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There is not any specific brain area for writing: From cave-paintings to computers

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In this paper it is pointed out that human brain adaptation was accomplished to survive in certain living conditions that existed long before classical civilizations did. It is argued that there is no brain area specialized for writing, but rather that writing relies on some basic abilities that existed long before writing was invented. Pre-writing was initially a visuoconstructive and ideomotor ability, and only later did it become the language-related ability of writing. It is also emphasized that most of the neuropsychological syndromes, including agraphia, were described during the late 19th and early 20th century, but living conditions have changed dramatically during the last 100 years. Writing no longer means only using pencil and paper, but using computer word processing programs. Writing using paper and pencil does not require the same cognitive, motor, and spatial tasks as those required when using a computer keyboard. Although the conceptual knowledge of written language can be the same, the motor activity and the spatial abilities that are used are rather different. It can be anticipated that new neuropsychological syndromes resulting from these new living conditions will be described in the future.

Cet article attire l'attention sur le fait que le cerveau humain s'est adapté afin de survivre dans des conditions de vie existant longtemps avant les civilisations classiques. Il est proposé qu'il n'y a aucune zone cérébrale spécialisée pour l'écriture, mais plutôt que l'écriture repose sur certaines habiletés de base existant bien avant que l'écriture soit inventée. La pré-écriture était initialement une habileté visuoconstructive et idéomotrice et ce n'est que plus tard qu'elle est devenue une habileté reliée au langage (écriture). Par ailleurs, cet article met l'emphase sur le fait que la plupart des syndromes neuropsychologiques, incluant l'agraphie, furent décrits au cours de la fin du 19ème siècle et le début du 20ème siècle. Cependant, les conditions de vie ont énormément évoluées durant les 100 dernières années. Écrire ne représente plus uniquement le fait d'utiliser un papier et un crayon, mais également l'utilisation d'un programme de traitement de texte informatisé. L'écriture au moyen d'un papier et d'un crayon ne fait pas référence aux mêmes tâches cognitives, motrices et spatiales que l'écriture à partir d'un clavier d'ordinateur. Quoique la connaissance conceptuelle du langage écrit puisse être la même, l'activité motrice et les habiletés spatiales utilisées sont différentes. Il peut être anticipé que, dans le futur, les syndromes neuropsychologiques résultant de ces nouvelles conditions de vie seront décrits.

En este artículo se señala que la adaptación del cerebro humano fue lograda para sobrevivir bajo ciertas condiciones de vida mucho antes de las civilizaciones clásicas. Se discute que no existe un área especializada para la escritura, sino que, la escritura se basa en habilidades básicas que han existido desde antes que la escritura fuera inventada. La pre-escritura fue inicialmente una habilidad visuoconstructiva e ideomotora, y después se convirtió en una habilidad relacionada con el lenguaje (escritura). Se enfatiza que la mayoría de los síndromes neuropsicológicos, incluyendo la agrafía, fueron descritas durante finales del siglo 19 y principios del siglo 20, sin embrago, las condiciones de vida han cambiado dramáticamente durante los últimos cien años. La escritura ya no sólo significa el uso de papel y lápiz sino también el uso de programas de procesamiento de texto. La escritura con lápiz y papel no requiere las mismas tareas cognitivas, espaciales y motoras que se necesitan cuando se utiliza un teclado de computadora. A pesar de que el concepto de lenguaje escrito pueda ser el mismo, la actividad motora y las habilidades espaciales que son usadas son totalmente diferentes. Se anticipa que en el futuro se puedan describir nuevos síndromes neuropsicológicos resultado de las nuevas condiciones de vida.

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Anthropology has striven to adequately understand man's living conditions 10,000, 20,000, or 100,000 years ago. The Stone Age (usually divided into the early Stone Age, or Palaeolithic, and the later Stone Age, or Neolithic) extends to approximately 6,000 to 7,000 years ago (Hours, 1982). Agriculture appeared some 10,000 years ago. The first cities appeared some 6000 years ago and the first civilizations appeared about 5000 years ago. Writing only has a 5000- or 6000-year history and arithmetical abilities have a history of about 6000 years (Childe, 1936; Sampson, 1985). However, it has been thought that contemporary man (*Homo sapiens sapiens*) has lived on earth for at least 50,000 years but perhaps, according to current evidence, it may be since at least 100,000 years ago. We can state with some certainty that, during this time, the structural changes of the brain in man have been minimal (Harris, 1983; Kochetkova, 1973; Tomasello, 2000). Human brain adaptation was for survival in Stone-Age life conditions (existing for about 98% of this life span) rather than in those life conditions existing nowadays. Only by departing from the analysis of these original conditions can we understand the specific characteristics and idiosyncrasies of the brain's adaptation. It would seem reasonable for any neuroscientist to put the question: "What type of information did the human brain become adapted to process?" Consequently, "What are man's basic cognitive abilities?" The search for universals has guided an important proportion of anthropological and linguistic activity during the last decades.

