognitively relevant distinction between words and nonwords cannot be based on the content of the best dictionaries but on the subject's knowledge. For instance, some Portuguese words listed in the Methods section might sound like nonwords to some readers of the present paper (e.g, *musgo*, *gleba*, *passarinho*, or *jardinagem*; of course not *americano*). In this sense, a nonword is an early phase of a word, and a young child asking, "What does this mean?" is trying to transform a nonword into a word. This view is in accordance with that of the phonological loop as a language learning device (Baddeley et al., 1998), as well as with the observation of a strong relation between nonword repetition and vocabulary growth (Gathercole & Baddeley, 1989, 1990; Lewis et al., 2000). In addition, reading acquisition includes the mastery of a procedure allowing the automatic production of words but also (especially in the early phase of literacy) nonwords intended to become words. Accordingly, the literate, compared to the illiterate, is an individual with specific training in (or mastering a software for) the automatic production of nonwords.

According to the description of the phonological loop by Baddeley (1986), rehearsal would be mandatory in order to obtain a score of 3 or more on "span of short nonwords": The capacity of the phonological short-term storage, which automatically holds incoming auditory speech material in a phonological code, is less than 2 s and the short nonwords were presented at a rate of 1/s each. Given the scores obtained by the participants of the present study, it can be concluded that many of them do not use rehearsal at all or do not use it efficiently. There is evidence that European or North American children as young as 4 to 5 years of age do not use rehearsal, but that older children do (Bjorklund & Douglas, 1997; Flavell et al., 1966; Ornstein et al., 1975). The low performance of the Brazilian children 7 to 8 years of age at span for short nonwords and nonword repetition suggests that culturally based verbal activities in young

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European or North American preschool children might favor rehearsal.

Phonological Verbal Tasks and Semantic Verbal Tasks

Another point which appears in the present results is the clear distinction between phonological verbal tasks and semantic verbal tasks, which generate different factors in the principal component analysis. Furthermore, digit span and word list recall appear with coefficients of opposite sign than the speech segmentation tasks in the analyses selecting tasks which distinguish the best between readers and nonreaders. In the present study, adult nonreaders had better digit span than first- and second-grade school children and also showed better knowledge of digits than of letters. Given their low phonological memory, it can be assumed that they use this knowledge during the simple (forward) digit span task, and succeed by means of non-phonological strategies. That is, they refer to the meaning of the numbers to perform this task and not so to subvocal rehearsal.

Visual Tasks

The reading group effect was significant for all the visual tasks used in this study, including counting dots, which was succeeded at a relatively high level by adult illiterates (*M* percent correct: 77.5%), in accordance with previous reports (Deloche et al., 1999). The result of the logistic regression showed that visual retention of nonsense figures was one of the tasks selected for permitting the best distinction between readers and nonreaders. A different version of the embedded figures (especially with pointing to rather than drawing responses) was used by Kolinsky et al. (1987) in illiterates, ex-illiterates, preschool and school children. These authors found that preschoolers, illiterates and ex-illiterates performed in the same way, that is, worse than second-grade children. They concluded that instruction provided in the first school years probably includes activities that render the emergence of the ability to find deeply embedded segments necessary. There is a discrepancy between Kolinsky et al. (1987) and the present study concerning the presence of a difference between illiterates and semiliterates, most likely due to differences in the definition of the semiliterates and the nature of the task.

It is possible, as Kolinsky et al. (1987) seem to suggest, that the early school activities potentially critical for later good performance on visual tasks are not exclusively reading activities. In a previous study with the same visual retention task (Figure 1), 138 non-reading French preschoolers aged 4 to 5 years old obtained a score of 16.4 (*SD* = 4.0) which is the same performance as the 7 to 8 year old Brazilian readers (Jambaqué et al., 1993a, 1993b). Why are French preschoolers so successful at recognizing nonsense figures as compared to Brazilian unschooled adults or older Brazilian children? Contrary to Brazilian children, almost all French children start attending preschool at the age of 3 and one of the favorite activities in French preschools is scribbling-drawing. Some of these nonsense figures of the memory battery of Signoret (1991), resemble preschoolers' drawings (Figure 1). A tentative suggestion is that the scribbling-drawing experience is a critical factor for this task. In other words, the experience of producing similar figures probably improves their visual recognition.

Combined Evidence from Children and Illiterate Adults for the Literacy Dependent Nature of Some Cognitive Processes

As already mentioned in the introduction, a task that depends on reading acquisition should (1) be successfully performed by literates and impossible or almost impossible to execute by illiterates; and (2) present a dramatic increase of performance in children during the period of reading acquisition. Phonological fluency, which is a task involving phonological awareness, shows a dramatic increase at about 6 to 6.5 years of age (Kremin & Dellatolas, 1996), which is the age of reading acquisition for most French schoolchildren. Furthermore, there is converging evidence that phonological awareness is a strong correlative of word-level reading (e.g., Wagner et al., 1997). Thus, both evidence from illiterates and from studies of reading acquisition in children lead to the conclusion that tasks involving phonological awareness are literacy dependent. Such a conclusion does not imply that intensive artificial training without the use of written material cannot improve phonological awareness in some illiterate individuals (Morais et al., 1988) or in young preschoolers (Content et al., 1986a; Lundberg et al., 1988; Schneider et al., 1997).

As far as tasks exploring short-term verbal memory are concerned, there is no clear developmental evidence of a jump in performance at reading acquisition. This point needs further longitudinal investigation in children. For nonword repetition, there are reports showing that very young children are able to repeat nonwords fairly well. For instance, a selected sample of 54 children aged 3 years old who were asked to repeat trisyllabic nonwords obtained a 52.5% correct score (Gathercole & Adams, 1993), which is about the same performance as that of the adult nonreaders in the present study for nonwords of three to five syllables (58.7% correct). Also, the normative data of nonword repetition obtained by Gathercole et al. (1994) do not show any jump at the reading acquisition age, but a regular increase in performance from 4 to 8 years of age. As already noted, this task could be dependent on environmental factors (e.g., preschool or family related verbal activities) other than literacy. Another possibility is that in literates the reading experience activates the phonological loop; in illiterates the absence of such activation could lead to a decrease in the efficiency of the phonological memory from childhood to adulthood (see also Frost, 1998).

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Concluding Remarks

The above results emphasize the activity-dependent character of many cognitive tasks, which might be overlooked in cognitive studies focusing on literate individuals exclusively. Ingvar (1998) reports a brain activation (repetition of words and pseudowords) study comparing both dyslexic and illiterate subjects to literate controls. Findings in both dyslexic and illiterate repeating pseudowords were in favor of an absence of automaticity (prefrontal activation not observed in controls, absence of subcortical activation observed in controls), which according to Ingvar might demonstrate a poorly trained language system. Geary (1995) proposed to classify cognitive processes into primary abilities (i.e., those selected in evolution and found in similar forms across cultures) and secondary abilities (i.e., those that are shaped by one's particular culture, and especially formal schooling). Speech perception or elementary counting is probably in the first category and metaphonological skills probably in the second, although a great deal of uncertainty persists for most cognitive processes.

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