



Literature Review

Illiteracy: The Neuropsychology of Cognition Without Reading

Alfredo Ardila^{1,*}, Paulo H. Bertolucci², Lucia W. Braga³, Alexander Castro-Caldas⁴, Tedd Judd⁵, Mary H. Kosmidis⁶, Esmeralda Matute⁷, Ricardo Nitrini⁸, Feggy Ostrosky-Solis⁹, Monica Rosselli¹⁰

¹Department of Communication Sciences and Disorders, Florida International University, Miami, FL, USA

²Department of Neurology and Neurosurgery, São Paulo Universidade Federal de São Paulo, São Paulo, Brazil

³SARAH Network, Brasilia, Brazil

⁴Portuguese Catholic University, Lisbon, Portugal

⁵Seattle Pacific University, Seattle, WA, USA

⁶School of Psychology, Aristotle University of Thessaloniki, Thessaloniki, Greece

⁷Universidad de Guadalajara, Guadalajara, Mexico

⁸University of San Paulo, Sao Paulo, Brazil

⁹National Autonomous University of Mexico, Mexico DF, Mexico

¹⁰Psychology, Florida Atlantic University, Davie, FL, USA

*Authors are presented in alphabetical order pointing to a similar contribution, except that the project was initiated and coordinated by the first author.

Corresponding author at: Department of Communication Sciences and Disorders, Florida International University,

AHC3-431B, Miami, FL 33199, USA. Tel.: +1-305-551-7975.

E-mail address: ardilaa@fiu.edu (A. Ardila).

Accepted 17 September 2010

Abstract

Illiterates represent a significant proportion of the world's population. Written language not only plays a role in mediating cognition, but also extends our knowledge of the world. Two major reasons for illiteracy can be distinguished, social (e.g., absence of schools), and personal (e.g., learning difficulties). Without written language, our knowledge of the external world is partially limited by immediate sensory information and concrete environmental conditions. Literacy is significantly associated with virtually all neuropsychological measures, even though the correlation between education and neuropsychological test scores depends on the specific test. The impact of literacy is reflected in different spheres of cognitive functioning. Learning to read reinforces and modifies certain fundamental abilities, such as verbal and visual memory, phonological awareness, and visuospatial and visuomotor skills. Functional imaging studies are now demonstrating that literacy and education influence the pathways used by the brain for problem-solving. The existence of partially specific neuronal networks as a probable consequence of the literacy level supports the hypothesis that education impacts not only the individual's day-to-day strategies, but also the brain networks. A review of the issues related to dementia in illiterates is presented, emphasizing that the association between the education level and age-related cognitive changes and education remains controversial. The analysis of the impact of illiteracy on neuropsychological test performance represents a crucial approach to understanding human cognition and its brain organization under normal and abnormal conditions.

Keywords: cognitive abilities; dementia; education; illiteracy; neuropsychology tests; schooling

Introduction

Illiterates represent a significant proportion of the world's population. In 2000–2004, close to one-fifth of the world's population was illiterate: 13% of men over 15 years of age and 23% of women (UNESCO, 2005). Only a few centuries ago, reading and writing abilities were simply uncommon among the general population. Writing has only a 6,000-year history; for about 95% of our history, *Homo sapiens* were preliterate. We hypothesize that the acquisition of literacy skills has somehow changed the brain organization of cognition.

Table 1. World-wide illiteracy rate during 1970–2015 (projected) (UNESCO, 2005)

Year	Illiteracy rate (%)
1970	37
1980	30
1990	25
2000	20
2005	18
2010	16
2015	15

When studying illiteracy, the most obvious factor is the generational effect found in most countries (Table 1). Elders in most societies generally have a lower-educational level than their children and grandchildren. Moving back in history, the duration of education is progressively shorter on average.

Reasons for Illiteracy

Two major classes of reasons account for illiteracy:

- (a) *Social reasons.* Illiteracy may be due to the absence of schools, social disapproval of literacy, child labor, and/or poverty.
- (b) *Personal reasons.* For a subgroup of illiterates, learning difficulties, mental retardation, significant motor and/or sensory problems, early central nervous system pathologies, and similar conditions may account for their failure to learn to read despite adequate exposure to education.

There is a significant diversity in literacy rates among countries, from 99% (e.g., Japan, Canada, and Finland) to below 20% (e.g., Mali, Niger, and Burkina Faso; [International Adult Literacy Survey, 1998](#)). Illiteracy due to personal reasons (learning difficulties, mental retardation, significant motor and/or sensory problems, early central nervous system pathologies, and similar conditions) likely accounts for only a small percentage of illiteracy in industrialized countries and potentially somewhat higher in poor countries with increased prevalence of early central nervous system pathologies.

These two main classes of reasons for illiteracy present potential confounds for research. Populations that are illiterate for social reasons are likely to differ in important ways other than literacy from the schooled, literate populations that have been the subjects of most research in cognitive psychology (prototypically U.S. college students). In general, illiterates are more likely to be of a lower socioeconomic class, they may have a variety of health problems, they may have less exposure to media of communication, and they may have limited experience with testing and, thus, distrust of researchers, among other differences. Those who are illiterate due to personal reasons are quite likely to have atypically functioning brains and cognitive systems.

One way around this problem is to compare individuals to themselves rather than to other populations. Studies of adults before and after they acquire literacy can help to control for these factors and can furthermore control, to a large extent, for the effects of development. An alternative is the sample used in a series of Portuguese studies (e.g., [Reis & Castro-Caldas, 1997](#)) comparing sisters, one of whom is literate and the other illiterate due to social demands placed on the eldest daughter to take on the responsibility of child care of younger siblings.

Why Is It Important to Study Illiteracy?

Different fundamental and practical reasons to study illiteracy could be distinguished ([Olson & Torrance, 2009](#)). There are, however, at least four important reasons to study the neuropsychology of illiteracy:

- (a) *(Neuro)cognitive Theory.* The study of illiteracy can contribute to a broader understanding of the organization of cognition.
- (b) *Clinical Neuropsychology.* The analysis of illiteracy can help to discern the influence of both literacy and schooling on cognitive test performance. Educational variables significantly influence performance on a diversity of neuropsychological tests ([Lezak, Howieson, & Loring, 2004](#)).

- (c) *Teaching Literacy*. Understanding the basic brain mechanisms, subserving cognition in illiterates may contribute to improving reading and writing teaching methods for illiterate adults (e.g., Ardila, Ostrosky & Mendoza, 2000).
- (d) *Literacy and Neuropsychological Functioning*. Exploring the effects of education on literacy and neuropsychological functioning.

This article will focus primarily on those aspects of the study of illiteracy most pertinent to the neurocognitive theory, and clinical neuropsychology, as well as the analysis of the effects of education on neuropsychological functioning.

Conceptual Issues in the Study of Illiteracy

A fundamental conceptual presumption of neuropsychology is that the potential for basic cognitive abilities, and correspondingly, their brain mechanisms, are universal and inherent for any human being with normal brain development, regardless of the specific language spoken and one's environmental conditions. Literacy (i.e., extending spoken language to a symbolic visual representation) plays a major role in mediating cognitive processes. Luria (1931, 1933, 1966, 1973) and Vygotsky (1934/1978) developed the concept of extracortical "organization of higher mental functions" to account for the interaction of biological and cultural factors in the development of human cognition (Kotik-Friedgut & Ardila, 2004).

Historical Development of Writing and Schools

Historically, writing is thought to represent an evolution of painting, whereas painting is the evolution of representation capabilities, intentional gestures, and visually guided movements (No author, 1993). Wall paintings appeared in Europe during the Paleolithic era, some 30,000–35,000 years ago (Childe, 1936) representing mainly animals, but also people, instruments, and environmental conditions. Prewriting evolved with the gradual standardization of paintings to represent specific elements (i.e., a standard bird reflected the general category "bird"). This suggests an emerging human ability to imitate complex behavioral patterns (Blackmore, 1999). Thus, writing began with concrete pictograms that reflected realities accessible to the senses, particularly to vision (Lecours, Peña-Casanova, & Ardila, 1998). These pictograms further evolved and became abstract, progressively diverging from concrete representation toward representation of the phonological structure of language. Today's simple and straightforward alphabetic systems in fact are the outcome of a very long and complex process that took many centuries to reach its present form (Haarmann, 1991). The earliest generally accepted beginning of writing in human history was in Sumer (contemporary Iraq) about 53 centuries ago (Schmandt-Besserat, 1996; but see Haarmann, 2008, regarding earlier Danube script; and Li, 2003, regarding earlier Chinese). Symbols (graphemes) reflected the meaning of words, so these original writing systems are regarded as logographic. Graphemes representing sounds (syllables) appeared about 4,000 years ago in Phoenicia (Sampson, 1985), and graphemes representing phonemes appeared even later in Greece. Over the course of this transition, several languages developed with a coexistence of ideograms and phonological representations, such as cuneiform writing and the Egyptian hieroglyphic system (Haarmann, 1991). Writing systems evolved independently in pre-Columbian civilizations in Central America, most notably Mayan writing (Coe & Vanstone, 2005). The sequence of the evolution of writing in consequence was:

Drawings—> *pictograms*—> *logograms*—> *syllabic graphemes*—> *phonemic graphemes*

Several existing writing systems use a mixture of logograms, syllabic graphemes, phonemic graphemes, and extraphonemic markers such as capitalization, punctuation, and spatial layout. The relative emphasis on each level of representation varies from system to system. For example, the Chinese system is predominantly based on logograms with some phonemic graphemes, and extraphonemic markers, and with an alternate phonemic grapheme system available. Likewise, the above sequence is not meant to imply that any one system is more efficient or superior.

Thus, initial writing (or rather, prewriting) was a visuoconstructive ability (i.e., representing external elements visually), and only later did it become an ideomotor praxis ability (i.e., making specific learned and fixed sequences of movements with the hand to create a pictogram—a standardized representation of external elements). Still later, writing became a linguistic ability (i.e., associating the pictogram with a word, and further analyzing the word into its constituent sounds; Ardila, 2004). It is not surprising that three major disorders in writing can be observed as a result of brain pathology: Visuoconstructive (spatial or visuospatial agraphia: Impairment in letter, word, and text formation due to disturbed visuospatial skills), ideomotor (apraxic agraphia: Selective disorder of letter formation caused by ideomotor apraxia), and linguistic (aphasic agraphia: Writing impairment due to a language disturbance; Table 2). The evolution of writing has continued with the development

Table 2. Representational forms of writing and corresponding cognitive skills

Representational form	Historical example	Neurocognitive skill	Form of agraphia
Drawings pictograms	Cave paintings Egyptian hieroglyphics	Visuoconstructive ability	Visuospatial
Logograms	Sumerian	Ideomotor praxis	Apraxic
Syllabic graphemes	Japanese Kana	Linguistic ability	Aphasic
Phonemic graphemes	Spanish		

of different technical instruments for writing: The stylus for etching in clay, feathers, the pencil, the typewriter, and the computer, as well as the development of different writing styles (e.g., handwriting, script, uppercase, lowercase) and different media (e.g., clay, papyrus, paper, computer screens). Moreover, images first and writing later allowed the possibility of representation; thus, they enable humans to think and act beyond their immediate needs (Suddendorf & Corballis, 1997) and promote abstract thinking.

Defining Literacy

The definition of literacy is not definitive, nor is there an overt cut-off point; consequently, intermediate stages, such as semiliteracy and functional illiteracy, are often recognized. UNESCO (http://www.uis.unesco.org/i_pages/indspec/TecSpe_literacy.htm) defines adult illiteracy as the percentage of the population aged 15 years and over who cannot both read and write a comprehensible short simple statement on their everyday life. Literate does not necessarily mean schooled, even though literacy is usually highly associated with formal schooling. Reading can be transmitted from parents or tutors to children without formal school attendance (Berry & Bennett, 1992; Scribner & Cole, 1981). Under normal conditions, reading is not learned by simple exposure, even though illiterates can develop some ability to holistically recognize a few highly frequent words, such as the name of their country, and the name of some popular commercial products (Goldblum & Matute, 1986). Extremely infrequently, the ability to read can be acquired without any deliberate training (so-called “hyperlexia” usually associated with autism, Martos-Perez & Ayuda-Pascual, 2003; Nation, 1999).

The degree to which contemporary illiterates are confined to access to immediate sensory information probably also reflects the degree to which they are confined in their access to various media of information and communication and, possibly, also to formal education. Da Silva, Petersson, Faisca, Ingvar, and Reis (2004) demonstrated in Portugal that whereas literates and illiterates perform equally well on a fluency task asking for elements known through direct sensory information (“items that can be found in a supermarket”), the two groups differed on a semantic fluency task requiring naming animals. In contrast, literate people can name dinosaurs, camels, or kangaroos, evidently unknown in Portugal, but learned by reading; whereas illiterates can only name cats, dogs, horses, and other animals existing in the immediate surrounding environment and known through direct sensory experience. When the information is related to real life and direct experience, it can be considerably easier to understand. Thus, for the illiterate person, it is easier to repeat a word than to repeat a pseudoword (Castro-Caldas, Petersson, Reis, Stone-Elender, et al., 1998; Kosmidis, Tsapkini, & Folia, 2006) and to remember objects presented to them visually than word lists (Folia & Kosmidis, 2003).

The impact of literacy is reflected in all spheres of cognitive functioning. Learning to read reinforces certain fundamental abilities, such as verbal and visual memory, phonological awareness, executive functioning, and visuospatial and visuomotor skills (Bramão et al., 2007; Matute, Leal, Zarabozo, Robles, & Cedillo, 2000; Petersson, Reis, Askelof, Castro-Caldas, & Ingvar, 2000; Petersson et al., 2001). It is not surprising that illiterate people underachieve on cognitive tests that assess these particular abilities. Furthermore, attending school also reinforces certain attitudes and values that may speed the learning process, such as the attitude that memorizing information is important or that knowledge is highly valuable; that learning is a step-by-step process moving from the simple to the more complex. It has been emphasized that schooling improves an individual’s ability to explain the basis of performance in cognitive tasks (Laboratory of Comparative Human Cognition, 1983). Whether a fundamental aim of education, or a by-product, the fact remains that all schools and schooling, regardless of their location, have a common influence on those who go through the system, namely, they train students and reinforce certain values. Hence, school may be seen as a culture unto itself, a transnational culture, and the culture of school.

