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Foreword

Forensic science is constantly looking for effective research methods that will allow them to be used in the detection and evidence processes. Among the many issues related to the broadly understood forensic science are questioned document examination and fingerprint examination. It should be emphasized that these areas still require constant initial experimental research and theoretical-practical analyses in order to improve the quality and effectiveness of methods so that they can be applied in practice. The present volume is a collection of articles written by an international group of experts in forensic documents examination and fingerprint research. It allows the reader to familiarize themselves with selected issues related to the use of modern technologies in document examination and to the discussion regarding fingerprint research problems. The volume includes studies on handwriting examination and its practical use, as well as the possibilities and limits of expert opinion. A separate group consists of studies devoted to problems in questioned documents analysis as well as to the use of false documents in committing accounting crimes. The specificity of contemporary document research requires a multidisciplinary approach and fully justifies the need to internationalize research. In this context, an exchange of views, including critical remarks on the basis of document research and fingerprint examinations, is indispensable. This volume may constitute an important element of forensic science and its contemporary selected research.

dr Rafał Cieśla

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The authorship of disguised handwriting written with the unaccustomed hand: A preliminary study

Anita Rani

ORCID: 0000-0002-8928-223X
Formerly Senior Research Fellow, Department of Forensic Science
Punjabi University, Patiala

Mohinder Singh

ORCID: 0000-0002-2649-1616
Formerly Government Examiner of Questioned Documents
Central Forensic Science Laboratory, Hyderabad, India

Om Prakash Jasuja

ORCID: 0000-0002-2221-1242
Department of Forensic Science, Chandigarh University
Gharua, Punjab, India

Abstract

Sometimes, a writer may try to disguise their normal handwriting to hide their identity. One of the most effective and less frequent modes of disguise is to write with the unaccustomed hand. In this type of disguise, due to a sudden loss of pen control, pictorial appearance of handwriting changes to such an extent that the writer assumes success and gets convinced that the disguised handwriting they have produced cannot be attributed to them by comparison with their normal writing style. In the present study, handwriting samples of several persons, both with the normal hand and the unaccustomed hand, were obtained and an attempt has been made to find out and identify those features that

survive the hazards of disguise and could be helpful to accurately determine the authorship of such disguised handwriting in comparison with one's normal handwriting samples. A detailed study of letter-forms, the connecting strokes between letters, and t-crossing written by several persons has been carried out. It has been found that, despite pictorial dissimilarities, there are certain unconscious features that are rarely disguised which could either form the basis for their association with a particular writer or indicate its probability for further investigation. The analysis, comparison, and evaluation of features unconsciously left by the writer, including the parameters selected for the present study, can be carried out by a trained forensic document examiner; and they can give whatever opinion is possible and justifiable in facts and circumstances of a case.

Keywords: forensics, handwriting, disguise, unaccustomed hand, authorship, identification

Introduction

Handwriting is an acquired skill that can be neither discarded nor developed at will. Particularly at the stage of graphic maturity, the production of natural handwriting becomes so automatic that it does not require any conscious direction. All the master patterns of handwriting that are acquired and practiced become fixed in the brain and, during the process of writing, they are retrieved and physically produced on paper by human hand through the muscular system. Being a neuromuscularly controlled motor activity, the production of natural handwriting is almost automatic; the writer does not need to concentrate on how to write, they rather concentrate on what to write. Once the writing habits get fixed, it becomes difficult for a writer to either successfully disguise their own handwriting or to forge somebody else's. Though it is difficult to maintain consistently, some of the writers still attempt to disguise their handwriting, with the possible objective of hiding their identity for subsequent denial. Not only are these cases frequent, but also people adopt novel methods of disguise, principal among them being: a change of slant, a change of size, substituting letter forms, using block capitals, opposite-hand writing, inverted writing, using a broad tip pen, or a change in speed of writing. Several features of disguised writings, including the line quality defects, are well documented[1] and through them it can be determined whether or

[1] A.S. Osborn, *Questioned documents*, Rochester, NY 1929, p. 34; W.R. Harrison, *Suspect documents: Their scientific examination*, London 1958, pp. 365–369; O. Hilton,

not the handwriting is disguised.[2] Harrison[3] has reported eight general principles for detection and identification of disguise that are still relevant and being followed by forensic document examiners.

Most of the attempts to disguise handwriting are ineffective and can be detected, though the writers assume they can achieve that by simply changing the pictorial effect of handwriting. They are perhaps unaware of some unconscious writing habits that are involuntarily reflected in their handwriting. An interesting observation reported by Harrison is that only one out of nine people (i.e. about 11%) can change their handwriting appearance to the extent that makes it impossible to identify at a glance. Furthermore, the average writer cannot consistently maintain the disguise for a considerable length of time. As soon as the attention given to the writing process is unconsciously withdrawn, the writer reverts to their normal writing style.

Handwriting could more appropriately be called brain-writing, because a hand only acts as a servant of the brain. Therefore, theoretically speaking, the production of writing is almost independent of the physical part that brings it on paper, be it the right hand or the left hand. As stated by Harrison,[4] developed handwriting is substantially the unconscious product of the mind; it is, therefore, independent of the hand that produced it. Although some of the writers could be ambidextrous too, most writers favor one hand over the other and have accordingly developed their own pen control, muscular coordination, and writing skill with respect to the dominant hand. When writing with the opposite hand or the unaccustomed hand, the writer loses their rhythm and muscular control, resulting in inferior quality of handwriting, which some of the writers consider as an effective disguise, capable of hiding their identity. Because the pictorial effect produced by unaccustomed-hand writing is considerably different from that of the accustomed hand; most of the time the writer prefers

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Scientific examination of questioned documents, New York 1982; K.M. Koppenhaver, *Forensic document examination: Principles and practice*, Totowa, NJ 2007; E.F. Alford, "Disguised handwriting: A statistical survey of how handwriting is most frequently disguised", *Journal of Forensic Science* 15, 1970, no. 4, pp. 476–488.

[2] K.M. Koppenhaver, op. cit.

[3] W.R. Harrison, op. cit.

[4] Ibid.

to use the unaccustomed hand as a mode of disguise.[5] Harrison[6] has since reported that disguised writing produced by the unaccustomed hand will bear little general resemblance to that written by the dominant hand; and about 5% (one in twenty) of the people going for disguise chose writing with the unaccustomed hand as the preferred mode of disguise, since it produced an unrecognizable script.

Some of the features of unaccustomed-hand writing are: lack of muscular control, poor skill, poor line quality, poor rhythm, induced tremor, uneven base line, and abrupt changes in direction of movement while forming loops and circles. Sometimes reverse movement of letter forms could also be found. However, since the master patterns are stored in the brain, handwriting features habitual and peculiar to the individual such as: letter designs, spacing, proportions, initials, terminals, connecting lines, hooks, and ticks, will naturally carry over from the dominant to the non-dominant hand. Therefore, it becomes important to recognize those features in disguised handwriting which could be solely attributed to the unaccustomed hand. Jasuja and Anita[7] reported several such features. Once the disguise has been detected, the next challenge is to ascertain the identity of the writer. For this purpose, the forensic document examiner needs to compare the questioned writings purportedly written with the unaccustomed hand with the standard writings of the suspect.

Since originality in disguise is rare, it is easily detectable; however, as mentioned above, there are also certain (unconscious) features that are rarely disguised even in unaccustomed-hand writing, which could bear similarities to the accustomed-hand writing of the same person.[8]

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[5] K.M. Koppenhaver, op. cit.

[6] W.R. Harrison, op. cit.

[7] Anita, O.P. Jasuja, "Mirror writing: A trait of writing with unaccustomed hand", *Problems of Forensic Science* 106, 2016, pp. 444–455.

[8] G.A. Dawson, "An identification of handprinting produced with the unaccustomed left hand", *Canadian Society of Forensic Science Journal* 26, 1993, no. 2, pp. 61–67; M. Conrad, "Left-hand writing vs. right-hand writing", *Journal of the American Society of Questioned Document Examiners* 11, 2008, no. 1, pp. 19–27; G.A. Dawson, "Brain function and writing with the unaccustomed left hand", *Journal of Forensic Science* 30, 1985, no. 1, pp. 167–171; J.E. Franks et al., "Variability of stroke direction between left-and right-handed writers", *Journal of the Forensic Science Society* 25, 1985, no. 5, pp. 353–370; J.A. Joseph, "Left-hand and opposite-hand writing features useful as a basis

In addition to these features, there exists a possibility that even more features, such as the design of letters, the connecting strokes between letters, and the inconspicuous t-crossing, may remain unaffected by switching from the dominant hand, which could be helpful in identifying disguised handwriting. It has, therefore, been considered more appropriate to carry out a study to find out and evaluate if such features continue to persist in disguised handwriting produced by the opposite hand. The present study makes an attempt to examine in detail whether the changes in handwriting due to the use of the unaccustomed hand are only superficial, solely affecting the pictorial appearance, or if they are deeply rooted, affecting letter formations and rendering the writing unidentifiable. Additionally, features such as diacritic marks on letters 'i' and 'j' and the formation of letter 'o' have also been included in this preliminary study.

Materials and methods

The vast majority of people are natural right-handers. Left-handers, as reported by Everyday Health,[9] make up about 10% of the population, while ambidextrous people, according to Reader's Digest,[10] constitute only about 1%.

In the present study, handwriting samples were collected from university and college students who were very comfortable with English (Roman) script writing and can be categorized as skilled writers. Out of the 200 volunteer students, 100 were natural right-handers comprising 50 males and 50 females; and the remaining 100 were left-handers, comprising 50 males and 50 females. All volunteers were in the age group ranging between 17 and 32 years. Prior consent was obtained from the volunteers to using their handwriting samples for research purposes. The text selected for the volunteers to write is provided in Figure 1.

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of forming expert opinions of authorship", *National Association of Document Examiners Journal* 2004.

[9] K. Kerns Geer, "12 little known facts about left-handers", *Everyday Health*, 13.08.2015, https://www.everydayhealth.com/healthy-living-pictures/little-known-facts-about-lefthanders.aspx.

[10] M. Jones, "10 fascinating facts you never knew about ambidextrous people", *Reader's Digest*, 29.05.2019, https://www.rd.com/list/facts-ambidextrous-people/.

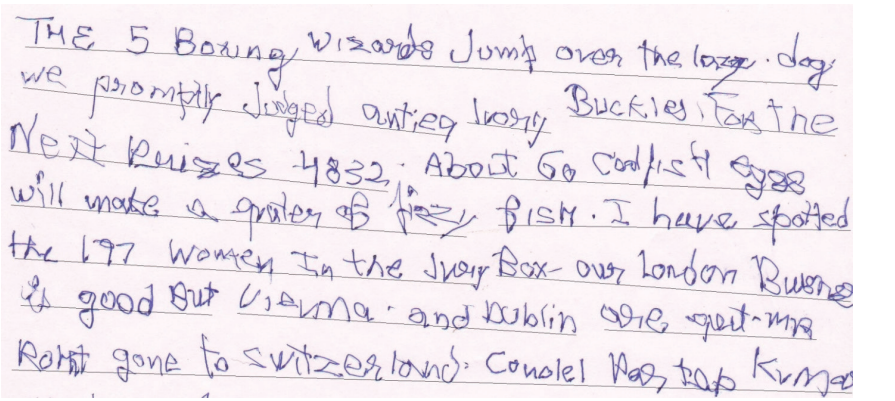


Figure 1. The text selected for the volunteers to write

These handwriting samples were collected in two ways.

1. Copying method: the standard passage was given to the volunteers, who were asked to write with both hands on separate A4 plain sheets.

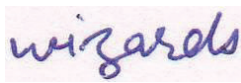
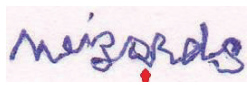
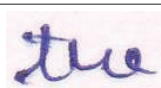
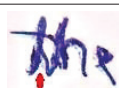
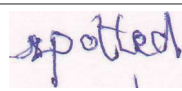
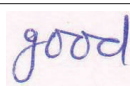
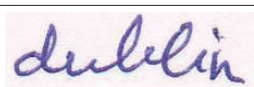
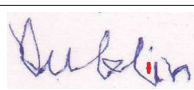
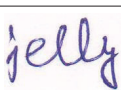
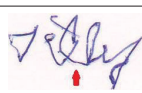
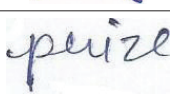
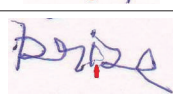
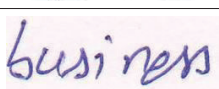
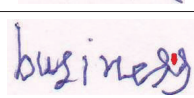
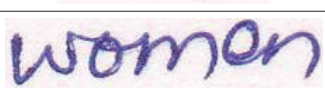
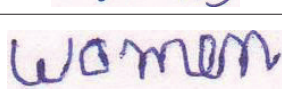
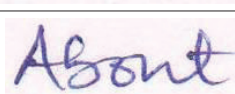
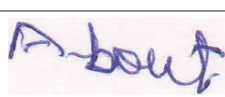
2. Dictation method: dictation was given to the volunteers, who were asked to write with both hands on separate A4 plain sheets, while each word was repeated three times.

In this way, four handwriting samples were collected from each subject, thus the total number of handwriting samples was 800.

None of the subjects was given any prior training to write with the unaccustomed hand, nor were they related to one another. A standard passage of handwriting was given to all the volunteers, which included all lowercase as well as capital letters in English (Roman) script and numerals from 0 to 9 (reference Figure 1 above). The handwriting samples obtained from the subjects contained mostly cursive handwriting produced with a ballpoint pen.

Two examiners with 5 and 30 years of research experience in handwriting examination respectively were asked to evaluate the collected handwriting samples. Each sample was examined with the help of a magnifying glass (10 ×) to study the formation of strokes, particularly the connecting strokes in both the accustomed- and unaccustomed-hand writings. The extent of similarity or difference in both types of handwriting samples was observed for each selected feature.

Features of the connecting strokes were studied in 15 particular letter combinations selected from the passage used for handwriting analysis. These can be found in the words: wizards (ar), the (th), spotted (ot), good (oo), Dublin (li), jelly (ll), prize (ri), business (ss), women (om), about (ab), gone (go), jury (ju), Vienna (Vi), fizzy (zy), and Hongkong (Ho). Similar manners of connecting strokes are marked with red arrows and shown in Figure 2.

Words	Accustomed hand	Unaccustomed hand
ar (wizards)		
th (the)		
ot (spotted)		
oo (good)		
li (Dublin)		
ll (jelly)		
ri (prize)		
ss (business)		
om (women)		
ab (about)		

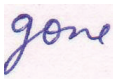
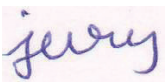
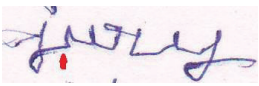
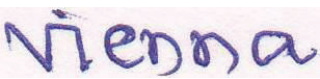
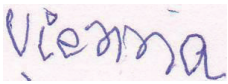
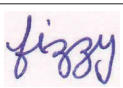
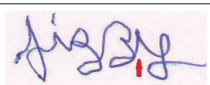
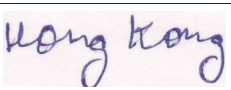
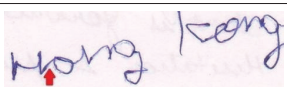
go (gone)		
ju (jury)		
Vi (Vienna)		
zy (fizzy)		
Ho (Hongkong)		

Figure 2. Presence of letter connections in both accustomed- and unaccustomed-hand writing samples

Additionally, the formation of strokes in particular part of the grapheme and t-crossings were studied. The formation of strokes in ovals and loops was studied in terms of the direction of the pen movement, while t-crossing was studied regarding the direction of the crossing bar over the staff; that is, if it was right to left or left to right. Also, diacritic marks on letters 'i' and 'j' were studied in terms of their shape and position, while the letter 'o' was studied regarding the direction of its stroke formation – clockwise or anticlockwise.

All the results were presented in the form of observations and illustrated with the help of figures. No statistical tools were applied at this stage.

Results and discussion

Connecting strokes

In the present study, various letter combinations were selected and the types of connecting strokes were observed in handwritings of both left-handers as well as right-handers. A similar way of connecting the two letters was observed and indicated in Figure 2. However, it has been observed that in accustomed-hand writing the connections are smooth while unaccustomed-hand writing possesses angularities, hesitations,

abrupt directional changes, hairline connections, uncertain movements, as well as tremulous strokes. This could be due to the poor neuromuscular coordination of the unaccustomed hand, resulting in inferior 'finger' writing movement in the disguised writing. It was consistent with the observation that connections were certainly absent in the unaccustomed-hand writings if there were no corresponding connecting strokes present in the accustomed-hand writings. However, connections were also found to be absent in writings with the unaccustomed hand in places where such connecting strokes were present in the corresponding accustomed-hand writings. This is consistent with the statement of Huber and Headrick[11] that writing with the non-dominant hand displays a loss of skill and fluency as well as reduction in writing speed which may result in a poorer line quality, tremors in writing, abrupt changes in pen pressure, and absence of connections between the letters. Furthermore, Joseph[12] reported various features of unaccustomed-hand writing such as acute angles in connecting strokes, flattened bottom loops of letters 'g,' 'j,' and 'y,' dragging terminal strokes of letters, low level of skill, tremors and lack of smoothness in line quality, abrupt directional changes etc. Results of the study consistent with similar observations made by the above mentioned authors are presented along with specific reasons for variation, if any.

As far as the type of the connecting strokes is concerned, it was observed that there seems to be very little difference in connecting strokes between writing with the accustomed hand and that with the unaccustomed hand when it was copied from the text; but with the unaccustomed-hand writing in dictation mode, there are unpredictable changes in the connecting strokes, as illustrated in Figure 4. This could be due to the obvious loss of freedom to write as one has to follow the dictation and their attention is diverted from the writing process. Consequently, the writer becomes helpless to move the writing instrument in an unpredictable way. To establish the authorship of disguised writings, there must be significant similarity in execution of strokes in both the questioned and the standard writings. In the present study, no practice or training was imparted to the volunteers to write with the unaccustomed hand; and even

[11] R.A. Huber, A.M. Headrick, *Handwriting identification: Facts and fundamentals*, Boca Raton, FL 1999.

[12] J.A. Joseph, op. cit.

then, some similarities were observed in the formation of the connecting strokes between letters in both sample types. Had the volunteers gotten the opportunity for training and practice before giving their handwriting samples, their level of performance and consequently the results of the analysis could have been much better.[13]

Formation of strokes

In the present study, letters – namely 'a,' 'k,' 'f,' 'z,' 'j,' 'd,' and 'g' – were selected to examine the accustomed and unaccustomed-hand writings of both the left-handed and right-handed writers. These letters were taken from the same word in accustomed- as well as unaccustomed-hand writings in order to compare both types and see if the writing changes with the change of hand. In the case of unaccustomed-hand writing, most strokes were found to be similar to unaccustomed-hand writing, but the letters showed variations in the form of hesitations, large letter size, angular strokes, etc. in handwriting produced with both the copied and the dictation methods, due to unnatural and uncontrolled holding of the writing instrument (Figure 3). Hilton[14] reported that in writings created with the unaccustomed hand, same general features of movement and proportion were found, with the exception of a few letters which may be constructed with a different stroke direction. Kelly and Lindblom[15] reported that writing with the unaccustomed hand affects the writing's pictorial appearance.

Interestingly, wherever a writer wrote the letters with embellishments with their accustomed hand, the same writer while writing with the unaccustomed hand tried to insert the embellishments. It was clearly seen in all the samples of unaccustomed-hand writing. Because the activities of each hand are controlled by the opposite brain hemisphere, when

[13] T. Dziedzic, "The development of left-handed writing features of a right-handed person who has undertaken training in writing with his left hand", *Problems of Forensic Sciences* 83, 2011, pp. 93–102; idem, "Right hand writing vs. left hand writing of one person: A comparative study", *Problems of Forensic Sciences* 94, 2013, pp. 564–577.

[14] O. Hilton, op. cit.

[15] J.S. Kelly, B.S. Lindblom, *Scientific examination of questioned documents*, Boca Raton, FL 2006.

a writer writes with the unaccustomed hand, proper signals for making the letter designs are not received, as the writer may not be used to writing with the opposite hand.

Letter 'z'	Accustomed copied	Accustomed dictation	Unaccustomed copied	Unaccustomed dictation
Writer 1				
Writer 2				
Writer 3				
Writer 4				
Writer 5				

Figure 3. Formation of strokes in samples produced by copying and dictation methods, in both the accustomed and unaccustomed hand writings (right-handed writers)

The formation of strokes in accustomed-hand writing shows similarity in both copied and dictated samples. As is evident from Figure 5, the strokes were found to be similar in accustomed- as well as in unaccustomed-hand writings. However, letters showed variations in the form of hesitations, large letter size, angular strokes, etc. in both copied and dictated samples of unaccustomed-hand writing due to an uncontrolled hold on the writing instrument. This could create confusion while making opinions on authorship.

T-crossing

T-crossing (t-bar) is a feature which is habitual and personal to every writer. There are generally two ways to make the cross of letter 't'; from left to right or right to left. But many writers may have the habit of making this crossing stroke in both ways (i.e. left to right as well as right to left)

in their handwriting. In present study, all the three types of t-crossing have been observed and illustrated through Figure 4, in both accustomed- and unaccustomed-hand writing samples.

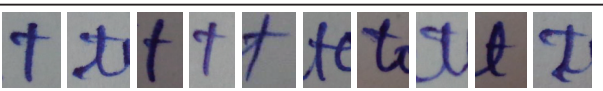
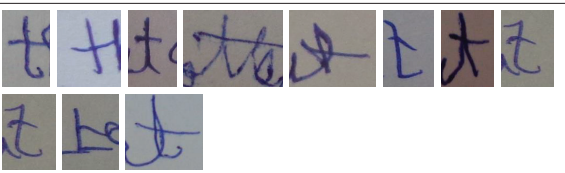
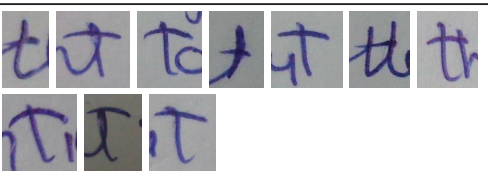
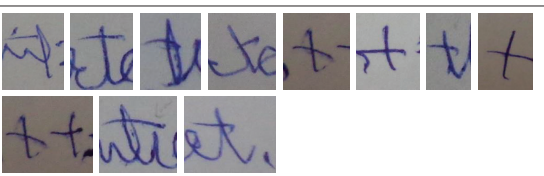
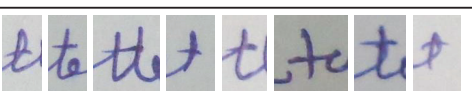
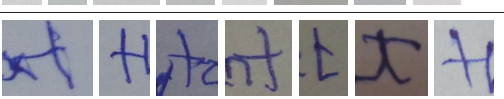
T-crossing	Left to right
Accustomed hand	
Unaccustomed hand	
	Right to left
Accustomed hand	
Unaccustomed hand	
	Mixed
Accustomed hand	
Unaccustomed hand	

Figure 4. Habit of t-crossing in both accustomed- and unaccustomed-hand writings

In accustomed-hand writing no difference was found between copied and dictated samples as well as between the writings of male and female writers. A considerable difference has been observed in the writings of right-handed and left-handed writers with respect to t-crossing.

As Table 1 indicates, all the right-handed writers wrote the t-bar from left to right with their accustomed hand. No writer was found to write the t-bar from right to left except one male writer who wrote it in a mixed form with his accustomed right hand. On the other hand, in unaccustomed-hand writing, the majority of the writers wrote the t-bar from left to right and in mixed form; some of the writers were found to write it from right to left. As mentioned earlier, in the case of accustomed writings of the right-handed writers, t-crossing was written from left to right; but when they wrote with their unaccustomed hand, their neuromuscular co-ordination did not remain normal and they got confused while forming the stroke in the correct direction. That is why the t-bar was formed in both directions in the unaccustomed-hand writings of the right-handed writers. Franks[16] examined the t-crossing in 52 right-handed and 17 left-handed writers in their accustomed-hand writing and it was found that 50 right-handed writers formed the t-crossing from left to right, while left-handed writers showed variations; i.e. 10 writers formed the right to left t-crossing, whereas 6 writers formed the t-crossing from left to right. In the case of left-handed writers, the majority wrote the t-bar from left to right, while some (both male and female) wrote it from right to left, and in mixed form with the accustomed hand. It means that both types of t-crossing have been made by the left-handed writers with their accustomed hands. Saran et al.[17] examined the cross strokes in 50 left-handed and 50 right-handed writers in their accustomed-hand writings, and the results showed that cross strokes of left-handed writers were made from right to left while cross stroke of right-handed writers were made from left to right. In the present study, the frequency of left-handed writers having t-crossing from right to left was found to be higher than that of the right-handed writers writing with their accustomed hands. It was observed that a writer has the habit of making horizontal strokes in right to left direction because of the use of the left hand.