Anthropologists and linguists have attempted to find out basic and universal ways of social organization in different human groups (Van den Berghe, 1979) and fundamental language characteristics (Greenberg, 1978; Hagége, 1982). Attempts are made to infer the social organization of prehistoric man and languages existing before living languages. An excellent example of this last point is the reconstruction obtained for the Indo-European language (Anderson, 1973; Lehmann, 1974; Martinet, 1975), whose last speaker passed away several thousands of years ago. Efforts are currently being made to reconstruct even older proto-languages (Shevoroshkin, 1990).

Undoubtedly, neuropsychology has advanced tremendously in some specific areas. Significant advancements have been in the assessment of the sequelae of brain pathology and in the establishment of clinical/anatomical correlations. However, we do not yet sufficiently understand or know what can be considered as "basic cognitive abilities." Our understanding of cultural differences is optimistic yet limited (Ardila, 1995; Fletcher-Janzen, Strickland, & Reynolds, 2000; Uzzell, Pontón, & Ardila, in press). Matthews (1992), in his International Neuropsychological Society presidential address, accurately observed that "... a very limited kind of neuropsychology, appropriate to only a fraction of the world's population, is presented to the rest of the world as if there could be no other kind of neuropsychology, and as if the education and cultural assumptions on which ... neuropsychology is based were obviously universals that applied everywhere in the world" (p. 421).

Furthermore, most of the neuropsychological syndromes were described during the late 19th and early 20th century: aphasia (Broca, 1863; Wernicke, 1874), alexia (Déjèrine, 1891, 1892), agraphia (Exner, 1881), acalculia (Henschen, 1925), apraxia (Liepmann, 1900), spatial orientation disturbances (Jackson, 1874/1932), prosopagnosia (Bodamer, 1947), visuoconstructive disturbances (Henschen, 1925; Poppelreuter, 1917), and executive functioning defects (Harlow, 1868), among others. Nonetheless, living conditions have changed dramatically during the last 100 years. Writing no longer means only the use of a pencil and a paper, but also the use of a computer word processor program. Arithmetical abilities, too, have changed; instead of writing numbers down on paper and applying certain computational rules, we more often require the ability to use a pocket calculator. One major source of knowledge of other people's faces is through television, and a major source of knowledge of other people's voices is through the telephone. Intensive exposure to these media has been observed only over the last few decades.

The need for a clear understanding of the origins of current cognitive abilities is evident (Ardila, 1993a, 1993b, 1993c, 1993d). The example of reading and writing may be illustrative of the need for a historical/anthropological analysis of neuropsychological syndromes. Varney (2002) points out that reading is a cultural, not an evolutionary, development. He emphasizes that "our capacity of reading did not evolve biologically; it evolved through cultural developments that were only acquired as 'typical' human abilities within the last 200 years in Europe and America, and only after World War II in the rest of the World" (p. 3). The origins of reading can be found in certain abilities that existed long before reading was developed.

Reading and writing were far from "universal" even at the beginning of the 21st century. According to the United Nations, "a person who is literate can, with understanding, both read and write a short simple statement on his or her everyday life.... A person is functionally literate who can engage in all of those activities in which literacy is required for effective function of his or her group and community and also for enabling him or her to continue to use reading, writing, and calculation for his or her own and the community's development" (UNESCO, 2003). Surveys throughout the world have been conducted to observe populations speaking various languages and their inability to read or write a simple message. In the first survey (1950), at least 44% of the world's population were found to be illiterate. A 1978 study showed the rate to have dropped to 32.5%. In 1990 illiteracy worldwide dropped to about 27%, and by 1998 to 16%. However, a study by the United Nations Children's Fund (UNICEF) published in 1998 predicted that the world illiteracy rate would increase in the 21st century because only a quarter of the world's children were in school by the end of the 20th century. The highest illiteracy rates were found in the less developed nations of Africa, Asia, and South America. The lowest illiteracy rates were found in Australia, Japan, North Korea, and the more technologically advanced nations of Europe and North America. Currently, there are an estimated *862 million* illiterate adults in the world, of whom about two thirds are women (UNESCO, 2003). The mean educational level of contemporary man is only about *3–4 years of school!*

Varney (2002) analysed the origins of reading ability. He suggested that the ancient skills of gesture comprehension and animal tracking were the underpinnings of brain organization that permitted reading to occur. He demonstrated that alexia is significantly associated with impaired pantomime and animal footprint recognition. Thus, these abilities, existing since early human history, were prerequisites that led the way to the cultural development of reading. Gesture recognition may have existed for several millions of years, but reading developed just a few millennia ago.