School not only teaches, but also helps in developing certain strategies and attitudes that will be useful for future learning. Cibrowski (1979) observed that schooled and nonschooled children can learn a new rule equally well, but once acquired, schooled children tend to apply it more frequently in subsequent similar cases. School attendance, however, does not mean that educated people simply possess certain abilities that less-educated individuals lack. It does not mean that highly educated people have the same abilities as less-educated individuals, plus something else (Ardila, Ostrosky & Mendoza, 2000). The

individual with no formal education most likely has acquired knowledge, skills, and values that educated people have not. Nonetheless, formal cognitive testing evaluates those abilities in which educated people were trained; therefore, it is not surprising that they will outperform those with no formal education. In fact, one study demonstrated that once the effects of education and literacy were separated from each other, some types of language processing were enhanced by any level of literacy, whereas others continued to improve with an increasing level of education (Kosmidis et al., 2006). It is noteworthy that the educational level has a substantial relationship with performance on some cognitive tests, but is not systematically related to everyday problem-solving (functional criterion of intelligence; Cornelious & Caspi, 1987). As a matter of fact, when functionally oriented tests, such as the Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 1985) and the Fuld Object Memory Evaluation (Fuld, 1980), are administered to people with low education, no significant differences with high-educated people have been observed (Yassuda et al., 2009).

Although schooling represents, in some respects, a transnational culture, that culture is not uniform. Literacy and numeracy are almost universal as the major focus of primary education, but beyond that the qualities of the educational experience vary considerably. Wealthy educational systems are likely to have low student:teacher ratios, abundant teaching materials, extensive communication outside the school (Internet, field trips, visiting instructors), ancillary services (psychologists, therapists, parent services), and instruction in a wide variety of subjects and skills. Schools with less funding often lack these resources. Manly (2006) has demonstrated a relationship between school expenditure and neuropsychological test performance.

School qualities depend on much more than funding. Schools vary greatly in their formal curricula and also in unwritten characteristics. There is much variability in schools' behavioral expectations and institutional cultures, as well as in their emphasis on bilingualism, visual-spatial skills, abstract reasoning, problem-solving, speeded performance, social skills, individualism, collectivism, moral values, and religious instruction, among other themes. These varying characteristics can reasonably be expected to have an impact on neuropsychological test performance, and this impact is not likely to be entirely linear nor unifactorial, but these relationships have not yet been systematically explored.

Contemporary illiteracy is not the same as historical preliterate. Literacy facilitates a number of cognitive technologies that may have replaced preliterate cognitive skills. Those preliterate cognitive skills may require intact preliterate societies and may be extinct or vestigial in the contemporary world and in contemporary marginalized illiterates. A functioning illiterate or preliterate society may be required to foster the full flowering of such skills. For example, there are many cultural traditions of bards who memorize long poems and pass them on through generations (Lord, 1995). We tend to think of illiterates as concrete thinkers, yet the fables, proverbs, myths, idioms, and even the metaphors built into the very structure of our languages that have come to us from largely preliterate societies from millennia ago are often quite abstract.

Literacy Versus Schooling

Very important cognitive consequences of learning to read and write have been suggested: Changes in visual perception, logical reasoning (i.e., executive functions), remembering strategies (Laboratory of Comparative Human Cognition, 1983), as well as access to lexical storage and explicit phonological processing (Kosmidis et al., 2006) and improved working memory. Schooling appears to influence formal operational thinking (Laurendeau-Bendavid, 1977) and functional brain organization (Castro-Caldas, Petersson, Reis, Stone-Elander, et al., 1998; Ostrosky-Solis, Ramirez, Lozano, Picasso, & Velez, 2004) and to reinforce particular attitudes and values related to learning. Conversely, training these abilities may make it easier to learn to read and write. Interestingly, adults who received training in those abilities in which illiterates significantly underscore (e.g., verbal memory, phonological abstraction, etc.) showed a significant improvement in neuropsychological test scores and a facilitation in their learning-to-read process (Ostrosky-Solis et al., 2003).

Literacy without schooling: The Vai. Scribner and Cole (1981) attempted to separate the effects of literacy from the effects of formal schooling by studying Vai people in Liberia who were literate in the Vai script, but who had not attended school. Vai people have their own script. The script is taught at home, rather than school, allowing the researchers to separate school-based education from literacy. Indeed, there are three educational systems in the Vai culture: (a) Traditional socialization—the bush school, taught by men for boys, and by women for girls; (b) English schooling—much like American schooling, and (c) Quranic schooling—conducted in Arabic. They found that there were no general effects of literacy on a battery of cognitive tests, but performance on some tests was related to particular features of the Vai script and literacy practices. Scribner and Cole proposed that there are definite cognitive skills associated with literacy, but not necessarily with classroom learning. And these cognitive skills are dictated by each culture and situation. Berry and Bennet (1989) carried out a partial replication of this study among the Cree of Northern Ontario.

Comparison of groups with low and high education

Kosmidis, Tsapkini, Folia, Vlahou, and Kiosseoglou (2004) and Kosmidis et al. (2006) attempted to disentangle the effect of education from literacy in a sample of urban dwellers (illiterates, low-education literates, and high-education literates). They found that education influenced lexical decision-making, concluding that the greater the amount of education, the more effective access to, and, perhaps, the greater the size of the lexical store. In contrast, literacy influenced the capacity of the phonological loop: Low- and high-education literates performed equally well on pseudoword repetition, and better than illiterates. Therefore, they concluded that literacy influences the effectiveness of the direct route from the auditory analysis system to the phoneme level, whereas education influences lexical processing. Similarly, Kosmidis and colleagues (2004) found that semantic processing was affected by the level of education attained, whereas phonological processing depended on whether the individual had attained symbolic representation *per se* through learning grapheme–phoneme correspondence or had been exposed to formal schooling.

Neither literacy nor school attendance is a simple and linear variable. Reading ability is not only correlated with training time, but also with the idiosyncrasies of the reading system. For example, learning to read is easier in a transparent writing system (regular spelling, e.g., Spanish, German, Greek) than in an opaque writing system (irregular spelling, e.g., English, French; Paulesu et al., 2001). Furthermore, school attendance goes far beyond learning to read, write, and calculate. School provides background knowledge in many areas (geography, history, language, etc.), but also contributes to developing learning skills. In school, children are exposed to information that is neither part of their immediate environment nor part of their direct experience. They learn how to establish taxonomies of their newly learned concepts, they learn to use paper and pencil, and they use a language different from that used in their everyday life (Montiel & Matute 2006). School develops and reinforces certain cultural and socialization values by creating alternative parental and authority images; certain forms of group behavior; attitudes toward government, church, or other institutions sponsoring their education; and the process of being tested (Serpell, 1993). Children learn from their teachers, their peers, the group activities at school, and the new context.

The Illiterate Brain

Two different approaches can be used to understand the potential differences between the literate and the illiterate brain: Functional and anatomic measures.

Traditional Functional Measures: Dichotic Listening

Several studies have used dichotic listening paradigms to study the potential influence of literacy on cerebral lateralization for language (Castro & Morais, 1987; Damasio, Damasio, Castro-Caldas, & Ferro, 1979; Karavatos et al., 1984; Kosmidis et al., 2004; Tzavaras, Kaprinis, & Gatzoyas, 1981) yielding conflicting results. Some investigators reported decreased laterality for language among illiterates relative to literates (Joanette et al., 1983), others no laterality differences (Damasio, Castro-Caldas, Grosso, & Ferro, 1976; Kosmidis et al., 2004), and yet others stronger lateralization among illiterates relative to literates (Tzavaras et al., 1981). Potential reasons for the conflicting results may relate to characteristics of the stimuli used in each investigation, such as the nature of the stimuli (i.e., words, pseudowords, numbers, syllables), the phonetic and the acoustic characteristics of the sounds (i.e., stop, nasal, fricative and liquid consonants, or consonants with abrupt onset), and differences in onset and intensity of stimuli in a pair (Ahonniska et al., 1993; Castro & Morais, 1987). More recent investigations of the dichotic listening process (among literate individuals) have highlighted the role of attentional resource activity in addition to cerebral dominance for language (Reinvang et al., 1994; van Ettinger-Veenstra et al., 2010; Westerhausen & Hugdahl, 2008). Unfortunately, none of the studies of dichotic listening in illiteracy took this parameter into account. Therefore, although not informative with regard to the question of hemispheric dominance for language processing in illiterates in general, past studies on dichotic listening among illiterates highlight the need for breaking down language processing into more specific cognitive mechanisms.

Contemporary Functional Measures

Recent studies using different functional measures have demonstrated that literacy and education influence the pathways used by the brain for problem-solving. Schooled literates and illiterates show equivalent left hemisphere attenuation of cortical event-related potentials during a verbal memory task (for instance, memorizing words), but intrahemispheric differences at parietotemporal areas, suggesting that learning literacy produces intrahemispheric specialization (Ostrosky-Solis et al., 2004).

Similarly, several studies using positron emission tomography (PET) and statistical parametric mapping or functional magnetic resonance imaging (fMRI) found additional differences between schooled literates and illiterates in the brain areas activated during language-based tests (i.e., left hemisphere perisylvian area). Interestingly, in one study using repetition of words and repetition of pseudowords, these differences were much more relevant during pseudoword repetition suggesting that the inability to process phonological segmentation was the inability to activate the brain regions responsible for doing it; the only activation in words versus pseudowords that was greater in the literate than in the illiterate group was the more prominent left-sided posterior parietal activation. In particular, when masking with the activation pattern defined by the words–pseudowords contrast in literates, there was increased activation of a left inferior parietal region (BA 40) in literates compared with illiterates in words versus pseudowords. During real-word repetition, the difference was confined to a left parietal region that can be related to the process of writing (Castro-Caldas, Petersson, Reis, Stone-Elander, et al., 1998; Fig. 1). This differential activation of neural structures to real versus nonreal words suggested fundamental differences in cognitive processing based on phonological information. A subsequent replication of the aforementioned PET findings (Petersson et al., 2000) traced differences in the neuronal networks used by illiterates versus schooled literates in pseudoword repetition to the interaction between Broca's area and the inferior parietal lobe, as well as the posterior-midinsula bridge between Wernicke's and Broca's areas. Finally, education-related differences were reported in an fMRI study of the effects of education on neural activation in healthy right-handed Chinese subjects (Li et al., 2006). These differences in activation patterns emerged in the left inferior/middle frontal gyrus and both sides of the superior temporal gyrus for a silent word recognition task and in the bilateral inferior/middle frontal gyrus and limbic cingulate gyrus for a silent word and picture-naming task. It was suggested that these results indicate that the patterns of neural activation associated with language tasks are strongly influenced by education. Education appears to have enhanced cognitive processing efficiency in language tasks.

Even when their cognitive performance is equivalent, schooled literates and illiterates appear to use different brain activation patterns to perform the same task. Deloche, Souza, Braga, and Dellatolas (1999) studied healthy right-handed Brazilians (unschooled illiterates and college graduates) on a task judging the magnitude of numbers within a familiar context (e.g., 10 people in a standard-sized car, 9 students in a school: Is this a lot, average, or too little?). Both groups performed similarly well with regard to the correctness of their judgments. Functional MRI scans, however, demonstrated different brain activation patterns: The college graduates used the left hemisphere exclusively, specifically, the left frontal (BA 47), inferior parietal (BA 40), and temporal lobes (BA 42, 21, and 22). In contrast, the illiterates activated both hemispheres during the task, specifically, the temporal (BA 39, 20, and 22) and the occipital lobes (BA 19 and 37) bilaterally. Activation of the left temporal lobe (BA 21 and 22) was the only finding common to both groups in the number processing task. In post-fMRI interviews inquiring about the strategies that the participants used to perform the judgment task, 95% of the illiterates reported having used visual images, which may explain the activation of the occipital lobe in this group. The college graduates predominantly used abstraction to solve the problems, which corresponds to their left hemisphere activation.

Carreiras and colleagues (2009) compared structural brain scans from those who learned to read as adults (late literates) with matched illiterates. It was observed that late literates had more white matter in the splenium of the corpus callosum and more grey matter in bilateral angular, dorsal occipital, middle temporal, and left supramarginal and superior temporal gyri. It was

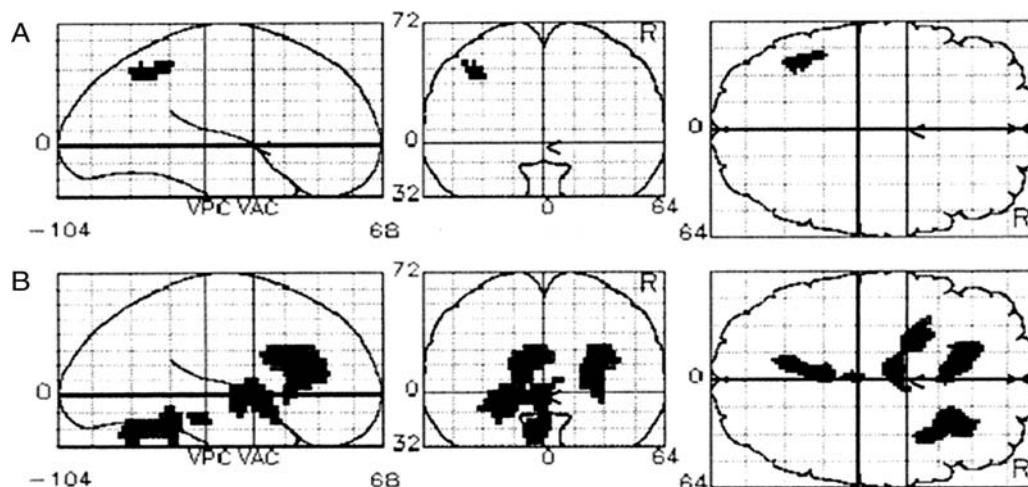


Fig. 1. Maximum intensity projections of all significant activations thresholded. Results of the interaction analysis (A) word repetition (literate–illiterate) and (B) pseudo-word repetition (literate–illiterate; adapted from Castro-Caldas, Petersson, Reis, Stone-Elander, et al., 1998).

also disclosed that the anatomical connections linking the left and right angular and dorsal occipital gyri through the area of the corpus callosum white matter was larger in late literates than in illiterates. Results were interpreted to suggest that reading increased the interhemispheric functional connectivity between the left and right angular gyri.

In sum, the data produced by functional imaging studies on brain activation during cognitive tasks support the contention that learning literacy impacts not only the individual's day-to-day strategies, but also influences the functional architecture of the adult human brain.

