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THE BRAIN IMPRINT: THE NEUROLOGICAL INFLUENCES UPON THE SIGNATURE AND THE HANDWRITING

C.-D. CIOCHINA

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Claudiu-Dănuț CIOCHINA
PhD. Student, "Dunărea de Jos" University from Galati, Romania, Faculty of Law and Administrative Sciences, Doctoral School of Social and Human Sciences
E-mail: ciochinaclaudiu@gmail.com
ORCID ID: https://orcid.org/0009-0006-0584-5784

Abstract

The handwriting and the signature constitute essential indentitary elements frequently used in the forensic practice for authenticating documents and identifying persons. Besides their judicial and cultural dimension, these graphic manifestations are direct expressions of the functionality of the central nervous system.

The neurobiological features of the act of writing determine a "cerebral print" (Finn E. & al, 2015) that is unique to each individual, reflected in the graphic parameters as pressure, speed, proportions and coherence of the shapes. However, the neurological influences – whether of pathological nature (i.e. Parkinson's disease, Alzheimer's, strokes), or of emotional or cognitive nature – can alter the characteristics of handwriting and signature, complicating the forensic examination process.

This article aims to analyze the neurobiological mechanisms involved, the way how these are reflected in the handwriting and signature, as well as the practical implications incurred in the graphoscopic expertise and the process of identifying persons.

Key words: *handwriting; signature; forensic; identification; motor cortex; neurological pathologies; graphoscopic expertise.*

INTRODUCTION

The forensic identification of persons based on their handwriting and signature has an ample tradition, as it has been an essential instrument in analyzing documents, technique that has been approached since 1931 in The Forensic Treaty, chapters V and VI, by the Frenchman Edmond Legard, chapters that debated the expertise of written documents, secret correspondence and forgeries[1]. The relative stability of the signature, correlated with the uniqueness of the graphic style, constitute the fundamental premises of its probative value.

Nevertheless, recent neuroscientific research shows that handwriting is not just a cultural habit, but a complex expression of the cerebral activity, influenced by both neurological and psychological factors, as the completion of a graphic act requires the simultaneous coordination of several cerebral areas (*Planton S. & al, 2013*).

This interdisciplinary perspective is essential in forensics, acknowledging the fact that handwriting alterations can be generated by neurological or emotional processes, allows a more nuanced interpretation and a reduction of errors in investigations. In order to issue accurate conclusions in the process of analyzing a handwriting or a signature, it is highly important to know the way they have developed.

By studying the handwriting, one can decode the indissoluble bond between written and oral language and they can identify elements that indicate the fact that the psychological dynamics have been disrupted, but they cannot foresee the transition to the act. (*Elena-Ana Iancu, 2009, p.98*).

The writing systems are considerably different among cultures, as there is a fundamental distinction between the alphabetical ones and the hieroglyphical or logographic ones. The alphabetical systems use a relatively short set of symbols (letters) that regularly combine in order to form words. On the other hand, the hieroglyphical and logographic systems, like Chinese or Ancient Egyptian writings, require using complex and visually distinctive symbols, each one representing a concept or a word. The neuroimaging research show that the writing in logographic systems activate different cerebral regions than the alphabetic writing. Precisely, written rendering of the Chinese characters or hieroglyphs involves an increased activity of the right hemisphere, especially of the areas responsible for visual-spatial processing, as a result of complex and nonlinear organizing of these systems. By contrast, the alphabetical writing engages predominantly the left hemisphere, particularly the areas involved in phonological processing (*Marano G. & al, 2025*). The cognitive efforts of

[1] https://www.alainbrieux.com/traite-de-criminalistique-ako93686.html?utm_source=chatgpt.com

hieroglyphical writing can contribute to the development of visual-spatial memory and motor coordination to a greater extent than the alphabetical writing, thus highlighting notable differences in the modality of neural processing between the two types of systems (*Feng J. & al, 2022).*

I. BRAIN IMPRINT

It appeared as a concept in the early 1990's (*Lawrence A. & Emanuel D. 1991)* who used it in a different context that the actual one, namely to refer to the ability of the brain to preserve as many aspects regarding an event, aspects that once stimulated, could transmit to the markers registered by the polygraph, if the person is lying or telling the truth with regards to the event (*Lawrence A. Emanuel D. 1991*)

The most relevant current definition of the brain imprint comes from 2015 when Emily S. Finn modernly defined the concept of *brain fingerprint* (*cerebral imprint*) as being the *"unique pattern of functional connectivity of a person's brain, sufficient for individual identification"* (*Finn E & al, 2015*).