[16] J.E. Franks, "The direction of ballpoint pen strokes in left and right-handed writers as indicated by the orientation of burr striations", *Journal of Forensic Science Society* 22, 1982, no. 3, pp. 271–274.

[17] V. Saran et al., "Differentiation of handedness of writer based on their strokes and characteristic features", *Journal of forensic research* 4, 2013, no. 5, pp. 1–3.

Joseph[18] reported that left-handed writers cross the lower case letter 't' from right to left. In the present study, the majority of left-handed writers cross the letter 't' from left to right; but it is true that the frequency of right to left t-crossing was far higher in the case of left-handed writers as compared to the right-handed writers, in accustomed-hand writings, as is clear from Table 1. In the case of unaccustomed-hand writing, all left-handed writers wrote the t-bar from left to right except one female writer who wrote it in a mixed form. No left-handed writer wrote the t-crossing in right to left direction with their unaccustomed hand. There is a natural tendency for most of the writers to make horizontal strokes from left to right. When a left-handed writer used their right hand as the unaccustomed hand, t-crossing stroke was automatically formed in left to right direction. Actually, the brain is divided into the right hemisphere and the left hemisphere. Right-handers (95–99%) receive motor signals (hand, arm, wrist, etc.) and sensory signals (vision and touch) from the left hemisphere, while left-handers receive motor signals from the right hemisphere. In 60–70% left-handers, the faculty of language and speed is located in the left hemisphere. Hence, it is necessary for the impulses to travel from the left hemisphere to the right one to receive appropriate motor information by the left hand.[19] This transfer of motor signals from the left hemisphere to the right hemisphere might be responsible for the left-handed writers making the stroke from right to left with their accustomed left hand. As mentioned above, no left-handed writer wrote the t-crossing in right to left direction with their unaccustomed hand. The reason for this may be that 60–70% left-handers receive motor signals from the left hemisphere and the left hemisphere virtually controls the right hand. When a left-handed writer writes with the right unaccustomed hand, they receive motor signals directly from the left hemisphere, as the right-handers do.

On the one hand, it was observed that when written with the unaccustomed hand, the shape of the t-crossing changed into a curved or wavy form; or sometimes it remained straight. On the other hand, it was found to be straight in the accustomed-hand writing – its direction goes either

[18] J.A. Joseph, op. cit.

[19] G.A. Dawson, "Brain function and writing…".

upward or downward. Dawson examined the t-crossing in right-handed unaccustomed-hand writing and found that with the unaccustomed hand, the stroke was curved, straight, or wavy, but failed to determine the direction of t-crossing. Findings of the present study are also in accordance with the results reported by Dawson. The horizontal stroke of the t-bar was found to be curved, wavy, or straight when written with the unaccustomed hand.[20]

Table 1. T-crossing (right-handed and left-handed writers, 50 males and 50 females)

Types	Males		Females		Males		Females	
	AC	AD	AC	AD	UC	UD	UC	UD
Left to right	49 (33)	49 (33)	50 (36)	50 (36)	32 (50)	31 (50)	18 (49)	18 (49)
Right to left	00 (11)	00 (11)	00 (09)	00 (09)	04 (00)	06 (00)	10 (00)	07 (00)
Mixed	01 (06)	01 (06)	00 (05)	00 (05)	14 (00)	13 (00)	22 (01)	25 (01)

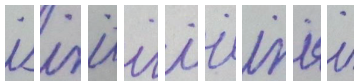
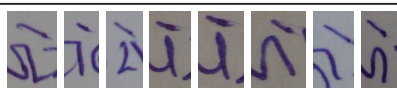
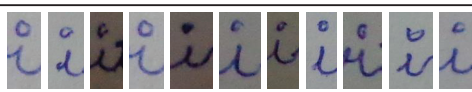
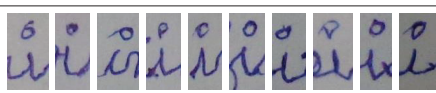
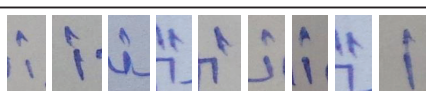
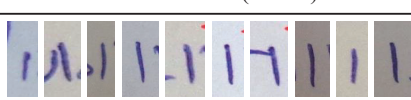
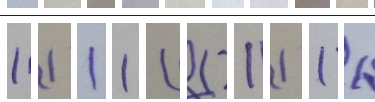
Abbreviations used in tables

AC: Accustomed hand, normal writing
AD: Accustomed hand, disguised writing
UC: Unaccustomed hand, normal writing
UD: Unaccustomed hand, disguised writing

Diacritic mark over the letters ‘i’ and ‘j’

I-dot is a diacritic mark which is present over the letter ‘i’ and the similar diacritic mark is also present over letter ‘j.’ In the present context, diacritic on both the letters ‘i’ and ‘j’ will be called a diacritic only irrespective of the letter containing it. Different types of diacritic marks have been observed in handwritings of accustomed as well as unaccustomed hand and were classified as ‘dot,’ ‘tick,’ ‘circle,’ ‘mixed,’ and ‘inverted-v,’ which have been demonstrated through Figure 5 both in accustomed- and unaccustomed-hand writings. Table 2 shows different classes of i-dots in both the right-handed and left-handed writers.

[20] Ibid.

Diacritics	Dots
Accustomed hand	
Unaccustomed hand	
	Tick
Accustomed hand	
Unaccustomed hand	
	Circle
Accustomed hand	
Unaccustomed hand	
	Inverted v
Accustomed hand	
Unaccustomed hand	
	No dot (absent)
Accustomed hand	
Unaccustomed hand	

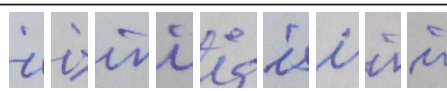
	Mixed
Accustomed hand	
Unaccustomed hand	

Figure 5. Various types of i-dots in accustomed- and unaccustomed-hand writings

As indicated in Table 2, 'dot' and 'mixed' types of diacritic were found to be the most common in all the writings irrespective of the writer's sex and the hand used for writing; though the dot type was observed more than the mixed type. This was found to be correct for both sexes as well as hands of writing. With the dot, the frequency increased further in the unaccustomed-hand writing.

In the case of accustomed-hand writing, not much variation has been observed in copying and dictation method of collecting writing samples. Results showed that 30–62% writers made the diacritic in the form of a dot in both left-handed and right-handed handwritings with their accustomed hand. Around 20–50% writers made the i-dot in mixed form, 6–14% writers made the i-dot in the form of a 'tick,' and 4–6% writers made the i-dot in 'inverted v' form. As was already discussed, the 'tick' and 'inverted v' forms were found in very small numbers in accustomed hand. 6–26% writers made the i-dot in 'circle' form. Those subjects who do not have the habit of making any i-dot were considered as absent. 6% writers do not form any diacritic mark over 'i' in accustomed-hand writing. The same subjects while writing with unaccustomed hand also did not form any diacritic mark over 'i.' With unaccustomed hand 44–92% writers made a diacritic in the form of a dot in both left-handed and right-handed writings. Results showed that a diacritic mark in the form of a dot is most frequently used in unaccustomed-hand writing as compared to accustomed hand in both right-handed and left-handed writers. The probable reason could be that the writer was unable to make other types of i-dots easily except the 'dot' with their unaccustomed hand. Some of the writers have mixed i-dots in their unaccustomed-hand writing, and mixed i-dots mostly included only the dots and ticks. The 'inverted v' diacritic could not be found in unaccustomed-hand writings of any writer.

Dawson[21] examined the i-dots in the writings of 20 right-handed writers. It was observed that with the unaccustomed hand, diacritics were placed either directly above, to the right, or to the left of 'i.' The shape of dots varies in left- and right-handed writings – commas, small vertical or horizontal slashes were made with unaccustomed hand, while these unusual shapes were rarely found in their right hand. It was also found that if a dot was not present in right-hand writing, then it was also not present in left-hand writing. In the present study it was also observed that if the writer had not placed any diacritics in their accustomed-hand writing, then they were not found in the unaccustomed hand writing either.

Table 2. Diacritic mark over 'i' (right-handed and left-handed writers, 50 males and 50 females)

Types	Males		Females		Males		Females	
	AC	AD	AC	AD	UC	UD	UC	UD
Dot	21 (29)	19 (31)	18 (17)	19 (15)	32 (43)	32 (46)	24 (35)	22 (36)
Tick	07 (07)	07 (03)	03 (03)	03 (03)	00 (01)	02 (00)	02 (00)	02 (01)
Circle	03 (03)	03 (03)	12 (13)	09 (07)	02 (00)	02 (00)	09 (03)	06 (02)
Mixed	14 (10)	17 (12)	17 (17)	19 (25)	14 (05)	12 (03)	15 (12)	20 (11)
Inverted v (^)	03 (00)	02 (00)	00 (00)	00 (00)	00 (00)	00 (00)	00 (00)	00 (00)
Absent	02 (01)	02 (01)	00 (00)	00 (00)	02 (01)	02 (01)	00 (00)	00 (00)

Letter 'o'

Letter 'o' is drawn in the form of a circle or oval which can be constructed in two ways; namely, anti-clockwise or clockwise. Most of the people write the letter 'o' anti-clockwise; therefore, it can be considered the normal way of writing, although writing the letter 'o' clockwise is also observed. In addition to this, some writers may write the letter 'o' in both directions. In the present study the letter 'o' with anti-clockwise move-

[21] Ibid.

ment was also found to be the most frequent type. The results of the study are presented in Table 3.

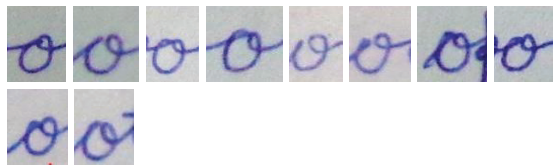
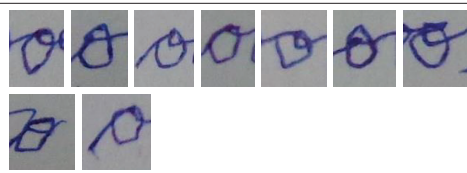
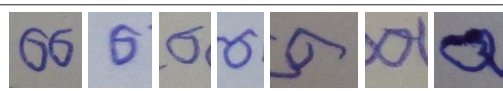
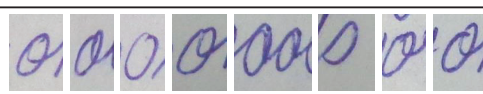
Letter 'o'	Anti-clockwise
Accustomed hand	
Unaccustomed hand	
	Clockwise
Accustomed hand	
Unaccustomed hand	
	Mixed
Accustomed hand	
Unaccustomed hand	

Figure 6. Different classes of the letter 'o' in accustomed- and unaccustomed-hand writings

Table 3 indicates that in accustomed hand writing, majority of right-handers wrote letter 'o' anti-clockwise. One male and one female writer wrote the letter 'o' clockwise in both copied and dictated samples. Not much variation was observed in copied and dictated samples. Male and female writers also do not show any significant differences in both left- and right-handed writers. The frequency of left-handed writers writing the let-

ter ‘o’ clockwise was quite high (7 males and 5 females) as compared to the right-handed writers. The majority wrote the letter ‘o’ anti-clockwise (40 males and 43 females) and two writers wrote it in both directions in mixed type. Talbot-Wilson[22] estimated that 42% left-handed and 1% right-handed writers wrote the circular strokes in a clockwise manner. Franks[23] examined the letter ‘o’ in 52 right-handed and 17 left-handed writers in their accustomed-hand writing. It was found that all right-handed writers formed the letter ‘o’ anti-clockwise, while left-handed writers showed variations, i.e. 10 writers formed it anti-clockwise, while 7 writers – clockwise. These findings are in accordance with the studies reported earlier. In the present study, as discussed above, the majority of right-handed writers formed the letter ‘o’ anti-clockwise, while left-handed writers showed variation in clockwise and anti-clockwise accustomed hand movement. At the same time, in the case of unaccustomed-hand writing the majority of the writers wrote the letter ‘o’ anti-clockwise (approximately 33 right-handed and 44 left-handed writers) irrespective of their dominant hand. Two left-handed female writers were found to have written the letter ‘o’ clockwise, while five right-handed writers (3 male and 2 female) wrote it clockwise with the unaccustomed hand. The frequency of the letter ‘o’ in both directions (mixed type) was higher in the case of right-handed writers as compared to the left-handed ones in unaccustomed-hand writings. This observation clearly indicates that the anti-clockwise formation of the letter ‘o’ can be seen as the most natural and ergonomic one for a writer. The preferred anti-clockwise trend could also be seen in unaccustomed-hand writing, indicating the fixed writing habit of the writer concerned. There was a visible increase of mixed type (both types) letter ‘o’ formation in unaccustomed-hand writings particularly in right-handed writers. This may be due to the inadequate neuromuscular co-ordination with the unaccustomed hand, which thus creates confusion in making out the correct direction in forming the letter ‘o.’

[22] M.G. Talbot-Wilson, “Variability of stroke direction between left- and right-handed writers”, *Journal of the Forensic Science Society* 26, 1986, no. 3, pp. 177–179.

[23] J.E. Franks, op. cit.

Table 3. The letter ‘o’ (right-handed and left-handed writers, 50 males and 50 females)

Types	Males		Females		Males		Females	
	AC	AD	AC	AD	UC	UD	UC	UD
Anti-clockwise	49 (41)	49 (40)	49 (43)	49 (43)	32 (44)	32 (42)	30 (43)	33 (41)
Clockwise	01 (07)	01 (07)	01 (05)	01 (05)	03 (00)	03 (00)	02 (02)	02 (02)
Mixed	00 (02)	00 (03)	00 (02)	00 (02)	15 (06)	15 (08)	18 (05)	15 (07)

Conrad[24] examined the direction of the letter ‘o’ in 30 left-handers and 30 right-handers in accustomed-hand writings in order to establish the handedness of the writer, and classified the letter ‘o’ into three types: counterclockwise, clockwise, and a combination of counterclockwise and clockwise. The results showed that most writers in both the groups wrote circular strokes in counter-clockwise direction: 13.3% left-handed writers used clockwise circles, while a combination of both movements was seen only in left-handed writers. In the present study results show consistency with Conrad’s findings. Left-handed as well as right-handed writers wrote the letter ‘o’ in anti-clockwise direction, in majority of the cases, in copied as well as dictated samples of accustomed writing. Very few writers wrote this letter clockwise; whereas negligibly small number wrote the letter ‘o’ with mixed type of movement. As evident from Table 4, in the case of unaccustomed writing, forming the letter ‘o’ anticlockwise remained the preferred choice; however, its numbers decreased significantly when the element of disguise was brought in. At the same time, the frequency of the clockwise direction remained unaffected by the introduction of disguise. The decrease in the number of those writing in anticlockwise direction was probably due to the shifting of such writers to the mixed category – the same writer writing the letter ‘o’ in both the clockwise and anticlockwise directions. The results of the study indicate a writer’s weakening neuromuscular coordination due to the change of the writing hand.

[24] M. Conrad, op. cit.

Table 4. The formation of letter 'o' (right-handed and left-handed writers, 50 males and 50 females)

Types	Males		Females		Males		Females	
	AC	AD	AC	AD	UC	UD	UC	UD
Anti-clockwise	49 (41)	49 (40)	49 (43)	49 (43)	32 (44)	32 (42)	30 (43)	33 (41)
Clockwise	01 (07)	01 (07)	01 (05)	01 (05)	03 (00)	03 (00)	02 (02)	02 (02)
Mixed	00 (02)	00 (03)	00 (02)	00 (02)	15 (06)	15 (08)	18 (05)	15 (07)

Generally, the letter 'o' is long, elliptical, and round when written with the dominant hand. But when the writer uses their unaccustomed hand, it affects the shape of this letter; i.e. angular or squarish shapes are observed, the direction of the letter 'o' is changed, as was discussed earlier. Normally, its opening and closing location is on the upper side, but with the unaccustomed hand its opening and closing location are sometimes changed to the lower side, which is illustrated through Figure 7. It shows the opening and closing locations of the letter 'o' in both the accustomed and unaccustomed hand, which clearly indicates the differences that occur due to the use of the unaccustomed hand.

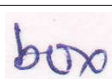
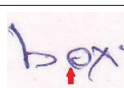
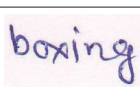
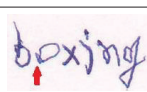
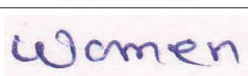
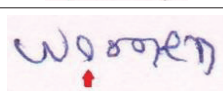
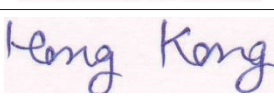
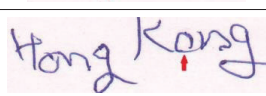
S.No.	Accustomed hand	Unaccustomed hand
1.		
2.		
3.		
4.		
5.		

Figure 7. The opening and closing location of the letter 'o' in the accustomed and unaccustomed hand

Conclusion

It is said that handwriting characteristics of an individual, even over a period of time and under varying conditions, remain similar; and whatever differences are observed remain within the range of natural variation. This means all the usual handwriting variations of an individual, as a rule, will fit into a master pattern; but in the case of unaccustomed-hand writing by the same person there is an exception that may not always follow the said pattern. Such an exception may jeopardize the observations made by a forensic examiner and result in an erroneous conclusion if adequate precautions are not taken. The results of the study indicate that, despite the change in pictorial appearance, the connecting strokes between letters still remained intact; and in combination with more such features, they could form the basis of identification of the unaccustomed-hand writing. The possibility of using the unaccustomed hand as a mode of disguise must always be kept in mind by the examiner while handling such problems involving unnatural handwriting produced by a writer's unaccustomed hand. In such cases, the examiner may study and evaluate several unconscious features that are rarely disguised, including the connecting strokes of letters that appear to be formed irrespective of the writer's handedness. The identification of writings disguised with the use of the unaccustomed hand is a difficult task; unless a sufficient number of unconscious lapses of the writer is found between the questioned and the standard writings, a definite opinion regarding their common or different authorship may not be possible.

Although there may be certain similarities in the formation of several handwritten strokes, due to the presence of usual unaccustomed hand characteristics in the questioned disguised writings – such as angularity, hesitations, abrupt directional changes, hair line connections, uncertain movements, as well as tremulous strokes – it is not safe to make conclusions about the authorship of that writing.

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Tax crimes in Italy using accounting documents

Rafał Cieśla

ORCID: 0000-0002-8479-288X
Department of Forensic Sciences, Faculty of Law, Administration and Economics
University of Wrocław, Poland

Pietro Pavone

ORCID: 0000-0001-5880-8609
University of Sannio, Italy

Jolanta Grębowiec-Baffoni

ORCID: 0000-0002-5739-8190
Center for Economics and Law Studies, Legnano, Italy

Abstract

Contemporary document research involves the need to use the latest technologies and analytical techniques that provide the most complete possible knowledge of contemporary issues and methods of document research. Documents are used to record legal actions and events of legal significance. By their essence, they are therefore closely related to the sphere of rights and obligations of a specific person or institution. Crimes against documents pose a threat to the proper functioning of the state and thus the development of every enterprise. They affect, directly or indirectly, the misallocation of financial resources at the disposal of an enterprise. Forging documents may be aimed at obtaining unauthorized access to specific sources of financing, influencing key management decisions made in the company, or, finally, concealing inconvenient facts. On the other hand, the social harm suffered as a result of forging documents of evidence significance in tax matters may be enormous. For this reason, it is necessary to deepen the knowledge

of the dynamics characterizing document forgery in the sphere of economic activity in order for the state to activate mechanisms able to prevent this type of crime. The article describes the issues of selected tax frauds in Italy with the use of accounting documents.

Keywords: document forgery, tax fraud, tax crimes, forensic science, questioned document examination

Introduction

Contemporary document examination involves the need to use the latest technologies and analytical techniques providing the most complete possible body of knowledge on contemporary forensic document examination issues and methods. The examination of classical documents most often involves determining the author of a particular entry or signature on a document by comparing handwriting or computer-generated "handwriting." It may also include detecting changes in a document due to the use of a photocopier or printer as well as various types of computer manipulation, the reconstruction or decryption of erased and obliterated writing, the visualisation of latent entries, the identification of printing processes, and the differentiation of widely understood covering agents (pen pastes, pen gels, pen and printer inks, or printer powders). The examination may also include one of the most difficult research issues faced by forensic science, i.e. examining the age of documents. In the modern world, computer-generated documents are increasingly replacing entirely handwritten ones. The digital revolution we are currently experiencing has undoubtedly accelerated the process of replacing traditional documents with alternatives. Therefore, electronically recorded signatures are becoming more and more common, which makes the knowledge of technological advances and the creation of new validated techniques and methods for examining documents increasingly desirable.[1]

[1] *Forensic document examination in the 21st century*, eds. M. Angel, J.S. Kelly, Boca Raton, FL 2020, pp. 157–172. D. Ellen, S. Day, Ch. Davies, *Scientific examination of documents. Methods and techniques*, Boca Raton, FL 2018; D. Ellen, *The scientific examination of documents. Methods and techniques*, Boca Raton, FL 2003, pp. 1–7; R. Cieśla, *Technical examination of documents within the scope of Polish evidence law*, Wrocław 2006, pp. 435–441.

The purpose of documents is to record legal actions and events of legal significance. By their very nature, they are closely linked to the sphere of a specific person or institution's rights and obligations. They ensure efficiency and security of widely understood legal transactions. Sometimes they are the only proof of possession of certain rights or a title to receive a given good. Documents also perform important functions in finances. Even these briefly presented uses clearly indicate the necessity to take all possible and necessary steps to ensure the credibility of documents. Crimes against documents constitute a threat to the proper functioning of the state and, consequently, to the development of every enterprise. They directly or indirectly affect improper allocation of financial resources available to a business entity. Falsification of documents may aim at gaining unauthorized access to specific sources of financing, influencing key management decisions made in a company, or covering up inconvenient facts. A beneficiary of falsification may be an ordinary employee, a specific department or division of an entity, or, in extreme cases, a business entity. Forgery of documents, which is a negative phenomenon in itself, is not only a serious offence punishable under criminal laws of the states,[2] but also it is above all a preliminary, preparatory behaviour to much more serious offences that directly or indirectly damage the interest and security of the state.[3]

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[2] In Italy, the falsification of documents is penalised by the Penal Code (Codice Penale Italiano) approved by Royal Decree No. 1398 of 19 October 1930, articles 476–493, Gazzetta Ufficiale (OJ) No. 251 of 26 October 1930.

[3] Money laundering is criminalized in the Italian Penal Code in Book II – On crimes in particular, Title XIII – Crimes against property, Chapter II – Crimes against property through fraud. Article 648-bis of the I.P.C., enacted by Legislative Decree 59/1978, stipulates: "whoever, except in cases of participation in a crime, substitutes or transfers money, goods, or other gains resulting from a non-culpable crime, or carries out activities related to a crime in order to impede the identification of their criminal origin, shall be punished by imprisonment for a term of four to twelve years and a fine of between €5,000 and €25,000." In turn, article 640 of the I.P.C., Book Two – On crimes in particular, Title XIII – Crimes against property, Chapter II – Crimes against property by fraud. Whoever, by deception or fraud, misleads someone, causing harm to himself or others, shall be punished by imprisonment from six months to three years and a fine from 51 euros to 1032 euros. Imprisonment from one to five years and a fine from 309 euros to 1549 euros shall be applied: 1) if the fact has been committed to the detriment of the State or another public authority or of the European Union, or under the pretext of releasing someone

Forgery of documents, which can take the form of intellectual falsification or material forgery, is an offence defined by the Italian Penal Code (I.P.C.). Intellectual forgery refers to the case of certifying an untruth in a document.[4]

Indeed, the I.P.C. treats as an intellectual forgery only when the content of the document relates to the sphere of public activity. According to article 479 of the I.P.C., intellectual forgery is the concealment of the truth of a real situation. The characteristic of this offence is the risk of the offence itself and not the damage that could result from it. In particular, articles 479–493 of the I.P.C. define the penalties for intellectual impersonation of a public officer or appointed public official, committed in a public act. Article 480 of the I.P.C. deals specifically with certificates and administrative authorisations, while article 483 tackles sanctions against private individuals committing intellectual forgery in a public act. Italian case law defines the document as an object of legal protection – protection of the authenticity and truthfulness of the public document not only as an evidentiary instrument, but also as a means by which public activity is carried out. In intellectual forgery, it is an element of the offence for an official to certify an untruth in a document that has legal significance. An example of such a document is a residence permit. The psychological element of this offence is the awareness and the will to falsely certify something in an official document (art. 2699 I.P.C.). Material forgery, on the other hand, occurs when an authentic document is forged or counterfeited in its entirety or in a specific part. Article 5, § 8-bis of the Legislative Decree on

from military service (7) (8); 2) if the fact has been committed causing the victim to fear an imaginary danger or to mistakenly believe that it is necessary to comply with an order of the Office [649] (9); 2-bis) if the fact has been committed in the presence of a circumstance referred to in article 61(5)(10).The offence shall be punishable at the request of the victim, unless there is one of the circumstances provided for in the preceding paragraph or an aggravating circumstance referred to in article 61(1)(7) (11).