Anatomical Interhemispheric Comparisons

Comparing schooled literates and illiterates, [Castro-Caldas and colleagues \(1999\)](#) observed a slightly thinner corpus callosum in illiterates, specifically the region where parietal fibers are thought to cross. The morphology of the corpus callosum appears sensitive to the quality of the information content of the brain. The corpus callosum is larger for instance, in musicians presumably because their performance with musical instruments requires the involvement of both hemispheres ([Norton et al., 2005](#)). In the aforementioned PET scan study ([Castro-Caldas, Petersson, Reis, Stone-Elander, et al., 1998](#)), differences between groups indicated a dissociation between the superior and the inferior parts of the angular-supramarginal regions, that is, the superior parts being more active on the left than on the right in illiterates compared with literates, whereas the reverse was the case for the inferior parts and the precuneus. This suggests differential recruitment of right and left regions of the parietal lobe related to literacy and is in accordance with the finding reported above for magnitude judgments.

Some authors have postulated that hemispheric specialization is dependent on the nature of the task rather than the nature of the stimulus; for instance, [Stephan and colleagues \(2003\)](#) used fMRI in a group of normal subjects during letter and visuospatial decision tasks with identical word stimuli to address two unresolved problems. It was noted that hemispheric specialization depended on the nature of the task rather than on the nature of the stimulus. Furthermore, the increased coupling between left anterior cingulate cortex and left inferior frontal gyrus during letter decisions was observed, whereas right anterior cingulate cortex showed enhanced coupling with right parietal areas during visuospatial decisions; these authors suggested that cognitive control is thus localized in the same hemisphere as task execution. We would propose an additional point based on the aforementioned findings: Hemispheric specialization may also be related to the strategy used to solve the problem (verbal, spatial, etc.), which is dependent on the individual's skills acquired by learning.

Neuropsychological Test Performance in Illiterates

General Cognitive Functioning

Mini-Mental State Exam. The Mini-Mental State Examination (MMSE) is a brief exam widely used by physicians primarily to screen for the level of delirium or dementia. It consists of items of orientation, memory, attention, drawing, reading, writing, repetition, naming, and following directions, scored on a 30-point scale ([Folstein, Folstein, & Mchugh, 1975](#)). The total MMSE scores for illiterate samples average around 15–20 points (Table 3), in the range of severe cognitive alterations according to the 23 of 24 point cut-off suggested by [Folstein and colleagues \(1975\)](#).

Given its widespread use as a screening instrument for cognitive dysfunction, potential effects of literacy on performance may be biased against those who are illiterate (Table 3). In fact, [Bertolucci, Brucki, Campacci, and Juliano \(1994\)](#) found that illiterates differed from schooled literates on the MMSE not only on items related to writing and arithmetic (calculation, reading a command, writing a sentence, and copying a line drawing), but also on orientation to time. Other studies have found even more extensive differences; in one study, 16 of 19 questions differentiated schooled literates from illiterates at a level of significance of $P < .001$, where only repetition, recall, and naming were unrelated to literacy ([Rosselli et al.,](#)

Table 3. Scores for illiterates on the MMSE in different normative studies

Author	Age	<i>M</i>	<i>SD</i>
Ostrosky and colleagues (2000)	16–50	19.7	3.7
	51–65	16.7	4.4
	66–89	16.4	4.2
Brucki and colleagues (2003)	65–92	18.8	2.9
Laks and colleagues (2003)	65–84	17.2	4.4
	>84	14.3	3.9

Note: MMSE = Mini Mental State Exam.

2000), with differences in performance being observed even between illiterates and people with as little as 1 year of education at a level of significance of $P < .0001$ (Brucki, Nitrini, Caramelli, Bertolucci, & Okamoto, 2003).

Motor Functions

Writing is a fine movement activity; therefore, illiterate people may be less proficient with complex motor tests when compared with people able to write. In fact, several studies have supported this hypothesis. Rosselli, Ardila, and Rosas (1990) found statistically significant differences between illiterates and university-educated individuals in clinical tests of apraxia (buccofacial and ideomotor praxis, finger alternating movements, meaningless movements, coordinated movements with both hands, and motor impersistence tasks). When mimicking movements, illiterates frequently used the hand as instrument (body-part-as-object). Illiterates also tended to replace the movement for the corresponding verbalization. Nitrini, Caramelli, Herrera, Charchat-Fichman, and Porto (2005) administered Luria's fist-edge-palm test to 745 individuals with different educational levels, including 238 illiterates. Logistic regression showed that illiteracy was associated with failure, whereas gender and age were not. The proportion of individuals failing was inversely related to years of schooling. For those able to reproduce the sequence, the number of demonstrations for successful reproduction was also inversely related to years of schooling. Finally, Ostrosky, Ardila, and Rosselli (1999) investigated performance on four motor tests—changing left-hand position, changing right-hand position, alternating movements with both hands, and Luria's opposite reactions test—across different educational levels. On all four motor tests, performance was higher in the participants with a higher educational level. The effect of level of education was robust on the first three tests, but minimal on the fourth.

Bramão and colleagues (2007) corroborated the association between reading skills and performance on visuomotor tasks. They instructed illiterate and literate (Portuguese) participants to use the right or the left index finger to touch a randomly presented target on the right or left side of a touch screen. The literate subjects were significantly faster in detecting and touching targets on the left compared with the right side of the screen. Presentation side did not affect performance of the illiterate group.

In conclusion, illiterates demonstrate poorer performance in a diversity of motor tests, including reproducing movements and sequences of movements, alternating movements with both hands, and imitating meaningless movements.

Calculation and Number Processing

The assessment of calculation and number processing in illiterates and semiliterates after a brain injury is often a complex task because these processes are closely linked to education. On the other hand, calculation is present in myriad daily life situations, such as in the use of money, means of transportation (bus routes, subways, trains), telephone numbers, and mental calculations.

An international group of neuropsychologists created a battery of tests (EC 301) for evaluating calculation and number processing in literate brain-damaged adults (Deloche et al., 1994). This instrument was adapted into several languages (English, Finnish, French, German, Greek, Italian, Portuguese, and Spanish), thus providing a common tool for structurally equivalent evaluations of examinees' abilities. Nevertheless, the use of this tool in illiterates and semiliterates was shown to be ineffective. A standardized, validated version of the original EC 301 Battery in Portuguese was developed in Brazil. Ten simple tasks assessing counting, number processing, elementary calculation, and quantity estimation were presented to 122 normal Brazilian adults, aged between 18 and 58 years with 0, 1, 2, 3, or 4 years of education (Deloche et al., 1999). Tasks such as counting the number of elements in small sets were almost perfectly mastered by these illiterates and semiliterates; however, a sizeable proportion of the sample made errors on other tasks (e.g., those assessing knowledge of the correspondence between numbers and banknotes).

Language

Language abilities have been strongly correlated with a socioeducational level. Low socioeconomic parents use more non-verbal than verbal strategies with children (Robinson, 1974). Along the same lines, the language used by people with a low socioeconomic level is less fluent and has a simpler grammatical structure; it relies much more on emotional than on logical strategies (Bernstein, 1974). Similarly, rural, unschooled children may lack symbolic representation skills because their linguistic ability is tied to the immediate context of the referent (Bruner, Oliver, & Greenfield, 1966). Thus, it appears that formal education facilitates the development of language into a fully symbolic tool. At least one study (Lantz, 1979), however, showed that rural unschooled children performed better than schooled Indian or American children in coding and decoding culturally relevant objects, such as grain, and seeds. Thus, children without formal schooling were able to separate language symbols from the physical referent and to use those symbols for communicating accurately, but display of this ability

depended on the cultural relevance of the stimuli used (Laboratory of Comparative Human Cognition, 1983). In fact, the significance of schooling lies not just in the acquisition of new knowledge, but in the creation of new motives and formal modes of discursive verbal and logical thinking divorced from immediate practical experience (Luria, 1976).

Verbal fluency tests have been administered to illiterate populations in several countries. Table 4 presents the results of the available normative studies for the category “animals.” Most frequently, the number of animals found in 1 min is about 10–12. With increasing education, the number of items progressively increases.

Performance on phonemic or letter fluency tests is extremely difficult for illiterates. Available data suggest that letter fluency in illiterates may be about 3–4 words in 1 min, at least for Spanish and Greek, although this could vary by language (e.g., Kosmidis et al., 2004; Montiel & Matute, 2006; Ostrosky et al., 1999, 2004).

Language repetition ability in illiterates is equivalent to that of schooled literates if real, high-frequency words are presented. However, when using pseudowords, difficulties are observed (Kosmidis et al., 2004; Petersson et al., 2000; Reis & Castro-Caldas, 1997). Similarly, illiterates repeat high-frequency, but not low-frequency, words normally (Rosselli et al., 1990). Of course, low-frequency words may be equivalent to pseudowords for a person with a limited vocabulary. Reis and Castro-Caldas (1997) proposed that illiterate individuals (a) have difficulties in repeating pseudowords, (b) are worse at memorizing pairs of phonologically related words compared with pairs of semantically related words, and (c) have difficulties in generating words according to a formal criterion. Illiterate persons use strategies that are good for semantic processing, but inadequate for explicit phonological analysis, while literate individuals are able to use several parallel running strategies.

It can be conjectured that vocabulary size is significantly correlated with educational level, considering that current educational systems are especially directed toward reinforcing verbal abilities and verbal knowledge. Reis, Guerreiro, and Castro-Caldas (1994) and Reis, Petersson, Castro-Caldas, and Ingvar (2001) compared schooled literates and illiterates on the task of naming real objects, naming photographs of these objects, and naming drawings of them. Results showed that although both groups performed similarly at naming real objects, illiterates performed more poorly on naming photographs and even more poorly on naming drawings. The authors suggested that introducing color information was useful in improving the performance of illiterates in naming drawings (Reis et al., 2001). Therefore, increasing the amount of information contributed to better access to the name.

Metalinguistic Awareness

It has been observed that illiterate versus literate people do not differ in categorical perception of phonemes, but illiterate people display a less precise categorical boundary and a stronger lexical bias (Serniclaes et al., 2005; Ventura, Kolinsky, Querido, Fernandes, & Morais, 2007). Literacy, however, has been related to metalinguistic awareness (which can be regarded as an executive function), since it is by means of the latter that it is possible to turn aspects of language into objects of reflection. Specifically, studies associated with phonological awareness suggest that learning to read leads children to dissect language into small, nonmeaningful units. Illiterate adults find it difficult to consider words and nonwords as sequences of phonemes (Morais, Cary, Alegria, & Bertelson, 1979) and, as a consequence, they underperform on tasks that require thinking about the words' phonemic characteristics (e.g., phonemic fluency tasks; Kosmidis et al., 2004; Reis & Castro Caldas, 1997).

Table 4. Animal fluency in illiterates

Author	Place	<i>n</i>	Mean age	<i>SD</i>	Animals	<i>SD</i>
Ardila and Moreno (2001)	Aruaco Indians (Colombia)	5	26.2	2.9	9.8	1.5
Brucki, Malheiros, Okamoto, and Bertolucci (1997)	Brazil	—	—	—	11.9	—
Brucki and Rocha (2004)	Brazil	—	—	—	12.1	—
Kosmidis and colleagues (2004)	Greece	19	72.0	7.6	11.8	3.2
Manly and colleagues (1999)	USA	43	74.8	5.7	11.5	3.1
Montiel and Matute (2006)	Mexico	10	38.2	10.7	13.5	3.0
Matute (1986)	Mexico	25	46	—	10.4	—
Ostrosky and colleagues (1999)	Mexico	50	21.3	3.3	13.2	3.7
	Mexico	50	39.6	6.7	13.7	4.5
	Mexico	49	58.8	4.1	12.7	5.0
	Mexico	50	71.2	4.0	13.1	7.1
Ostrosky and colleagues (2004)	Maya Indians (Mexico)	7	58.4	8.8	11.0	2.5
Ostrosky, Ramirez, and Ardila (2004)	Pame Indians	7	53.6	6.1	11.8	4.0
Reis & Castro Caldas (1997)	Portugal	23 F	62.0	7.1	10.8	3.7
Rosselli and colleagues (1990)	Colombia	100	16–65	—	10.6	3.4

However, illiterate performance is better, although still inferior to that of schooled literates, when the critical unit is the syllable rather than a phoneme, as well as on rhyme detection (Morais, Bertelson, Cary, & Alegria, 1987). When comparing illiterate to literate nonschooled groups on explicit phonological awareness tasks, Montiel and Matute (2006) found equivalent performance between groups when dealing with syllables, but differences on the onset detection task and on the initial phoneme detection test. Nonetheless, both groups diverge from the schooled literate group on more complex phonemic awareness tasks, such as phonemic segmentation, phoneme blending, and initial phoneme deletion. Illiterate children had difficulty in identifying the number of words in an oral sentence, suggesting that illiterate children find it difficult to think about language as a string of words.

The aforementioned findings suggest that the influence of literacy extends beyond mere explicit phonemic awareness to affect metalinguistic awareness, as well.

Visuoperceptual and Spatial Abilities

One visual-spatial effect of reading is the training of a specific direction of visual scanning (left to right, for most European-origin writing systems). Using nonlinguistic stimuli, Ostrosky-Solís, Efron, and Yund (1991) studied the scanning mechanism through a computer target detection paradigm in 60 illiterate and 60 literate individuals matched on a socioeconomic level. Although target detection accuracy was identical in the two groups, there were significant differences between the detectability gradients of the literate and illiterate groups, suggesting that learning to read trains the scanning mechanisms toward more consistent scan paths. Padakannaya and colleagues (2002) administered a picture array naming and recall task to three groups of child readers—unidirectional right-to-left readers of Arabic, unidirectional left-to-right readers of Kannada, and bidirectional readers of Urdu and English—and one group of Urdu illiterate adults. The results showed a right-to-left direction of visual scanning in the Arabic and Urdu readers. In the latter group, the strength of the scanning effect decreased with more schooling in English. No right-to-left effect was observed in Kannada readers or Urdu illiterates. These results suggest that the reading direction can affect scan habits in nonlinguistic tasks. The same effect has been documented in drawing.

Vaid, Singh, Sakhaja, and Gupta (2002) analyzed the influence of reading/writing direction and handedness on the direction of stroke movement in free-hand figure drawing. Adult readers of scripts with opposing directionality (Hindi vs. Urdu) and illiterate controls were observed while drawing a tree, a hand, a house, an arrow, a pencil, and a fish. Right-handers (including right-handed illiterates) and left-to-right readers drew most figures from left to right, whereas left-handers (including left-handed illiterates) and right-to-left readers more often drew the figures from right to left.