As a new category of biometric characteristics, the cerebral imprints have become an intensively studied subject in neuroscience, not only for their safe ability to identify individuals, but also for the possibility of highlighting the particularities of cerebral activity between individuals.

These unique biometrical data are obtained by means of varied neuroimaging technologies (*Zhang S. & al, 2024, pp.151-164*).

The profile of functional connectivity of a person's brain is not only distinct, but also stable in time, similar to a digital print. In numerous situations, this allows identifying with an almost perfect accuracy, an individual in a large group, using exclusively his pattern of cerebral connectivity (*Dimitri Van De Ville & al, 2021*).

II. THE NEUROBIOLOGICAL FUNDAMENT OF HANDWRITING AND SIGNATURE

The graphic act implies complex neuronal networks: the motor cortex (planning and execution of movement), the Cerebellum (the control over the precision and coordination), basal ganglions (automation of gestures), parietal areas, integration of sensory feedback and prefrontal cortex (cognitive and attention control). This network determines the stability of writing, but also the variation of it depending on the neurological and emotional state of the person (*Bauman A. & al, 2022*).

The ability of writing is considered to be an intellectual habit and is based on a multitude of nervous connections set in the cerebral cortex and which

transmitted through the hand movement to the scriptural element, inscribes the graphic signs on the support[2].

The handwriting is a biometric feature that works on a profound level of the subconscious, providing substantial and reliable information for identifying individuals (*Srihari SN & al, 2014, pp. 601-606).*

In what the signature is concerned, it serves as an authentication means accepted on a wider scale. The handwriting and signature of a person can be analyzed with the purpose of identifying the person who created them in forensic investigations that determine or certifies the author of a document.

The nervous activity specific to each person directly influences their handwriting precisely because handwriting elaboration modality is a very complex one (*Lucian Ionescu, 1973, pp 39-40*).

The finding is in agreement with Planton's study, who showed that handwriting activates a visual-motor network more extensive that typewriting, suggesting that the multisensorial integration has an essential role in the process of memory encoding. Overall, these researches indicate the fact that handwriting can offer benefits for the memory not only though a deeper encoding but also through a wider implication of the neuronal circuits responsible for the motor control, visual-spatial integration and semantic processing. This effect is particularly obvious in children that learn how to write, because handwriting supports the development of neuronal ways involved in alphabetization (*Planton S. & al, 2017, pp. 66-80*).

III. FORENSIC RELEVANCE

In order for a graphic examination to be valuable, this must be done on a handwriting with a certain level of evolution. Examining the handwriting of a person that is in the stage of learning is not relevant, because it focuses on copying the tracks of a graphism as it was taught, and not on the contents of the text[3].

From the principle of identity, it results that an object is identical just with itself, at a certain given moment in time. In the process of forensic identification, on one hand, as a result of the fact that both the object that creates the shapes, and the object that receives them can suffer modifications, and on the other hand, given the fact that this preservation of marks is dependent of the environmental factors that act upon them, the identity is relatively stable, being the result obtained by going through the process of identification.

[2] Tratat Practic de Criminalistică, Ediţia 1978, vol.II, p.112.
[3] Ibidem

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As in the case of identifying persons based on their handwriting the scientific fundament results from the ability of the handwriting to be individual and relatively stable. (*Iancu Elena-Ana, 2019, p.460*).

Due to each person's unique formation of neuronal connections at the level of the cortex, this method of identifying the persons based on examining their handwriting is a very solid one. There may be cases where certain characteristics can be found in the handwriting of several persons, but not all of them can be found in the handwriting of several persons[4].

