Neurosciences Applied to Handwriting Examination

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Some difficult cases for forensic document examiners can be related to brain illnesses that affect handwriting. As a brain-governed function, handwriting has been studied by medical science for many years. Those studies could be crucial to guiding the expert in evaluating causes of variability in handwriting. A. R. Luria was a neuropsychologist at the University of Moscow who studied consequences of different injuries to the human brain. Part of Luria's work focused on the handwriting of patients with brain wounds. Our objective was to review some of Luria's most relevant findings compiled in the book, *The Working Brain, An Introduction to Neuropsychology.* Some neuroscience findings from other authors who studied handwriting from a medical point of view are also included.

Introduction

Paul Kirk, a famous American forensic scientist, said that testimony on handwriting identification is often the most difficult of all to offer (Kirk 1974). Diverse specialties of medicine such as psychology and neurosciences can help forensic document examiners (FDEs) to find scientific reasons for the uniqueness and individuality of human handwriting. Many authors, including Alexander Rabinovich Luria, have studied brain illnesses and brain wounds that can affect writing.

A review of the medical literature related to the capacities of the brain and its relationship to handwriting discloses medical concepts supporting the hypothesis that a person's writing will repeat his basic letter constructions and other habits, whether written with hands, feet, or mouth.

A historical case of individualization of human habitual motor activity dates from World War II. Researchers who intercepted Morse code transmissions developed the ability to identify different senders by the rhythm, pitch, and speed of the broadcasts even though the transmitted text was encrypted.

Examination of questioned handwriting and signatures can be especially difficult when there are different styles used by one person, cases of ambidexterity (the ability to use both hands with equal ease), changes in health conditions, or deliberate changes in handwriting (disguise).

Psychologists and Handwriting

A relationship among brain, fine motor control, and handwriting was established 100 years ago. Today, handwriting is understood as a functionally complex system. Medical concepts of psychomotor activity and *graphic motor control* (psychomotor control associated with drawing and writing) are important. They imply management of direction, muscle tone, and visual motor coordination. Graphic motor control is a type of micro-motor control, or fine praxis (the ability of the brain to conceive, organize, and carry out a sequence of events).

Alexander Rabinovich Luria was a Soviet neuropsychologist, professor at the Public University of Moscow, and director of its Department of Neuropsychology. He was influenced in his investigations by his mentor, Lev Semenovich Vygotsky (1896-1934), a Soviet developmental psychologist and the founder of the cultural-historical psychology. Luria studied language disorders and other mental illnesses. He made important advances in brain surgery during WWII, worked in posttrauma function restoration, and developed theories about frontal lobe functions. He also developed a theory that certain brain cells in discrete zones worked in concert.

According to Luria, writing is not innate in human beings. Handwriting is a final step in motor development, related to codified (alphabet) information and thoughts. Humans first have to

Figure 1. Alexander Rabinovich Luria.

form a mental representation of a character before it can be physically created. Handwriting ability is the product of a learning process initiated by copy and repetition of letters and words. Handwriting movements reach an unconscious level when the brain develops an automatic motor programming control for execution of characters, words, and, in some cases, drawings. (Luria 1973)

Movement is the final function of the psychomotor system. Scientific studies indicate that handwriting is possible because of a combination of many processes. Sense organs, skin, muscles, nerve connections, and memory take part in the handwriting process. With sufficient repetition, writing movements become habitual.

Handwriting movements can be called graphic gestures. Handwriting as a kind of movement is considered a specialized type of fine praxis or micro-motor control (Da Fonseca 2004) .