Various neuropsychological studies have shown significant differences between schooled literates and illiterates in performing spatial and visuoperceptual tests. Ardila, Rosselli, and Rosas (1989) administered a basic neuropsychological test battery to two extreme educational groups: Illiterate and professional adults, matched by sex and age. All of the visuospatial tasks (copying a cube, a house, and the Rey–Osterrieth Complex Figure; telling the time on a clock; recognizing superimposed figures; recognizing the national map; and drawing the plan of the room) differentiated the two extreme educational groups. Matute and colleagues (2000) used four stick construction tasks (a test with a higher ecological validity for illiterates than copying figures) in illiterate, semiliterate, and literate participants. Although illiterates generally made more errors than semiliterates and semiliterates more than schooled literates, only some of these differences were statistically significant. Significant differences were found for lack of global fidelity and disarticulation errors when all four figures were considered together. Dansilio and Charamelo (2005) used both figure copying and constructional abilities in 15 illiterates and a matched group with about 6–7 years of school. The most frequent and relevant findings in illiterates in figure copying were an inability to reproduce the perspective (13 of 15), unfolding (4 of 15), and unstructured copying (3 of 15). No errors were observed on the stick construction task.

Gonçalves (2004) emphasized the difficulty illiterates had in copying drawings. As can be seen in Fig. 2 (reproduced from Castro-Caldas, 2004), an illiterate copied one of the Bender drawings following a sequence that did not respect the idea of two separate but connected elements, which is the way literate individuals tend to read the drawing. This resembles the concept of integrative agnosia proposed by Riddoch and Humphreys (1987). Visually guided hand motor behavior may also be biased by literacy. In a test paradigm in which literate and illiterate individuals were asked to direct the cursor toward a target on the screen of a computer using the mouse, illiterate individuals were slower than literate controls, in particular when the right hand had to move the cursor to the left side of the screen. This crossed condition is apparently trained by writing (Reis & Castro-Caldas, 1997).

Memory

Culture and literacy can affect strategies used to recall information. Bartlett (1932) proposed that illiterates more frequently use rote learning whereas literate people use more active information integration procedures (“metamemory”). Cole and

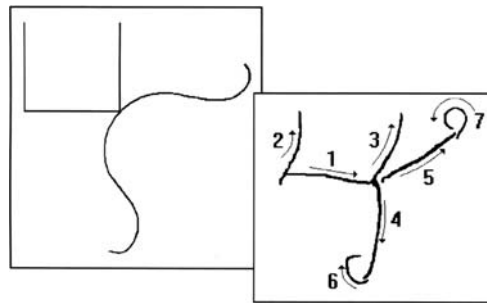


Fig. 2. Sequence of copying (right) of a Bender drawing (left).

Scribner (1974) observed that when memorizing information, schooled literates and illiterates make use of their own groupings to structure their recall; for instance, high-school students rely mainly on taxonomic categories, whereas illiterate bush farmers make little use of this principle. The authors argue that cultural differences in memorizing do not consist in the presence or the absence of mnemonic techniques in general, but in the utilization of a specific technique: Reorganization of the to-be-remembered material. This particular strategy for recall could be tied to school learning experiences.

Illiterates generally perform more poorly than schooled literates on conventional neuropsychological memory measures such as wordlist learning and recall (Ardila et al., 1989; Cole, Frankel, & Sharp, 1971; Cole, Gay, Glick, & Sharp, 1971; Folia & Kosmidis, 2003; Montiel & Matute, 2006; Nitrini et al., 2004), story learning and recall (Montiel & Matute, 2006), verbal paired associates (Montiel & Matute, 2006; Reis & Castro-Caldas, 1997), digits backwards (Montiel & Matute, 2006), number-months (an adaptation of the Wechsler Memory Scale III Letter-Number Sequencing task), and complex figure drawing (Ardila et al., 1989). However, the performance of illiterates seems to approach that of literates on object memory (Folia & Kosmidis, 2003; Nitrini, Caramelli, Herrera, Porto, et al., 2004) and wordlist recognition memory (Ardila et al., 1989). Illiterates' low performance in memory tests may be specific to some of the psychometric procedures generally used in testing memory.

The discrepancy observed between poor free recall and good recognition of illiterate individuals on object learning tasks suggests inefficient encoding and retrieval strategies or poor organization of the material to be learned (Eslinger & Grattan, 1993). Recall of learned information generally occurs without cues or external support, requiring considerable self-initiated activity and executive skills in addition to memory abilities (see Parkin & Leng, 1993). Among illiterates, these skills may be adequate for a relatively passive cognitive process such as efficient recognition of stimuli learned through repetition, yet inadequate to support a relatively active and effortful cognitive process such as free recall. This contention is supported by the findings of an improvement in cognitive functions, including verbal memory, not specifically targeted in an adult learning-to-read program; presumably, learning to read enhanced metacognitive abilities such as using analytic strategies, planning, and organizing output sequences, in this sample (Ardila, Ostrosky & Mendoza, 2000). Whether this improvement is a direct result of literacy acquisition or of schooling is not clear.

A PET scan study found no group differences between schooled literates and illiterates on encoding and retrieving paired associate words (Pettersson et al., 2000). Both groups showed a positive correlation between cued-recall success and the activation of the left inferior prefrontal cortex and the medial temporal lobes during encoding, suggesting that literacy and schooling do not alter the basic neuroanatomy of encoding verbal material.

Educational Effects in Test Performance

Test-Wiseness

Test-wiseness refers to the examinee's knowledge of how tests are designed, the expectations behind tests, and strategies for taking tests, independent of the content the tests are designed to measure Thorndike (1951). It is seen as a nuisance variable that gives its possessors better scores on tests which may not necessarily reflect better abilities on the capacity being measured. Much of the literature on test-wiseness has investigated students well-entrenched in an educational career and examined relatively sophisticated test strategies in group administered tests, suggesting that effects are modest (Green & Stewart, 1984). However, what few studies are available for very young children and for those from developing countries suggest that the effect is more substantial for these populations. Therefore, an important part of the differences between illiterates and literates

on cognitive tests may have to do not so much with cognitive abilities *per se*, as with test-taking abilities and familiarity. Test taking and, consequently, test-wiseness are most likely skills learned primarily in school (Nell, 2000).

The Effect of Increasing Schooling Time

Even 1 or 2 years of school can make a significant difference in performance on some neuropsychological tests. Ostrosky, Ardila, Rosselli, López-Arango, and Uriel-Mendoza (1998) examined 64 illiterates, 64 adults with 1–2 years of school, and 64 adults with 3–4 years of school with the NEUROPSI. Statistically significant differences were found between the illiterates versus 1–2 years of school—favoring the latter—on the Language Comprehension, Phonological Verbal Fluency, and Similarities subtests. Significant differences were observed between illiterates versus 3–4 years of school—favoring the latter—in the following subtests: Visual Detection, 20–3, Copy of a Semicomplex Figure, Calculation Abilities, Sequences, Alternating movements, Recall of words: Cueing, and Recall of a Semicomplex Figure (Table 5).

Nonetheless, when comparing the scores in the same NEUROPSI test battery of participants with 10–12, 13–17, and 18–24 years of school, only a few significant differences were found. These observations indicate that the educational effect on neuropsychological test performance is “not” linear. Differences between zero and 3 years of education are usually highly significant; differences between 3 and 6 years of education can be lower; between 6 and 9 are even lower; and so forth, with virtually no differences between, for example, 12 and 15 years of education. This means that on neuropsychological tests, education effects represent a negatively accelerated curve, tending to plateau. This is not surprising, considering that, in general, neuropsychological tests have a low ceiling. Another consequence of this finding is that neuropsychological tests that show no education effect between, for example, North Americans with fewer and greater than 12 years of education (but with no fewer than 8 years of education) cannot be safely extrapolated to assume no educational effect for fewer than 8 or as low as 0 years of education.

The length, qualities, and content of the school day and year vary considerably from country to country and even from school to school. More refined measures of length and qualities of schooling are needed in future studies.

Studies in Illiterate Children

In almost all occidental cultures, formal reading acquisition starts as soon as aged 5–6. Thus, the process to become literate starts early in childhood; however, little attention has been paid to illiterate condition in children. A pioneer study in illiterate children was performed in Mexico, with the aim to investigate whether or not the effects of literacy on neuropsychological test performance are already evident during childhood, as has been reported previously for illiterate adult populations. Seeking that purpose, the performance of 21 illiterate children and 22 literate children aged 6–13 was compared on 13 cognitive domains of the “Evaluación Neuropsicológica Infantil” (ENI; “Child Neuropsychological Assessment”): Attention, constructional abilities, verbal memory coding and delayed recall, visual memory coding and delayed recall, tactile perception, visual perception, auditory perception, oral language, metalinguistic awareness, calculation, and spatial abilities. Demographic variables were controlled to avoid effect of socioeconomic characteristics. For the illiterate group, school nonattendance was due to social-family reasons, thus controlling learning disabilities effects. Results showed that the illiterate group significantly

Table 5. Mean (*SD*) performance and comparisons of groups by the level of education on NEUROPSI neuropsychological tests (adapted from Ostrosky et al., 1998)

Tests	Score range	Years of schooling			Significant differences
		0	1–2	3–4	
Visual detection	0–16	9.9 (4.5)	11.2 (4.1)	12.5 (3.2)	G3 versus G1
20 minus 3	0–5	3.1 (1.9)	3.1 (1.7)	4.1 (1.2)	G3 versus G1,G2
Semicomplex figure (copy)	0–12	7.5 (2.0)	8.8 (2.4)	9.4 (1.9)	G3 versus G1,G2
Language: Comprehension	0–6	3.7 (1.2)	4.4 (0.8)	4.6 (1.0)	G1 versus G2,G3
Phonological fluency	0–15	3.1 (3.7)	6.5 (4.0)	7.0 (4.1)	G1 versus G2,G3
Similarities	0–6	2.1 (2.2)	3.5 (2.1)	3.9 (1.9)	G1 versus G2,G3
Calculation abilities	0–3	0.9 (1.0)	1.5 (1.1)	1.6 (1.1)	G3 versus G1,G2
Sequences	0–1	0.1 (0.3)	0.2 (0.4)	0.4 (0.5)	G3 versus G1,G2
Alternating movements	0–2	0.8 (0.7)	1.1 (0.7)	1.3 (0.7)	G3 versus G1
Recall: Words Cueing	0–6	4.1 (1.4)	4.3 (1.4)	4.7 (1.4)	G3 versus G1
Semicomplex figure	0–12	6.3 (2.2)	7.0 (2.4)	8.4 (2.3)	G3 versus G1,G2

Notes: G1 = illiterates; G2 = 1–2 years of school; G3 = 3–4 years of school.

underperformed the literate group in mostly all measures except tactile perception. Moreover, age was a significant covariant, where higher scores were related to older ages in both groups. However, when analyzing the cognitive domains that it is known that are related to schooling (metalinguistic awareness and calculation), it was found that metalinguistic awareness task performance improve with age in literate children but it was not the case for the illiterate group; at the same time for the calculation abilities, an effect of age was evident in both groups suggesting that math learning is school and environment-dependent (Matute et al., Submitted).

Executive Function was also investigated in these two groups (Matute et al., unpublished) four domains were analyzed: Verbal fluency, mental flexibility, planning and concept formation, and reasoning where 8 measures were compared: Verbal fluency, semantic verbal fluency, phonemic verbal fluency, categories achieved in the card sorting test (mental flexibility test), number of correct designs done with the minimum number of movements in the Pyramid of Mexico Test (a planning and organization test), similarities, and matrices and arithmetic problems. With the exception of the matrices test, the illiterate children scored significantly below the literate children suggesting that differences in the development of executive functions between these two populations are already evident in childhood. The absence of difference in matrices test is related to low score in both groups; thus, it could be possible that those skills underlying this type of test are acquired at a later stage, and intergroup differences would not be evident in childhood.

Learning to Read in Children Versus Learning to Read in Adults

Several studies were designed to compare brain activation of individuals who learned to read and write in childhood at the usual age and those who learned in adulthood. In one of these studies, participants were asked to identify written words during magnetoencephalography (MEG). Results showed that late literates had more late sources of activity in right temporoparietal areas than their controls, who, on the other hand, had more early activation of left inferior frontal areas (Castro-Caldas, Peterson, Reis, Askelof, et al., 1998; Castro-Caldas, Petersson, Reis, Stone-Elander, et al., 1998). This suggests that the mechanisms related to reading are different in late literates despite similar performance on the task for both groups. Castro-Caldas and colleagues (2009) in a further study compared late literates to controls to subjects that learned at school at the usual age. MEG was done while subjects were reading words. It was found that although the reading performance was the same in both groups while performing the task, the pattern of source distribution was different between groups. There were more late sources in the right temporoparietal areas of late literates compared with controls and more late sources in the left inferior frontal cortex in control subjects. It is concluded that learning to read in adulthood is a process supported by different brain structures from the ones used when learning occurs at the usual age. Castro-Caldas, et al., (2009) compared seven women who learned how to read and write after the age of 50 (ex-illiterates) and five women with 10 years of regular schooling (controls) in a language recognition test while brain activity was being recorded using MEG. It was found that both groups performed similarly on the task of identifying target words. Analysis of the number of sources of activity in the left and right hemispheres revealed significant differences between the two groups, showing that ex-illiterate subjects exhibited less brain functional asymmetry during the language task. These findings were interpreted as reinforcing the concept that poorly educated subjects tend to use the brain for information processing in a different way to subjects with a high-educational level or who were schooled at the regular time.

The Gender Effect

Gender differences in cognitive abilities have been widely analyzed during the last decades (e.g., Buffery & Gray, 1972; Caplan, Crawford, Hyde, & Richardson, 1997; Hedges & Nowell, 1995; Maccoby & Jacklin, 1974). Three major differences between men and women in cognitive abilities have usually been reported: (a) verbal abilities, favoring women; (b) spatial abilities, favoring men; and (c) arithmetical abilities, favoring men. Differences in calculation abilities have sometimes been interpreted as a result of men's superior spatial abilities (Benbow, Libinski, Shea, & Eftekhari-Sanjani, 2000; Geary, 1996).

The origin of these differences is not clear, even though some neurological (e.g., Blanch Brennan, Condon, Santosh, & Hadley, 2004; Rilea, Roskos-Ewoldsen, & Boles, 2004) and environmental (e.g., Quaiser-Pohl & Lehmann, 2002) factors have been proposed. Gender differences have also been associated with hormonal influences (e.g., Aleman, Bronk, Kessels, Koppeschaar, & van Honk, 2004).