[4] Italian Penal Code (Codice Penale Italiano) approved by Royal Decree No. 1398 of 19 October 1930, articles 476–493, Gazzetta Ufficiale (OJ) No. 251 of 26 October 1930. Article 476 of the Italian Penal Code reads as follows: "A public official who, in the exercise of his functions, creates in whole or in part a false act or alters a true act, shall be punished by imprisonment of one to six years. If the falsification concerns an act or a part of an act, which until the filing of a complaint of falsification is considered real, the punishment of imprisonment shall be from three to ten years."

Immigration defines two types of offences relating to material forgery for the purpose of obtaining entry and residency permits for foreigners: forgery or falsification of a residency permit (art. 5, § 8-bis of Legislative Decree 286/98). This provision, introduced by Legislative Act 189/02, concerns anyone who forges or falsifies an entry or return visa, a residency permit, a residence contract, or a residence card (currently called the EU residency permit for long-term residents), or falsifies other certificates with the aim of obtaining the above-mentioned documents allowing entry into residency in Italy. Whoever commits these crimes is punished with imprisonment from one to six years. In article 476 I.P.C., the legislator has also provided for penalties that are one-third more severe for public officials who commit this type of offence.[5]

The list of cases related to criminal behaviour by persons involved in document forgery is quite long. Most frequently it includes organised crime, economic and financial crimes, crimes against a person, property, and public trust. One of the most recent phenomena showing close connection with forgery of documents is illegal deduction of amounts of taxes due.[6]

The social harm done as a result of falsifying documents of evidential value in tax matters is considerable. The first victim is certainly the state, since it does not receive the assets due in tax; others include honest members of companies who, unaware of the fraudulent mechanism, may become involved in the criminal procedure (criminals often use data of third parties, ignorant of their role in the crime). Furthermore, tax evading companies are able to sell their products at more favourable prices and are thus more competitive, damaging free and fair market competition. All the above-mentioned factors also have political implications. Tax evasion by companies that are growing rapidly due to their crime can increase the tax burden on honest, already operating companies that meet their tax obligations. For this reason, it is necessary to

[5] R. Cieśla, J. Grębowiec-Baffoni, "Problematyka fałszerstw zezwoleń na pobyt we Włoszech", *Człowiek i Dokumenty* 53, 2019, pp. 21–32.

[6] J. Sawicka, A. Strączek, E. Marcinkowska, "Przestępstwa przeciwko wiarygodności dokumentów jako obszar zainteresowana audytu zewnętrznego", *Studia i prace Kolegium Zarządzania i Finansów Szkoła Główna Handlowa* 152, 2016, p. 96; J. Wojtasik, "Fałszerstwo dokumentu", Prokuratura Okręgowa w Zielonej Górze, http://www.zielona-gora.po.gov.pl/index.php?id=36&ida=2858 (accessed: 10.12.2020).

deepen the knowledge of the dynamics characterising document forgery in the sphere of economic activity in order for the state to activate mechanisms preventing this type of crime.

In practice, tax fraud is detected too late, often during legal proceedings due to actions taken by law enforcement agencies. The phenomenon of economic and financial crime is important in that a falsified accounting document only produces extra-legal effects after a certain period of time, for example after a complex process of posting or declaring for tax purposes.

The function of accounting documents in company accounts

Tax fraud in Italy is on the increase despite the constant commitment of the tax authorities to combat it. Moreover, this phenomenon has taken on transnational characteristics, making the task of those responsible for controlling, preventing, and curbing it more difficult.[7]

Experience shows that tax fraud stems from the misuse of certain accounting and/or corporate or commercial documents. The resulting offences, in addition to causing damage to public treasuries caused by the failure to receive the amounts due in accordance with the applicable legislation, also have a serious impact on the relationship of trust that usually develops over time between the company and all those who place legitimate hopes and/or expectations in it (stakeholders). The main accounting document from which this trust develops is the company's balance sheet.

Nowadays, in an increasingly dynamic and globalised economy, the balance sheet is no longer limited to an internal information function, but has grown into a document intended for publication. Initially it was used to make the companies' shareholders aware of their managements' actions and at the same time provide them with periodic economic results. Over the years, it has taken on a much broader public and

[7] Data on the amount of tax fraud in Italy: Documento di Economia e Finanza 2020. Nota di Aggiornamento. Relazione sull'economia non osservata sull'evasione fiscale e contributiva 2020 (art. 10-bis.1 c. 3 Legge 31 dicembre 2009, n. 196), https://www.finanze.gov.it/export/sites/finanze/.galleries/Documenti/Varie/Relazione_evasione_fiscale_e_contributiva_-Allegato-_NADEF_2020.pdf (accessed: 25.02.2021).

outward-looking information function. It is central to the expectations of a wide range of stakeholders (suppliers, customers, banks, investors, employees, etc.) who, necessarily, are at an information disadvantage. This is primarily because those reading the financial statements are outside the company and therefore did not participate in its decisions, so they do not know their origin or results. Moreover, financial statements are a summary document containing selective information, which is also prepared in accordance with the company's communication policy.

For these reasons, the person reading the balance sheet must rely on their own considerable interpretative efforts. The degree of difficulty increases when the mutual information exchange relationship between the company and external parties does not take place in a transparent and correct manner.

Before dealing with ways of manipulating the information process on which the business-external relationship is based, it is necessary to describe the cycle leading to the creation of the balance sheet. Indeed, it is in the nature of the administrative accounting document of the balance sheet that all its fragility lies, given that it is in the accounting process that the risk of damaging action can occur.

The first representation of the company's operations (speaking in technical language: of "corporate events" or "management facts") is found in the documents supporting the operations (invoices, receipts, correspondence, telegrams, letters of intent, contracts, etc.). The management facts, represented by the related accounting documents, must then be recorded in the so-called accounting records (a structured set of written documentation concerning the company, suitable for keeping a faithful record of the company's facts). With advanced accounting methods applied to the set of records, we arrive at the formulation of the financial statement document, which represents the epilogue of the accounting process initiated by the management facts.

The accounting process, understood as the process of defining and expressing in mathematical language business facts and operations that can be conveyed in monetary terms, is designed to enable the preparation of financial statements and to determine the profitability of the company (profit or loss) as well as the consistency of its assets (Figure 1).

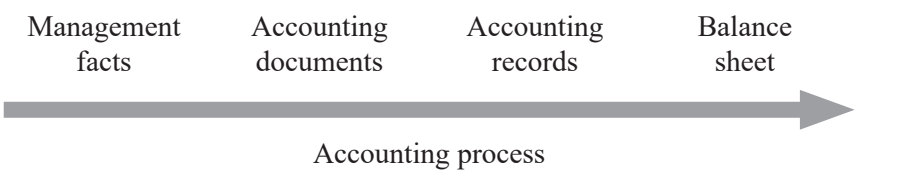

Figure 1. Source: own elaboration

It is, of course, essential that the transcription of the documents supporting the management facts is correctly carried out in the letters, and a correct summary of the results of the entries is necessary in financial statements. The first risk that stands out is that the facts to which the documents refer never took place ("objective non-existence") and the accounting documents contain false data ("subjective non-existence" when the transaction refers to parties other than the ones concerned, and "relative non-existence" when the falsehood concerns remuneration or VAT whose indicated amount is different from the real one). Take, for example, the main tax document, the invoice. It is a typical document certifying the commercial relationship between economic operators, intended to ensure the regularity of the relationship as well as to provide the financial administration with information considered important for tax purposes. This document is issued by the seller of goods or the service provider, giving them the right to collect the amount indicated. An invoice presupposes the existence of a legal transaction in which essential elements are indicated. In terms of taxation, it can be considered one of the main documents, since it is proof of the commercial transaction and its taxability. Precisely because of the special nature of the invoice, the law stipulates that this document contains certain essential elements, regardless of whether paper or electronic format is used and how the information is placed in its text. In any case, it must contain the details of the parties to the transaction, a description of the goods or services supplied, the price, the taxable amount for VAT purposes, and the VAT rate applied.

On the basis of constitutive elements of the invoice, it is possible to confirm the veracity of the whole document: if even one of the parts summarised in it does not correspond to the transaction carried out, it is enough to consider the whole transaction as fictitious. This situation would be of significant fiscal importance given that the numerical values relevant for determining the taxable amounts would also be considered false.

With regard to tax evasion, the offence of issuing invoices for non-existent transactions occupies an important place. The criminal conduct manifests itself from the very beginning of the process of realising a false document, which in most cases will lead to the application of that document and thus to concretising the offence of fraudulent tax declaration – fully realising the objective of allowing third parties to evade taxes. The issuance and application of false documents are offences related to the same objective, which means that the first is a means to the realisation of the second. Usually, the person issuing a false invoice in the name of another entity (the potential user) comes to a prior agreement with them. The phenomenon of false invoicing can lead to a series of "tricks" aimed at circumventing indirect taxation (VAT evasion), making it possible to create a commercial circuit in which activity is carried out only at a formal level (usually the goods do not change location), thanks to the action of companies commonly referred to as paper mills (ones that only issue "paper," but never actually operate) and filter companies (designed to lengthen the chain of companies involved in the fraud in order to complicate identifying the criminal mechanism). These entities do not declare their earned income and sometimes have neither employees nor the means to transport the object of sale.

It is clear that anyone who operates by taking advantage of a fraud mechanism created by the fictitious intervention of other companies, whose sole purpose is producing false accounting documents, usually applies the complex accounting and documentation necessary to commit the fraud and lose the traces of the financial operation. In addition to illegally obtaining a tax reduction, it should be noted that in many cases tax violations alter the results of operations by manipulating the values of costs and revenues. For example, in the case of invoicing non-existent transactions, a double result will occur. On the one hand, the fictitious beneficiary will be able to prove, through a document, that he has incurred costs or expenses; on the other hand, the transferor will be able to justify the operation actually carried out "in the black," omitting the due payment to the state. It follows that the perpetrators may be very numerous and may develop their clandestine activities on more levels thanks to the introduction of more intermediaries. At the same time, in the case of a discrepancy between the actual transaction and its documentation

(i.e. documentation concerning only one part of the operation), although the transaction was actually carried out, the invoice will show an amount (for example) higher than the actual one. This is so-called over-invoicing, making the operation appear non-existent for that part of the surplus. This is one of the most insidious cases of forgery from an evidentiary standpoint, especially when the payment – seemingly constant and complete – indicated on the invoice is followed by a partial reimbursement, with a combination of appropriate methods that constitute an obstacle to the reconstruction of the related financial flows. The transfer of falsified data to the financial statements by indicating fictitious costs in the accounting data may affect the falsification of the financial balance.

Continuing the analysis, it is worth considering the case where a company has issued invoices for services which in reality were never rendered: on the one hand, it can be said with certainty that such a procedure allowed a third party (usually a user) to save tax unduly. On the other hand, the same procedure, to the extent that by indicating "fictitious revenues" the tax base was increased, could at the same time influence higher results of economic activity in comparison with real data. This possibility jeopardises the good protected by law, the transparency and truthfulness of corporate information, and can also be used for specific purposes such as, for example, the desire to present a better financial performance to lenders in order to obtain more financing. Indeed, it is important to emphasise that the balance sheet is not created from an automatic epilogue of records but from the choices of broader corporate strategies, which, however, become disadvantageous as they move through the opaque terrain of manipulation.

Case of evasion of value added tax (VAT) by means of false invoices

The case in question relates to a recent investigation by Italian tax authorities.[8] As is known, a company cannot change its accounting information on its own without input from other natural or legal persons.

[8] The crime is defined in Italian Legislative Decree No 70 of 2010 and the investigation was conducted by the Guardia di Finanza.

The falsification of company documents necessarily implies the use of data relating to third parties, more or less aware of the precise objective of the crime. In fact, the investigation allowed the reconstruction of an illegal scheme in which as many as 50 companies participated, to various degrees. The lengthy investigative follow-up made it possible to determine the exact role of each company in the overall fraud scheme. The perpetrators were identified immediately and turned out to be individuals who did not hold any formal positions in the companies involved. Based on the elements gathered during the investigations, it was established that a criminal organisation had committed VAT fraud in the food trade sector. The organisation acted in the following way in order to illegally take possession of the VAT which it should have paid into the state coffers:

1. the first step included identifying companies with large VAT debts generated by perfectly legal activities (so-called launching companies). These were generally medium-sized or large companies with a significant number of transactions that provided services or goods to end customers such as electronics chains, supermarkets, hypermarkets, and discount shops;

2. once the launching companies had been identified, members of the criminal organisation would propose – to the heads of the purchasing departments or directly to the directors of these companies – that instead of paying the proportion of VAT due to the state they should transfer the tax obligation to another company designated by the same parties and obviously belonging to the criminal organisation (the so-called filter company).

To make the proposal more attractive, a remuneration of between 6% and 8% was offered to the triggering company, awarded in successive phases of the fraudulent scheme. If the launching company accepted the criminal proposal, the first accounting document was falsified: an invoice confirming the sale of goods by the filter company to the launching company. According to the law in force, the invoice issued by the filter allowed the launching company to calculate a (fictitious) VAT value, equal to the VAT indicated on the invoice. In this way, the obligation to pay was transferred from the launching company to the filtering company.

After this initial phase, the criminal plan developed in stages.

Stage 1. The criminal organisation identified to the launching company a foreign company (which we will call a conduit company) to which the previously purchased goods had to be resold. This was a community company managed, in reality, by the same criminal organisation that "bounced" the goods before sending them back to Italy. The resale of the goods from the launching company to the conduit company took place by means of an invoice, not subject to VAT. Here a surcharge was applied, on average around 6 to 8% on the purchase price – for example, the pass-through company sold goods previously purchased for 100 with an 8% profit surcharge (108).

Stage 2. The conduit company invoiced the same goods to another pass-through company based in another European Union country, applying a surcharge of 3% (108 + 3% profit = 11.24). The sole function of this transfer, foreign to other countries and also not subject to VAT, was hindering the reconstruction of the fraudulent supply chain further, making the control authorities' task more difficult.

Stage 3. The second pass-through company invoiced the same goods to the paper mill company again, applying a 3% surcharge; this transaction too was not subject to VAT (111.24 + 3% profit = 114.57).

Stage 4. The paper mill, having received an invoice without VAT from the pass-through company, in turn invoiced the filter company (the so-called first level filter) with VAT because it was a domestic transfer. The invoice issued by the paper mill indicated a taxable amount (in our example 95.09), which is about 17% lower than the amount indicated on the intra-community purchase invoice. The paper mill was operating systematically below cost.

Stage 5. The first level filter re-invoiced the same goods to another filter (second level filter), generally applying a minimum profit of 1.5–2% (95.09 + 2% profit = 97). Such "passing" essentially served to make fraud reconstruction more difficult for investigating authorities.

Stage 6. The second level filter could in turn issue a sales invoice to the same launching company if it still had a VAT debt, or it could issue an invoice to another vulnerable company with a significant VAT debt, i.e. another launching company.

The second-level filter, i.e. the second entity dealing with the purchase and sale of non-existent goods, which charged a margin of 2.5 to 3 percent from the profit for this "service," 97 is an example of the profit sum obtained from the first-level filter, to which, after adding a 3% margin, the sum was 99.91, approximately 100.

It should be noted that the launching company ended its involvement by repurchasing the same goods at the same price (100). In essence, the cyclical chain of transactions is merely a tool enabling the criminal organization to take possession of VAT, bypassing the obligation to remit it to the state, which should be done by the launching company and which, on the basis of false invoices, therefore fell to the paper mill. It was therefore irrelevant for the purposes of the fraud whether the goods – the subject of the false invoices – actually existed, and even if they had, it would not have made any difference whether they were transported or not. In this type of fraud no goods are physically moved: all stages are purely "paper." In fact, often the same goods remain the object of purchase and resale for years (precisely because it is sufficient to indicate this on the false invoices). In the presented system there was no real purchase or sale transaction, except for the (illegal) purchase of the VAT debt by the criminal organisation from the launching company, in return for which the latter received a substantial profit of 8%.

Conclusions

The analysed case illustrates how the objective of tax evasion can be achieved by using false accounting documents which prove the movement of goods that never took place. As has been presented, such complex fraud requires the participation of various actors: each link in this fraudulent chain plays a specific role. Essential here is the role of paper mills, whose sole reason for existence is "producing paper" (i.e. printing false invoices). Filter and pass-through companies, on the other hand, do not carry out real economic activity and do not have an effective corporate structure: they are used to prolong the illicit chain and make it difficult to identify the criminal organisation's targets. As has been shown, the role of the only genuinely existing and operating company (pass-through) – corrupted and entangled in the schemes – is to evade

tax obligations through the promise of additional profit. Placed at the top of the various corporate structures are people lending their name (so-called poles), where in reality these companies are managed by third parties who want to remain hidden from the tax authorities.

In Italy, the social harmfulness of falsifying documents in the tax sector is further increased by the fact that the control action is only possible after the social harm has been realised.[9]

In addition to this, a tax document that is not limited to reflecting reality but significantly alters it by incorporating it – as we have seen – into a broader system of accounting records, undermines the credibility of the entire balance sheet presented by the company, creating false expectations for a high number of entities. Some companies engaged in counterfeiting for tax evasion purposes usually do not present any budget, preferring to leave the economic scene after a year or two of illegal activity (this is a typical case for paper mills). After their closure, other new "businesses" belonging to the same entities appear, which makes it more difficult for law enforcement and judicial authorities to combat criminal structures.

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Using forensic handwriting principles for rapid signature screening

Brian Craythorne

ORCID: 0000-0002-7142-8843
Forensic Science Agency of Northern Ireland
Carrickfergus, United Kingdom

Abstract

Examination of a signature is a lengthy process conducted under laboratory conditions, requiring precision and caution. When a rapid screening of signatures is required, the basic principles of forensic signature comparison can be adapted. Learning points from signature screening examinations are outlined to aid handwriting experts in carrying out similar procedures.

Keywords: signature examination, screening, best practice, comparison

This paper has been compiled from the experiences of handwriting experts carrying out rapid screening of numerous signatures to aid the election process in Northern Ireland. The details of the rapid screening procedure are detailed as follows. The questioned document is a proxy voting form bearing a questioned signature requesting a proxy vote. The specimen signatures are held on a database and may be months or years old, and range from only one signature to up to six written over a period of several years. The specimens are digital images of scanned signatures and the questioned signature is usually in the form of a copy image. A decision has to be made in a few minutes as to whether or not the signature is genuine. There should be a bias towards declaring signatures genuine – unless there is a good reason to declare them forgeries – so that

the voter is not incorrectly denied a vote. As it is a real possibility that family members may have forged the questioned signatures, the signatures of close family members are available for comparison. The examination is carried out with no magnification equipment, but it is sometimes possible to zoom in on the digital images of the questioned signatures.

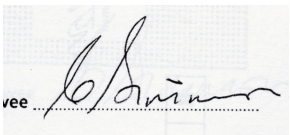
Thus the conditions are set for a rapid screening process of hundreds of signatures. In order to carry out the examination in less than ideal conditions, the handwriting expert has to draw upon certain principles of forensic handwriting examination in order to maximise the number of correct opinions whilst erring on the side of caution in order not to mistakenly deny someone a vote.

The principles applied begin with the basis that handwriting is a complex fine motor skill involving the writing of subtle strokes while at the same time incorporating from memory details of written and spoken language as well as spatial distribution. The signature is also treated as a special piece of writing, usually written by the writer and adapted to be a personal identifier.

The next principle to consider is how signatures change with the age of a person. The signatures on voting forms, which are most likely to be forged, are the signatures of the young (as they are often away from home at university and have their vote cast by their parents) and the elderly (as they are often too infirm to vote and have their vote cast by their adult children).

Once again we use the basic principle that handwriting is taught at school from a copybook and almost immediately – due to differences in mental and physical ability – the handwriting of an individual begins to divert from the copybook style. The handwriting develops during school days and can change markedly in college/university days when a lot of writing is required, and upon starting work which can require regular signing. It is at this stage that the final signature design is formed. In mid-life, the signature shows only small changes and development. Unfortunately, in later life, changes to mental and physical ability with the onset of age-related infirmities and illnesses lead to a deterioration in signature quality.

Using this principle, one can postulate that it is possible to expect major changes in the signatures of the young – particularly the development of the signature from visual similarity to the person's handwriting to becoming more stylized, with loops and curves replacing actual structured letter designs.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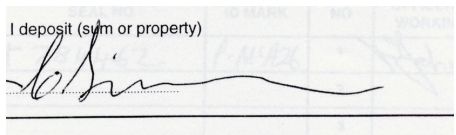

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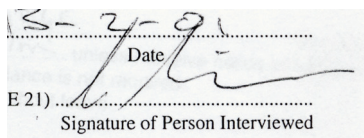

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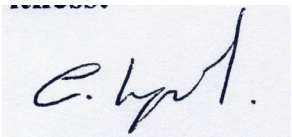
Figure 1. From left to right: the development of a signature to a more stylized form over time

So if one uses this principle to compare a recent signature of a young person against previously written specimens, one therefore should expect the signature to have developed from a more structured form to a less structured one.

Applying this particular handwriting rule to the rapid screening of signatures, it is assumed that the development of a signature is from more structured to less structured. So if the recently written questioned signature is less structured than the older specimen signatures, that could mean that the signature is genuine. However, another factor must be taken into consideration, namely if the questioned signature can be shown to have logically developed from the earlier specimen signatures. In order to do this, there need to be some features in common between the earlier specimen signatures and the recent questioned signature. In some signatures this is obvious, while for some it is not and a more detailed (although still in a matter of minutes rather than hours) investigation needs to be carried out. The examiner must therefore ask if there is some feature present in a similar structural form in the specimen signatures which is also present in the more recent questioned signature.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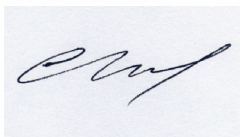
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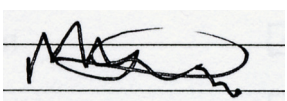
Figure 2. The loop at the top of the 'C' can be used to link an earlier specimen signature (1) to the newer less structured form of the signature (2)

If we find this similarity or similarities between older specimen signatures and the newer questioned signature, then the examiner is likely to conclude that the signature is genuine.

If there are no features to tie a questioned signature to previously written specimen signatures, then there is no evidence of common authorship and the questioned signature could easily have been written by someone else attempting a generic stylized signature with little or no attempt to copy the person's genuine signature.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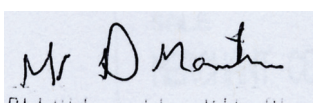
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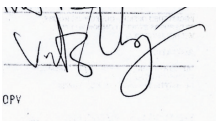
Figure 3. There is nothing to link the questioned signature (2) to the specimen (1) in terms of letter designs, and the writer of the stylized signature (1) is unlikely to revert back to a more structured signature which is also written with a poorer artistic quality

This feature of signatures developing from structured forms to less structured stylized patterns is of particular relevance for the young writer – in his or her late teens and early twenties. When someone is older, the handwriting expert must assume the signature is relatively fixed for the purposes of rapid signature screening. What comes into play now is the principle of variability – no one writes exactly the same way every time.

So for the many signatures of people who are of "mid-life" age the examiner has to consider whether the differences between the questioned and specimen signatures are due to variation or someone forging the signature.

The overall limitation in the number of specimens hinders the handwriting expert and this would be a major problem in conventional forensic handwriting analysis. However, in the rapid screening of signatures

the expert needs to make a decision based on what evidence can be seen from the signatures, and needs to call on his or her expertise to decide if any differences are due to variation or point to a different writer being involved. Other factors to consider are the fluency of the signature and the fact that many people signing voting forms may not sign their name on many other occasions, which can lead to greater variation between the few signatures they do write.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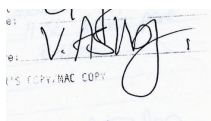
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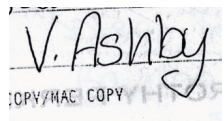

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Figure 4. The consideration of variation is important with a limited number of specimen signatures

So when considering variation as well as the variation of signatures written by people who do not write very often, the expert needs to take account of factors such as whether the person wrote their name in a slightly different format or switched from upper case to lower case/cursive letters, or vice versa.

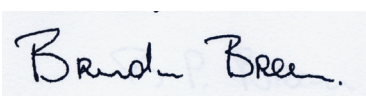
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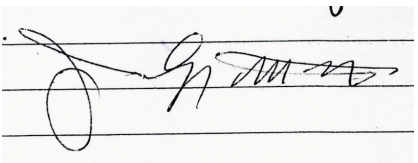
Figure 5. Another point to consider is whether the signature was written in a slightly different format

Regarding the writer's age, the questioned signatures of the elderly often provide interesting comparisons. Once more, basic principles need to be followed in order to use a consistent approach. It is taken as the most logical assumption that even if an elderly and infirm person is incapable of writing their usual healthy signature, they still try to write their normal signature to the best of their current ability. The second logical assumption is that as their handwriting is deteriorating, a signature written with a better artistic quality is to be viewed with suspicion. In normal circumstances, the handwriting expert has access to more information on the person's state of health at the time of signing, even to the details such as if they have taken medicine which momentarily improves their condition.