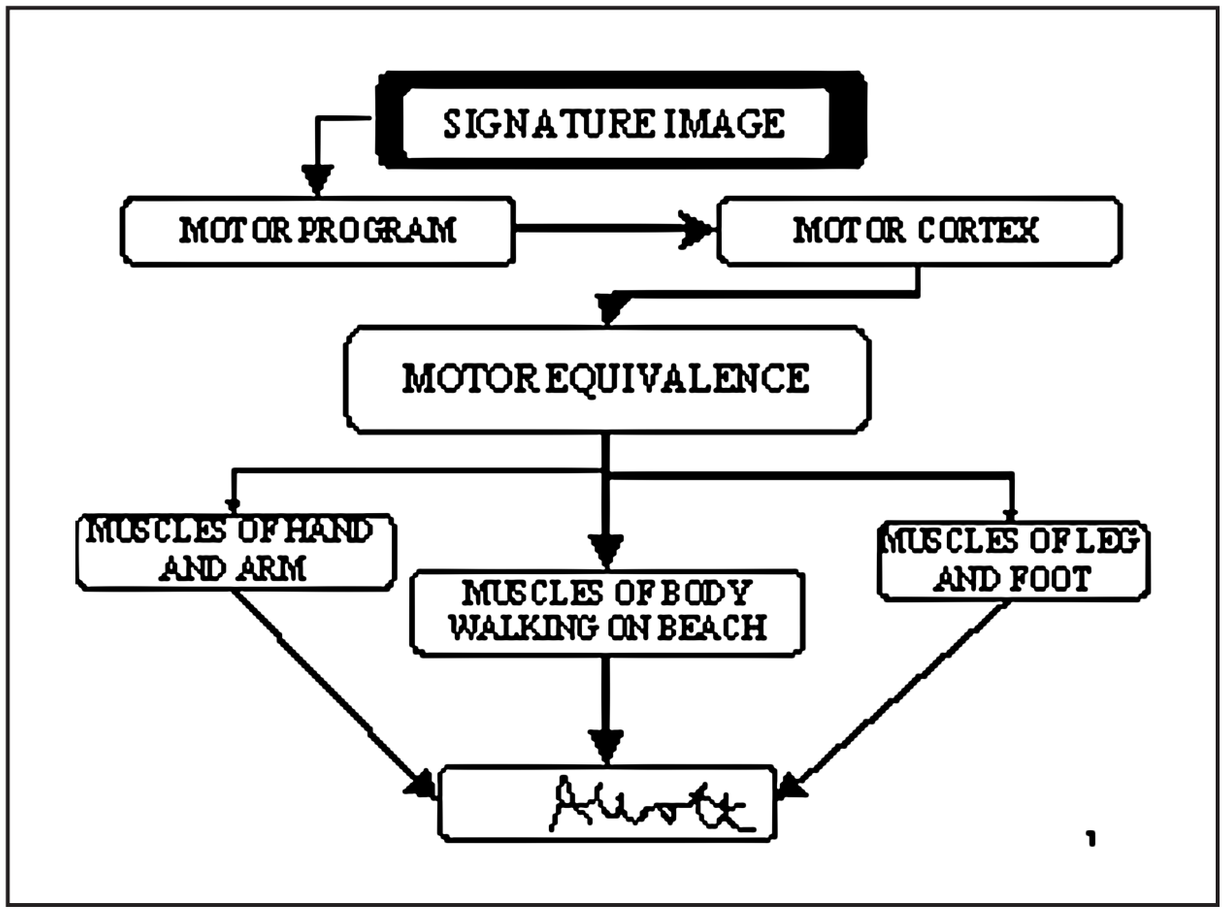

Figure 2. Motor equivalence and signatures (Allot 2003).