The collaborative Mexican–Colombian research program on the effects of education on neuropsychological test performance has consistently found over the last 30 years that education significantly interacted with gender (e.g., Ardila et al., 1989, 1992; Ostrosky et al., 1985, 1986, 1998; Rosselli et al., 1990). On most neuropsychological tests, among illiterates or people with limited education, men outperformed women, a gender difference which decreased as the level of education increased and

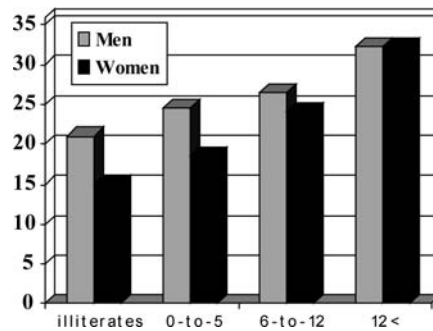


Fig. 3. Performance in the Rey–Osterrieth Complex Figure in normal adults with different levels of education (age = 21–75 years; $N = 824$) (adapted from Ardila et al., 1989; Rosselli & Ardila, 2003).

virtually disappeared at about the level of a high-school education. To the best of our knowledge, such an interaction between gender and education on cognitive testing has not been reported elsewhere. As an illustration, Fig. 3 presents the scores obtained from individuals with different levels of education in the Rey–Osterrieth Complex Figure. As clearly observed, scores are about 20% higher in illiterate men than in illiterate women. When increasing the education level, differences become progressively smaller and after about 12 years of school, performance is virtually identical.

We may assume that this gender difference can be partially due to the characteristics of the population from which the sample was recruited. In Latin American countries, it is not unusual to find that low-educated women remain at home and are solely responsible for child care and house work, particularly for the historical age cohorts in which these studies were carried out. Men go to the factory (or elsewhere) to work and, thus, acquire a more complex understanding of their environment (navigating around the city, taking buses, and similar); they maintain a higher level of social interaction, they handle money, and they are much better informed about national and international events. Simply speaking, they have a higher level of stimulation and use a greater amount of information than women, at least regarding skills needed for the tests used. Studies in other populations are required in order to support or reject this interpretation. This effect suggests that, at least for this population, formal education may have an equalizing gender effect on some cognitive skills, rather than being responsible for gender differences. In any case, these findings suggest that education does have an impact on gender differences in cognitive tests.

Age-Related Cognitive Decline in Illiterates

Capitani, Barbarotto, and Laicana (1996) proposed three possible patterns of association between age-related decline and education: (a) Parallelism: Age-related decline runs the same course in different educational groups, that is, no interaction; (b) Protection: Age-related decline is attenuated in well-educated participants; and (c) Confluence: The initial advantage of well-educated groups in middle age is reduced in later life. The researchers explored these hypotheses in a group of 307 Italians aged 40–85 and mean education levels of 6 versus 13 years; their data supported the parallelism theory for verbal fluency, spatial memory, and Raven's Progressive Matrices, but the protection theory for visual attention and verbal memory. Confluence was not observed on any of their five tests. They concluded that the protective effect of education is not ubiquitous, but depends on the specific cognitive ability measured.

With a wider age and education range on the NEUROPSI, Ardila and colleagues (2000) found parallelism, protection, and two different subtypes of confluence (upward and downward; Table 6). For some subtests, a specific pattern was not evident. They, too, concluded that different patterns of age-related cognitive decline and education may be found, depending on the specific cognitive domain. These results agree with Capitani and colleagues for verbal memory, but not for verbal fluency, and other domains (and the participant samples) are not comparable. Furthermore, these are cross-sectional studies and subject to possible cohort effects.

Dementia in Illiterates

Decreased prevalence and incidence of dementia among persons with a higher level of education have been reported by some population-based studies (Qiu et al., 2001; Zhang et al., 1990), findings that have been explained by the cognitive reserve hypothesis, which holds that the individual differences in how tasks are processed provide differential resistance against brain pathology or age-related changes (Katzman et al., 1989; Stern, 2006). According to this hypothesis, highly educated individuals may either have greater neural reserve, that is, brain networks that are less susceptible to disruption, or they may have more neural compensation, which renders them more capable of developing efficient strategies to cope with the

Table 6. Examples of different patterns of cognitive decline across age ranges; mean scores and standard deviations (in parentheses) are presented

	Age (years)			
	16–30	31–50	51–65	66–85
Parallelism: Copy of a Figure				
Over 10 years	11.8 (0.5); 100%	11.7 (0.5); 99%	11.3 (1.2); 95%	10.9 (1.4); 92%
Illiterates	8.1 (2.1); 100%	7.9 (1.8); 97%	7.6 (2.2); 94%	7.2 (2.7); 89%
Protection: Recall of Words				
Over 10 years	5.3 (0.9); 100%	4.9 (1.2); 92%	4.6 (1.5); 87%	3.7 (1.8); 70%
Illiterates	4.3 (1.6); 100%	3.6 (2.2); 84%	2.4 (2.4); 56%	2.1 (2.3); 49%
Confluence upwards: Digits Backwards				
Over 10 years	4.3 (1.0); 100%	4.4 (1.0); 102%	4.0 (1.0); 93%	3.9 (1.1); 90%
Illiterates	2.2 (1.1); 100%	2.8 (1.1); 127%	2.9 (1.0); 132%	2.7 (0.9); 123%
Confluence downwards: Semantic Verbal Fluency				
Over 10 years	21.6 (5.4); 100%	22.3 (5.0); 103%	20.1 (5.1); 93%	18.4 (4.8); 85%
Illiterates	13.2 (3.7); 100%	13.7 (4.5); 104%	12.7 (5.0); 96%	13.1 (7.1); 99%

Note: In each case, performance at the 16–30 years is taken as 100% (adapted from Ardila, Ostrosky & Mendoza, 2000).

Table 7. Prevalence of dementia in relation to educational level (adapted from Herrera et al., 2002)

Schooling	N	Mean age (SD)	Dementia (N)	Dementia (%)	Prevalence ratio
Illiterate	567	74.6 (7.1)	69	12.2	3.5
1–3 years	590	72.2 (5.9)	26	4.4	1.2
4–7 years	356	72.1 (6.4)	18	5.0	1.4
8 years or more	143	72.5 (6.7)	5	3.5	1 ^a

^aThe prevalence in this age group was taken as reference.

negative effects of disease and ageing (Stern, 2006). In a postmortem study of a large number of elderly individuals, between 12%–19% of the individuals fulfilled neuropathological criteria for Alzheimer's disease (AD), although they had not been considered demented during life. When the authors investigated this phenomenon, they found that as the number of years of formal education increases, the odds of a clinical dementia diagnosis decreases by approximately 0.82–0.87 with each additional year of education, thus supporting the cognitive reserve hypothesis (Roe, Xiong, Miller, & Morris, 2007).

A positive association between AD and low education has been found in many studies (e.g., Callahan et al., 1996; Friedland, 1993; Katzman, 1993; Letenneur, Commenges, Dartigues, & Barberger-Gateau, 1994; Liu et al., 1994; Mortimer & Graves, 1993; Rocca et al., 1990; Yu et al., 1989; Zhang et al., 1990) carried out in different countries: Brazil (Caramelli et al., 1997), China (Hill et al., 1993; Yu et al., 1989), Finland (Sulkava, Wikstrom, & Aromaa, 1985), France (Dartigues, Gagnon, & Michel, 1991), Italy (Bonaiuto, Rocca, & Lippi, 1990; Rocca et al., 1990), Israel (Korczyn, Kahan, & Gulper, 1991), Sweden (Fratiglioni et al., 1991), and the USA (Stern et al., 1994). In a Brazilian population study (Herrera, Caramelli, Silveira, & Nitrini, 2002), the prevalence ratio of dementia in illiterates was 3.5 times higher than in those with 8 or more years of schooling (Table 7). Given that the low-educational level is often coupled with the low socioeconomic level, the authors performed a multivariate analysis, which confirmed that the low-educational level was associated with the higher prevalence of dementia (Herrera et al., 2002).

In a recent analysis of six Latin American studies, which included 26,199 elderly, dementia was two times more frequent in illiterate than in literate individuals, a relevant finding because the pooled data show that the rate of illiteracy among the elderly was approximately 10%. Significant differences of prevalence between illiterate and literate individuals were observed in seven out of the eight population studies (Nitrini et al., 2009).

Negative results, however, have also been reported (e.g., Christensen & Henderson, 1991; Knoefel et al., 1991; O'Connor, Pollitt, & Treasure, 1991; Rocca et al., 1990). For instance, the Framingham study found no association between the educational levels and the risk of AD (Knoefel et al., 1991) in a predominantly literate population. Furthermore, a pooled analysis of European data (Launer, Dinkgreve, Jonker, Hooijer, & Lindeboom, 1993) showed that the deleterious effect of a lower education was more marked in women than in men. Neither gender nor education was associated with a positive family history of dementia or the presence of the APOe4 allele (Duara et al., 1996). Finally, a study of a predominantly illiterate population in the rural areas of India also failed to detect an influence of education on the prevalence of dementia (Chandra et al., 1998).

The higher prevalence of dementia among illiterates could be explained by possible overdiagnosis in this group due to a lack of test-wisness. However, a majority of studies adjusted cut-off scores or used tests more appropriate for populations with

educational heterogeneity (Zhang et al., 1990), as well as informant questionnaires (Herrera et al., 2002; Nittrini et al., 2004), decreasing the likelihood of this possibility.

In an investigation of the factors affecting age of onset and rate of progression of AD, the researchers concluded that AD progresses steadily, regardless of education, occupation, and other factors tested (Bowler, Munoz, Merskey, & Hachinski, 1998); however, the age of referral to a memory clinic, which was correlated with the age of onset, differed according to the educational level. Those with a high level of education tended to be younger upon referral than those with a low level of education. However, the scores in the extended scale for dementia on initial assessment were similar between patients with a low and those with a high level of education. The authors further investigated the influence of education and socioeconomic status in the autopsy-confirmed cases of AD (Munoz et al., 2000). They compared two groups of autopsied patients, 115 confirmed AD and 142 patients 65 years or older without dementia who died in the hospital without neurodegenerative disease. They found no substantial differences in education, occupation, and socioeconomic or income levels between groups.

Hendrie and colleagues (2001) and Ogunniyi and colleagues (2000) compared the prevalence rate of dementia of 2,494 elderly poorly educated Nigerian residents in Nigeria to the prevalence rate of 2,212 African Americans with similar education, living in the USA. The rates of the Nigerians (2.29%) were much lower than the rates for the U.S. group (8.24%), which suggests that education is not the relevant factor for dementia. Furthermore they report different risk factors in these two groups. In Nigeria, old age and female gender were revealed to be significant risk factors, whereas among African Americans old age, rural living below the age of 19 years, low education, and family history of dementia were the risk factors. In addition, the frequencies of the vascular risk factors investigated were lower in Nigerians, which may suggest involvement of environmental factors in disease processes.

In conclusion, the issue of the influence of the educational level on the clinical diagnosis, prevalence, progression, or severity of AD is still far from fully understood. Indeed, we may find some differences between the well-selected groups of participants. These differences may be a reflection of cognitive strategies used based on different levels of school achievement. More prospective and well-designed studies are needed to further clarify this topic.

Brain Damage and Illiteracy

Two opposing points of view have emerged in the neuropsychological literature regarding the influence of education on brain organization of language. Cameron, Currier, and Haerer (1971) reported a lower frequency of aphasias associated with injuries of the left hemisphere among right-handed illiterate patients than among educated ones. The authors concluded that language is more bilaterally represented in the illiterate group. In contrast, Damasio and colleagues (1976) claimed that there is no qualitative or quantitative difference between the aphasias of educated and illiterate patients. The aphasia of schooled literates or illiterates did not differ in the prevalence rate, distribution of clinical types, or semiological structure.

Matute's research (1988) supports the Damasio and colleagues (1976) conclusions. She compared three groups of right-handed Mexican adults: Brain-damaged illiterates, brain-damaged literates, and normal illiterates. An aphasia test was given to all three groups in the context of a more extensive neuropsychological assessment. No differences between the two brain damaged groups were evident in regard to language measures related to repetition, oral expression, and comprehension. However, when analyzing incidence of aphasia due to unilateral brain lesions, all left hemisphere-damaged illiterates presented aphasia, although the lesion locus for some of them were out of the perisylvian area, whereas none presented aphasia after right hemisphere damage. Thus, the data obtained in this study suggest a less intrahemispheric specialization for language on the left hemisphere in illiterates.

The hypothesis that illiterates might have a different cerebral organization for language and, therefore, deviate from literates in their clinical profile; the severity of their aphasia or their prognosis was evident as early as 1867 with Scoresby-Jackson's observation of an illiterate patient. This author presented a case of an illiterate patient with a severe motor aphasia. After the postmortem exam, the author found that although the lesion was very extended in the left hemisphere, the frontal lobe was attained only in the posterior part of the third frontal circumvolution, where Broca had located the spoken language. Since it was only the posterior part of the third frontal circumvolution that was attained, Scoresby-Jackson suggested that a bigger part of this circumvolution would participate in language only with a grater language acquisition (given by reading acquisition). Thus, in the illiterate people, it would be only the posterior extreme of the third frontal circumvolution that will be active in language expression, whereas in a literate person, all the circumvolution will be employed. Finally, the author stated that language and writing will be learned with the posterior part of the left third frontal circumvolution and with the experience given by the "exercise in the art of speaking and writing" a larger part of this circumvolution will be employed. Critchley (1956) was probably the first author to suggest that hemispheric functional asymmetry could be influenced by schooling. He suggested that low-educated persons tended to have less left hemispheric lateralization for language

functions. This suggestion was supported by Wechsler's (1976) interpretation of the crossed aphasia in his illiterate patient (Castro-Caldas et al., 1987).

Fonseca and Castro-Caldas (2002) compared the recovery process of literate and illiterate aphasics. They studied 24 illiterates and compared those with 42 schooled literates matched for age, gender, and type of aphasia. Generally, all scores obtained in subtests of the Aphasia battery were lower in illiterates than they were in literate controls. Patients were tested in the first month of their disease and 6 months later. The global scores of aphasia improved similarly in both groups; however, the correlation between the test scores suggested that the process of recovery was different for each group.