HOW DID WRITING APPEAR?

Wall paintings appeared during the Palaeolithic era, some 30–35,000 years ago (Childe, 1936). Across Europe, particularly in France and Spain, cave paintings dating from the Palaeolithic age have been found. Mainly animals, but also people, instruments, and environmental conditions, are represented in these paintings. Further evolution in pre-writing is represented by paintings becoming standardized for representing specific elements (i.e., a standard bird means "bird"). Lecours, Peña-Casanova, and Ardila (1998) point out that writing begins with concrete pictograms that reflect realities accessible to the senses, particularly to vision. These pictograms further evolved and became abstract, progressively separating from the concrete representation. This situation was observed in Sumer (contemporary Iraq) about 53 centuries ago, and it is usually regarded as the beginning of writing in human history. Symbols (graphemes) referred to the meaning of the words, so these original writing systems are regarded as logographic. Graphemes representing sounds (syllables) appeared later, about 4000 years ago in Phoenicia (Sampson, 1985), and graphemes representing phonemes appeared even later in Greece.

The sequence of the evolution of writing in consequence was:

> Drawings → pictograms → logograms → syllabic graphemes → phonemic graphemes

Writing systems can be divided in different ways; a major distinction between logographic (representing meanings) and sonographic (representing sounds) systems can be established (OMNIGLOT, 2003; Sampson, 1985).

The fundamental difference between logographic writing systems and other scripts is that each logographic symbol means something. As a result, logographic writing systems generally contain a large number of symbols: anything from several hundred to tens of thousands. In fact there is no theoretical upper limit to the number of symbols in some logographic scripts, such as Chinese. Logographic scripts may include the following types of symbols.

1. Logograms—symbols that represent parts of words or whole words. Some logograms resemble the things they represent and are sometimes known as pictograms or pictographs.
2. Ideograms—symbols that graphically represent abstract ideas.
3. Semantic-phonetic compounds—symbols that include a semantic element, which represents or hints at the meaning of the symbol, and a phonetic element, which denotes or hints at the pronunciation.

4. Sometimes symbols are used for their phonetic value alone, without regard for their meaning.

In sonographic writing systems, syllables (syllabic alphabets) or phonemes (phonemic alphabets) can be used. Alphabetic writing systems come in two varieties.

1. Abjads (consonant alphabets) represent consonants only, or consonants plus some vowels. Even though not common, full vowel indication (vocalization) can be added, usually by means of diacritics.
2. Alphabets (phonemic alphabets) represent consonants and vowels.

Thus, initial writing (or rather, pre-writing) was a visuoconstructive ability (i.e., representing external elements visually), and only later did it become an ideomotor praxis ability (i.e., making certain learned and fixed sequences of movements with the hand to create a pictogram—a standardized representation of external elements). Still later, after writing became an ideomotor praxis ability, it became a linguistic ability (i.e., associating the pictogram with a word, and further analysing the word in its constituting sounds). It is not surprising that three major disorders in writing can be observed as a result of brain pathology: visuoconstructive (spatial or visuospatial agraphia), ideomotor (apraxic agraphia), and linguistic (aphasic agraphia). In addition, of course, writing requires visual and motor integrity.

HOW MANY PEOPLE CAN WRITE?

Even though writing began several millennia ago, as recently as the 1950s about half of the world's population was illiterate. The percentage of illiteracy dramatically increases as we go back in time, and up to only a couple of centuries ago, the overwhelming majority were illiterate. Until the 15th century, when the printing press was invented, writing may well have been limited to a few intellectual people and monks. Even though there are no statistics available, it may be conjectured that 99% or more of the population was illiterate. Furthermore, it has to be kept in mind that the mean level of education of contemporary man is about 3 years of school, which may not be enough to develop automatic reading and writing.

It is evident that writing represents an unusual ability in humans. The overwhelming majority of members of our species who have lived could not read or write. Reading and writing is obviously far from being a "primary" or "biologically based" cognitive ability. Clearly, writing represents a cognitive ability that depends on the human cultural evolution (Vygotsky, 1962).