Initially, the handwriting is a conscient and deliberate act, but with time and practice, it becomes rooted in our subconscious, thus becoming a reflexive action. This transition from voluntary writing to the reflex explains the durable and unique graphic characteristics, specific to each person, that allow the differentiation and distinguishing of one from the others. (*Luis Vasquez – Vasquez J. & M. Travieso Gonzalez, 2024*)

Along these neurobiological functions there appear psychological, cognitive and emotional processes, that cause the handwriting to become a unique trait of each person, similar to their personality. For this reason, the handwriting represents essential scientific evidence in the forensic investigations, and recent literature suggests that its role may overcome this field and may extend significantly in the medical practice. Even though the basic structure of the handwriting stays mostly constant, the mental and emotional status of the individual may influence certain elements of the way in which they write and of the contents they deliver. (*Heghes N.E & al, 2024).*

The graphoscopic expertise is based on the comparative analysis of the handwriting's and signature's characteristics. In this context, the neurological influences can represent both *sources of error*, interpreting a micrography as an intention of dissimulation, when in fact it is an effect of an affection, and as *sources of supplementary evidence* through which you can identify stable neurological traits that can confirm the authenticity.

It is important, in the given context not to neglect the handwriting that comes from elder persons, where the aging process can affect in a great extent the quality of the handwriting. That is why, it is necessary, upon the comparative examination, that the handwriting or the comparison model signature to have been done in a period close to the litigation (*Luis Vasquez-Vasquez J. & M. Travieso Gonzalez, 2024)*

The study of the characteristics of the handwriting has an crucial importance in the forensic investigation, where is often necessary to compare documents drafted by the same person in distinct moments. A main objective of the current paper is represented by approaching the difficulties generated by the possible

[4] Ibidem , pp.112,113.

variations of the handwriting. By identifying the stable graphic traits, we are seeking to perfect the identification process of the author, increasing the reliability and reducing the risk of error *(Luis Vasquez-Vasquez J. & M. Travieso Gonzalez, 2024)*.

Constant research and development in the field of biometric identification have extended the interest for identifying persons by analyzing their handwriting, transforming this subject in one that is current and continuously evolving. Specialists are investigating modern methods, as also detailed examination of the structural and dynamic traits of handwriting, as well as applying automated learning algorithms (*Antony Robert Raj & al, 2023*), and neuronal networks (*Zang G. & all , 2023*), to increase precision and reliability of the system for handwriting recognition.

The rapid evolution of this field opens up new perspectives for the optimization of the accuracy and efficiency of the biometric process based on writing.

Therefore, the analysis of the handwriting remains an active field, in expansion, that continues to exceed the current limits and to facilitate significant progress in identifying persons through the unique particularities of their graphism.

In what the stability of the dynamic stereotype/ motor program is concerned, in the execution of handwriting or of the signature, the opinions vary.

Michael P. Caligiuri şi Linton A. Mohammed present in *The Neuroscience of Handwriting (pp.37-40)* the idea that a motor program stores sequences that remain constant regardless of the group of muscles used. In other words, the writer maintains the characteristics of his handwriting, regardless of the hand with which they write, statement that is based on the idea that the motor program is generalized to the entire nervous system in the cerebral cortex, the group of muscles used in the completion of the act of writing, without influencing in a decisive manner the particularities of the handwriting.

At the same time, there are opinions with regards to the relative stability of the handwriting, and one way in which this can be altered is " caused by the state of some organs that participate in the completion of the handwriting" [5].

The supporters of this idea state that in the situation of losing the right hand, the writer is obligated to write with their left hand, fact that determines significant differences between the two handwritings, claiming that a mechanical transfer of the habit cannot be done from a hand to the other.[6]

In the sense of both opinions, we wish to present an example in which a loan agreement has been signed with the left hand by an ambidextrous person.