(1) (2)

Figure 6. Signatures of the elderly – comparison of questioned (1) with specimen (2) show clear differences in fluency, handwriting ability, and letter designs

Following these principles, experts are most likely to exclude signatures that are in a different handwriting style and ones of much better artistic quality than the specimen signatures. From experience, it is fairly common for the elderly to have their vote taken by one of their children who forges their signature on the voting forms.

Fluency is an important factor in the examination of elderly people's signatures, as well as in the general examination of forged signatures. Many forged signatures as seen in rapid signature screening were written with a shaky and hesitant fluency, which marks them out as different from the specimens. Of course, the specimens are searched to see if the voter has a naturally shaky signature. It is difficult to assess other factors that the handwriting expert would normally consider as alternate hypotheses, such as: whether the voter is an alcoholic and the shakiness of the signature improves with consumption of alcohol; if the voter consumed alcohol, leading to differences in fluency and letter designs; whether the form was signed on an uneven surface or even standing up.

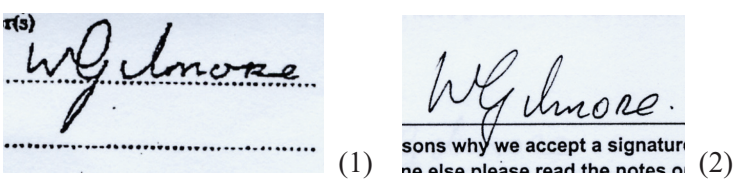


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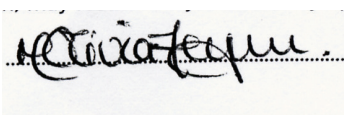
Figure 7. A difference in fluency between the questioned (1) and the specimen (2) signatures is always a cause for concern, but there is little opportunity to explore alternative hypotheses in rapid signature screening

To summarise, a marked difference in fluency would likely lead to a signature being rejected as a forgery. Likewise, a marked improvement in fluency for no apparent reason where several recent specimen

signatures show a poor handwriting style could also very well lead to the signature being rejected. Furthermore, a complete difference in handwriting style will lead to the signature being rejected, and these are usually the easiest comparisons to carry out.

Comparison of reasonably skilful forgeries is the most difficult examination to carry out within the limited resources of rapid signature screening. With no microscope and no set of specimens showing the full range of variation of the writer, it can be difficult to spot skillful forgeries. Fortunately, many of the forgeries seen are poorly executed by people who do not write much themselves in everyday life. Poorly executed letter designs, disjointed lettering, and – of course – hesitant fluency characterise these signatures.



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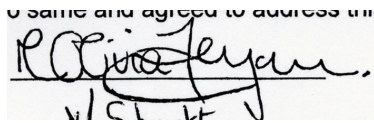

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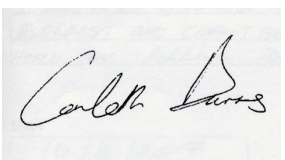
Figure 8. The conventional accomplished freehand forgery (2) is identified when compared against numerous suitable specimens (1). It is not necessarily discovered in rapid signature screening

Overwriting of a signature is something that always flags up concern to a handwriting expert. However, in rapid signature screening overwriting flags up two different possibilities, one of which is: has the overwriting been done to cover up a badly produced copied forgery? However, as the forms have to be completed in black ink, its presence written over blue ink is more likely to indicate overwriting has occurred so that the signature is in the correct colour of ink. A closer look at the signature, perhaps aided by digital zoom, should determine which scenario is the more likely one.

Figure 9. Overwriting is often a cause for suspicion but in cases of black/blue ink overwriting, a mistake in signing may be the explanation

Finally, as an aid to the examination, the signatures of family members are also present on the database of specimen signatures. Thus, if a forgery is suspected, the signatures of family members are also compared against the questioned signature of the voter. Quite often it can be seen that the questioned signature more closely resembles the signature of a family member than it resembles the signature of the voter. In such cases this additional evidence aids the declaration of a forgery with greater confidence.



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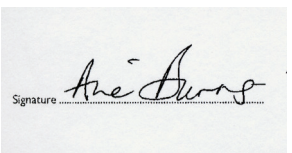

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Figure 10. Comparison of the formation of the surname should be investigated against specimens of other family members

Conclusions

Rapid signature screening is different to conventional forensic handwriting comparison, but the same principles can be applied to obtain the best possible conclusion. Whilst the examination will always be a compromise, the examiner must draw upon much knowledge and expertise to make rapid decisions based upon a few signatures.

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The effect of photocopier types on line quality features of handwriting in multi-generational photocopies

Om Prakash Jasuja

ORCID: 0000-0002-2221-1242
Department of Forensic Science and Chemistry, Chandigarh University
Gharua, Punjab, India

Suryakant Mishra

ORCID: 0000-0001-5220-9066
Research Scholar, Department of Forensic Science, Punjabi University
Patiala, India

Mohinder Singh

ORCID: 0000-0002-2649-1616
Formerly Government Examiner of Questioned Documents
Central Forensic Science Laboratory, Hyderabad, India

Abstract

The present research was aimed at finding out the relative effect of advancement in photocopier technology on the analysis of handwriting line quality features in multi-generational photocopies. Five subsequent multi-generational photocopies of 50 signature samples from different individuals which were produced by 75 black and white photocopiers were used for line quality assessments. Variations in line quality features in different photocopy generations, such as: smooth edges or ragged edges, broken or continuous stroke, fine tapering changes, and some identification details of features like pen lifts,

retouching, and hesitation were carefully observed in sample photocopies, which were recorded according to the brand and model of photocopier machines, as well as their size and speed. The results of the study revealed that raggedness in line was often observed in third generation (G3) and higher generations, in samples produced by some low speed copiers (copying speed < 30 cpm) or very high speed copiers (copying speed ≤ 80 cpm). However, their line quality was still found to be good enough for handwriting analysis up to the fifth generation (G5) in photocopy samples produced by some medium speed copiers (copying speed 30 to 50 cpm). It was, however, observed that, usually, continuity of line and smoothness of line were appreciably lost in G3 and higher generations in photocopies which were produced by portable desktop printers. Exceptionally, certain artifacts that are usually found in some higher generation copies were conspicuously absent in all photocopy generations (G1–G5) which were produced by some advanced third generation photocopiers. Hopefully, the information obtained from the study will be found useful to document examiners when examining certain cases involving multi-generations of photocopier reproductions.

Keywords: photocopy, questioned documents, forensic science, handwriting examination, line quality of handwriting

Introduction

Forensic document examiners commonly scrutinize different types of questioned document problems such as identification of writing, security records, currency notes, authentication of stamps, etc., to solve the legal issues by analysing the original as well as non-original documents. Photocopying has become a common mode of document reproduction and is routinely used by most people. Photocopies could be accepted as secondary evidence under the Indian Evidence Act, 1872, in the case of disputed handwriting. Line quality is an important attribute of handwriting, often used to characterise the genuine and forged handwriting. It is derived from a combination of factors, including writing skill, speed, rhythm, freedom of movement, shading, and pen position.[1] Maintaining smoothness of the writing line without losing identifying attributes is important in case of reproduction of documents.[2] Some experts have expressed the view that multi-generation photocopying degrades

[1] O. Hilton, *Scientific examination of questioned documents*, Boca Raton, FL 1993, pp. 361–388.

[2] K.M. Koppenhaver, *Forensic document examination: Principles and practice*, Totowa, NJ 2007, pp. 83–84.

the quality of documents.[3] The present research was conducted to find out some new information on the effect of advancement in photocopier technology on the analysis of handwriting line quality features in multi-generational photocopies.

1. Methodology

For the present study, signature samples of 50 individuals were collected on A4 size paper using ballpoint pens. The original signature samples went through up to five subsequent generations of photocopy using 75 different photocopiers (Table 1). Photocopies of signatures were examined and compared with original samples using a magnifying lens (5×) and stereomicroscope to find out the variations in line quality according to the brand, model, speed, and size of photocopiers.

Table 1. List of photocopiers used for the collection of black and white photocopy samples

Make and model	Size	Speed CPM	Input resolution in dot per inch	Output resoloution in dot per inch	Drum	AX [%]
Canon IR 2270	MS	22	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2270	MS	22	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2270	MS	22	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2270	MS	22	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2270	MS	22	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2830	MS	28	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2870	MS	28	1200 × 6001	2400 × 6001	OPC	1
Canon IR 2870	MS	28	1200 × 6001	2400 × 6001	OPC	1
Canon IR 3025	MS	25	1200 × 6001	2400 × 6001	OPC	1
Canon IR 3245	MS	45	1200 × 6001	1200 × 12001	OPC	1

[3] O. Hilton, op. cit.; R. Morris, *Forensic handwriting identification, fundamental concepts and principles*, San Diego 2000; M. Allen, *Foundations of forensic document analysis: Theory and practice*, Chichester 2016.

Canon IR 3235N	MS	35	1200 × 6001	1200 × 12001	OPC	1
Canon IR 3235N	MS	35	1200 × 6001	1200 × 12001	OPC	1
Canon IR 3235i	MS	45	1200 × 6001	1200 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3300	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3320i	MS	33	1200 × 6001	2400 × 12001	OPC	1
Canon IR 3530	MS	35	1200 × 6001	2400 × 6001	OPC	1
Canon IR 6000	LS	60	1200 × 6001	2400 × 6001	OPC	1
Canon IR 6000	LS	60	1200 × 6001	2400 × 6001	OPC	1
Canon IR 7095	LS	95	1200 × 6001	2400 × 6001	OPC/ A Si	1
Canon IR 7095	LS	95	1200 × 6001	2400 × 6001	OPC/ A Si	1
Canon IR 7095	LS	95	1200 × 6001	2400 × 6001	OPC/ A Si	1
Canon IR 7105	LS	105	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7105	LS	105	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7200	LS	72	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7200	LS	72	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7200	LS	72	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7200	LS	72	1200 × 6001	2400 × 6001	A Si	1
Canon IR 7200	LS	72	1200 × 6001	2400 × 6001	A Si	1

Canon IR 8070	LS	80	1200 × 6001	2400 × 6001	A Si	1
Canon IR 8070	LS	80	1200 × 6001	2400 × 6001	A Si	1
Canon IR 8500	LS	85	1200 × 6001	2400 × 6001	A Si	1
Canon IR 8500	LS	85	1200 × 6001	2400 × 6001	A Si	1
Canon IR 8500	LS	85	1200 × 6001	2400 × 6001	A Si	1
Canon MF 3010	PD	18	600 × 600	600 × 600	OPC	1
Canon MF 4320	PD	22	600 × 600	600 × 600	OPC	1
Canon MF 4412	PD	23	600 × 600	600 × 600	OPC	–
Canon MF 241	PD	38	600 × 600	600 × 600	OPC	–
Canon MF 241	PD	38	600 × 600	600 × 600	OPC	–
Develop 213	PD	21	600 × 600	600 × 600	OPC	1
HP 1005	PD	15	300 × 300	300 × 300	OPC	–
HP 1005	PD	15	300 × 300	300 × 300	OPC	–
Konica MB 215	MD	21	600 × 600	600 × 600	OPC	0.1
Konica MB 215	MD	21	600 × 600	600 × 600	OPC	0.1
Konica MB 215	MD	21	600 × 600	600 × 600	OPC	0.1
Konica MB 423	MS	42	600 × 600	600 × 600	OPC	0.1
Konica MB C458	MS	45	600 × 600	1800 × 600	OPC	0.1
Konica MB C552	MS	55	600 × 600	1800 × 600	OPC	0.1
Ky EM 2040	PD	40	600 × 600	600 × 600	OPC	1
Ky EM 2040	PD	40	600 × 600	600 × 600	OPC	1
Ky EM 2040	PD	40	600 × 600	600 × 600	OPC	1
Ky EM 2040	PD	40	600 × 600	600 × 600	OPC	1
Ky EM 2040	PD	40	600 × 600	600 × 600	OPC	1
Ky FS 1035	PD	35	600 × 600	600 × 600	OPC	1

KyTA 300i	MS	30	600 × 600	600 × 600	OPC	1
Samsung 4521	PD	20	600 × 600	600 × 600	OPC	–
Sharp AR 5620	MD	20	600 × 600	600 × 600	OPC	–
Sharp ARM 205	MD	20	600 × 600	600 × 600	OPC	–
Xerox V L 7030	LS	30	600 × 600	600 × 600	OPC	1
Xerox 440	MS	40	600 × 600	600 × 600	OPC	1
Xerox 440	MS	40	600 × 600	600 × 600	OPC	1
Xerox 440	MS	40	600 × 600	600 × 600	OPC	1
Xerox 440	MS	40	600 × 600	600 × 600	OPC	1
Xerox WC 5755	LS	55	600 × 600	4800 × 6001	OPC	1
Xerox WC 5755	LS	55	600 × 600	4800 × 6001	OPC	1
Xerox WC 5755	LS	55	600 × 600	4800 × 6001	OPC	1
Xerox WC 5755	LS	55	600 × 600	4800 × 6001	OPC	1
Xerox WC 5755	LS	55	600 × 600	4800 × 6001	OPC	1
Xerox WC 5790	LS	90	600 × 600	4800 × 6001	OPC	1
Canon NP 3050@	MD	–	150 × 150	150 × 150	OPC	1

Abbreviations

MS: medium size multifunction floor standing copier
LS: large size multifunction floor standing copier
PD: portable desktop MF printer
MD: medium size desktop MF printer
CPM: copy per minute
@: analogue photocopier
A Si: amorphous silicon drum
OPC: organic photoconductor drum
X^1: interpolated resolution
AX: additional magnification

2. Results

To facilitate systematic study, the used photocopiers have been divided into 14 different groups according to their make and model/series:

1. Canon IR series,
2. Canon MF series,
3. Develop Ineo 213,
4. HP 1005,
5. Konica MB series,
6. Kyocera EM series,
7. Kyocera FS 1035,
8. Kyocera TA 300i,
9. Samsung 4521,
10. Sharp AR series,
11. Xerox DC 440,
12. Xerox V L 7030,
13. Xerox WC series,
14. Canon NP 3050.

Photocopy quality variations were observed in different generations based upon the same line quality features such as: smooth/ragged edges, broken/continuous stroke, etc. These findings are presented below, according to the make and model/series of the photocopiers and including their sizes and speed.

Canon Image Runner (IR) series. Line quality in G1 and G2 was found good enough for the analysis of handwriting in all the copiers from this series. However, raggedness in line was often seen in G3 and higher generations of photocopies produced by some low speed copiers (copying speed < 30 cpm) such as Canon IR 2270, or very high speed copiers (copying speed ≤ 80 cpm), including Canon IR 8500 and Canon IR 7105. Artifacts such as thinning in line strokes were also seen in photocopy samples produced by high speed copiers. However, in photocopy samples produced by some medium speed copiers (copying speed 30 to 50 cpm) such as Canon IR 3320i, the line quality was found good enough for analysis up to G5 (Figure 1).

Figure 1. Showing line quality in the original signature (O1) and its photocopies (G1 to G5), line quality features such as (1) an inkless start with an ink blob at initial stroke, (2) a tapered end, and (3) an ink gooping could be identified in G1 to G5 (Canon IR 3235i)

Canon MF series printers. Portable desktop printers. Line continuity and smoothness were lost in G3 and further generations of photocopies. Overall line quality was not found good enough for forensic analysis of fine line quality features such as pen pause, retouching, etc. beyond G2.

Develop Ineo 213. A low speed desktop multifunction printer; line quality in photocopies was found similar to Canon MF series printers.

HP 1005 series. A portable desktop multifunction printer; line quality in photocopies was found similar to Canon MF series printers.

Konica MB series. This series includes one of the best photocopiers available on the market. Artifacts such as breaks and raggedness were not found in any photocopy generations G1 to G5; normally, line quality was deemed good enough for analysis in G1 to G5. Line quality features such

as fine tapering strokes, ink gooping, hesitations, retouching, or excessive ink deposition could be identified up to G5.

Kyocera EM 2040. A medium speed portable desktop printer. Average photocopy quality was found in early generations G1 and G2, after that intense raggedness in line edges had appeared (Figure 2).

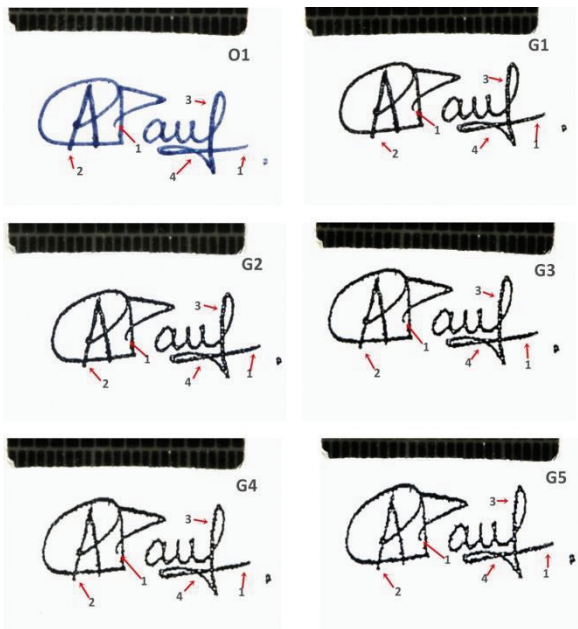

Figure 2. Showing deterioration in line smoothness in G1 to G5; line features such as (1) tapering, (2) a blunt initial, (3) a smooth stroke, and (4) the direction of pen movement are identifiable in G1 and G2; thereafter, intense raggedness is seen in G3 to G5 (Kyocera EM 2040)

Kyocera FS 1035. A medium speed desktop printer. Line quality in photocopies was almost similar to Ky EM 2040.

Kyocera TA 300i. A floor standing multifunction copier. Raggedness in strokes was found in subsequent generations of photocopies, as well as, at places, large dots forming in photocopied strokes. Thus, some important line quality features such as tapering, ink goopings, pen lifts, retouching, and joining were not identifiable.

Samsung SCX 4521F. A low speed portable desktop printer. Faint or light inked strokes of original handwriting could not be reproduced by this machine; the resultant photocopy was light. Additionally, raggedness and breaks in strokes had appeared in subsequent generation of copies.

Sharp AR series. Low speed desktop copiers. Breaks and raggedness were found in subsequent photocopy generations. Pixilation appeared in G1 in diagonal and curved strokes. First and second generation copies could be considered good enough for analysis of handwriting strokes.

Xerox VL 7030. An advanced third generation copier. Noticeable artifacts were absent in all photocopy generations (G1–G5). Fine line quality features such as ink gooping, hesitations, retouching, pen lift were identified in all generations of copies. Overall line quality was found good enough for forensic analysis and comparison in G1 to G5 (Figure 3).

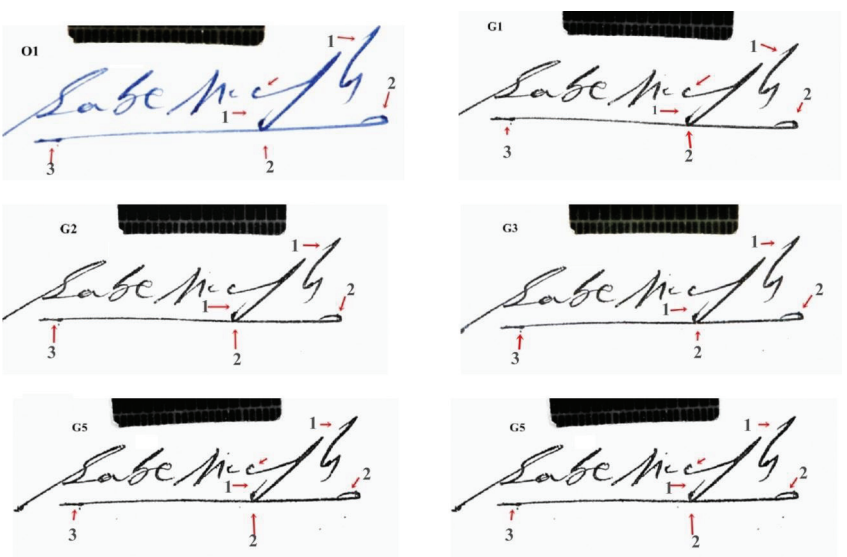

Figure 3. Showing line quality characteristics in the original (O1) and photocopy generations (G1 to G5) of a signature; line features marked as: (1) fine tapered strokes, (2) ink goopings, (3) excessive ink deposition could be identified in G1 to G5 (Xerox VL 7030)

Xerox DC 440. A medium speed floor standing copier. Extra smoothening and darkening in line strokes was found in photocopies, thus natural irregularities of original line edges were lost in photocopies, specifically in G2 and higher generations. Usually fine line quality features such as ink gooping, hesitation, retouching, excessive ink deposition were lost in or after the second generation of photocopy (G2). However, G1 and G2 photocopies were found suitable for forensic analysis of line quality features handwriting (Figure 4).

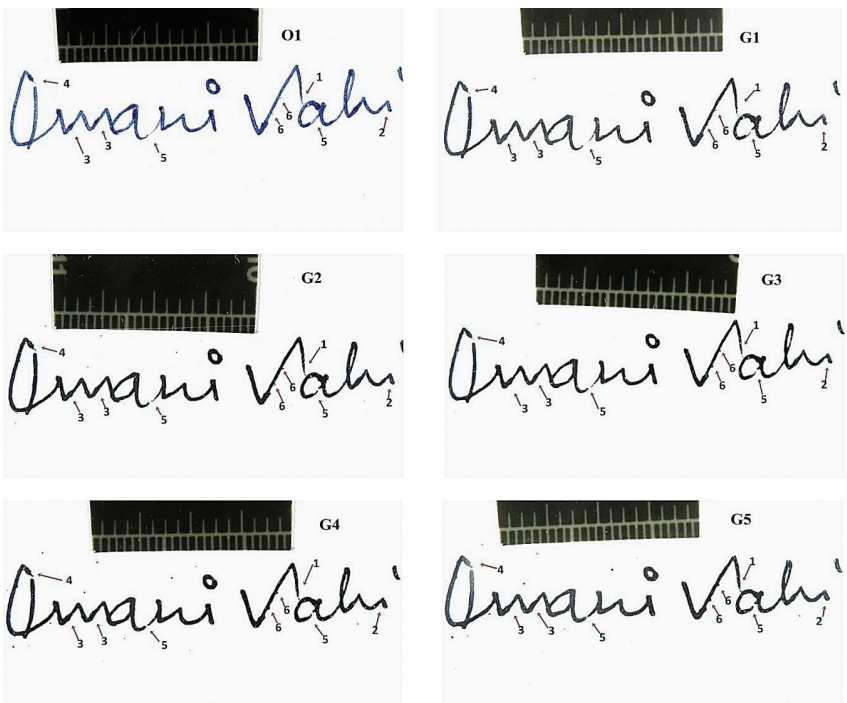

Figure 4. Showing line darkening in photocopy generations (G1 to G5). Line edges are smooth up to G5; line quality features marked as: (1) tapering, (2) blunt ending, (3) and (4) ink goopings, are lost in G3 and higher generations; (5) pen skipping is changed to breaks in G1 to G5, (6) ink traces along the line side are merged and changed to dents (Xerox DC 440)

Xerox WC Series. This series included some high speed floor standing copiers (55 to 90 cpm). The overall line quality was found to be similar to Xerox DC 440.

Canon NP 3050. A desktop analogue copier. It generally produced poor quality photocopies. Breaks in light inked strokes were seen in G1, but overall the line quality was found suitable for forensic analysis in G1.

3. Discussion

3.1. Reasons for poor line quality in subsequent photocopy generations produced by portable desktop printers

Printing resolution and the photoconductor drum quality are the main factors causing variation in quality of photocopies produced by small, medium, and high volume copiers. Single layer organic photoconductors (OPCs) used in low speed printers are less expensive and less sensitive than the dual layer OPCs used in high speed printers or copiers.[4] Photocopiers of several makes could also differ, to some extent, in their print quality due to structural difference in the toner fixing unit.[5] Medium and high speed floor standing copiers have advanced quality toner fixing unit compared to the low speed portable desktop printers.

3.2. Reasons for good line quality in subsequent photocopy generations produced by advanced generations copiers

Local or universal defects, which could be found in the form of spots and patches resulting from a printer's malfunctions such as foreign contamination on glass platen and photoconductor drum, often degrade the photocopy quality.[6] However, most of the advanced multifunction copiers have integrated systems/computer programs for detecting and re-

[4] D.S. Weiss, M. Abkowitz, "Advances in organic photoconductor technology", *Chemical Reviews* 110, 2010, no. 1, pp. 479–526.

[5] D. Thompson, D. Tyagi, "Fusing technologies and toner materials relationships", slideshow presented at NIP 24: 24th International Conference on Digital Printing Technologies, Society for Imaging Science & Technology, 6–11 September 2008, Pittsburgh, PA.