AGRAPHIA AS A NEUROPSYCHOLOGICAL SYNDROME

Agraphia can be defined as the partial or total loss of the ability to produce written language, and is associated with brain pathology. The ability to write can be impaired as a result of linguistic defects (aphasia), but other elements not related to language (e.g., motor and spatial) also participate in the writing ability. It supposes at least a knowledge of the language codes (phonemes, words), an ability to convert language sounds in graphemes, a knowledge of the graphemic system (alphabet), an ability to perform fine movements, and an appropriate use of the space for distributing, joining, and separating letters. It is evident that diverse types of writing disturbances can be found in clinical practice.

Different attempts to classify writing disturbances are found in the history of neuropsychology. Goldstein (1948) distinguished two major types of agraphia: apractoamnesic and aphasic-amnesic. Luria (1976, 1980) referred to five different types of agraphia, three of them associated with aphasia (sensory agraphia, afferent motor agraphia, and kinetic agraphia) and two associated with visuospatial defects. Hécaen and Albert (1978) distinguished four types of agraphia: pure, apraxic, spatial, and aphasic.

Regardless of the diversity of classifications of agraphia, a basic distinction can be established between (1) agraphias due to a language impairment (linguistic or aphasic agraphias), (2) agraphias due to other types of impairments (most often, motor or spatial) disturbing the normal ability to write (Benson & Ardila, 1996), or simply (3) central and peripheral agraphias (Ellis, 1988). In the first case, agraphia is just a secondary manifestation of the aphasic syndrome. In the second, it can be interpreted as a result of a broader visuoconstructive/visuospatial impairment (Ardila & Rosselli, 1993), or motor-apraxic disturbance (Hécaen & Albert, 1978). Consequently, writing can be interpreted as a particular type of cross-modal learning. Certain visuoconstructive and ideomotor abilities become associated with language.

IS ANY AREA IN THE BRAIN SPECIALIZED FOR WRITING?

Writing is a "functional system" (Luria, 1976) that requires, and is based on, some more fundamental abilities: praxis abilities (i.e., learning sequences of movements required to write the letters), spatial abilities (distributing letters and words in the space, and understanding the value of space in writing), constructional abilities (reproducing a model using certain movements), and obviously, the knowledge of the language and the association between verbal auditory elements and visual symbols.

Varney (2002) refers to the anthropological concept of pre-adaptation, which states that the evolution of a structure for one purpose can enable that structure to perform another purpose. This must be true for writing (as for any other abilities depending on cultural evolution). Visuo-constructive and ideomotor abilities represent prerequisites for writing; they are probably related to the ability to make tools and weapons and generally to use the hands in a skilled way.

FROM "AGRAPHIA" TO "DYSTYPIA"

Contemporary literate man is using handwriting less and less, and relying on computers more and more. In an informal survey to 40 people with a college-level education background, they reported using a computer about 90% of the time when writing and handwrote only 10% of the time. Obviously, this sample does not represent all of humankind, and computers are not accessible to a large percentage of the human population. But this sample seems to illustrate the way in which writing is evolving: from handwriting to typing on a computer.

Handwriting and using computers represent significantly different cognitive and motor abilities. During handwriting, fingers are maintained in a relatively steady position while the hand moves. In typing, the opposite pattern is observed. When typing, the right hand does not move from one side to the other and back as in handwriting, but the hands remain relatively stationary and only the fingers are moved. Letters are not written but selected. Both hands have to be used in a similar way when typing. Because of using both hands, we have to assume that a major interhemispheric integration is required. It is obvious to assume that right-hemisphere lesions located in the frontal and parietal areas should significantly impair the typewriting ability of the left hand.

Similarly, the use of the space is different. The normal spatial distribution of the words on the page is automatic on the computer and, hence, writing in this way cannot be spatially disorganized, as may be the case in handwriting. By the same token, letters are neatly written and easily recognizable. When typing, we are not using a space that is directly manipulated with the hands ("constructional space"), but only a "visual space." Furthermore, typing is not a constructional task (we do not have to construct the letters) but rather a motor-spatial task.

Many people type using a spatial memory for the position of the letters in the keyboard. This is a type of memory not required in handwriting, and it probably depends on right hippocampal and parietal activity (Moser, Hollup, & Moser, 2002). Other people have to look at the keys to select the letters when typing. In this case, literal reading is a prerequisite for writing. Letters have to be recognized visually before they are written. In handwriting, we use a mental representation of the visual form of the letters. Interestingly, few people—if any, regardless of how well they can type—are able to reproduce (i.e., describe verbally or by drawing) how the different letters are arranged on the keyboard. Memory for their location seems to be a purely spatial and motor memory of which we are poorly aware.