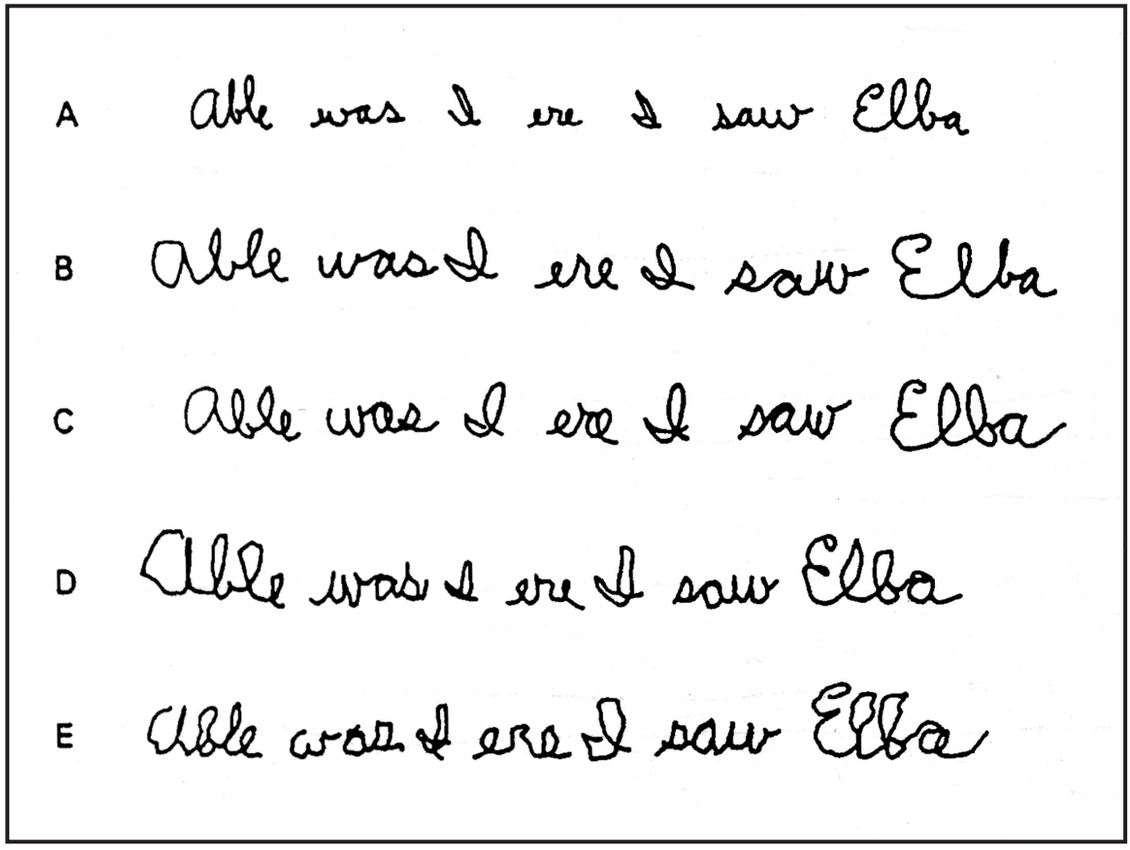

Figure 3. Writing using Motor Equivalence: (A) right hand; (B) right hand, wrist immobilized; (C) left hand; (D) pen in mouth; (E) pen attached to foot (Kandel and others 1997).

Motor Equivalence and Cerebral Plasticity

Edmond Solange Pellat introduced the "First Law of Handwriting" (Del Picchia 1993). He proposed that a graphic gesture is produced under direct influence of the brain and is not modified by the extremities of the writer. In neurosciences, there is a concept related to this principle called "Motor Equivalence" (Kandel and others 1997). Motor Equivalence explains why a person can write with different parts of the body, no matter whether it is the dominant hand, the off hand, the mouth, or the foot.

Another interesting neuroscience concept for FDEs is applicable to cases of ambidexterity. "Cerebral Plasticity" is the capacity of the brain to create or to seek alternative routes between the specific control centers and its associated processes (Costa I Miserachs 2007). This allows one to acquire the ability to write with the other hand in case of amputation.

Solange Pellat proposed in the "Second Law of Handwriting" (Del Picchia 1993) that when someone starts to write, the "Self" is in action initially; but unconscious processes become active, and later, continuous interaction of habit and the Self occur. Volition and motor processes are not linear consequences but are supportive and dialectical. We can conclude that Solange Pellat was right, because fine motor control is a relational process (Red Internacional de Investigadores de la Motricidad Humana) where the knowledge is interrelated with motor praxis.