Lecours and colleagues (1987a, 1987b, 1988) studied the relationship between brain damage and schooling with regard to aphasic impairments of language. On the basis of their findings, the authors concluded that: (a) There was a greater right-hemisphere language involvement in illiterates than in the well-educated patients; and (b) left-stroke school-educated patients seemed to be "sicker," as it were, than their illiterate counterparts, that is: (i) The classical symptoms of aphasia (suppression stereotype, jargon aphasia) were more apparent among left stroke schooled literates than among left-stroke illiterates; and (ii) auditory comprehension was more frequently impaired among the left stroke literate patients.

Lecours and colleagues (1987b) also studied the influence of education on unilateral neglect syndrome. They analyzed a large sample of right-handed unilingual brain-damaged individuals: Illiterates (left stroke and right stroke) and schooled literates (left stroke and right stroke). Evidence of a unilateral neglect syndrome was found in both left- and right-brain-damaged schooled literates and illiterates. Their results provided no indication that tropisms were globally stronger depending on the side of the lesion or on the educational level of the patients. Rosselli, Rosselli, Vergara, and Ardila (1985), however, reported a higher frequency of right hemispatial neglect in low-educated patients.

In summary, studies of brain-damaged illiterates, when compared with brain-damaged literates, have indicated that: (a) Literacy does not change the dominance of the left hemisphere for language, illiterates as well as literates present aphasia most often after left brain damage, and not after right brain damage; and (b) the right hemisphere appears to have a disproportionate involvement in language in illiterate when compared with literate individuals. This is based on the following evidence: Left-damaged literates present a larger number of errors in aphasia tests than left-damaged illiterates (Lecours et al., 1988; Matute, 1988) and right-damaged illiterates more frequently present poorer performance in aphasia tests than right-damaged literates (Lecours et al., 1987a, 1987b).

Some Clinical Implications

Brain injury, either due to stroke or TBI, may have various clinical manifestations, depending on the brain areas affected. The individual may develop isolated or associated disorders of language, reading, writing, calculation, memory, attention, vision, visuoconstruction, behavior, and/or movement. These problems need to be identified in order to establish an adequate rehabilitation program. However, identifying many of these disorders is sometimes difficult because there are still very few neuropsychological tools created for, standardized, and normed on illiterates. Furthermore, many existing tests depend on content or processes related to education. It is often challenging to distinguish whether test difficulties experienced by an illiterate individual are due to brain injury or if they are preexistent, because the individual never learned the skills being measured.

Tests that have already been standardized on illiterates in different countries, include the MMSE, NEUROPSI, NEUROPSI Attention and Memory, Rey-Osterrieth Complex Figure, Luria's fist-edge palm test, motor tests, verbal fluency tests, visuo-perceptual and spatial tests, memory tests, executive function tests, calculation, number processing, and others (Ardila et al., 1989, 1992, 2000, 2003; Bertolucci et al., 1994; Brucki et al., 2004; Dansilio et al., 2005; Deloche et al., 1999; Folia & Kosmidis, 2003; Kosmidis et al., 2004; Loureiro et al., 2004; Nitrini, Caramelli, Herrera, Porto, et al., 2004; Nitrini et al., 2004, 2005; Ostrosky-Solis et al., 1985, 1986, 1998, 1999, 2004; Rosselli et al., 1990). Additional research is needed to determine if these norms can be generalized to other illiterate populations and to determine their sensitivity to brain impairment and their prediction of functional abilities. More tools are also needed. However, tests not normed on these populations may be helpful in demonstrating preserved abilities and strengths.

Neuropsychological assessment of illiterates should emphasize history taking, understanding their functioning within their social and cultural context, and exploration of the ways in which that functioning differs from that of their peers and/or from their own premorbid functioning. That history should also include distinguishing whether their illiteracy is due to lack of opportunity or failure to learn.

The neurorehabilitation of illiterate people after brain injury or illness presents challenges to rehabilitation programs oriented toward literates. Neuropsychological rehabilitation yields much more effective results when it is adapted to the individual's specific context (Lave, 1996; Rogoff, 1990). Consequently, any such program must take into consideration the person's work environment, family life, and cultural context to maximize success. Current cognitive rehabilitation techniques

for memory, and, to some extent, executive functions, tend to favor written compensatory techniques such as memory books and written directions. Such techniques need to be adapted to serve the illiterate patient (Judd & DeBoard, 2007).

Conclusions Regarding Human Cognition Through the Study of Illiteracy

Literacy is strongly reflected in the performance of tasks used in psychological, as well as neuropsychological evaluations. Acquiring literacy appears to influence visual perception, logical reasoning, remembering strategies (Laboratory of Comparative Human Cognition, 1983), and formal operational thinking (Laurendeau-Bendavid, 1977). It is a mistake to assume that the inability to perform simple cognitive tasks, such as those frequently incorporated in current neuropsychological test batteries, necessarily means abnormal brain function. The degree of literacy can often represent the crucial variable.

The influence of literacy seems to go further: Literacy may somehow change the brain organization of cognition. Studies of the consequences of brain damage in illiterate populations evidence a more bilateral representation among illiterates than literates not only for linguistic, but probably also for visuospatial abilities. Apparently, literacy does not change the direction of laterality in the brain organization of cognition, but the degree of this lateralization.

School attendance does not mean that educated people simply possess certain abilities that less-educated individuals lack. Reading ability rather seems to represent an additional instrument to extend cognition. Illiteracy does not mean either that highly educated people have the same abilities as less-educated individuals, plus something else. Nonetheless, formal cognitive testing evaluates those abilities in which the educated child was trained. Therefore, it is not surprising that he or she will outperform the child with no formal education. It must be emphasized that the educational level has a substantial relationship with performance on some cognitive tests, but is not systematically related to everyday problem-solving (functional criterion of intelligence; Cornelious & Caspi, 1987). It is not totally accurate to assume that people with low levels of education are somehow “deprived”. It may be more accurate to assume that they have developed different types of learning, more procedural, pragmatic and sensory oriented.

Therefore, the effects of literacy and schooling on cognition include the following:

- (1) *Literacy provides an additional instrument for acquiring information.* Information can be obtained not only using oral tradition, but also from books, journals, and so forth.
- (2) *The process of learning to read and write may train specific additional abilities,* such as explicit phonological awareness, spatial perception, and fine movements.
- (3) *Reading and writing implies an additional instrument of conceptualization, interpretation, and mediation of the world* (Luria, 1966; Vygotsky, 1934/1978). Memory not only means being able to recall something, but also recording the information in a notebook (“auxiliary hippocampus”); social communication not only means speaking and listening, but also reading and writing. An explanation about how to improve agriculture can be replaced by a written pamphlet. The instruction about how to go to a particular place can be found through reading a paper or using written street names.
- (4) *Attending school also has certain consequences on cognition, independent of reading and writing.* It contributes to the development of specific attitudes toward knowing, understanding, and thinking. School provides training in reading, but also in mathematics, geography, drawing, history, and natural sciences. Furthermore, school represents a special type of setting centered on specific values: Learning, memorizing, understanding, and achieving. This is not necessarily valid to the same extent in every type of school (e.g., in a school of arts, a trade school or a religious school).

Consequently, many of “the effects of literacy are not only due to learning to read, but also to attending school,” and, thus, developing a way of interpreting the world—a cosmivision, so to speak—the cosmivision of learning and understanding.

It also appears that lateralized fine motor skills develop in the process of learning to write. Habits in directions of visual scanning also appear to develop with the acquisition of literacy.

It is fairly clear that illiterates generally perform more poorly than literates on a variety of cognitive and neuropsychological tests. The reasons for this are not obvious, but candidate explanations are:

- (a) Acquiring literacy develops cognitive skills that are measured by the tests.
- (b) Cognitive instruction that is part of schooling but not specifically part of learning literacy develops some of the cognitive skills measured by the tests.
- (c) Schooling develops an understanding of what is expected in testing and how to go about taking tests effectively.
- (d) Schooling develops a predisposition toward achievement in testing.

The relative weight of each of these factors, or perhaps even other, unknown factors, on the neuropsychological performance of illiterates is not yet known. Future studies in this area are needed to determine the factors that may contribute to differential neuropsychological performance between literates and illiterates, as well as the relative role of the particular cognitive functions being tested, the educational system and philosophy to which examinees were exposed, the particular language, writing system, and/or population from which they have been influenced.

The process of elucidating cognitive mechanisms particular to illiteracy, especially as they contrast with those involved in literacy, may help to expand our understanding of human cognition and functional brain organization as they relate to both normal and pathological conditions.

Conflict of Interest

None declared.

References

- Aleman, A., Bronk, E., Kessels, R. P., Koppeschaar, H. P., & van Honk, J. (2004). A single administration of testosterone improves visuospatial ability in young women. *Psychoneuroendocrinology*, *29*, 612–617.
- Ahonniska, J., Cantell, M., Tolvanen, A., & Lyytinen, H. (1993). Speech perception and brain laterality: The effect of ear advantage on auditory event-related potentials. *Brain and Language*, *45*, 127–146.
- Ardila, A. (2004). There is not any specific brain area for writing: From cave painting to computers. *International Journal of Psychology*, *39*, 61–67.
- Ardila, A., & Moreno, S. (2001). Neuropsychological evaluation in Aruaco Indians: An exploratory study. *Journal of the International Neuropsychological Society*, *7*, 510–515.
- Ardila, A., Ostrosky, F., & Mendoza, V. (2000). Learning to read is much more than learning to read: A neuropsychologically-based learning to read method. *Journal of the International Neuropsychological Society*, *6*, 789–801.
- Ardila, A., Ostrosky-Solis, F., Rosselli, M., & Gomez, C. (2000). Age related cognitive decline during normal aging: The complex effect of education. *Archives of Clinical Neuropsychology*, *15*, 495–514.
- Ardila, A., & Rosselli, M. (2003). Educational effects on the ROCF performance. In J. Knight & E. Kaplan (Eds.), *Rey-Osterrieth complex figure handbook* (pp. 271–281). Lutz, FL: Psychological Assessment Resources.
- Ardila, A., Rosselli, M., & Ostrosky, F. (1992). Socioeducational factors in neuropsychological assessment. In A. E. Puente & R. J. McCaffrey (Eds.), *Handbook of neuropsychological assessment: A biopsychosocial perspective* (pp. 181–192). McCaffrey: Plenum Press.
- Ardila, A., Rosselli, M., & Rosas, P. (1989). Neuropsychological assessment in illiterates: Visuospatial and memory abilities. *Brain and Cognition*, *11*, 147–166.
- Bartlett, F. C. (1932). *Remembering*. Cambridge: Cambridge University Press.
- Benbow, C. P., Libinski, D., Shea, D., & Eftekhari-Sanjani, H. (2000). Sex differences in mathematical reasoning ability at age 13: Their status 20 years later. *Psychological Science*, *11*, 169–232.
- Bernstein, B. (1974). Language and roles. In R. Huxley & E. Ingram (Eds.), *Language acquisition: Models and methods* (pp. 220–256). New York: Academic Press.
- Berry, J. W., & Bennet, J. (1989). Syllabic literacy and cognitive performance among the Cree. *International Journal of Psychology*, *24*, 429–450.
- Berry, J. W., & Bennett, J. A. (1992). Cree conceptions of cognitive competence. *International Journal of Psychology*, *27*, 73–88.
- Bertolucci, P. H. F., Brucki, S. M. D., Campacci, S., & Juliano, Y. (1994). O Mini-Exame do Estado Mental em uma população geral: impacto da escolaridade. *Arquivos de Neuropsiquiatria*, *52*, 1–7.
- Blackmore, S. (1999). *The Meme Machine*. New York: Oxford University Press.
- Blanch, R. J., Brennan, D., Condon, B., Santosh, C., & Hadley, D. (2004). Are there gender-specific neural substrates of route learning from different perspectives? *Cerebral Cortex*, *14*, 1207–1213.
- Bonaiuto, R., Rocca, E., & Lippi, A. (1990). Impact of education and occupation on the prevalence of Alzheimer's disease (AD) and multi infarct dementia in Appignano, Macerata Province, Italy [abstract]. *Neurology*, *40*, 346.
- Bowler, J. V., Munoz, D. G., Merskey, H., & Hachinski, V. (1998). Factors affecting the age of onset and rate of progression of Alzheimer's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, *65*, 184–190.
- Bramão, I., Mendonça, A., Faisca, L., Ingvar, M., Petersson, K. M., & Reis, A. (2007). The impact of reading and writing on visuo-motor integration task: A comparison between illiterate and literate subjects. *Journal of the International Neuropsychological Society*, *13*, 359–364.
- Brucki, S. M., Malheiros, S. M., Okamoto, I. H., & Bertolucci, P. H. (1997). Dados normativos para o teste de fluência verbal categoria animais em nosso meio. *Arquivos de Neuropsiquiatria*, *55*, 56–61.
- Brucki, S. M., & Rocha, M. S. (2004). Category fluency test: Effects of age, gender and education on total scores, clustering and switching in Brazilian Portuguese-speaking subjects. *Brazilian Journal of Medical and Biological Research*, *37*, 1771–1777.
- Brucki, S. M. D., Nitrini, R., Caramelli, P., Bertolucci, P. H. F., & Okamoto, I. H. (2003). Sugestões para o uso do Mini-Exame do Estado Mental no Brasil. *Arquivos de Neuropsiquiatria*, *61*, 777–781.
- Bruner, J., Oliver, R., & Greenfield, P. (1966). *Studies in cognitive growth*. New York: Wiley.
- Buffery, A., & Gray, J. (1972). Sex differences in the development of spatial and linguistic skills. In C. Ounsted & D. C. Taylor (Eds.), *Gender differences, their ontogeny and significance*. New York: Churchill Livingstone.