[6] J. Wang et al., "Local defect detection and print quality assessment", *Electronic Imaging* 2016, no. 13, pp. 1–7.

moving some of the local defects.[7] These advancements in photocopier technology may be one of the reasons for better photocopy quality.

3.3. Cause of variation in quality of photocopies produced by same-technology based photocopiers

The input image coming from the reading unit passes through several steps, such as shading correction, enlargement or reduction, edge emphasis, editing, and binary processing. These image processing steps vary depending on the manufacturer and model of a photocopier (Working manual, Canon IR 7200, Xerox WC 5755). Some abrasive actions (cleaning, development, and separation steps) in the copy cycle continuously reduce the thickness of charge transfer layer (CTL). This reduction in thickness of CTL reduced the chargeability of the OPC drum.[8]

Conclusion

The present study clearly reveals that photocopy quality improves with advancements in the photocopier technology. Line quality features of handwriting could be analysed up to fifth copy generations. The findings of the present study reinforce the necessity of innovation in portable photocopier technology towards continuous improvement of the photocopy quality for forensic analysis of handwriting line quality features.

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[8] RICOH CO., LTD, *OPCs (Organic Photoconductors)*, 1995, https://www.hobbielektronika.hu/forum/getfile.php?id=125448 (accessed: 8.04.2020).

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Anchoring: Cognitive bias and numerical conception

Pàvlos Kipouràs

ORCID: 0000-0002-4021-7584
Scuola di Grafopatologia Forense (SGF), Naples, Italy
Department of Forensic Science, Criminal Procedure and Judicial Expertise
Institute of Law, South Ural State University, Russia

Abstract

Anchoring is a cognitive bias connected to the conception of information by every individual. The initial notion created becomes a significant point of reference for all future interpretations of the same object or data, so as to block any further re-elaboration to the initially defined information. The article presents a practical case of a false numerical conception due to anchoring

Keywords: anchoring, bias, cognitive, date, conception, morphology

Bias is prejudice in favor of or against one thing, person, or group compared with another, usually in a way considered to be unfair. Biases can be learned implicitly within cultural contexts. People may develop biases toward or against individuals, ethnic groups, sexual or gender identities, nations, religions, social classes, political parties, theoretical paradigms and ideologies within academic domains, or species. "Biased" means one-sided, lacking a neutral viewpoint, or not having an open mind. Bias can come in many forms and is related to prejudice and intuition.

Cognitive bias involves a deviation from the rational conception of information, which leads to falsely estimating a situation or fact. It is the source and cause of creating an individual reality regarding a particular event or the way one evaluates the data of a given analysis object, which results in a distorted vision inconsistent with objective reality.[1] It can arise in any individual's common life and behavior, or it might become the reason for a misleading conception of the elements of an analysis object in various scientific approaches. In the case of Forensic Document Examination (FDE), this bias can provoke the so-called confirmation bias,[2] which could lead to a selective approach to the case data. This could negatively affect the expert's final conclusion, since they only focus on several elements of the case or the investigation object.

One of the cognitive biases is anchoring. Anchoring,[3] or focalism, is a cognitive bias that describes the tendency for an individual to rely too heavily on an initial piece of information offered (known as the anchor) when making decisions. During decision making, anchoring occurs when individuals use this initial piece of information to make subsequent judgments. Once the value of this anchor is set, all future negotiations, arguments, estimates, etc. are discussed in relation to the anchor. This bias is present when one uses the anchor to interpret future information. For example, the initial price offered for a used car, set either before or at the start of negotiations, sets an arbitrary focal point for all following discussions. Prices discussed during negotiations that are lower than the anchor may seem reasonable, perhaps even cheap to the buyer, even if said prices are still relatively higher than the actual market value of the car. The most important element of this term concerns the focusing

[1] M.G. Haselton, D. Nettle, P.W. Andrews, "The evolution of cognitive bias", [in:] *The handbook of evolutionary psychology*, ed. D.M. Buss, John Wiley & Sons Inc., Hoboken, NJ 2005, p. 968, https://doi.org/10.1002/9781119125563.evpsych241.

[2] M. Merlino, *Validity, reliability, accuracy, and bias in forensic signature examination*, 2014, p. 11, https://www.ojp.gov/library/publications/validity-reliability-accuracy-and-bias-forensic-signature-identification.

[3] F. Kieder et al., "The anchoring bias reflects rational use of cognitive resources", *Psychonomic Bulletin and Review* 25, 2018, no. 1, pp. 322–349, https://doi.org/10.3758/s13423-017-1286-8.

effect (or focusing illusion), which occurs when people place too much importance on one aspect of an event. Anchoring is a psychological heuristic characterized by a difficulty in avoiding its negative effect on one's behavior and durability. According to this heuristic, people start with an implicitly suggested reference point – the anchor – and then make incremental adjustments based on additional information. These adjustments are usually insufficient, giving the initial anchor a great deal of influence over future assessments. Anchoring is connected to several causes.[4]

– Anchoring-and-adjusting: the initial information used as an anchor remains the point of reference, which leads to insufficient subsequent adjustments. For this reason, the final decision remains closer to the anchor.

– Selective accessibility: when given an anchor, the person making a decision is unconsciously looking for the hypothesis closer to the value of the anchor, which is considered the most suitable answer.

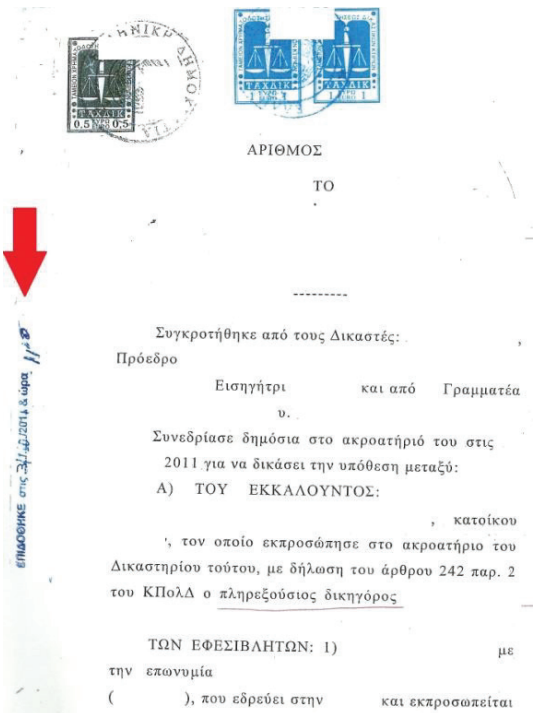
– Attitude change: the anchor is indirectly affecting the elaboration of information and biases following judgments towards the answers that are more compatible with it.

Further influencing factors could regard: mood, experience, personality, cognitive ability, and overconfidence.

Practical case

A negative decision of the court is notified to an attorney of a plaintiff, who has 30 days at their disposal to appeal against it to the Supreme Court. In the document, the court's secretary has to sign the date and time of notification, which is the starting point of the 30-day deadline. This notification takes place on 31.10.2011 and the chronological information is handwritten by filling in the appropriate spaces in the **official stamp** by the secretary of the court who delivers the notification to the attorney.

[4] A. Furnham, H.C. Boo, "A literature review of the anchoring effect", *Journal of Socio-Economics* 40, 2011, no. 1, p. 37.



ΑΡΙΘΜΟΣ

ΤΟ

Συγκροτήθηκε από τους Δικαστές:

Πρόεδρο

Εισηγήτρι και από Γραμματέα

υ.

Συνεδρίασε δημόσια στο ακροατήριό του στις 2011 για να δικάσει την υπόθεση μεταξύ:

Α) ΤΟΥ ΕΚΚΑΛΟΥΝΤΟΣ:

, κατοίκου

', τον οποίο εκπροσώπησε στο ακροατήριο του Δικαστηρίου τούτου, με δήλωση του άρθρου 242 παρ. 2 του ΚΠολΔ ο πληρεξούσιος δικηγόρος

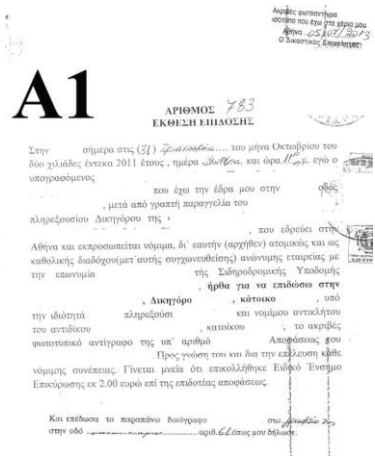
ΤΩΝ ΕΦΕΣΙΒΛΗΤΩΝ: 1) με την επωνυμία

( ), που εδρεύει στην και εκπροσωπείται

ΕΠΙΔΟΘΗΚΕ στις 31/10/2011 & ώρα 11:10

The handwritten information refers to the date (31.10.2011) and the time (11:10 am) of notification. The attorney, when reading the date which defines the deadline of 30 days, that is "31/10/2011," understands the handwritten date as "3/11/2011." Hence they present the appeal in the court on 2.12.2011 instead of 30.11.2011 and, as a result, the appeal is rejected because of a late submission. The plaintiff sues their attorney, who was to blame for the oversight regarding the date written on the notification.

We are dealing with a pure case of cognitive bias and, in particular, anchoring. The attorney, after first seeing the written date, conceives the information of "3/11/2011" and "locks" it in their memory. Before analyzing and explaining why, we have to take a closer look at the particularities of the genuine handwriting of the secretary, who – along with filling in the stamp's empty spaces – has to certify the notification with another official document, which is delivered to the case file:

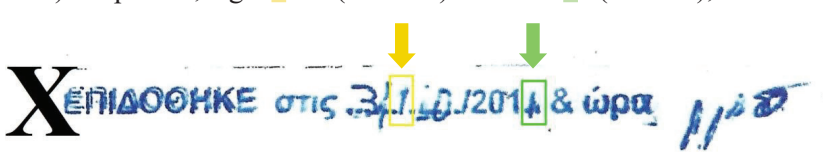


Α1

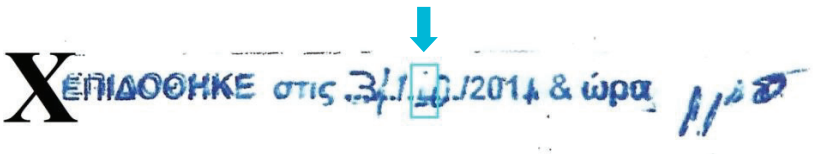
ΑΡΙΘΜΟΣ 783
ΕΚΘΕΣΗ ΕΠΙΔΟΣΗΣ

Let us understand and explain why the attorney misunderstood the written date as 3.11.2011 instead of 31.10.2011. Practically, we can read "3/110/2011" (obviously we have the number "1" in the center of "110," which is not so clear in the photocopy) in the date, that is day/month/year. The date is written in the appropriate spaces of the stamp with the handwritten text regarding number 3, the slash ("/"), probably number "110," and the last number "1" in the year "2011." In the final part of the stamp, we find the written time: "11[10]." The morphology of the number 1 presents the following variations:

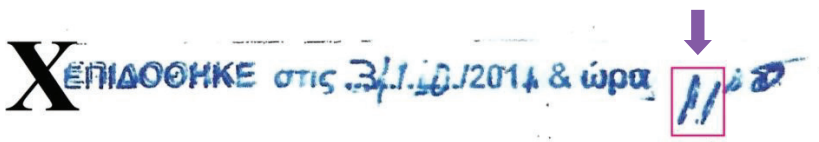
a) simple bar, e.g. "**1**10" (first "1") and "201**1**" (last "1"),



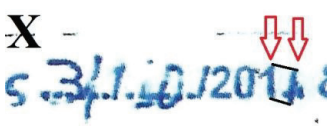
b) number 1 as bar-horizontal basis, as written in the second "1" of the central number "110,"



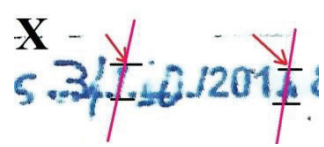
c) double bar, forming a shape similar to a closed "loop," as it appears in the hour of the time "**11**."



In addition, we have to consider the dimension of the printed characters in the stamp, which subconsciously submits the dimension of the handwritten numbers. To be more specific, the last "1" of "2011" is almost exactly of the same dimension as the previous "1," taking into account that the basis of the two specimens is not the same (**black** lines define the lower and upper endings of the specimens – they are almost parallel).

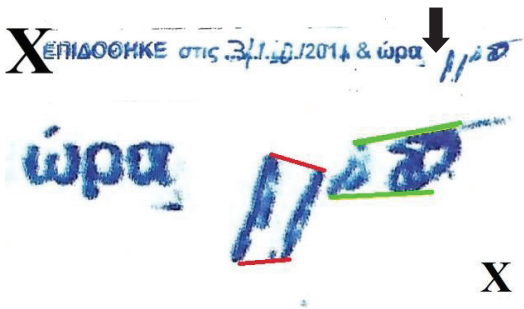


We can also notice that the last number "1" in "2011" has almost the same dimension (about 3 mm in the copy in our disposal) as the first number "1" of "110," which have both the form of a simple bar **leaning to the right** (and at the same **angle**).

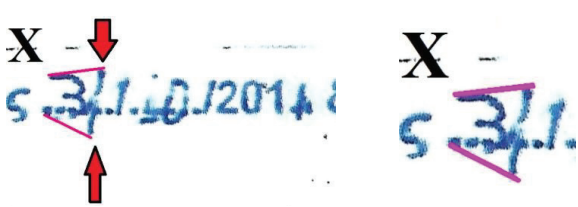


The written time "11^{10}" indicates the tendency of the hand to write the second number **smaller** or **larger**. We have to notice that the time is written in the final part of the stamp in a free space of the paper where

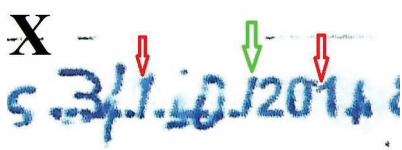
there is no more subconscious influence of the printed fonts' dimension. This is the reason why the dimension of the numbers in this part is bigger than the ones in the date at the start or in the middle of the stamp.



As a result, it is rather logical for the reader to achieve the information of "3/110/2011" without having any information about the intended date, since the reason why we have three numbers in the central part of the month ("110") cannot be explained. So, we do not have a clear notion about the number which defines the month, if it is "10" or "11." In any case, the way of forming the numbers does not indicate specifically and legibly "31/10," because the height of the second character (next to "3") is considerably bigger than the first handwritten number 3, and this fact rather indicates a slash and not number 1, as shown in the analysis above. In addition, it is a common practice to separate the numbers of the date, which define date/month/year, by forming slashes in a much more significant dimension, in order to give a clear indication of the numerical information. This is exactly what seems to have happened in this case, since it is very obvious that the written character next to "3" **is the biggest** of all the handwritten information and **much bigger than the first "3,"** which directly gives the idea of a slash and not number 1.

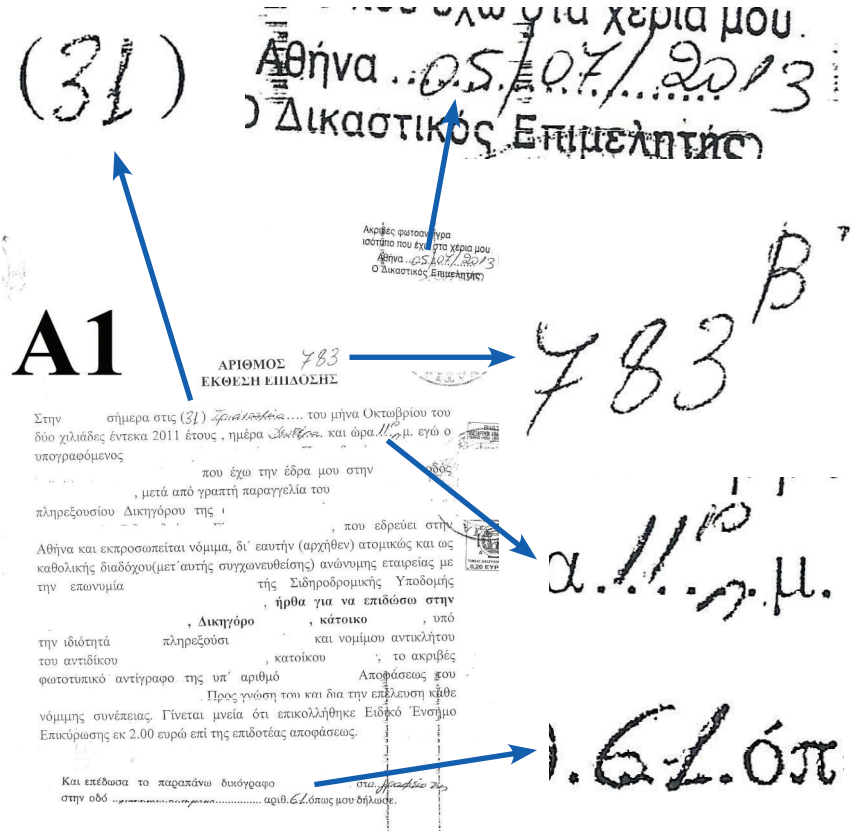


If we consider the second character as number 1 and not a slash, then we can read "31/10/2011" only if we combine this interpretation with reading the third character (or form) as a stamp slash and not number 1. So, in order to understand the written date as 31.10.2011, we have to read the second character as 1 and at the same time read the third form as a slash (and not 1). In this case, the hypothetical first slash (third character) presents characteristics analogous to "1" in the stamped "201" of the year – it presents the tendency of forming **a "hook" in the upper line of "1,"** which probably has not been well formed for several reasons (e.g. bad application of the stamp in the paper, bad quality of the copy, bad condition of the stamp due to extended use). On the other hand, **the stamped slash before "201"** does not present this tendency in the upper part.

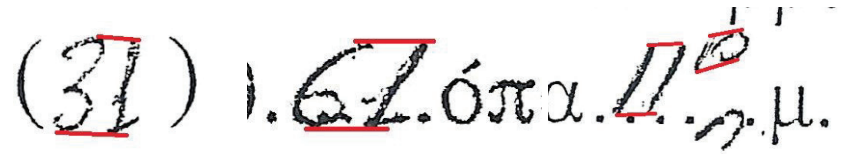


As a result, the written date is not clear and according to the above analysis we can rather read "3/110/2011," which means "3 November 2011," although we still have to explain the reason for the number 0 in the middle (between month and year). However, the justification of the existence of "0" in the middle does not allow to clearly, safely, specifically determine the date written.

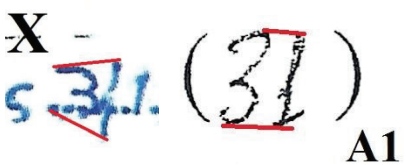
The interpretation as "3 November 2011" is confirmed by the characteristics of the number in the certificate of the secretary, which was not delivered to the attorney at first.



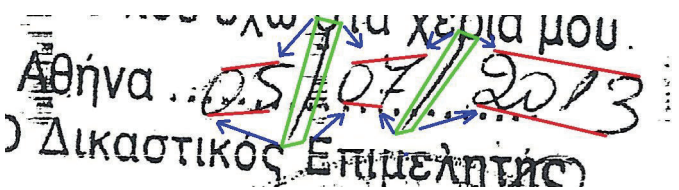
In these various combinations of two numbers, we do not find the second number written in significantly bigger dimensions in comparison to the first. There is always a **slight or non-existent difference**. This is a stable characteristic of numbers "(31)," "61," and of the time ("11^{10}").



In the case of numbers 31, where we can have a direct comparison, there is an obvious and undeniable difference between the suspected document and the comparative one in the formation of the dimensions of the numbers.



The conception of the date as "3 November" is further confirmed by the way the date was written by the same secretary in the validation of the document A1 copy. The separation between day/month and month/year using slashes confirms their graphic habit to **clearly differentiate** the dimension of the **slashes** compared to the **dimensions of the numbers**. The slashes are much bigger than the numbers.



In conclusion, document A1 confirms that the conception of the date in the suspected document, which is not clear and specific, could be rather understood as "3/110/2011," a date which is also not clearly "3 November 2011," but much closer to it. The conception of the date as "31/10/2011" is less probable due to the previously stated reasons. Afterwards, in every attempt by the attorney to re-read the date in the suspected document, they will recall the same date, the "anchor." The eye reads the information starting from the left. For the reader, having understood the second character (after number 3) as a slash means that their mind is "locked" in

that first impact as "3/." Then, they achieve the information of the month in the first two "1"s as "11" and, although they cannot logically explain the presence of the following number "0," they do not attempt to resolve the problem, because they have already completed the information needed, that is "3/11." The conception of the year is not important, since we are all aware of the current year, and the main information needed here is the starting date of the period of 30 days. So, the individual tends to rely too heavily on an initial piece of information (the "anchor") when making further decisions, a psychological process called anchoring or focalism. Every time the individual tries to read the information again, due to anchoring the initial piece of information is recalled in order to make all subsequent judgments. Once the value of this anchor is set, all future negotiations, arguments, estimates, etc. are discussed or applied in relation to the anchor. This means that every time the attorney thinks or tries to re-read the date in the notified document they will read "3/11." In addition to this, the anchor will define their behavior (in this case: the date of presenting the appeal to the court).

The effect of anchoring is very important in the cases of forgery due to the fact that the forger may misunderstand several parts of the model to imitate (handwriting, signature, or squiggle). We typically expect a morphological difference in a suspected specimen to be the result of the writer's genuine graphic variability. This might be a misleading hypothesis which could distort our conclusion, especially if we take into consideration the potential effect of anchoring.

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Chosen problems in forensic examining of signatures placed on paintings

Marek Leśniak

ORCID: 0000-0002-1204-0988
University of Silesia, Katowice, Poland

Abstract

In the context of current forensic knowledge and practice, using the handwriting analysis method to examine a painter's signature does not give rise to any objections. It allows such an examination to be more transparent. The article presents a certain specificity which characterizes painter signatures. Such distinctions reveal themselves at various stages of analysis: examining the location of the questioned signature; qualifying examination of the questioned signature; determining the scope of handwriting features considered under the examination; determining the range of variability in handwriting characteristics in the comparative material; determining the degree of variability in the same characteristics in the questioned signature. The article also raises the issue of experts' competencies, particularly significant in examining painting signatures.

Keywords: handwriting analysis methods, analysis of signatures on paintings, experts' competencies

Introduction

There is no doubt that examining a painter's signature is among the elements essential for validating the authenticity of art pieces (if a work is signed, of course). The results of such an investigation are respected both

in scholarly elaborations[1] and in guides for art collectors.[2] Therefore, its quality is of significant importance for forensic sciences and art markets.

The primary purpose of the article is to review the existing method of examining painters' signatures, and indicate issues that differ from other signature examinations. Nowadays, researchers implement handwriting analysis procedures to investigate painters' signatures.[3] Based on descriptions from the Polish and international literature on the subject,[4] it is possible to separate six stages of handwriting examinations.

1. Examining the location of the questioned signature.
2. Qualifying examination of the questioned signature.
3. Determining the scope of handwriting features considered under the examination.
4. Determining the range of variability in handwriting characteristics in the comparative material.
5. Determining the degree of variability in handwriting characteristics in the questioned signature.
6. Establishing whether the degree of variability described in item 5 is within the range described in item 4.
7. Drawing more far-reaching conclusions.

In the subsequent parts of this article, the stages are presented in the context of painter signature examination. The goal is to identify differences unique to this area of study. And finally, the article considers the question of the experts' qualifications. Who should analyze a painter's signature? Who does it in art market practice?

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[1] For example: O. Rybak-Karkosz, *Badanie autentyczności grafiki artystycznej – aspekty kryminalistyczne*, Toruń 2020, pp. 248–260; D. Wilk, "Ekspertyza dzieł sztuki", [in:] *Ekspertyza sądowa. Zagadnienia wybrane*, eds. M. Kała, D. Wilk, J. Wójcikiewicz, Warszawa 2017, pp. 624–626.

[2] M. Bryl, *Rynek sztuki w Polsce. Poradnik dla kolekcjonerów i inwestorów*, Warszawa 2016, p. 114.

[3] T. Widła, *Ekspertyza sygnatury malarskiej*, Katowice 2016, pp. 29–33.

[4] For example: E. Gruza, M. Goc, J. Moszczyński, *Kryminalistyka, czyli o współczesnych metodach dowodzenia przestępstw*, Warszawa 2020, pp. 493–499; T. Widła, "Badania dokumentów", [in:] *Kryminalistyka*, ed. J. Widacki, Warszawa 2018, pp. 274–275; R. Saferstein, *Criminalistics: An introduction to forensic science*, Upper Saddle River, NJ 2007, pp. 498–501.

1. Examing the location of a questioned signature

At this stage of signature examination, experts search for any signs of changing the substrate of the signature or its fragments. Finding such changes in a questioned document usually indicates counterfeiting. In works of art, however, creators often change the work before they are satisfied enough with its realization. Such changes may occur in different parts of the original piece, including the location of the signature. And finally, the signing was generally associated with finishing the artwork.[5] We cannot rule out the situation that a painter has corrected their signature.