How Handwriting Works

Handwriting fine motor control is an upper cerebral function that requires hand-eye coordination. Posture control is necessary for motor planning. Motor learning for handwriting starts with a long phase where construction of letters is deliberate and conscious. After this learning process, the

information for handwriting action passes to the long-term memory and is then stabilized as a functional piece of the motor system. To reach a level of dexterity, practice and automation have to be consolidated. After control of handwriting is established, other advances related to copying, dictation, creative writing, orthography, and style can develop.

The elements needed for psychomotor activity are a) muscular tone: the state of preparation of the muscles to take action at any moment; b) posture control: necessary before cognitive learning starts; c) praxis: or capacities of kinetic movement; d) experience: a component proportional to cultural integration.

Psychomotor activity is a process where kinetic organs participate with hearing and vision, organized into functional systems. According to current theories, functional systems for handwriting are motor programs prestructured commands for specific movements [Smith 1975]). Handwriting as a psychomotor program can be used as the foundation of the uniqueness of handwriting.

Motor programs are a series of impulses prepared and related to upper-level cerebral processes which include feedback processes for quality control during the execution. Once handwriting is initiated, movements are involuntary. They are executed without the need for specific attention.

Kinetic Melody

Julian de Ajuriaguerra said that handwriting is an extremely complex psychomotor activity. Writing, as well as other actions, are sequences of movements called psychomotor chains. Each step should be deactivated after completion before the next movement starts. Each movement or impulse is isolated. With practice, the chain of movements flows continuously without stopping, creating a kinetic melody.

Handwriting Learning

Many authors have studied the process of learning handwriting. L. S. Svetkova (1977) worked in depth on the rehabilitation of patients with brain injuries for relearning of writing skills. In addition to those who lost handwriting ability due to brain damage, many individuals discontinue formal education before they have become skilled writers. After World War II, many European immigrants to Latin America, Italy, Portugal, Spain, and in the Middle East did not continue their primary education, and their handwriting remained pre-calligraphic.

According to some authors, the different phases or stages in the handwriting learning process are:

1. Pre-calligraphic. This phase occurs between 6 and 9 years of age. Children who do not pass this phase develop dysgraphia (difficulty expressing ideas through handwriting [Masson 2001]. Spatial disgraphy causes line, margin, punctuation, and accents misalignment.) This phase is characterized by immaturity, lack of control, and irregularity of handwriting movements. Slowness is typical. Straight lines are replaced with trembling or curved lines. Angles could appear in curve and semi-curve strokes. Dimensions and slant are not regular. Links among letters are done with clumsiness. Alignment of words is not straight and could be undulating. It is not possible to pass to the phases of copy and dictation if this phase has not been mastered.
2. Calligraphic. Modifications of the original graphic model begin here. Velocity of handwriting is increased up to 130 letters per minute. Union among letters is progressively higher, as well as simplification of forms and elimination of useless details. The writing becomes individualized as the student incorporates his own idiosyncrasies.
3. Post-calligraphic. The original graphic model can disappear with evident individualization. This is only possible if calligraphic modeling succeeds. The post-calligraphic phase is not reached by all students. This phase can be inhibited because of imposed rules for legibility in school.

Effects of Cerebral Wounds in Handwriting

Wounds in cortical zones do not affect praxis or voluntary movements (Luria 1973). Patients write normally at first, but changes due to fatigue can quickly appear in their writing.

According to Luria, wounds in the occipital region of the brain produce irregularities in spacing of letters and words. In some cases, this produces an inability to create letter connections.