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[5] Ibidem, p.115

[6]Ibidem

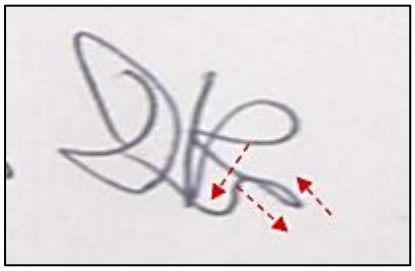

Photo 1 .Disputed signature

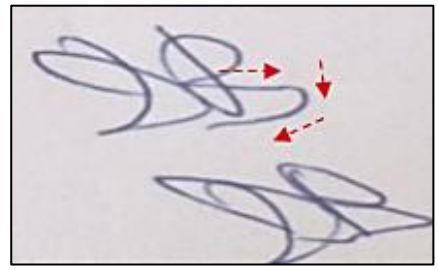

Photo 2. Comparison model signature- right hand

Analyzing the signature in Photo 1 – DISPUTED, we can state that it is a signature within which we encounter the uppercase “D” and “R”.

The same statement can be made for the signatures in Photo 2 – Comparison model signature. The debate whether the signature has been executed by the same person rises when we analyze the final part of the signature where we can notice differences in the execution of the tracks. In photo 1, the signature has a more complex ending by creating a supplementary loop.

Even though there are common elements as shape, type of execution, speed, signature composure, in order to issue a correct conclusion, we must explain the difference that appears in the ending part of the two signatures.

In this case, additional data has been requested to the institution that requested the investigation, and following a more thorough investigation, the person whose signature has been examined, declared that she is ambidextrous, writing and signing with both hand by instinct, without previously planning the hands she chooses to write with.

The institution has ordered taking comparison model signatures executed with the left hand, and the result was a clarifying one. In photo 4 we notice the graphic construction of the ending of the signature, construction that only appears when executed with the left hand.

Photo 3 – Disputed signature.

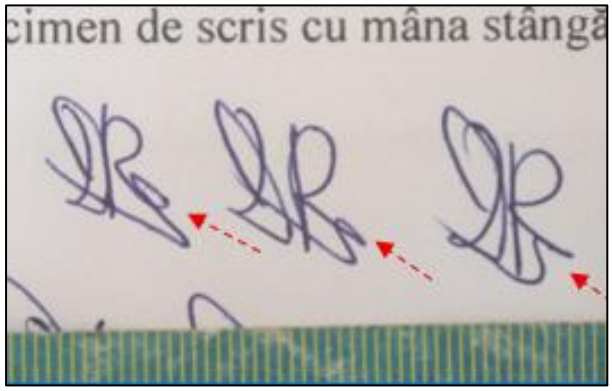

Photo 4 – Comparison model signature - left hand.

An explanation of the resemblances between the two signatures left hand/right hand is that the person who executed the signatures has the tracks the would be written memorized and they have practice in writing with both hands, the dynamic stereotype being developed in both situations.

Analyzing the manner of writing the graphisms, we notice a modification of the tracks when writing the ending of the letter "R", in the situation where they wrote with their left hand. This aspect is explained by the engaging of the cerebral cortex of some various nervous stimulus and by some different muscular groups used in performing the two signatures.

Even if the writer is ambidextrous, having writing practice in both hands and dynamic stereotype developed in both cases, we notice differences between the signature done with the left hand compared to the signature done with the right hand. This fact shows that a person who does not have the ability to write with both hands, will show major differences between the handwriting made with the left hans in comparison with the one performed with the right hand.

In this situation, we tend to agree with the second opinion that states that a mechanical transfer of the habits or abilities cannot be done from one hand to the other.

It is very important that in the process of completing the Law, in all its stages, that we respect the procedural warranties from the perspective of ensuring both the compliance with the fundamental law in an a fair trial, and of the fair solutioning of the criminal causes by finding out the truth and exercising the educational role of the criminal trial *(Lorincz, A.-L. and Ciurea, Ştefan T. 2024).*

CONCLUSION

The handwriting and signature represent unique cerebral imprints, that are relevant not only for the personal identity, but for the neurological state of the individual. In forensics, their analysis remains a highly important instrument, but its' applicability requires a profound understanding of the neurological influences. Integrating knowledge from neuroscience and medicine in the graphoscopic investigations contributes to the increase in the accuracy of identifying and consolidating the probative value of documents.

Therefore, the signature and the handwriting become not only judicial tools, but also expressions of the complexity and uniqueness of the human brain.

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