Independent of chemists and art restorers, handwriting experts should exam the surface of the questioned art piece in the signature area as well as around it. Such non-destructive testing is based on observation using a professional magnifying device. For the most part, such a procedure is identical to a non-damaging technical document examination.[6] It includes exposing the signature to light under various conditions – besides microscopic examination in visible light, it may involve using filters with different light wavelengths, visible luminescence excited by ultraviolet or infra-red (including visible fluorescence excited by ultraviolet radiation).

For purposes of forensic technical document examination, experts often use video spectral comparators, which allow a comprehensive optical analysis. Experts may also use the device for non-destructive examination of artwork, but due to its size it allow an expert to examine only relatively small paintings. Therefore examining artworks demands preparing a professional test site.

This stage of analysis is conducted in the presence of the artwork's owner (owners). When examining other kinds of handwriting, an expert deals with the original writing on their own. Here, however, the owner watches the expert's actions. In this way, the expert may avoid risky situations, since in Poland, handwriting experts generally are not insured. In the case of artwork with disputed authenticity, it is not easy to evaluate the cost of the applicable premium rate. Supposedly it would

[5] T. Widła, *Świat sygnatur*, Katowice 2017, p. 19.

[6] R. Cieśla, *The technical examination of documents within the scope of Polish evidence law*, Wrocław 2006, pp. 131–146.

be beyond the the expert's financial capacity. For this reason, the artwork is under the control of its owners during all analyses. It is very often the only stage when experts deal with the original work.

2. Qualifying examination

The second stage includes the qualifying examination of a questioned painter signature. An expert must determine if the signature is suited for handwriting examination in general, depending on its graphic content and imaging performance.

The more letters the signature includes, the greater the chance of carrying out an effective analysis. Different types of letters (capital and lowercase) allow an expert to extend the examination range. There is a possibility to study graphic signs other than letters and figures.

In paintings (particularly oil ones) the signature quality may be lacking due to a thick varnish layer. The signature may have been damaged during a restoration. In such a situation, signature examination may be very limited or impossible.

3. Determining the scope of handwriting features considered under the examination

There is no one commonly accepted range of all handwriting characteristics that must be taken into consideration in every handwriting analysis. However, the catalogs of features suggested in professional literature are very similar to each other.[7] Experts may use only some of them when analyzing signatures located on paintings (for example, due to the properties of a particular substrate, tool, paint, or pastel). In related professional Polish literature, Tadeusz Widła[8] presents three groups of characteristics of signature analysis:

[7] For example: O. Hilton, *Scientific examination of questioned documents*, New York 1984, pp. 153–171; R.A. Huber, A.M. Headric, *Handwriting identification: Facts and fundamentals*, Boca Raton, FL 1999, pp. 89–139.

[8] T. Widła, *Ekspertyza*…, p. 235.

– features of the area of the inscription – the placement of the graphism (signature/date) on the surface of the painting, spacing between letters, spacing between words, spacing between lines, the slant of axes of letters and words as well as the form of angles between strokes, the sizes of characters, the proportions between their hights and the shapes formed by the contouring of extremities;

– descriptive features (construction features) with concern the shaping of the characters – the connectedness between characters (the number of items created with one continuous movement of the writing tool), the forming the majuscule and minuscule, the rounding of the tops and poligrammes, the rounding of loops, the attachment of lateral elements to oval and to vertical elements, the forming and placement of diacrtitcal signs, etc.;

– content and language features – the presence of mistakes in wording and spelling, the presence of foreign words and interferences of foreign languages to the painter's residence in areas these languages were spoken and other linguistic phenomena.

The range of characteristics (i.e. elements such as: the type of signature, the number of lines, words, and letters, the type of letters and handwriting tools, the covering material) considered in the analysis of a particular signature depends on its graphic context. Handwriting characteristics divide into quantitative and qualitative traits. The measurement of the former is less subjective;[9] in turn, the latter better represent the complexity of handwriting. Every examination should cover both quantitative and qualitative features.

The list of handwriting characteristics is constantly expanding. Some of the new traits were discovered thanks to computer algorithms.[10] The software used in Polish practice only supports the expert's decision and does not substitute an expert. It facilitates the measurement of already known handwriting features or allows an expert to measure new ones. It may be used for examing painting signatures, too. Some researchers will strive to develop softwares designed specifically for analysing painters' signatures.[11] In Poland, such programs are not yet used in practice.

[9] For example: M. Leśniak, O. Rybak, T. Widła, "Badania cech grafometrycznych sygnatur Teodora Axentowicza w pracach wykonanych techniką olejną", [in:] *Zagadnienia dowodu z ekspertyzy dokumentów*, ed. R. Cieśla, Wrocław 2017, pp. 266–272.

[10] M. Goc, *Współczesny model ekspertyzy pismoznawczej. Wykorzystanie nowych metod i technik badawczych*, Warszawa 2015, pp. 235–318.

[11] K. Kapłon, R. Ptak, "Wspomagana komputerowo analiza podpisu na dziele malarskim na przykładzie sygnatur Władysława Podkowińskiego", [in:] *Zagadnienia dowodu…*, pp. 203–209.

4. Determining the range of variability in handwriting characteristics in the comparative material

Comparative material should only comprise artworks with known provenance and signatures of undisputed origin. However, even then the expert should conduct a qualifying examination. After all, it cannot be excluded that an artwork (or at least the signature placed on it) generally considered to be authentic is fake. The expert may also reject some of the comparative signatures independently of the artworks' provenance – provided that they justify such a decision in their report, of course. The expert should name the signatures used as comparative materials. It is a significant element of their report because different comparative materials may cause divergences between expert opinions. This solution may allow recipients to find the cause of the contradiction.

The signatures should reflect the signer's habit and the entire scope of their graphical changeability. It demands using non-questioned signatures from all periods of the painter's artistic activity. When the creation time of the questioned signature is known, comparative material should include signatures that originated around the same period. Suppose a disputed signature is combined with other words or figures (for example, painters sometimes put the date of creation, the place of production, and other notations near the signature). In that case, comparative material should, if possible, include similar inscriptions (this also concerns handwritings created outside of artworks).

When a handwriting expert acts as an expert witness in Polish court, procedural decision-makers (police officers, prosecutors, judges) are responsible for providing the expert with proper comparative material. In examinations made for non-public entities, this obligation falls on the contracting authority. This can be different for examing signatures placed on paintings – an expert may search for comparative signatures in the public space. They most commonly find such samples in three kinds of sources. First, they could watch the signature and photograph it in public museums and galleries. Additionally, for some painters, extended catalogs are created, incorporating high-quality reproductions of many

artworks with separate pictures of signatures.[12] There are also multiple websites which provide high-quality photographs of paintings and signatures, usually made by public museums and galleries (and often created under the national art digitalization programs), and private art dealers (it allows potential buyers to watch art pieces subsequently offered at auctions). But sometimes, private art collectors own most paintings by a particular painter and prohibit the public (and experts) from accessing them. It reduces the number of comparative signatures and thus hampers examinations of disputed signatures.

After selecting the comparative material and evaluating its quality, an expert measures the quantitative characteristics with proper devices and determines values of qualitative traits. The expert takes into consideration the scope of handwriting features chosen in the previous stage. They assess the range of changeability, considering the features separately.

5. Determining the range of variability in handwriting characteristics in the questioned signature

The collection of measured or estimated features is the same as during the comparative signatures analysis stage. Experts assess the range of values (variability) on every characteristic separately. In the case of a painter's signature, they usually have limited access to the signature. Contrary to classical handwriting analysis, here the expert measures and determines the range of handwriting traits based on photographed signatures instead of the original ones.

Sometimes the area surrounding the examined signature greatly complicates examination. The presence of other background elements and colors may cover parts of the signature. An expert may use software to reveal sequence of lines from the signature placed on a painting. In Poland, experts often use software that allows them to extract lines of the signature from the background.[13]

[12] For example: *Maksymilian Gierymski (1846–1874). Katalog dzieł zebranych*, ed. A. Krypczyk-de Barra, Kraków 2019.

[13] The example using such a software toward a signature placed on an artwork: M. Leśniak et al., "Badania sygnatur Markusa Lüpertza", [in:] *Problematyka dowodu z dokumentu*, ed. R. Cieśla, Wrocław 2019, p. 249.

6. Establishing whether the degree of variability described in item 5 is within the range described in item 4

After determining the range of variability in particular handwriting features both in the comparative material and the disputed signature, an expert can investigate whether the values of the disputed signature are located within the variability range of the comparative material. An expert may come to three kinds of conclusions: the degree of variability in the examined comparative signatures includes values of the disputed signature; the degree of variability in the examined comparative signatures does not include values of the disputed signature; and, the expert does not find explanations to the observed differences, the degree of variability in the examined comparative signatures does not include values of the disputed signature but the expert may find reasons for the observed differences. These expert decisions are transparent (susceptible to being checked by another expert).

In regards to the third conclusion type, what explanations may an expert find for the observed differences? They may look for answers within the outcomes of published scientific empirical research. The differences may be pathological in nature – professional literature presents many studies on the influence of particular disorders or substance abuse on handwriting performances.[14] There are also some occasional factors which may impact the signature, such as environmental temperature or an unusual type of surface.

7. Drawing more far-reaching conclusions

In Polish practice, experts formulate more far-reaching conclusions than those described in the previous section. They state whether it was the same person who wrote the comperative signatures and the disputed signature (compared signatures are manifestations of the same formed

[14] For example: M. Całkiewcz, *Kryminalistyczne badania patologicznego pisma ręcznego*, Warszawa 2009; T. Widła, "Z problematyki patologii pisma ręcznego", [in:] *Kryminalistyka i nauki sądowe wobec przestępczości*, ed. H. Kołecki, Poznań 2008, pp. 139–177.

habit). This kind of conclusion is based on the expert's experience and refers to subjective probability.

According to empirical studies, the accuracy of handwriting expert opinions remains between 45% and 95%.[15] The lowest accuracy is connected to disguised handwritings, in which "the person has made a deliberate attempt to remove or to modify all or some of his or her regular writing habit."[16] Fortunately for analysing signatures placed on paintings, this kind of signature is not mentioned in the context of disguised handwriting.[17] In the case of spontaneous writing analysis, the accuracy of correctly-executed handwriting analyses reaches 90%.[18] It should be noted that, similarly to classical handwriting examination, an expert may decide that the signature placed on a painting is inauthentic without describing the manner of forgery.[19]

8. Competencies of experts

Many different kinds of specialists speak about the authenticity of painters' signatures in the art market practice.[20] These include art historians, art restorers, members of the painters' families (sometimes a relationship with the painter appears to be the only requirement for a position of authority regarding the painting's and signature's authenticity), employees of art museums and art galleries, antiquarians, and others. It should be emphasized that excellent knowledge of the painter's life and creative work does not give enough competence to conduct a handwriting examination of the painter's signatures. The analysis of signatures demands knowledge and skills from the area of forensic handwriting examination. The expert does not need to be an enthusiast of the painter chosen as the investigation subject – they should have the competencies

[15] M. Leśniak, *Wartość dowodowa opinii pismoznawczej*, Pińczów 2012, pp. 292–296.

[16] A. Koziczak, *Autofałszerstwo*, Warszawa 2020, p. 31 [trans. ML].

[17] Ibid.

[18] M. Leśniak, *Wartość*…, p. 293.

[19] T. Tomaszewski, "Oczywiste fałszerstwo, nieoczywista metoda jego dokonania", *Człowiek i Dokumenty* 57, 2020, pp. 40–47.

[20] N. Fryderek, "Eksperci rynku sztuki w Polsce – sytuacja prawna i praktyka", [in:] *Rynek sztuki aspekty prawne*, Warszawa 2011, pp. 108–118.

necessary for handwriting analysis, as well as access to proper equipment (including a professional test bench). Moreover, they should be aware of the specificities unique to this type of signature (such as the use of particular painting tools, paints, pastels, crayons).

However, sometimes even regular handwriting experts may not possess sufficient skill to examine not only painters' signatures, but also handwriting in general. There are expert witnesses in Poland, which means persons present on the 45 lists administered by presidents of regional courts (under the Regulation of the Minister of Justice of 24 January 2005 on expert witnesses[21]). According to the regulation (§ 12), a person to be appointed as an expert witness should have, among other qualifications, theoretical and practical knowledge of a particular field of science, technology, arts, crafts, or other skills relevant to the court appointment which should guarantee proper performance of their duties as an expert. The responsibility of verifying the experts' knowledge and experience before putting them on one of the the lists rests with the president of a regional court. The existing regulations and practices do not guarantee the presence of persons with the highest professional qualifications on the expert witness list.[22] However, many expert witnesses in the field of handwriting are highly qualified.

To obtain a valuable expert opinion on the authenticity of painters' signatures, art market participants should verify the person's qualifications before ordering analysis. The best way to do it would include becoming familiar with analyses performed in prior cases. However, an expert cannot reveal their report independent of the ordering party, which decides whether to make the report public. The most effective solution would be to create a public institution whose purpose would be monitoring the quality of expert assessment in the art market. The institution could cooperate with art market participants and disseminate information about "good practices" in other authenticity investigations (including painters' signature examination).

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[21] Dz.U. (*Journal of Laws*) of 2005, no. 15, item 133.

[22] S. Ławrentjew, *Opiniowanie pismoznawcze w sprawach testamentowych*, Toruń 2019, pp. 171–183.

Conclusion

Managing the quality of the analysis requires setting and sustaining certain standards. Treating painters' signature analysis as a kind of forensic handwriting examination allows using criteria from forensic sciences literature. If an expert maintains standards, their opinion may be subject to other experts' control. Forensic handwriting examination standards oblige experts to justify their conclusion correctly. Of course, experience may play a vital role in drawing conclusions, but it cannot substitute rational arguments. Relying only on somebody's experience is not scientific because it is something another expert cannot verify. It may happen that different experts reach contrary conclusions. Only after gaining insight into the experts' arguments can the art market participants know the essence of their inconsistency. It also allows evaluation when the submitted analysis of the painter's signature is deemed unprofessional.

Painters' signatures are among the fundamental pieces of information about the provenance of artworks. However, art market participants should keep in mind that the masterpiece and its signature belong to different spheres. It is possible to encounter four situations:[23] both the signed artwork and its signature are authentic, or both are fake; the painting is authentic, but the signature is not; the painting is not authentic, but the signature is. Therefore, the authenticity or inauthenticity of the signature does not determine the authenticity or falsification of the submitted painting.

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[23] T. Widła, "Autentyczność sygnatury a autentyczność dzieła sztuki", [in:] *Meandry ochrony dziedzictwa narodowego. Aspekty prawnokarne i kryminalistyczne*, eds. M. Sabaciński, M. Trzciński, Warszawa 2019, pp. 175–179.

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Myths about fingerprint evidence: Basic facts countering miscarriage of justice. Part 1

Saleh Mansour

ORCID: 0000-0002-4111-4704
Faculty of Criminology, Lebanese University
Beirut, Lebanon

Shital Zade

ORCID: 0000-0003-1976-8477
International Forensic Science Pvt. Ltd
Pune, Maharashtra, India

Shipra Rohatgi

ORCID: 0000-0003-0532-9908
Amity Institute of Forensic Sciences, Amity University
Noida, India

Slobodan Oklevski

ORCID: 0000-0002-1116-5631
Ministry of Interior, Republic of North Macedonia

Abstract

The long practice of fingerprint science is accompanied by confusing thoughts affecting the interpretation of the fingerprint evidence recovered from a crime scene, and, consequently, prosecutors and judges' decisions as well. However, despite the tremen-

dous scientific and technological developments relating to fingerprint enhancement, processing, and usage, which clarify precise facts regarding the influence of deposition circumstances, substrate, light, air, temperature, and time factors on fingerprint secretions, misconceptions about fingerprints are still widespread within the law enforcement and judicial system. This problem prevents the proper usage of fingerprints in fighting crimes and supporting the justice system by strong physical evidence. This study aims to highlight some scientific facts about fingerprints as well as a new approach and reconceptualization of fingermarks as a tool for crime scene investigation and training. The article discusses twenty-four myths about fingerprints – part 1 covers ten of them and part 2 discusses the other fourteen.

Keywords: fingerprint aging, constituents, skin anatomy, processing techniques, delicate surfaces, fingerprint sensitivity, evidence interpretation, ACE-V methodology, AFIS

Introduction

A fingerprint or friction ridge is the skin located on the fingers, palms, and soles of human beings as well as animals such as chimpanzees and koalas.[1] Most individuals are known to have unique, persistent, and permanent fingerprints,[2] with an exception of people born with rare genetic conditions.[3] When an item is touched, intentionally or unintentionally, there is always a transfer of material between it and the skin. Thus, the word "fingerprint" refers to the shapes of papillary ridges left on bearer surfaces when they are touched.

The fingermark is the trace left by a fingerprint and recovered at crime scenes. It has three main types regarding its visibility: latent, patent, and plastic/molded. Latent fingermarks are the most common – they require development and enhancement of some sort to be visualized. Patent fingermarks are visible and include fingermarks in blood, ink, or other colorants, and plastic prints are impressions left in soft material substrates such as wax, paint, putty, or any other substance that will soft-

[1] W.D. Hopkins et al, "Grip preference, dermatoglyphics, and hand use in captive chimpanzees (Pan troglodytes)", *American Journal of Physical Anthropology* 128, 2005, no. 1, pp. 57–62, https://doi.org/10.1002/ajpa.20093.

[2] H.M. Daluz, *Fingerprint analysis laboratory workbook*, Boca Raton, FL 2018.

[3] R. Kaufman, "Mutated DNA causes no-fingerprint disease", *National Geographic*, 10.08.2011, https://www.nationalgeographic.com/news/2011/8/110809-fingerprints-skin-disease-health-science-weird/ (accessed: 17.08.2020).

en when handled. Fingermark enhancement can at times be complex and require sequential processing utilizing various spectroscopic, physical, chemical, physiochemical, and/or multi-nature techniques. It is important to realize that the most recognized and widely known process is dusting by fingerprint powder, which, despite its prevalence, is not the ideal process to develop fingermarks from all the substrates and in all cases.

This point is often overlooked, which poses a serious problem when many people concerned, such as law enforcement officers, investigators, prosecutors, and judges, are convinced that if the latent print could not be revealed by powder dusting of a certain substrate or delicate surface at the crime scene, that means the fingermarks have been disappeared, demolished, or destroyed. Consequently, they base their decisions on this myth. The fundamental role of fingerprints is to reveal crimes and deliver a solid proof of individual identification to the court.

What are the myths about fingerprint evidence? What is their weight in the scientific balance? This study is going to answer these two main questions.

1. The fingerprint evidence is unreliable

The fingerprint evidence, similarly to other disciplines of forensic science, faced plenty of criticism by scientific and legal analysts regarding the reliability of investigation and examination methods which rely on personal subjective conclusions.[4] The main criticism of the National Research Council (NRC) of the National Academies of Science (NAS) and the President's Council of Advisors on Science and Technology (PCAST) was the lack of scientific and empirical basis to authenticate conclusions, which restricts their reasonable demonstration to the judiciary.[5] Moreover, the mistaken practice of fingerprint individualization supports this kind of criticisms.

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[4] S.L. Cooper, "Challenges to fingerprint identification evidence: Why the courts need a new approach to finality", *Mitchell Hamline Law Review* 42, 2016, no. 2, http://open.mitchellhamline.edu/mhlr/vol42/iss2/8 (accessed: 20.06.2020).

[5] H.J. Swofford et al., "A method for the statistical interpretation of friction ridge skin impression evidence: Method development and validation", *Forensic Science International* 287, 2018, pp. 113–26, https://doi.org/10.1016/j.forsciint.2018.03.043.

One of the most famous cases is that of Brandon Mayfield, an American lawyer. Fingerprint traces were developed from a blue plastic bag containing detonators found at a railway station near the bombing terrorist crime scene in Madrid (Spain) on 11 March 2004, where several bombs exploded in a railway station, killing 191 people and wounding 2050. After identification, a digital copy of the traces was sent to the FBI in the United States, who identified Mayfield as the source of one of them, with 15 matching characteristics, which led to his arrest in May 2004 as a material witness in the case. Moreover, the FBI brought an independent fingerprint expert who stated that the quality of the prints' copy delivered from the Spanish police was poor and the image possibly included an overlay of another print, and highlighted the importance of examining the original image.[6] The Spanish authorities disputed the FBI's conclusions and confirmed that the fingerprint traces had a positive match in their database, matching the thumb and middle of another individual called Ouhnane Daoud. This led to Mayfield's release after a two-week detention in a Multnomah County jail in Oregon.[7]

A comprehensive investigation of Mayfield's case held by the US Inspector General's Office, who in 2006 released a 273-page report, concluded that there is "unusual similarity" of the two fingerprints, and bias from the known prints of Mayfield led to the confusion of the three FBI examiners and the court-appointed expert. However, it also admitted the examiners' failure to adhere to the bureau's rules for identifying latent fingerprints, highlighted the FBI's overconfidence in its skills and the superiority of its examiners as well as in the power of IAFIS, and the pressure of working on a high-profile case as contributing to the error. As for the case's conclusion, the mistaken individualization was related to a substandard image, erroneous adhering to the standard operating procedures and human error, but not to the fingerprint science.[8]

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[6] OpenLearn, The Open University, https://www.open.edu/openlearn/health-sports-psychology/health/forensic-science-and-fingerprints/content-section-0?active-tab=description-tab (accessed: 14.06.2020).

[7] S. Kershaw, E. Lichtblau, Kershaw S., Lichtblau E., "Questions about evidence in U.S. arrest in bombing", *The New York Times*, 22.05.2004, https://www.nytimes.com/2004/05/22/us/questions-about-evidence-in-us-arrest-in-bombing.html (accessed: 14.06.2020).

[8] U.S. Department of Justice, *A review of the FBI's handling of the Brandon Mayfield case*, March 2006.

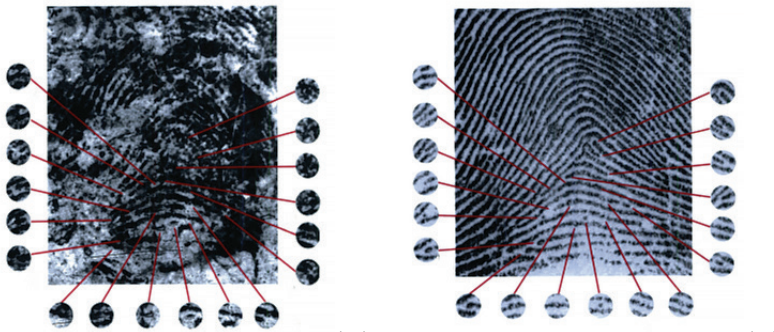

Figure 1. (A) Image of the fingermark developed from the plastic bag that was found near the scene of the March 2004 Madrid bombings. (B) Brandon Mayfield's fingerprint[9]

Two main methods were used to demonstrate the rareness of the fingerprint friction ridge characteristics.

1. Feature-based models, which involve calculating the probability estimates of the random correspondence minutiae distribution and configuration. Zhu et al. developed a family of mixture models to simulate the clustering property and tendency of minutiae features in fingerprint images, whereas the probability of random correspondence (PRC) was computed by a mathematical model, without investigating other mixture distribution on the minutiae locations and directions.[10] Su and Srihari developed a model to calculate the PRC, grounded on the spatial minutiae distribution, and the dependency of each one on nearby minutiae and the sureness of their occurrence in the evidence.[11]

2. Similarity matric models, which calculate the probability estimates from likelihood ratios determination for fingermark evidence evaluation based on the Automated Fingerprint Identification System (AFIS) distribution of similarity scores.[12]

[9] Ibid.

[10] Y. Zhu et al., "Statistical models for assessing the individuality of fingerprints", *IEEE Transactions on Information Forensics and Security* 2, 2007, no. 3.

[11] C. Su, S. Srihari, "Evaluation of rarity of fingerprints in forensics", P*roceedings of Neural Information Processing Systems*, 6–9 December 2010, Vancouver, Canada, https://cedar.buffalo.edu/~srihari/papers/nips2010.pdf.

[12] I. Alberink, A. de Jongh, C. Rodriguez, "Fingermark evidence evaluation based on automated fingerprint identification system matching scores: The effect of different

2. The fingerprint is composed of sweat and water which disappear rapidly by evaporation

Eccrine sweat glands constitute a single type of fingerprint component sources, such as water, which is one of many sweat secretions.[13] Although these components differ in quality and quantity from the general chemical composition of sweat, their mixture is individual to each case and more complex to be identified.

In the first place, fingerprint constituents are composed of endogenous and exogenous sources.[14] There are three main sources of endogeous components: eccrine glands, sebaceous glands, and apocrine glands.