He found that wounds in the temporal region affect the auditory perception and logical-grammatical relationships. Patients in these cases have difficulty with speech and comprehension as well. This can be called "Word Soup." With this type of wound, the ability to write can be lost entirely. Words cannot be identified before writing, causing incorrect writing of words or

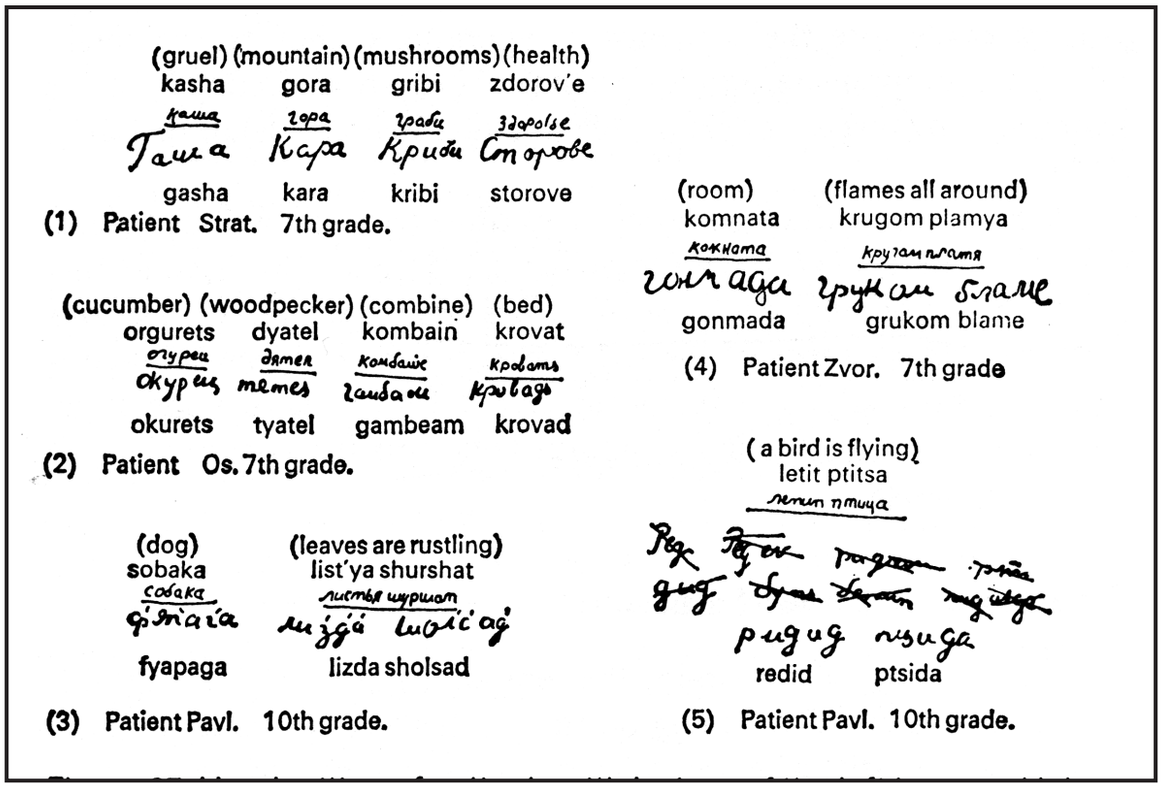

Figure 4. Handwriting of patients with lesions of the left temporal lobe (Luria 1973).

writing with many corrections. In this kind of illness there is an important fact for questioned document examiners and lawyers to understand. The patient may not be able to compose and write words but retains the ability to copy text because motor stereotypes of writing are not disabled. The program for creating the images of letters and characters is different from the program that allows the use of handwriting as communication tool.

A wound in the parietal region affects writing organization and coordination, causing constructional apraxia, a difficulty to draw letters and recall the spatial position of lines.

Alzheimer's Disease, Multiple Sclerosis, and Other Illnesses

Alzheimer's Disease

This illness decreases mental ability and affects memory. One of its symptoms is writing amnesia.

In the 1st phase, it is not possible to write the same number of names (e.g., animals and fruits) in a minute compared to normal people. This test can be used to identify people that may be suffering the 1st phases of the illness. Alzheimer's disease is the main cause of senile dementia. Today, over 12,000,000 people suffer from Alzheimer's.

Parkinson's Disease

Independent of motor alterations of language, Parkinson's disease and senile dementia patients preserve verbal-written comprehension, good spelling, and syntaxes, but exhibit poor quality handwriting. Smaller writing is a typical change in Parkinson´s disease patients (Webmd. com 2007).