- Callahan, C. M., Hall, K. S., Hui, S. L., Beverly, S. M., Unverzagt, F. W., & Hendrie, H. C. (1996). Relationship of age, education, and occupation with dementia among a community-based sample of African Americans. *Neurologic Reviews*, *53*, 134–140.
- Cameron, R. F., Currier, R. D., & Haerer, A. F. (1971). Aphasia and literacy. *British Journal of Disorders of Communication*, *6*, 161–163.
- Capitani, E., Barbarotto, R., & Laicana, M. (1996). Does education influence age-related cognitive decline? A further inquiry. *Developmental Neuropsychology*, *12*, 231–240.
- Caplan, P. J., Crawford, M., Hyde, J. S., & Richardson, J. T. E. (1997). *Gender differences in human cognition*. New York: Oxford University Press.
- Caramelli, P., Poissant, A., Gauthier, P., Bellavance, A., Gauvreau, D., Lecours, A. R., et al. (1997). Educational level and neuropsychological heterogeneity in dementia of the Alzheimer type. *Alzheimer Disease and Associated Disorders*, *11*, 9–15.
- Carreiras, M., Seghier, M. L., Baquero, S., Estevez, A., Lozano, A., Devlin, J. T., et al. (2009). An anatomical signature for literacy. *Nature*, *461* (7266), 983–986.
- Castro, S. L., & Morais, J. (1987). Ear differences in illiterates. *Neuropsychologia*, *25*, 409–417.
- Castro-Caldas, A. (2004). Targeting regions of interest for the study of the illiterate brain. *International Journal of Psychology*, *39* (1), 5–17.
- Castro-Caldas, A., Miranda, P. C., Carmo, I., Reis, A., Leote, F., Ribeiro, C., et al. (1999). Influence of learning to read and write on the morphology of the corpus callosum. *European Journal of Neurology*, *6*, 23–28.
- Castro-Caldas, A., Nunes, M. V., Maestu, F., Ortiz, T., Simoes, R., Fernandes, R., et al. (2009). Learning orthography in adulthood: A magnetoencephalographic study. *Journal of Neuropsychology*, *3*, 17–30.
- Castro-Caldas, A., Peterson, K. M., Reis, A., Askelof, S., & Ingvar, M. (1998). Differences in inter-hemispheric interactions related to literacy, assessed by PET. *Neurology*, *50*, A43.
- Castro-Caldas, A., Petersson, K. M., Reis, A., Stone-Elander, S., & Ingvar, M. (1998). The illiterate brain: Learning to read and write during childhood influences the functional organization of the adult brain. *Brain*, *121*, 1053–1064.
- Castro-Caldas, A., Confraria, A., Paiva, T., & Trindade, A. (1987). Contrecoup injury in the misdiagnosis of crossed aphasia. *Journal of Clinical and Experimental Neuropsychology*, *8*, 697–701.
- Chandra, V., Ganguli, M., Ratcliff, G., Pandav, R., Sharma, S., Belle, S., et al. (1998). Practical issues in cognitive screening of elderly illiterate populations in developing countries. The Indo-US Cross-National Dementia Epidemiology Study. *Aging (Milano)*, *10*, 349–357.
- Childe, V. G. (1936). *Man makes himself*. London: Pitman Publishing.
- Christensen, H., & Henderson, A. S. (1991). In age kinder to the initially more able? A study of eminent scientists and academics. *Psychological Medicine*, *21*, 935–946.
- Ciborowski, I. J. (1979). Cross-cultural aspects of cognitive functioning: Culture and knowledge. In A. J. Marsella, R. G. Tharp, & I. J. Ciborowski (Eds.), *Perspectives in cross-cultural psychology* (pp. 101–116). New York: Academic Press.
- Coe, M., & Vanstone, M. (2005). *Reading the Maya Glyphs*. London: Thames & Hudson.
- Cole, M., Frankel, F., & Sharp, D. W. (1971). The developmental of free recall learning in children. *Developmental Psychology*, *4*, 109–123.
- Cole, M., Gay, J., Glick, J., & Sharp, D. W. (1971). *The cultural context of learning and thinking*. Basic Books.
- Cole, M., & Scribner, S. (1974). *Culture and thought*. New York: Wiley.
- Cornelius, S. W., & Caspi, A. (1987). Everyday problem solving in adulthood and old age. *Psychology of Aging*, *2*, 144–153.
- Critchley, M. (1956). Premorbid literacy and the pattern of subsequent aphasia. *Proceedings of the Society of Medicine*, *49*, 335–336.
- Damasio, A. R., Castro-Caldas, A., Grosso, J. T., & Ferro, J. M. (1976). Brain specialization for language does not depend on literacy. *Archives of Neurology*, *33*, 300–301.
- Damasio, H., Damasio, A. R., Castro-Caldas, A., & Ferro, J. M. (1979). Reversal for ear advantage for phonetically similar words in illiterates. *Journal of Clinical Neuropsychology*, *1*, 331–338.
- Dansilio, S., & Charamelo, A. (2005). Constructional functions and figure copying in illiterates or low-schooled Hispanics. *Archives of Clinical Neuropsychology*, *20*, 1105–1112.
- Dartigues, J. F., Gagnon, M., & Michel, P. (1991). Le programme de recherche PAQUID su l'epidemiologie de la demence methodes et resultats initiaux. *Revue Neurologique*, *145*, 225–230.
- Da Silva, C. G., Petersson, K. M., Faísca, L., Ingvar, M., & Reis, A. (2004). The effects of literacy and education on the quantitative and qualitative aspects of semantic verbal fluency. *Journal of Clinical and Experimental Neuropsychology*, *26*, 266–277.
- Deloche, G., Seron, X., Larroque, C., et al. (1994). Calculation and number processing: Assessment battery; role of demographic factors. *Journal of Clinical and Experimental Neuropsychology*, *16*, 195–208.
- Deloche, G., Souza, L., Braga, L. W., & Dellatolas, G. (1999). A calculation and number processing battery for clinical application in illiterates and semi-literates. *Cortex*, *35*, 503–521.
- Duara, R., Barker, W. W., Lopez-Alberola, R., Loewenstein, D. A., Grau, L. B., Gilchrist, D., et al. (1996). Alzheimer's disease: Interaction of apolipoprotein E genotype, family history of dementia, gender, education, ethnicity, and age of onset. *Neurology*, *46*, 1575–1579.
- Eslinger, P. J., & Grattan, L. M. (1993). Frontal lobe and frontal-striatal substrates for different forms of human cognitive flexibility. *Neuropsychologia*, *31*, 17–28.
- Folia, V., & Kosmidis, M. H. (2003). Assessment of memory skills in illiterates: Strategy differences or test artifact? *The Clinical Neuropsychologist*, *17*, 143–152.
- Folstein, M. F., Folstein, S., & Mchugh, P. R. (1975). Mini-Mental State: A practical method for grading the cognitive state of patients for the clinicians. *Journal of Psychological Research*, *12*, 189–198.
- Fonseca, J., & Castro-Caldas, A. (2002). The knowledge of reading and writing rules influences aphasia outcome. *Journal of the International Neuropsychological Society*, *8*, 506.
- Fratiglioni, L., Grut, M., Forsell, Y., et al. (1991). Prevalence of Alzheimer's disease and other dementias in an elderly urban population: Relationship with age, sex, and education. *Neurology*, *41*, 1886–1892.
- Friedland, R. O. (1993). Epidemiology, education, and the ecology of Alzheimer's disease. *Neurology*, *43*, 246–249.
- Fuld, P. A. (1980). *Fuld Object-Memory Evaluation*. Wood Dale, Illinois: Stoelting.
- Geary, D. C. (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences*, *19*, 229–284.

- Goldblum, M. C., & Matute, E. (1986). Are illiterate people deep dyslexics? *Journal of Neurolinguistics*, 2, 103–114.
- Gonçalves, P. M. (2004). Parents, presence, and education. *Servir*, 52, 24–26.
- Green, D. S., & Stewart, O. (1984). Test wiseness: The concept has no clothes. *College Student Journal*, 18, 416–424.
- Haarmann, H. (1991). *Universalgeschichte der Schrift* (2nd ed.). Frankfurt (Main)/New York: Campus.
- Haarmann, H. (2008). Retrieved March 26, 2009, from http://www.archaeomythology.org/journal/read_article.php?a=0108_2_haarmann.pdf.
- Hedges, L. V., & Nowell, A. (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science*, 269, 41–45.
- Hendrie, H. C., Ogunniyi, A., Hall, K. S., et al. (2001). Incidence of dementia and Alzheimer disease in 2 communities: Yoruba residing in Ibadan, Nigeria, and African Americans residing in Indianapolis, Indiana. *Journal of the American Medical Association*, 285, 739–747.
- Herrera, E., Caramelli, P., Silveira, A. S. B., & Nitrini, R. (2002). Epidemiological survey of dementia in a community-dwelling Brazilian population. *Alzheimer Disease and Associated Disorders*, 16, 103–108.
- Hill, L. R., Klauber, M. R., Salmon, D. P., Yu, E. S., Zhang, M., & Katzman, R. (1993). Functional status, education, and the diagnosis of dementia in the Shanghai survey. *Neurology*, 43, 138–145.
- International Adult Literacy Survey. (1998). Organization for Economic Co-operation and Development (OECD) and Statistics Canada. Retrieved Jun 26, 2007, from <http://www.statcan.ca/english/Dli/Data/Ftp/ials.htm>.
- Joanette, Y., Lecours, A. R., Lepage, Y., & Lamoureux, M. (1983). Language in right-handers with right-hemisphere lesions: A preliminary study including anatomical, genetic and social factors. *Brain and Language*, 20, 217–248.
- Judd, T., & DeBoard, R. (2007). Natural recovery: An ecological approach to neuropsychological recuperation. In B. Uzzell, M. Pontón, & A. Ardila (Eds.), *International handbook of cross-cultural neuropsychology*. New York: Lawrence Erlbaum Associates.
- Karavatos, A., Kaprinis, G., & Tzavaras, A. (1984). Hemispheric specialization for language in the congenitally blind: The influence of the Braille system. *Neuropsychologia*, 22, 521–525.
- Katzman, R. (1993). Education and the prevalence of dementia and Alzheimer's disease. *Neurology*, 43, 13–20.
- Katzman, R., Aronson, M., Fuld, P., et al. (1989). Development of dementing illnesses in a 80-year-old volunteer cohort. *Annals of Neurology*, 25, 317–324.
- Knoefel, J. E., Wolf, P. A., Linn, R. T., et al. (1991). Education has not effect on incidence of dementia and Alzheimer's disease in the Framingham study. *Neurology*, 41, 322–323.
- Korczyn, A. D., Kahan, F., & Gulper, Y. (1991). Epidemiology of dementia in Ashkelom, Israel. *Neuroepidemiology*, 10, 100–120.
- Kosmidis, M. H., Tsapkini, K., & Folia, V. (2006). Lexical processing in illiteracy: Effect of literacy or education? *Cortex*, 42, 1021–1027.
- Kosmidis, M. H., Tsapkini, K., Folia, V., Vlahou, C. H., & Kiosseoglou, G. (2004). Semantic and phonological processing in illiteracy. *Journal of the International Neuropsychological Society*, 10, 818–827.
- Kotik-Friedgut, B., & Ardila, A. (2004). Systemic-dynamic Lurian theory and contemporary cross-cultural neuropsychology. In T. Akhutina, L. Moskovich, & T. Dorothy (Eds.), *Luria and contemporary psychology* (pp. 55–61). New York: Nova.
- Laboratory of Comparative Human Cognition. (1983). Culture and cognitive development. In P. Mussen (Ed.), *Handbook of child psychology: History, theories and methods*. New York: Wiley.
- Lantz, D. (1979). A cross-cultural comparison of communication abilities: Some effects of age, schooling and culture. *International Journal of Psychology*, 14, 171–183.
- Launer, L. J., Dinkgreve, M. A. H. M., Jonker, C., Hooijer, C., & Lindeboom, J. (1993). Are age and education independent correlates of the mini-mental state exam performance of community-dwelling elderly? *Journal of Gerontology*, 48, 271–277.
- Laurendeau-Bendavid, M. (1977). Culture, schooling and cognitive development: A comparative study of children in French, Canada and Rwanda. In P. R. Dasen (Ed.), *Piagetian psychology: Cross cultural contributions*. Cincinnati: Gardner.
- Lave, J. (1996). The practice of learning. In S. Chaiklin, & J. Lave (Eds.), *Understanding practice: Perspectives on activity and context*. New York: Cambridge University Press.
- Lecours, A. R., Mehler, J., Parente, M. A., et al. (1987a). Illiteracy and brain damage I: Aphasia testing in culturally contrasted populations (control subjects). *Neuropsychologia*, 25, 231–245.
- Lecours, A. R., Mehler, J., Parente, M. A., et al. (1987b). Illiteracy and brain damage 2, manifestations of unilateral neglect in testing "auditory comprehension" with iconographic material. *Brain and Cognition*, 6, 243–265.
- Lecours, A. R., Mehler, J., Parente, M. A., et al. (1988). Illiteracy and brain damage 3, a contribution to the study of speech and language disorders in illiterates with unilateral brain damage (initial testing). *Neuropsychologia*, 26, 575–589.
- Lecours, A. R., Peña-Casanova, J., & Ardila, A. (1998). Orígenes y evolución de la escritura. In A. R. Lecours, J. Peña-Casanova, & F. Dieguez-Vide (Eds.), *Dislexia y disgrafía: Teoría, formas clínicas y exploración*. Barcelona, Spain: Masson.
- Letenneur, L., Commenges, D., Dartigues, J. F., & Barberger-Gateau, P. (1994). Incidence of dementia and Alzheimer's disease in elderly community residents of south-western France. *International Journal of Epidemiology*, 23, 1256–1261.
- Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological Assessment*. New York: Oxford University Press.
- Li, G., Cheung, R. T., Gao, J. H., Lee, T. M., Tan, L. H., & Fox, P. T. (2006). Cognitive processing in Chinese literate and illiterate subjects: An fMRI study. *Human Brain Mapping*, 27, 144–152.
- Li, X. (2003). The earliest writing? Sign use in the seventh millennium BC at Jiahu, Henan Province, China. *Antiquity*, 77 (295), 31–44.
- Liu, H.-C., Teng, E. L., Lin, K.-N., Hsu, T. C., Guo, N.-W., Chou, P., et al. (1994). Performance on a dementia screening test in relation to demographic variables. *Archives of Neurology*, 51, 910–915.
- Lord, A. B. (1995). *The Singer Resumes the Tale*. Ithaca: Cornell University Press.
- Loureiro, C. S., Braga, L. W., Souza, L. N., Nunes Filho, G., Queiroz, E., & Dellatolas, G. (2004). Degree of illiteracy and phonological and metaphonological skills in unschooled adults. *Brain and Language*, 89, 499–502.
- Luria, A. R. (1931). Psychological expedition to central Asia. *Science*, 74, 383–384.
- Luria, A. R. (1933). The second psychological expedition to central Asia. *Science*, 78, 191–192.
- Luria, A. R. (1966). *Higher Cortical Functions in Man*. New York: Basic Books.
- Luria, A. R. (1973). *The Working Brain*. London: Penguin books.
- Luria, A. R. (1976). *Cognitive development*. Harvard University Press.

- Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Palo Alto, CA: Stanford University Press.
- Manly, J. J. (2006). Deconstructing race and ethnicity: Implications for measurement of health outcomes. *Medical Care*, 44 (11 Suppl. 3), S10–S16.
- Manly, J. J., Jacobs, D. M., Sano, M., Bell, K., Merchant, C. A., Small, S., et al. (1999). Effect of literacy on neuropsychological test performance in non-demented, education-matched elders. *Journal of the International Neuropsychological Society*, 5, 191–202.
- Martos-Perez, J., & Ayuda-Pascual, R. (2003). Autismo e hiperlexia. *Revista de Neurologia*, 36, S57–S60.
- Matute, E. (1986). Aphasia in illiterates. *Journal of Neurolinguistics*, 2, 115–130.
- Matute, E. (1988). El aprendizaje de la lectoescritura y la especialización hemisférica para el lenguaje. In A. Ardila & F. Ostrosky (Eds.), *Lenguaje oral y escrito*. Mexico, DF: Trillas.
- Matute, E., Leal, F., Zarabozo, D., Robles, A., & Cedillo, C. (2000). Does literacy have an effect on stick construction tasks? *Journal of the International Neuropsychological Society*, 6, 668–672.
- Matute, E., Montiel, T., Pinto, N., Rosselli, M., Zarabozo, D., & Ardila, A. Neuropsychological test performance on healthy illiterate children. Manuscript submitted for publication.
- Montiel, T., & Matute, E. (2006). La relación entre alfabetización y la escolarización con el desempeño en tareas verbales. In E. Matute (Ed.), *Lectura y diversidad cultural*. Guadalajara, Mexico: Universidad de Guadalajara.
- Morais, J., Bertelson, P., Cary, L., & Alegria, J. (1987). Literacy training and speech segmentation. In P. Bertelson (Ed.), *The onset of literacy. Cognitive process in reading acquisition*. Boston: MIT Press.
- Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition*, 7, 323–331.
- Mortiner, J. A., & Graves, A. B. (1993). Education and other socioeconomic determinants of dementia and Alzheimer's disease. *Neurology*, 43, 39–44.
- Nation, K. (1999). Reading skills in hyperlexia: A developmental perspective. *Psychological Bulletin*, 125, 338–355.
- Nell, V. (2000). *Cross-cultural neuropsychological assessment: Theory and practice*. New York: Lawrence Erlbaum Associates.
- Nitrini, R., Bottino, C. M. C., Albala, C., Custodio, N. S., Ketzoian, C., Llibre, J. J., et al. (2009). Prevalence of dementia in Latin America: A collaborative study of population-based cohorts. *International Psychogeriatrics*, 21, 622–630.
- Nitrini, R., Caramelli, P., Herrera, E., et al. (2004a). Incidence of dementia in a community-dwelling Brazilian population. *Alzheimer Disease and Associated Disorders*, 18, 241–246.
- Nitrini, R., Caramelli, P., Herrera, E., Jr, Charchat-Fichman, H., & Porto, C. S. (2005). Performance in Luria's fist-edge-palm test according to educational level. *Cognitive Behavioral Neurology*, 18, 211–214.
- Nitrini, R., Caramelli, P., Herrera, E., Porto, C. S., Charchat-Fichman, H., Carthery, M. T., et al. (2004). Performance of illiterate and literate nondemented elderly subjects in two tests of long-term memory. *Journal of the International Neuropsychological Society*, 10, 634–638.
- No author. (1993). *La naissance de l'écriture. L'histoire du Monde N°2*. Paris: Larousse.
- Norton, A., Winner, E., Cronin, K., Overy, K., Lee, D. J., & Schanlg, G. (2005). Are there pre-existing neural, cognitive, or motoric markers for musical ability? *Brain and Cognition*, 59, 124–134.
- O'Connor, D. W., Pollitt, P. A., & Treasure, F. P. (1991). The influence of education and social class on the diagnosis of dementia in a community population. *Psychological Medicine*, 21, 219–234.
- Ogunniyi, A., Baiyewu, O., Gureje, O., et al. (2000). Epidemiology of dementia in Nigeria: Results from the Indianapolis-Ibadan study. *European Journal of Neurology*, 7, 485–490.
- Olson, D. R., & Torrance, N. (Eds.). (2009). *The Cambridge Handbook of Literacy*. Cambridge: Cambridge University Press.
- Ostrosky, F., Ardila, A., & Rosselli, M. (1999). NEUROPSI: A brief neuropsychological test battery in Spanish. *Journal of the International Neuropsychological Society*, 5, 413–433.
- Ostrosky, F., Ardila, A., Rosselli, M., López-Arango, G., & Uriel-Mendoza, V. (1998). Neuropsychological test performance in illiterates. *Archives of Clinical Neuropsychology*, 13, 645–660.
- Ostrosky-Solís, F., Arellano, M., & Pérez, M. (2004). Can learning to read and write change the brain organization? An electrophysiological Study. *International Journal of Psychology*, 39, 27–35.
- Ostrosky, F., Quintanar, L., Canseco, E., Meneses, S., Navarro, E., & Ardila, A. (1986). Habilidades cognitivas y nivel sociocultural. *Revista de Investigación Clínica*, 38, 37–42.
- Ostrosky-Solís, F., Canseco, E., Quintanar, L., Navarro, E., Meneses, S., & Ardila, A. (1985). Sociocultural effects in neuropsychological assessment. *International Journal of Neuroscience*, 27, 53–66.
- Ostrosky-Solís, F., Efron, R., & Yund, E. (1991). Visual detectability gradients: Effects of illiteracy. *Brain and Cognition*, 17, 42–51.
- Ostrosky-Solís, F., Lozano, A., Ramírez, M., Picasso, H., Gomez, E., Velez, A., et al. (2003). Estudio Neuropsicológico de Población Mexicana en Proceso de Alfabetización. *Revista Mexicana de Psicología*, 20, 5–17.
- Ostrosky-Solís, F., Ramírez, M., Lozano, A., Picasso, H., & Velez, A. (2004). Culture or education: A study with indigenous Maya population. *International Journal of Psychology*, 39, 36–46.
- Padakannaya, P., Devi, M. L., Zaveria, B., Chengappa, S. K., & Vaid, J. (2002). Directional scanning effect and strength of reading habit in picture naming and recall. *Brain and Cognition*, 48, 484–490.
- Parkin, A. J., & Leng, N. R. C. (1993). *Neuropsychology of the amnesic syndrome*. Hove, UK: Erlbaum.
- Paulesu, E., Demonet, J. F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., et al. (2001). Dyslexia: Cultural diversity and biological unity. *Science*, 291, 2165–2167.
- Petersson, K. M., Reis, A., Askelof, S., Castro-Caldas, A., & Ingvar, M. (2000). Language processing modulated by literacy: A network analysis of verbal repetition in literate and illiterate subjects. *Journal of Cognitive Neurosciences*, 12, 364–382.
- Petersson, K.M., Reis, A., & Ingvar, M. (2001). Cognitive processing in literate and illiterate subjects: A review of some recent behavioral and functional neuroimaging data. *Scandinavian Journal of Psychology*, 42, 251–267.
- Qiu, C., Blackman, L., Winblad, B., et al. (2001). The influence of education on clinically diagnosed dementia incidence and mortality data from the Kungsholmen Project. *Archives of Neurology*, 58, 2034–2039.
- Quaiser-Pohl, C., & Lehmann, W. (2002). Girls' spatial abilities: Charting the contributions of experiences and attitudes in different academic groups. *The British Journal of Educational Psychology*, 72, 245–260.

- Reis, A., & Castro-Caldas, A. (1997). Illiteracy: A bias for cognitive development. *Journal of the International Neuropsychological Society*, 3, 444–450.
- Reis, A., Guerreiro, M., & Castro-Caldas, A. (1994). Influence of educational level of non brain-damaged subjects on visual naming capacities. *Journal of Clinical and Experimental Neuropsychology*, 16, 939–942.
- Reis, A., Petersson, K. M., Castro-Caldas, A., & Ingvar, M. (2001). Formal schooling influences two- but not three-dimensional naming skills. *Brain and Cognition*, 47, 397–411.
- Reinvang, I., Bakke, S. J., Hugdahl, K., Karlsen, N. R., & Sundet, K. (1994). Dichotic listening performance in relation to callosal area on the MRI scan. *Neuropsychology*, 8, 445–450.
- Riddoch, M. J., & Humphreys, G. W. (1987). A case of integrative visual agnosia. *Brain*, 110, 1431–1462.
- Rilea, S. L., Roskos-Ewoldsen, B., & Boles, D. (2004). Sex differences in spatial ability: A lateralization of function approach. *Brain and Cognition*, 56, 332–343.
- Robinson, W. P. (1974). Social factors and language development in primary school children. In R. Huxley & E. Ingram (Eds.), *Language acquisition: Models and methods*. New York: Academic Press.
- Rocca, W. A., Bonaiuto, S., Lippi, A., Luciano, P., Turtu, F., Cavarzeran, F., et al. (1990). Prevalence of clinically diagnosed Alzheimer's disease and other dementing disorders: A door-to-door survey in Appignano, Macerata Province, Italy. *Neurology*, 40, 626–631.
- Roe, C. M., Xiong, C., Miller, J. P., & Morris, J. C. (2007). Education and Alzheimer disease without dementia: Support for the cognitive reserve hypothesis. *Neurology*, 68, 223–228.
- Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. Oxford: Oxford University Press.
- Rosselli, D., Ardila, A., Pradilla, G., Morillo, L., Bautista, L., Rey, O., et al. (2000). El examen mental abreviado (Mini-Mental State Examination) como prueba de selección para el diagnóstico de demencia: estudio poblacional colombiano GENECO. *Revista de Neurología*, 30, 428–432.
- Rosselli, M., & Ardila, A. (2003). The impact of culture and education on nonverbal neuropsychological measurements: A critical review. *Brain and Cognition*, 52, 226–233.
- Rosselli, M., Ardila, A., & Rosas, P. (1990). Neuropsychological assessment in illiterates II: Language and praxis abilities. *Brain and Cognition*, 12, 281–296.
- Rosselli, M., Rosselli, A., Vergara, I., & Ardila, A. (1985). The topography of the hemi-inattention syndrome. *International Journal of Neuroscience*, 20, 153–160.
- Sampson, G. (1985). *Writing systems*. Palo Alto, CA: Stanford University Press.
- Schmandt-Besserat, D. (1996). *How writing came about*. Houston: University of Texas.
- Scribner, S., & Cole, M. (1981). *The psychology of literacy*. Boston: Harvard University Press.
- Serniclaes, W., Ventura, P., Morais, J., & Kolinsky, R. (2005). Categorical perception of speech sounds in illiterate adults. *Cognition*, 98 (2), B35–B44.
- Serpell, R. (1993). *The significance of schooling: Life-journeys in an African society*. Cambridge: Cambridge University Press.
- Stephan, K., Marshall, J., Friston, K., Rowe, J., Ritzl, A., Killes, K., et al. (2003). Lateralized cognitive processes and lateralized task control in the human brain. *Science*, 301, 384–386.
- Stern, Y. (2006). Cognitive reserve and Alzheimer disease. *Alzheimer Disease Associated Disorders*, 20, S69–S74.
- Stern, Y., Gurland, B., Tatemichi, T. K., Tang, M. X., Wilder, D., & Mayeux, R. (1994). Influence of education and occupation on the incidence of Alzheimer's disease. *Journal of the American Medical Association*, 271, 1004–1101.
- Suddendorf, T., & Corballis, M. C. (1997). Mental time travel and the evolution of the human mind. *Genetic, Social and General Psychology Monographs*, 123, 133–167.
- Sulkava, R., Wikstrom, J., Aromaa, A., et al. (1985). Prevalence of severe dementia in Finland. *Neurology*, 35, 1025–1029.
- Thorndike, R. L. (1951). In E. F. Lindquist (Ed.), *Reliability in educational measurement*. Washington, DC: American Council on Education.
- Tzavaras, A., Kaprinis, G., & Gatzoyas, A. (1981). Literacy and hemispheric specialization for language: Digit dichotic listening in illiterates. *Neuropsychologia*, 19, 565–570.
- UNESCO (2005). Literacy. Retrieved March 27, 2009, from http://portal.unesco.org/education/en/ev.php_URL_ID=40341&URL_DO=DO_TOPIC&URL_SECTION=201.html.
- Vaid, J., Singh, M., Sakhuja, T., & Gupta, G. C. (2002). Stroke direction asymmetry in figure drawing: Influence of handedness and reading/writing habits. *Brain and Cognition*, 48, 597–602.
- van Ettinger-Veenstra, H. M., Ragnehed, M., Hällgren, M., Karlsson, T., Landtblom, A. M., Lundberg, P., & Engström, M. (2010). Right hemispheric brain activation correlates to language performance. *Neuroimage*, 49, 3481–3488.
- Ventura, P., Kolinsky, R., Querido, J. L., Fernandes, S., & Morais, J. (2007). Is phonological encoding in naming influenced by literacy? *Journal of Psycholinguistic Research*, 36 (5), 341–360.
- Vygotsky, L. S. (1934/1978) *Mind in society*. Boston: Harvard University Press.
- Wechsler, A. F. (1976). Crossed aphasia in an illiterate dextral. *Brain and Language*, 3, 164–172.
- Westerhausen, R., & Hugdahl, K. (2008). The corpus callosum in dichotic listening studies of hemispheric asymmetry: A review of clinical and experimental evidence. *Neuroscience and Biobehavioral Review*, 32, 1044–1054.
- Wilson, B. A., Cockburn, J., & Baddeley, A. (1985). *Rivermead Behavioural Memory Test*. San Antonio: Psychological Corporation.
- Yassuda, M. S., Diniz, B. S., Flaks, M. K., Viola, L. F., Pereira, F. S., Nunes, P. V., et al. (2009). Neuropsychological profile of Brazilian older adults with heterogeneous educational backgrounds. *Archives of Clinical Neuropsychology*, 24 (1), 71–79.
- Yu, E., Liu, W. T., Levy, P., et al. (1989). Cognitive impairment among elderly adults in Shanghai, China. *Journal of Gerontology: Social Sciences*, 44, S97–S106.
- Zhang, M., Katzman, R., Salmon, D., Jin, H., Goujun, C., Wang, Z., et al. (1990). The prevalence of dementia and Alzheimer's disease in Shanghai, China. *Annals of Neurology*, 27, 428–437.