The eccrine glands are also known as merocrine glands[15] and their number is the highest in hands as well as soles of the feet. Their secretions are divided into inorganic and organic constituents.[16] Examples of the first type: ammonia, bromide, chloride, fluoride, cobalt, copper, phosphate, sulphide, and water, whereas examples of the second type: amino acids, creatinine, enzymes, glucose, glycogen, lactic acid, lactate peptides, phenols, proteins, pyruvic acid, pyruvate, urea, uric acid, and vitamins. Almost all mentioned materials are not sensitive to environmental factors, such as temperature, sunlight, humidity, airflow, etc., neither are they subject to the evaporation process, although the majority of them are water-soluble materials.[17]

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types of conditioning on likelihood ratios", *Journal of Forensic Sciences* 59, 2014, no. 1, pp. 70–81, https://doi.org/10.1111/1556-4029.12105; H.J. Swofford et al., op. cit.

[13] M.V. Buchanan, K. Asano, A. Bohanon, *Chemical characterization of fingerprints from adults and children*, Washington, D.C. 1996; R.S. Croxton et al., "Variation in amino acid and lipid composition of latent fingerprints", *Forensic Science International* 199, 2010, pp. 93–102; Victoria Forensic Science Center Fingerprint Branch, *Latent fingerprint composition*, FPB training unit module 9, 2011.

[14] A. Girod, R. Ramotowski, C. Weyermann, "Composition of fingermark residue: A qualitative and quantitative review", *Forensic Science International* 223, 2012, no. 1–3, pp. 10–24, https://doi.org/10.1016/j.forsciint.2012.05.018.

[15] "Merocrine gland", Biology Online, https://www.biologyonline.com/dictionary/merocrine-gland (accessed: 18.06.2020).

[16] G. de Paoli et al., "Photo- and thermal-degradation studies of select eccrine fingerprint constituents", *Journal of the Forensic Science Society* 55, 2010, no. 4, pp. 962–969, https://doi.org/10.1111/j.1556-4029.2010. 01420.x.

[17] The Home Office Centre for Applied Science and Technology (CAST), *Fingermark visualisation manual*, 2014, http://www.officialpublicationsonline.co.uk.libproxy.

In the same fashion, eccrine glands play a critical role in forensic science since they cannot be controlled intentionally by the perpetrator – they are innervated by the autonomic nervous system, along with smooth muscles of all visceral structures and coordinating bodily responses, without requiring conscious or voluntary control.[18] This gives an advantage to the criminal investigation: thermal and emotional provocations experienced throughout committing the crime activate the automatic response of sweat glands, granted that sweat constituents secreted through pores situated along the papillary ridges of the fingerprints, overlaying them, and deposited on the touched surfaces.[19]

This may be a comprehensive explanation for why the clarity of the perpetrators' fingermark impressions on a paper substrate is greater than fingermarks of other people who touched the same document. For instance, when attempting to cash out a fraudulent check from a bank, the perpetrator tries to control all indicators of their tension to avoid suspicion by bank employees. This leads to internal tension and acceleration in heartbeat and breathing, and an increase in secretions of amino acids and other constituents that will be transferred to the check through direct contact.

Sebaceous glands' secretions are only of the organic type; examples include: alcohols, fatty acids, fatty acid alkyl esters, glycerides, hydrocarbons, squalene, squalene degradation products (e.g. squalene epoxides, squalene hydroperoxides), sterols, sterol esters, wax esters. Although sebaceous glands are not found in the skin of palms and soles,[20] they occur everywhere hair follicles are present, mainly on the skin of the forehead, face, and neck.[21] Their secretions are transferred to the friction ridge areas by contamination when the hands touch the forehead, nose, chin, and scalp areas of the face, which is a typical human behavior,[22]

abertay.ac.uk/publications/download/9781782462347; H. Murota et al., "Sweat in the pathogenesis of atopic dermatitis", *Allergology International* 67, 2018, no. 4, pp. 455–459.

[18] M. Richter, R. Wright, "Autonomic nervous system", [in:] *Encyclopedia of behavioral medicine*, New York 2012, https://www.researchgate.net/publication/280650893_Autonomic_nervous_system.

[19] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

[20] A.V. Maceo, "Anatomy and physiology of adult friction ridge skin", [in:] National Institute of Justice, *The fingerprint sourcebook*, pp. 2-1–2-26.

[21] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

[22] S. Dimond, R. Harries, "Face touching in monkeys, apes, and man: evolutionary origins and cerebral asymmetry", *Neuropsychologia* 22, 1984, pp. 227–233.

regardless of whether it happens intentionally or not. Despite the majority of sebaceous secretions constituents being water-insoluble,[23] they are less sensitive to environmental circumstances.

Moreover, many scientific experimental studies found that both in fingermarks exposed to light and those stored in the dark, saturated fatty acids increased for 20 days, followed by a decrease below the initial amounts.[24] These observations can be interpreted as bacterial activities causing the increase in fatty acids as well as the subsequent decrease when triglycerides are completely broken down. By the same token, saturated acids with low molecular weights were also shown to increase over time by the effect of the oxidation products of squalene and some fatty acids such as nonanoic, hexadioic, and penta dioic acids. Since sebaceous secretions are not liquid, as a consequence they are not subject to evaporation.[25]

However, the exogenous constituents within the components of the fingerprint secretions that are foreign to the secretions of the different glands, are found on the friction ridge skin as a result of external contamination, and also might be found on the surface of the substrate before holding it. Among the most prominent pollutants that are found on the hands are the effects of foodstuffs, alcohol, cleaning materials, dirt, different oils, grease, charcoal, ink, chemicals such as soaps, skin moisturizers, and cosmetic products, traces of various narcotics, explosive substances, or body fluids such as blood. No matter how small the amounts of these substances are, they can help in developing the appearance of fingerprint impressions, either directly or through their interaction with the chemicals used in the development process.[26]

Furthermore, scientific research highlighted the inter-variation of the chemical composition of fingerprint secretions between one individual and another, as well as the occasional intra-variation of these

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[23] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

[24] De Paoli G. et al., op. cit.; N.E. Archer et al., "Changes in the lipid composition of latent fingerprint residue with time after deposition on a surface", *Forensic Science International* 154, 2005, no. 2–3, pp. 224–39, https://doi.org/10.1016/j.forsciint.2004.09.120.

[25] A. Girod, R. Ramotowski, C. Weyermann, op. cit.

[26] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

secretions within the same individual. These variations are due to several factors, including metabolites of the type of food and drink or medicines and drugs consumed, as well as diseases,[27] exercise, emotional and psychological conditions. It should be noted that the majority of the components from sweat glands are soluble in water, unlike the fatty components resulting from the secretions of the sebaceous and apocrine glands.[28]

The numerous factors that influence the fingermark constituents, which form a complex system, include the donor features, the deposition circumstances, the substrate nature, the environmental conditions, and the applied experimental techniques.[29]

Scientists have found about 346 materials in the mixture of the fingermark components.[30] This means that the evaporation process will not be able to make all these components disappear, as mentioned above. When the deposited fingermark is fresh, dusting by powder is a perfect way for its development because the powder will adhere to the "wet" secretions, and the latent fingermark will be clear and visible. However, when the deposited fingermark is not fresh and the "wet" secretions have already evaporated due to time and environmental factors, then dusting by powder will not be the perfect way for the development process. This does not mean that the fingerprint has already disappeared or been demolished, but rather the chosen processing technique has to be different from dusting by powder.

In such a case, the individual variable conditions of the surface, the expected time of deposition, and environmental factors have to be taken into consideration to design the appropriate procedures and processing techniques. The main factors of the study are: the type of latent fingermark residue (visible, latent, patent), the type of substrate (porous, semi-porous, non-porous), the texture of the substrate (soft, thick,), its condition (clean, dirty, tacky, sticky, greasy, etc.), environmental conditions during and following the deposition (light, humidity, airflow, temper-

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[27] S. Francese et al., "Beyond the ridge pattern: multi-informative analysis of latent fingermarks by MALDI mass spectrometry", *The Analyst* 138, 2013, no. 15, pp. 4215–4228.

[28] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

[29] A. Girod, R. Ramotowski, C. Weyermann, op. cit.

[30] "Morphogenèse et composition des empreintes digitales", Police Scientifique, https://www.police-scientifique.com/empreintes-digitales/composition.

ature, etc.), the time passed since the evidence was touched, the effects of destructive processing methods, and subsequent forensic examinations.[31] Consequently, the proper chemical, physical, physicochemical, and/or spectroscopic techniques have to be applied in an appropriate order to get the best possible results of fingermark visibility and clarity – otherwise the risk of ruining the fragile latent is significant.[32]

3. The fingerprint age does not exceed forty-eight hours

This old myth was spread globally.[33] Scientific research about fingerprint evidence constituents and behavior over time plays an important role in partially dispelling such an erroneous myth, even though it is still present and has a continuous negative influence on both criminal investigations and the judicial system.

Although the evaporation process of the fingerprint components has a great influence on water and water-soluble substances, it does not affect other components such as sebum, squalene, sulfate, magnesium, cholesterol, triglyceride, oleic acid, etc. in any way. In this context, Girod et al. examined the initial residues of fingerprint impressions and monitored the changes that occur over time within a period that extends up to 1, 3, 7, 9, 20, 34 days, by using Fourier Transform Infrared Microscopy Technology (m-FTIR). Where the result of examining the initial impressions are prepared with diluted total reflection and single-point reflection patterns (ATR), and Single-Point Reflection Modes, it is possible to find the residue of the sweat and sebaceous gland secretions in recent impressions on substrates stored in a dark place.[34]

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[31] B. Yamashita, M. French, "Latent print development", [in:] National Institute of Justice, *The fingerprint sourcebook*, pp. 7-1–7-67, https://www.ojp.gov/pdffiles1/nij/225320.pdf.

[32] M. Fulton, "Latent chemistry: Development of fingerprints", Fulton Forensics, 27.11.2017, https://www.linkedin.com/pulse/latent-chemistry-development-fingerprints-mike-fulton/ (accessed: 29.08.2020).

[33] K. Wertheim, "Fingerprint age determination: Is there any hope?", *Journal of Forensic Identification* 53, 2003, no. 1, pp. 42–49.

[34] A. Girod et al, "Fingermark initial composition and aging using Fourier transform infrared microscopy (μ-FTIR)", *Forensic Science International* 254, 2015, pp. 190, 194, https://doi.org/10.1016/j.forsciint.2015.07.022.

In this framework, the analysis of chemical measurements showed that it is possible to classify the effects of fingerprints into groups based on the age criterion, regardless of the carrier surface, if they are stored in a box placed in a laboratory and exposed to a temperature of 20 degrees Celsius near the window. When fingermarks are preserved in darkness, it is possible to classify impressions of fingerprints on the same substrate in groups according to the age criterion, and thus the effect of the surface on examining the age of fingerprint printing if stored in the dark.[35]

Equally important are the results of using Partial Least Squares Regression (PLSR) which showed that it is possible to determine the age of a fingermark by a difference of three days concerning impressions passed from twenty to thirty-four days prior, and by a difference of one day concerning the most recent impressions, that is, one passed a day, three, seven, nine days beforehand, regardless of the type of substrate and the level of illumination. These are important results about determining the age of fingermarks – they reinforce the need to conduct additional research to demonstrate this model scientifically, verify its reliability and the extent of its limitations.[36]

Besides, a study on fingerprint aging published by German scientists shows that the scientific analysis of oleic acid by the mass spectral gas chromatography-MS/GC can determine the estimated time of deposition, which will have a promising added value to the interpretation phase of the fingerprint evidence in the future.[37] Furthermore, the development of fingerprints from porous surfaces, such as paper, shows fingerprints deposited from a period exceeding one hundred years.[38] It is worth mentioning that porous surfaces absorb secretions as well as solid components – the secretions are traces of microelements, so they can penetrate through the porous surface along with the thin fibers of the substrate. Likewise, amino acids, which are among the twenty-two main compon-

[35] Ibid.

[36] Ibid.

[37] S. Pleik et al., "Dating of fingerprints by different mass spectrometric techniques: Analytical and forensic interpretation of latent fingerprint residue", paper presented at the 8th International Symposium on Fingerprints, 4 June 2014, Justus Liebig University Giessen, Lyon.

[38] K. Wertheim, op. cit.

ents of fingerprint secretions, are carried out through pores in paper surfaces and adhere to the molecules of cellulose, which is the main material of the paper, to ensure the stability of these secretions and protect them, which enables them to last for long periods of time.[39]

4. The information extracted from fingerprint evidence relate only to its physical appearance

This is a true statement, as almost all fingerprint usage practices have existed for more than 130 years. However, chemical and spectroscopic analyses of fingerprint constituents allow the investigators to gain plenty of information related to the perpetrator.

To emphasize, the external materials that mix with the secretions of the fingerprints are numerous, and they depend mainly on the objects that were held by the perpetrator before touching the bearing surface and depositing the fingermark. It is therefore difficult to limit them to one list or category, such as narcotic substances, pain relievers, tobacco, various types of alcohol, fats and oils from food – such as pizza, hamburgers, French fries, and their metabolites – explosive substances, blood residues, different types of paint and ink, skin moisturizers, cosmetics, oils and materials used in hairdressing, secretions and residues resulting from sexual relations, machinery oils and the fat used in them, etc. It is possible to determine the nature of these materials through laboratory analysis to obtain intelligence information about the lifestyle of the perpetrator as well as their activities and health issues.[40]

Correspondingly, several techniques can be used to extract such information, including Raman spectroscopy – which relies on a spectroscopic analysis of materials by measuring the vibrational molecule patterns – as well as SALDI-TOF-MS and MALDI/TOF MS, which are also spectroscopic techniques that rely on measuring the absorption of laser beams used to analyze the mass spectrometry of biomolecules, polymers,

[39] Ibid.

[40] W.V. Helmond et al., "Chemical profiling of fingerprints using mass spectrometry", *Forensic Chemistry* 16, 2019; L.S. Ferguson, *Analysis of the composition of latent fingermarks by spectroscopic imaging techniques*, doctoral thesis, Sheffield Hallam University, 2013, http://shura.shu.ac.uk/19645/.

and small organic molecules. These two techniques allow analyzing and measuring mass spectra to show the presence of codeine, cocaine, dimethyl morphine, morphine, papaverine and nonquinine in addition to their metabolites based on the present antigens. The main condition for their use is the prior knowledge of the concerned drugs, narcotics, and medications.[41]

Comprehensive spectroscopy via the laser mass spectrometry aided by laser ionization technology and mass spectroscopy (MALDI MSI) allow the extraction of in-depth information from the molecules of the fingermark constituents. These molecules make it possible to get more knowledge about the suspect, their identity, sex,[42] health, behavior, grooming habits, and lifestyle. They are the narrators of the perpetrators' secrets. Spectroscopy techniques, most notably FTIR and Raman spectroscopy, have helped to determine the presence of narcotic or explosive residue traces on fingerprints in a fingermark. These techniques are rapid, low-cost, and non-destructive to the surface bearing the fingermark.[43]

5. A lack of visualized fingermarks from the crime scene implies a person did not touch an item

Fingermarks play an important role in forensic science. Based on the assumption that every individual holds a unique pattern of friction ridge skin on their hands, this pattern can be used for identification. By determining the source of the fingermark, a link between a suspect and a crime scene can be established.[44] An important question that often comes up in court cases regarding forensic evidence is how or when a trace was deposited.

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[41] "Forensic breakthrough: Recovering fingerprints on fabrics could turn clothes into silent witnesses", *ScienceDaily*, 2.02.2011, https://www.sciencedaily.com/releases/2011/01/110131073141.htm (accessed: 21.06.2020); L.S. Ferguson, op. cit.

[42] C. Heaton et al., "Investigating sex determination through MALDI MS analysis of peptides and proteins in natural fingermarks through comprehensive statistical modelling", *Forensic Chemistry* 20, 2020, https://doi.org/10.1016/j.forc.2020.100271.

[43] L.S. Ferguson, op. cit.

[44] C. Champod et al., *Fingerprints and other ridge skin impressions*, Boca Raton, FL 2016; R. Cook et al., "A hierarchy of propositions: Deciding which level to address in casework", *Science & Justice* 38, 1998, pp. 231–239.

In the forensic expertise fields of DNA, fibers, glass, paint, and gunshot residues, the evaluation of evidence given activity level propositions is already being studied.[45] However, for fingermarks this topic is not yet explored. Many variables may provide information on how a fingermark was deposited on a surface. When multiple variables influence the interpretation of the evidence, it can be difficult to take their dependencies into account in a direct likelihood ratio calculation.[46] A method that is commonly used for cases where additional factors play a role is a Bayesian network. It is a graphical representation of a mathematical model that can be used to evaluate findings, particularly if there is a dependency between relevant variables.[47] A Bayesian network consists of nodes, directed arcs, and probability assignments of the nodes. It can, for instance, be used to compute a likelihood ratio of the evidence given the prosecution proposition and the defense proposition, based on all variables that are considered relevant in the interpretation of the evidence. This makes Bayesian networks an appropriate method to evaluate the evidence given at activity level within the field of forensic science.

6. A lack of fingermarks implies an item was cleaned or wiped up

A lack of retrieved fingermarks can be interpreted in many possible ways: the perpetrator did not leave any fingermarks, left an unidentifiable fingermark, the crime scene or laboratory technicians used inappropriate processing techniques, or the fingermark was cleaned or wiped up.

In 2001, Williams and McMurray[48] first observed that the SKP technique, traditionally used for detecting the onset of corrosion in metals, can be applied in the direct detection of fingermarks on metal surfaces. The process is found to remain effective even after the mark has been wiped from the surface.

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[45] F. Taroni et al., *Bayesian networks for probabilistic inference and decision analysis in forensic science*, Chichester 2014.

[46] C.G.G. Aitken, A.J. Gammerman, "Probabilistic reasoning in evidential assessment", *Journal of the Forensic Science Society* 29, 1989, pp. 303–316.

[47] F. Taroni et al., op. cit.

[48] G. Williams et al., "Time–lapse potentiometric imaging of active filiform corrosion using a scanning Kelvin probe technique", *PhysChemComm* 4, 2001, no. 16, pp. 26–31, https://doi.org/10.1039/b100835h.

7. Automated Fingerprint Identification System (AFIS) makes the identifications

AFIS does the identification of the ten-print files, as usually the threshold is set high enough, and the fingerprints of many are searched at the same time. However, identifying fingermark traces needs a different procedure. Although AFIS demonstrates a list of candidates to the expert, ACE-V methodology still has to be thoroughly implemented. The fingerprint expert plays a primary role in the process, which requires cooperation between them and the system. The expert needs to follow all the steps of the methodology, analysis, comparison, evaluation, and verification, as well as write the technical report, prepare the chart, interpret the conclusions, testify in court – all this while holding responsibility for the entire process.

The heart of AFIS technology is the ability of a computer to scan and digitally encode the fingerprints. The AFIS uses automated scanning devices that convert the fingerprint image into a digital minutia that contains data showing ridges at their points of termination (ridge endings) and the branching of single ridges into two (bifurcations). The relative position and orientation of the minutiae are also determined, making it possible to store each fingerprint in the form of a digitally recorded geometric pattern.

The computer search algorithm determines the degree of correlation between the locations and mutual relationship of the minutiae for both the search and file prints. In this way, a computer can make thousands of fingerprint comparisons within a second.[49]

8. Fingerprint conclusions are decisive

Fingerprint evidence has a high reliability rate. However, the identification process is conducted by human beings who can make mistakes, either by confusion, omission, mis-implementation of the correct procedures, typing errors, etc. Therefore, any genuine concerns about the conclusions have to be taken into consideration, and the conclusion should be rechecked in detail. "100% certainty" is a measurement of a person's confidence in the conclusion, not of its accuracy.

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[49] P. Komarinski, *Automatic Fingerprint Identification Systems (AFIS)*, Burlington, MA 2005.

9. It is impossible to retrieve fingerprints from surfaces which were wiped or cleaned

Even though fingerprint scientists are convinced that it is impossible to process fingermarks from wiped or cleaned substrates, which is partially true in case the object's surface has no reactions with the secretions of the skin, as is the case with glass, porcelain, and hard plastic materials.

Nevertheless, it is a false statement for many other subjects such as copper, stainless steel, iron, and other metal objects. Recently, researchers from Loughborough University in Leicestershire (U.K.) in partnership with the Defense Science and Technology Laboratory (DSTL) carried out an advanced detection technique which allows retrieving fingerprints from problematic exhibits, such as spent ammunition casings,[50] after being exposed to extremely high temperatures as well as surfaces that have been deliberately washed, wiped out, and cleaned, to get clear visible ridge details of fingermarks. This advancement will make it impossible for criminals to conceal or destroy their fingerprints when attempts have been made to destroy print evidence through burning or washing. These items had previously been extremely challenging or impossible to work with – in addition to fired ammunition cases, this included Improvised Explosive Device (IED) components as well as metal items that had been deliberately cleaned, such as knives and contaminated metallic items.[51]

By the same token, cellulose-based porous substrates such as wood, paper, and cardboard have a high capacity of absorbing fingerprint secretions; semi-porous materials, for instance glossy magazine paper, have a lower ability to absorb fingerprint secretions; non-porous materials, such as glass, have the advantage of being unable to absorb fingerprint components. Porous and semi-porous surfaces consisting of cellulose attract the amino acid components of fingerprint secretions, so these amino

[50] "Forensic technology developed at Loughborough University will make it 'impossible' for criminals to destroy fingerprint evidence", Loughborough University, 28.11.2017, http://www.lboro.ac.uk/news-events/news/2017/november/groundbreaking-fingerprint-technology-discovered-/ (accessed: 21.06.2020); Ploughshare Innovations, *Case study: Ground-breaking fingerprint technology*, 2019. https://www.ploughshareinnovations.com/wp-content/uploads/LFT-Case-Study.pdf (accessed: 21.06.2020).

[51] Ibid.

acids settle inside the texture of the substrate and are protected.[52] In this case they can persist for decades and scientific research even indicates the possibility of developing impressions of fingerprints on paper documents that are more than 100 years old.[53] Therefore, wiping these surfaces or cleaning them will have a minimal effect on protected materials that are found inside the substrate long after the cleaning process.

10. Water constitutes around 98% of the fingermark components

Many fingerprint scientists, and not only other fingerprint examiners, are convinced that water constitutes 98% of fingerprint components, and others admit that water accounts for between 98 and 99,5% of eccrine sweat secretions. However, the scientific facts are different from these claims[54]. It was evidently shown above how numerous factors that affect the final composition mixture of the fingerprint constituents are. Moreover, a recent study published in *Forensic Science International* emphasized how erroneous this claim is[55]. By using a method based on published analytical data, theoretical models, and common sense, with emphasizing the interfered exogenous and endogenous sources, it has been determined that sweat is not the mere source of the water content in fingermarks. Moreover, there is no scientific experimental evidence stating that purely eccrine fingermark secretions would contain approximately 98% of water, due to the evaporation of the water found on the skin, its re-absorption by the skin, as well as deposition mechanisms on the substrate. However, chlorides, amino acids, and other water-

[52] A. Girod et al., op. cit.

[53] P.D. Barnett, R.A. Berger, "The effects of temperature and humidity on the permanency of latent fingerprints", *Journal of the Forensic Science Society* 16, 1976, no. 3, pp. 249–254.

[54] The Home Office Centre for Applied Science and Technology (CAST), op. cit.; G. de Paoli et al., op. cit.; L.S. Ferguson, op. cit.; A. Girod, R. Ramotowski, C. Weyermann, op. cit.

[55] T. Kent, "Water content of latent fingerprints: Dispelling the myth", *Forensic Science International* 266, 2016, pp. 134–38, https://doi.org/10.1016/j.forsciint.2016.05.016.

soluble components affect the vapor pressure and consequently evaporation rates, whereas other deposited materials become more concentrated.[56]

Kent estimated the average water content of a natural fingermark would be nearer to 20% or even lower. Another research based on experimental analysis, hand-washing procedure before the deposition of the eccrine-rich fingermarks (sweat constituents), and the monitoring of mass loss due to substrate heating (40°C), within the first minutes after deposition observed mass loss ranging from 20 to 70%.[57]

Conclusion

Notwithstanding claims to the contrary, the study proves the reliability of fingerprint evidence, raising awareness of the complex mixture of fingermark constituents which supports its persistence over time, as well as the possibility of extracting criminal intelligence by a chemical and/or spectral analysis. At the same time, a lack of fingermarks from an item does not imply that the suspect did not touch it, nor that the item was wiped up. Moreover, it is the fingerprint expert, not the AFIS, who makes the fingerprint identifications, and that is why the fingerprint conclusions are not decisive. Furthermore, numerous technologies are being developed to make fingermarks retrievable from items after being wiped up or cleaned, and after being exposed to sunlight, water flow, rain, or humidity. That depends on the numerous types of molecules found within the fingermark constituents where the water percentage is usually under 98%. The second part of this study will discuss the other fourteen myths about fingerprint evidence.

Conflict of interest

The authors declare that there is no conflict of interest regarding the paper's publication.

[56] Ibid.

[57] A. Bécue, H. Eldridge, Ch. Champod, "Interpol review of fingermarks and other body impressions 2016–2019", *Forensic Science International: Synergy* 2, 2020, https://doi.org/10.1016/j.fsisyn.2020.01.013.