Multiple Sclerosis

Multiple sclerosis (MS) affects handwriting. Tremors affect 75% of people with this illness (Multiple Sclerosis Resource Centre 2007). MS produces involuntary, rhythmical, alternating movements that can affect the muscles of any part of the body. MS randomly attacks the ability

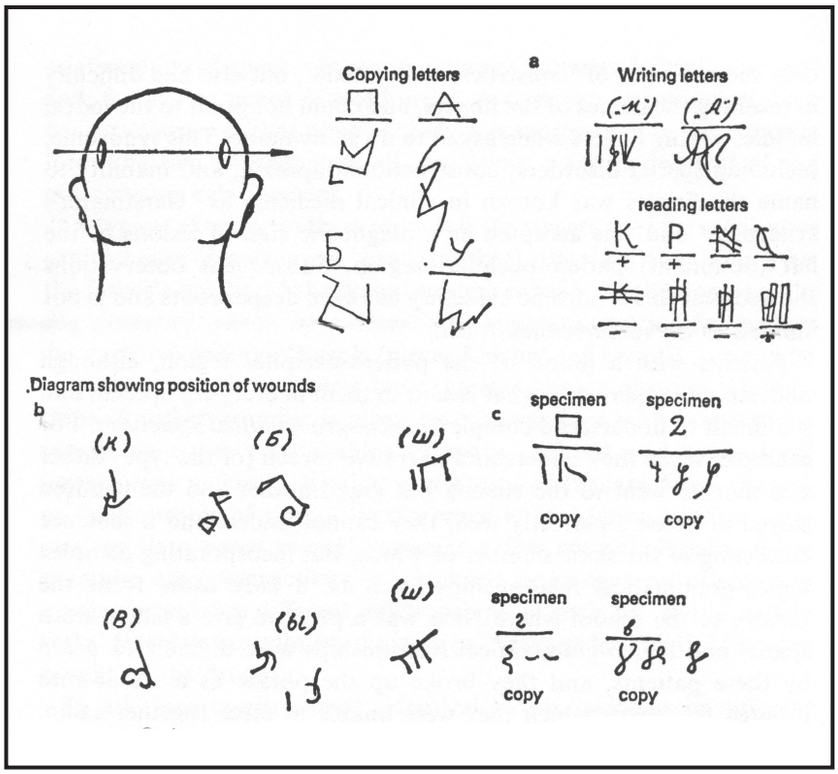

Figure 5. Handwriting of patients with optic-spatial disturbances in parieto-occipital region (Luria 1973).

to communicate and causes altering letters with exaggerated characters.

Other Diseases

Medical studies have established that after an encephalic thalamus stroke, small writing or micrographia can develop. In some cases of thrombosis, micrographia and hypotonia (deficiency of tone or tension of muscles) are produced. Strokes can produce distortion of handwriting.

Writing organization disorders can be caused by motor weakness, as well as in cases of hyperkinetic disorders and paratonia (exaggerated muscle tension [Masson 2001]). Hyperkinetic disorders cause exaggerated muscular movement (Masson 2001) and produce a combination of overactive, poorly modulated behavior with marked inattention and lack of persistent task involvement (World Health Organization 1992). Paratonia is the inability to voluntarily relax muscles which could affect handwriting.

Praxis is the ability of the brain to conceive, organize, and carry out a sequence of events. Dyspraxia is of forensic interest because it is an executive dysfunction of failure in psychomotor responses found in handwriting.

Illnesses that interfere with hand-visual coordination cause spatial dysgraphia, disturbing line orientation, margin alignment, punctuation, and accents (Serratrice and Habib 1997).

Conclusions

The neurosciences are very important to handwriting examination because they study neurological handwriting processes and help us to understand some of its anomalies. Concepts such as motor equivalence and cerebral plasticity could be used in court to explain some handwriting phenomena. Medical information about handwriting must be known by forensic document examiners. Neuroscience is a new field to be studied and used by handwriting analysis experts.

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