For typing some special symbols (e.g., interrogation marks) and letters (the Spanish Ñ), some relatively sophisticated motor manoeuvres are required, sometimes requiring the use of special keys or sequences of movements. In handwriting, however, special symbols are written using the mental forms that we have learned. When typing, if a letter needs to be lower or upper case, a key has to be pushed. No other change to the movement is made. We can also select different writing styles and letter sizes using some special commands and menus, all without changing the sequences of the hand movements.

In cases of brain damage, how is typewriting altered? To the best of my knowledge, only one case of agraphia for typewriting has been published (Otsuki, Soma, Arihiro, Watanabe, Moriwaki, & Naritomi, 2002). Nonetheless, it can be assumed that different types of brain pathology may affect the ability for typing on a computer word processor. The following can be conjectured.

1. An anterior callosal lesion would impair the ability to coordinate the movements between the hands. Furthermore, the left hand would be

isolated from the linguistic left hemisphere, and would be unable to write. Left-hand hemiagraphia in callosal lesions has been observed (Benson & Ardila, 1996).

2. By the same token, it has been observed that damage in the supplementary motor area results in disturbances in the coordinated movements between both hands (Middleton & Strick, 2001). We can anticipate supplementary motor area typing agraphia.

3. Spatial memory disturbances should result in difficulties in recalling the positions of the letters on the keyboard. Typing would be slow, and would require a continual search for the letters.

Otsuki et al. (2002) reported on a 60-year-old right-handed Japanese man who showed an isolated persistent typing impairment without aphasia, agraphia, apraxia, or any other neuropsychological deficit. They proposed the term "dystypia" for this peculiar neuropsychological manifestation. The symptom was caused by an infarction in the left frontal lobe involving the foot of the second frontal convolution and the frontal operculum. The patient's typing impairment was not attributable to a disturbance of the linguistic process, since he had no aphasia or agraphia. Nor was it attributable to an impairment of the motor execution process, since he had no apraxia. Thus, it was deduced that his typing impairment was based on a disturbance of the intermediate process where the linguistic phonological information is converted into the corresponding performance. The authors hypothesized that the foot of the left second frontal convolution and the operculum may play an important role in the manifestation of "dystypia."

Using a computer is somehow "equivalent" to a new writing system. Obviously, there is no brain area related to typing on a computer, as there is no brain area related to reading and writing. These are cultural and technological elements recently developed through human evolution. Rather, there are basic cognitive abilities (pre-adaptative abilities) that are required for the use of these new cultural elements: e.g., certain visuoperceptual abilities and cross-modal associations for reading, phonological awareness and some fine movements for writing, etc. Using computers is notoriously more complex, yet we can assume a "functional system" participating in their use.

It can be conjectured that using computers requires at least the following abilities.

1. A conceptual ability (executive functioning) to understand the principles governing the functioning of a computer.
2. Some visuoperceptual abilities to recognize icons, windows, etc.
3. Some skilled movements to type on the keyboard and manoeuvre the mouse correctly.
4. Some spatial abilities to handle the working space (monitor screen).
5. Some memory abilities to learn programs, to use the spatial position of the keys, etc.

Obviously, the ability to use computers can potentially be disrupted as a consequence of a failure in any one of these abilities ("acumputuria syndrome"). In the future, apart from "dystypia," more complex disturbances in the ability to use computers will probably be established.

CONCLUSION

The origins of writing can be traced back to cave paintings. Writing (or pre-writing) was initially a visuoconstructive ability, later involving some stereotyped movements to represent pictograms, and finally involving spoken language. It makes sense, therefore, that the ability to write can be disturbed in three major forms: as a visuospatial/visuoconstructive dexterity, as an ideomotor skill, and as a linguistic ability.

Writing has followed a long evolution since cave painting during the Palaeolithic times. Different strategies have been used to represent spoken language visually (ideograms, alphabets, etc). Writing, however, has continued to evolve since its initial invention. The use of punctuation marks and the distinction between upper and lower case in writing—to mention just two examples—are relatively recent in history (Sampson, 1985). Evolution has continued with the development of different technical instruments for writing: the feather, the pencil, the typewriter, and the computer. Brain representation of written language has necessarily changed in some way, too. Neuropsychological syndromes associated with brain pathology have evolved over time. We can assume that the consequences of brain pathology in a Palaeolithic man were not the same as for a 19th-century individual (when agraphia was first described), or for contemporary man or woman (some of whom frequently spending most of their working day in front of a computer screen). It can be anticipated that in the future new neuropsychological syndromes resulting from new living conditions will be described.

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