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Myths about fingerprint evidence: Basic facts countering miscarriage of justice. Part 2

Saleh Mansour

ORCID: 0000-0002-4111-4704
Faculty of Criminology, Lebanese University
Beirut, Lebanon

Shital Zade

ORCID: 0000-0003-1976-8477
International Forensic Science Pvt. Ltd
Pune, Maharashtra, India

Shipra Rohatgi

ORCID: 0000-0003-0532-9908
Amity Institute of Forensic Sciences, Amity University
Noida, India

Slobodan Oklevski

ORCID: 0000-0002-1116-5631
Ministry of Interior, Republic of North Macedonia

Abstract

This is the second part of the study that aims at highlighting twenty-four myths about fingerprint evidence. In this paper, the authors are going to explicate and clarify the difference between the scientific facts and the wrongful concepts that negatively affect

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the justice system and the effective usage of fingerprint evidence starting from the initial investigation at the crime scene until the final trial at the courtroom.

Keywords: fingerprint aging, constituents, skin anatomy, processing techniques, delicate surfaces, fingerprint sensitivity, evidence interpretation, ACE-V methodology, AFIS

Introduction

Myths about fingerprint evidence are conceptions acquired by law enforcement officers, investigators, prosecutors, judges, and even the public about issues related to fingerprints concerning their constituents, sensitivity against environmental factors – such as sunlight, airflow, temperature, water flow, humidity, etc. – their ability to be developed, and the influence of the time passed after the deposition on their constituents.

Currently, the preconceptions and confusion related to fingerprints lead to negative results regarding the investigation process, human rights issues, as well as criminal justice. For instance, admitting that a fingermark is demolished as a consequence of time and/or environmental factors tends to dismiss developing these fingermarks, which deprives the investigators of fundamental information about the crime scene, allowing the possibility to wrongfully proceed against an innocent person, and leaving the real perpetrator excluded.

As will be shown, there are also other myths which have a highly negative impact on the criminal investigation process as a whole.

1. Fingermarks deposited on surfaces touched by many people are highly sensitive to pollution

The most famous cases representing this myth involved fraud using bank checks without the provision fund, where the check leaf was touched by the perpetrator, the victim, the employees at the company, and the employees in the bank. In the majority of these cases the prosecutors as well as the investigators have not considered processing the fingermarks as an effective way to solve the crime, and consequently, they refrained from asking for that.

However, the check leaf substrate is paper-based, hence it is made up of cellulose, which is good for preserving amino acids for a long time, as mentioned in the previous part of the article.[1] Additionally, due to the psychological aspect and the automatic nervous system response,[2] when the perpetrator becomes highly excited, their various gland secretions multiply beyond the normal levels and penetrate the substrate texture, unlike the secretions from other persons who have touched the substrate, as the amount of their deposited materials is smaller than that of the criminal.

Even though the biological traces are highly sensitive to pollution, because the DNA analysis will show mixed components from different people, and this would negatively affect the biological evidence, the shape of the fingerprint itself is not sensitive to pollution, even when the surface has been touched by many individuals.

2. Developing a fingermark from a textile fabric substrate is impossible

Textile materials include items such as clothing, underwear, bedclothes, furniture, and curtains. Clothing evidence is typically found at crime scenes of physical violence such as murder attempts and sexual assault cases, hence visualizing identifiable fingermarks as well as finger and palmar flexion crease details will be an essential clue to solve such crimes.[3]

However, textile substrates have been excluded from consideration by prosecutors and investigators a long time ago, based on incorrect convictions about the delicate texture of fabrics and textiles. The majority

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[1] Police Technique et Scientifique (PTS), Division des Etudes des Liaisons et de la Formation, Centre Nationale de Formation, *Révélation Des Traces Papillaires Par Les Procédés Physico-Chimiques*, Ecully, 2011.

[2] M. Richter, R. Wright, "Autonomic nervous system", [in:] *Encyclopedia of Behavioral Medicine*, 2012, https://www.researchgate.net/publication/280650893_Autonomic_nervous_system (accessed: 16.06.2020).

[3] J. Fraser et al., "Visualisation of fingermarks and grab impressions on fabrics. Part 1: Gold/zinc vacuum metal deposition", *Forensic Science International* 208, 2011, pp. 74–78, https://doi.org/10.1016/j.forsciint.

of fabrics are porous surfaces, with different softness and porosity levels depending on their type and texture fabrication. For example, cotton and wool under microscopic level examination shows evident porosity and roughness, whereas synthetic fibers such as nylon and polyester are non-porous and have a more regular fractious texture. However, fibers usually contain dyes and stain-resistant substances. These factors give advantage to the visualization process and raise the chances of obtaining clear details of fingermark ridges – and if not, the examination could assist in locating the touched areas for DNA swabbing and affording contextual indication confirming push/grab scenarios.[4]

All things considered, visualization of fingermarks with clear ridge details from fabrics can be negatively influenced by other factors, for instance if:

– the fabric has a weave of fewer than three threads per mm;
– the fabric surface has been worn against the skin in warm environments, during physical activity, and/or for prolonged periods.[5]

In the same fashion, vacuum metal deposition is the most appropriate technique for processing fingermarks from natural fiber substrates (such as cotton and wool), whereas for synthetic fiber substrates the appropriate techniques are both VMD (gold/zinc and silver/zinc) and superglue fuming. IR reflection can effectively boost the fingermark contrast with the substrate after VMD.[6] Accordingly, powder dusting, DFO, ninhydrin, and physical developer are unsuitable for enhancing fingermarks from fabrics.[7]

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[4] The Home Office Centre for Applied Science and Technology (CAST), *Fingermark visualisation manual*, 2014, http://www.officialpublicationsonline.co.uk.libproxy.abertay.ac.uk/publications/download/9781782462347.

[5] Ibid.

[6] GoEvidence Forensic Laboratories, "Vacuum Metal Deposition (VMD)", http://www.goevidence.com/vacuum-metal-deposition-vmd (accessed: 21.06.2020); J. Fraser et al., op. cit.; University of Abertay Dundee, Scottish Police Services Authority, *Fingerprints lifted from fabric: A new twist on old school forensics lets investigators lift prints from fabrics*, https://www.cnet.com/news/police-researchers-lift-fingerprints-from-fabric/ (accessed: 21.06.2020); University of Abertay Dundee, "Forensic breakthrough: Recovering fingerprints on fabrics could turn clothes into silent witnesses", *ScienceDaily*, 2.02.2011, https://www.sciencedaily.com/releases/2011/01/110131073141.htm (accessed: 21.06.2020).

[7] The Home Office Centre for Applied Science and Technology (CAST), op. cit.

Fraser et al.[8] studied the influence of various factors on visualizing fingermark ridge details and flexion of the palm print on different fabric types and found that the potential of developing ridge details identified on the shiner tighter weave nonporous textiles such as nylon and polyester, is higher than on rough porous textiles such as cotton and wool, even though grab-impressions can still show. However, they reported that the fingermark age and donor characteristics are influencing factors on the clarity and reliability of fingermarks developed from textiles. Despite earlier development of samples that may allow us to better visualize details, old fingermarks can give another detail such as ridge or palmer flexion crease as well as allocate the touched area for DNA swabbing.

3. It is impossible to retrieve a fingerprint from human skin

Human skin, similarly to any other surface, can receive the deposited materials of the ridged skin which form the shape of the fingerprint. There are six main ways to reveal fingerprints from human skin: cyanoacrylate, the iodine-silver plate transfer method, magnetic powder, Dakty-foil, RTX (ruthenium tetroxide) process, and the X-ray method.[9] These could be refined by two secondary methods, namely the application of laser radiation and of photographic paper lift technique.[10] All these processes have already been tested and proven to have excellent outcomes.[11]

In physical violence crimes and sexual assaults, human skin can be a surface of deposited fingermarks, which is delicate due to its roughness, high flexibility, continuous secreting mechanism which will continue for several minutes after death, as well as hair presence, along with the level of deformation that can occur during contact. These are factors that make developing clear ridge details less likely and result in a very poor sig-

[8] J. Fraser et al., op. cit.

[9] C. Champod et al., *Fingerprints and other ridge skin impressions*, Boca Raton-London 2004.

[10] M. Trapecar, J. Balazic, "Fingerprint recovery from human skin surfaces", *Science and Justice* 47, 2007, no. 3, pp. 136–140.

[11] H.J. Hammer, "Methods for detection of latent fingerprints from human skin", *Forensic Science International* 16, 1980, no. 1, pp. 35–41, https://www.ncbi.nlm.nih.gov/pubmed/7399379.

nal to noise ratio.[12] However, hairless smooth skin areas are the most favorable for good fingermark recovery.[13] Despite these complications, certain cases, such as manual strangulation, would indicate the presence of fingermarks on the neck of the victim.[14]

Although laboratory experiments highlighted the influence of time elapsed after deposition on visualizing clear prints from live persons and cadavers and indicted that only fresh prints (< 15 min) can be consistently detected, many researchers reported successful visualization of fingermarks from cadavers: Delmas (1988), Hamilton and Dibattista (1985), Misner et al. (1993), Mashiko et al. (1991), Mashiko and Miyamoto (1998), Dolci (1992), Donche (1994).[15]

4. Eye biometrics represented by iris or retina biometrics is more important in human identification than the fingerprint

The iris is the annular region of the eye bounded by the pupil and sclera (white part of the eye), unique and immutable. Iris patterns are formed during the first period of fetal formation, and the iris is pigmented in the two years following the birth. However, the formation of its patterns is not related to any genetic factors, unlike the eye color, so the pattern in which the iris is formed is an individual and unique one. Even identical twins have different iris patterns. Besides, the iris is persistent – its unique characteristics remain stable throughout the life of adult individuals, which makes it highly acceptable as a biometric measure for identifying individuals and personal identification.[16]

Iris biometrics is an automated process of identifying individuals based on their unique iris pattern by comparing their iris digital templates against the ones stored in the database. Its main implementation fields are: immigration systems, passports, visas, ID issuing, passenger control

[12] C. Champod et al., op. cit.

[13] S.M. Bleay, R.S. Croxton, M. de Puit, *Fingerprint development techniques, theory, and application*, Hoboken, NJ 2018.

[14] C. Champod et al., op. cit.

[15] Ibid.

[16] P. Sevugan et al., "Iris recognition system", *International Research Journal of Engineering and Technology* 4, 2017, no. 12, pp. 864–868, https://www.researchgate.net/publication/322222447_IRIS_RECOGNITION_SYSTEM.

at the airports and other border checking points, providing positive identity assurance for larger transactions at live teller machines which lower the risk of losses due to identity theft, and all other areas where asserting an identity is necessary.[17]

On the other hand, retina recognition relates to the individual blood vessel pattern on the thin nerve on the back of the eyeball which processes light entering through the pupil. Similarly to the iris, each eye has its unique pattern of blood vessels, and this applies even to the eyes of identical twins. This distinctive pattern remains stable throughout an individual's life, but it can be affected by some diseases, such as increased pressure inside the eyeball which causes gradual loss of vision (glaucoma), diabetes, high blood pressure, and autoimmune deficiency syndrome.[18]

A point often overlooked is that physical evidence retrieved from the crime scene has two main roles: proving that a crime was committed and identifying the criminal. Nevertheless, the main question about iris and retina identification of criminals is whether iris or retina traces could ever be found at the crime scene. Hence, iris and retina recognition methods are considered particularly important in terms of securing border crossing points and various institutions relying on personal identification, but they are ineffective for investigating the crime scene.

5. A specific number of features should be used to reach a conclusion

Unlike DNA identifications, features within a fingerprint do not happen at a constant rate, making it impossible to establish a frequency distribution.[19] Even a large number of features does not necessarily prevent an error – the clarity and rarity of the features are vital.

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[17] M. Singh, D. Singh, P. Kalra, "Fingerprint separation: an application of ICA", *Proceedings of the SPIE, Mobile Multimedia/Image Processing, Security, and Applications* 6982, 2008.

[18] F. Sadikoglu, S. Üzelaltınbulat, "Biometric retina identification based on neural network", *Procedia Computer Science* 102, 2016, pp. 26–33. https://doi.org/10.1016/j.procs.2016.09.365.

[19] Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council, *Strengthening forensic science in the United States: A path forward*, Washington, D.C. 2009, p. 140, http://www.nap.edu/catalog/12589.html; J. Polski et al.,

Positive identification within the empirical approach of friction ridge requires an assessment of the presented information or empirical standards, which varies between states (usually between 8, 12, and 16),[20] as well as the validation of this information and the final conclusion of the comparison process.[21] In contrast, the holistic approach requires disseminating three levels of details. The first one is the overall pattern, which could be used only for exclusion. The second level relates to the ridge flow and other features such as flexion creases, the number and sequence of ridges, and the type and location of ridge characteristics. The third one includes the microscopic details of ridge edges (edgeoscopy), the number, shape, location, and distribution of the pores (poroscopy) as well as flexion lines, wrinkles, and scars. The last two-level details are used in correspondence with each other.[22]

Hence, the empirical approach needs a threshold of a minimum number of friction ridge details, whereas the holistic approach does not need such a threshold.

6. Fingerprints are the most certain form of identification

All epithelial skin is equally unique (retina, iris, lips, etc.). Fingerprints are collected more often from crime scenes because they are deposited there more often.

The general requirement to arrive at a conclusion regarding identity based on fingerprint evidence is to find a sufficient number of matching ridge characteristics in the questioned fingerprint and the known reference fingerprint. These ridge characteristics, for example, may be ridge endings or bifurcations. It is also required that there are no unexplainable differences between the two impressions. For instance, what to a lay-

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Report of the International Association for Identification, Standardization II Committee, 2011, https://nij.ojp.gov/library/publica tions/ (accessed: 28.06.2020).

[20] H.M. Daluz, *Fingerprint analysis laboratory workbook*, Boca Raton 2018.

[21] Interpol European Expert Group on Fingerprint Identification II, *Method for Fingerprint Identification*, part 2. *Detailing the method using common terminology and through the definition and application of shared principles*, Lyon 2004, http://www.latent-prints.com/images/ieegf2.pdf.

[22] Ibid.

person may appear as differences may simply be due to a natural skin distortion at the time the fingerprint was deposited. However, a difference in ridge count between two minutiae would be grounds for concluding that the two impressions are not from the same source. The methodology accepted by the international fingerprint community is referred to by the acronym ACE-V.[23]

– Analysis: the initial information-gathering phase in which the fingerprint examiner studies the questioned fingerprint to assess the quality and quantity of ridge details present.

– Comparison: the side-by-side observation of the two marks (the questioned fingerprint and the reference fingerprint) to determine the agreement or disagreement in the ridge detail.

– Evaluation: assessment by the examiner of the agreement or disagreement in the ridge detail observed during the analysis and comparison phases and the formation of a conclusion.

– Verification: an independent re-examination by a second examiner, preferably without the second examiner knowing the outcome of the first examination.

According to the Scientific Working Group on Friction Ridge Analysis, Study and Technology,[24] the current practice is that there are only three possible outcomes from applying this methodology.

– Individualization: there is a sufficient number of features in agreement to conclude that the two areas of friction ridge impressions originated from the same source and the likelihood that the impression was made by another (different) source is so remote that it is considered a practical impossibility.

– Exclusion: there is a sufficient number of features in disagreement to conclude that the two areas of friction ridge impressions did not originate from the same source.

– Inconclusive: the corresponding information in the latent and exemplar prints is inadequate to allow a conclusion. Typically, the exa-

[23] Scientific Working Group on Friction Ridge Analysis, Study, and Technology, *Standards for examining friction ridge impressions and resulting conclusions*, https://www.nist.gov/system/files/documents/2016/10/26/swgfast_examinations-conclusions_2.0_130427.pdf (accessed: 28.06.2020).

[24] Ibid.

miner provides no additional information regarding the chances that the two prints did or did not share a common source.

Some of the early guidelines were established around 100 years ago and there is no better example than the work published by dr. Edmond Locard, the scientist responsible for the Locard Exchange Principle (from 13 December 1877 to 4 April 1966). Concerning the comparison of a latent mark with a reference fingerprint, he stated in 1914 that:

> 1. If more than 12 concurring points are present and the fingerprint is sharp, the certainty of identity is beyond debate.
> 2. If 8 to 12 concurring points are involved, then the case is borderline and the certainty of identity will depend on the sharpness of the fingerprint, the rarity of its type, the presence of pores, etc. and,
> 3. If a limited number of characteristic points are present, the fingerprints cannot provide certainty for an identification, but only a presumption proportional to the number of points available and their clarity.[25]

However, the official position of the International Association for Identification, effective August 21, 2009, is as follows: "There currently exists no scientific basis for requiring a minimum amount of corresponding friction ridge detail information between two impressions to arrive at an opinion of single-source attribution."[26]

7. Overlays are a good way of verifying a conclusion

The skin is flexible. Overlaying images will *never* result in an exact match. It mainly occurs in latent fingerprints lifted from crime scenes.[27] When the same location of a surface is touched by two fingers at different times, the developed latent image may contain overlapped fingerprints. Overlapping may also occur in live-scan fingerprint images when the surface of fingerprint sensors contains residue of preceding fingerprints.

The overlapped fingerprints constitute a serious challenge to the current generation of fingerprint recognition technology. Manually marking features in overlapped fingerprints is also very difficult even for experi-

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[25] C. Champod et al., op. cit.

[26] J. Polski et al., op. cit.

[27] A.K. Jain, J. Feng, "Latent fingerprint matching", *IEEE Transactions on Pattern Analysis and Machine Intelligence* 33, 2011, no. 1, p. 99.

enced fingerprint experts. Although the basic Fourier domain band-stop filtering technique can be used to remove overlapping repetitive lines in latent images,[28] separating overlapped fingerprints, which are not straight lines, is much more complicated. Therefore, it is necessary to develop a technique that can automatically separate overlapped fingerprints into individual ones.

Forensic scientists have proposed separating overlapped latent fingerprints using gold nanomaterial during the latent development stage.[29] While this technology is very interesting, it is not convenient and only works for some types of overlapped latent fingerprints. A more universal solution would be to develop an image processing algorithm to perform the separation task. Such an algorithm would not only benefit fingerprint recognition systems, but also simplify manual feature marking. Its aim would be to separate overlapped fingerprints based on image enhancement using manually marked orientation field. Nevertheless, it is very tedious and time-consuming for the user to manually mark the orientation field of each component fingerprint in the overlapped fingerprint image,[30] and morphological component analysis is used to separate overlapped fingerprints. However, there is an experiment showing that this algorithm can only separate the component fingerprint which dominates the overlapped image.[31] Independent component analysis (ICA) can also be used to separate overlapped fingerprints.[32] Unfortunately, no details are provided on how to apply ICA to separating overlapped fingerprints.

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[28] S. Bramble, P. Fabrizi, "Observations on the effects of image processing functions on fingermark data in the Fourier domain", *Proceedings of SPIE* 2567, 1995; W.J. Watling, "Using the FFT in forensic digital image enhancement", *Journal of Forensic Identification* 43, 1993, no. 6, pp. 573–584.

[29] H. Tang et al., "Gold nanoparticles and imaging mass spectrometry: Double imaging of latent fingerprints", *Analytical Chemistry* 82 (5), 2010, pp. 1589–1593.

[30] Chen F., Feng J., Zhou J., "On separating overlapped fingerprints", *IEEE 4th International Conference on Biometrics: Theory, Applications and Systems (BTAS)*, 27–29 September 2010, Washington, D.C.

[31] R. Geng, Q. Lian, M. Sun, "基于形态学成分分析的指纹分离 (Fingerprint separation based on morphological component analysis)", *计算机工程与应用* (*Computer Engineering and Applications*) 44, 2008, no. 16, pp. 188–190.

[32] M. Singh, D. Singh, P. Kalra, op. cit..

8. Touching surfaces while wearing gloves will not leave fingerprints

The skin consists of three main layers: the epidermis, the dermis, and the hypodermis. Combined, the layers play crucial roles: providing the body with a protective barrier, regulating body temperature, sensation, various secretions, immunity, blood storage, and synthesis (vitamin D).[33]

Papillary ridges' formation

The outer layer of palms and soles consists of prominent papillae and recesses in the form of furrows, canals, or valleys. Papillary ridges are formed in the dermis or the inner skin layer, and these ridges have tiny niches known as sweat pores that connect to the sweat glands scattered under the surface of the skin with channels through which secretions pass. Additionally, papillary ridges begin to develop in the fetus starting at the sixth and seventh week of estimated gestational age (GA), and ends at about the seventeenth week. The friction ridge pattern itself is established between the tenth and fourteenth week of GA, when these ridges are separate cells that soon grow, multiply, and stick together to form the final shape in which they appear since there are accurate porous holes in the middle of these ridges that allow the secretion of the sweat glands.[34]

The roots of the papillary ridges and the separating furrows which are located on the outer layer of the skin are attached to and firmly rooted in the dermis, in which the primary and secondary ridges are formed. The primary ridges are below the ridges, while the secondary ridges are under the furrows. All of the aforementioned ridges are intertwined and interlocked with the dermis to provide support and strength to the outer

[33] A.V. Maceo, "Anatomy and physiology of adult friction ridge skin", [in:] National Institute of Justice, *The fingerprint sourcebook*, pp. 2-1–2-26, https://www.ojp.gov/pdffiles1/nij/225320.pdf; S.Z. Li, "Encyclopedia of biometrics", [in:] *Encyclopedia of biometrics*, New York 2009, pp. A25–A27, F462, F514, F538, S1225–S1226, https://doi.org/10.1007/978-3-642-27733-7.

[34] A.V. Maceo, op. cit.; S.Z. Li, op. cit.

skin layer, and the sweat glands extend from the primary hills to concentrate in the dermis or the inner skin layer.[35]

However, the average ridge thickness in the epidermis skin is 0.8–1.44 mm, whereas in other skin layers it is 0.07–1.12 mm[36], compared with the average thickness of the latex gloves which is between 0.1028, 0.1285, 0.1542, and 0.1799 mm for various brands.[37] Accordingly, papillary ridges are thicker than gloves when the ridged skin exceeds 0.18 mm, where the gloves play the role of an additional layer of the five consecutive epidermis layers, which depicts the same shape of the ridge pattern and is able to transfer this shape to the touched articles.

Hence, snug-fitting latex gloves act as another layer of skin and one can easily leave very clear fingerprints while wearing them. Leather gloves, on the other hand, can leave prints of the cowhide patterns.[38]

9. The error rate of fingerprint identification when implementing ACE-V methodology is zero

No research has ever indicated this or has stated the specific details of the tested ACE-V methodology. Researchers may have asked the examiner to use a certain method, but there has been no testing to indicate whether this method was used or not.

However, fingerprint identification includes human intervention which involves human bias, which negatively influences the conclusions. ACE-V methodology helps to minimize this bias in its narrower scope, but the accurate implementation of the methodology is still under question. In the same fashion, some fingerprint departments have standard operation procedures (SOP) which include rigid measures of blind verification as well as the independent intervention of higher qualified fingerprint experts to revise the whole identification process and validate it.

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[35] A.V. Maceo, op. cit.; University of Abertay Dundee, Scottish Police Services Authority, *Fingerprints…*

[36] Ibid.

[37] S.M. Bleay, R.S. Croxton, M. de Puit, op. cit.

[38] N.E. Archer et al., "Changes in the lipid composition of latent fingerprint residue with time after deposition on a surface", *Forensic Science International* 154, 2005, no. 2–3, pp. 224–239, https://doi.org/10.1016/j.forsciint.2004.09.120.

Equally important is the execution of the microscopic third-level details, which leads to additional checking of similarities and dissimilarities. There is also the condition of involving a minimum number of three fingerprint examiners to have a solid conclusion, where each applies the concerned methodology in blind verification. All these procedures play a significant role in decreasing error rates and overcoming human bias. Nonetheless, avoiding human bias and achieving the zero-error rate is still an unachievable goal in fingerprint identification.

10. Fingerprint identification is always solid evidence against the suspect

Missing the interpretation phase as well as bad interpretation of the fingerprint identification evidence can lead to wrong conclusions and accusing an innocent person of the crime. The interpretation phase must be conducted by three parties: the investigator, the prosecutor, and the laboratory technician for further clarifications.[39]

David Ashbaugh,[40] among others, has noted that fingerprint individuality – and therefore fingerprint identification – rest on four premises.

1. Friction ridges develop in their definitive form in fetuses.
2. Friction ridges remain unchanged throughout life except for permanent scar.
3. The friction ridge pattern and its details are unique.
4. The ridge patterns vary within certain boundaries that allow the patterns to be classified.

The primary limitation of fingerprint analysis is that there must be a known print to be compared with the collected print. Unless there is a suspect or the perpetrator's print is found in one of the many databases around the world, the collected prints will likely only be used to exclude individuals from the investigation.

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[39] S.L. Cooper, "Challenges to fingerprint identification evidence: Why the courts need a new approach to finality", *Mitchell Hamline Law Review* 42, 2016, no. 2, http://open.mitchellhamline.edu/mhlr/vol42/iss2/8.

[40] D.R. Ashbaugh, *Ridgeology: Modern evaluative friction ridge identification*, Ottawa 1989, https://onin.com/fp/ridgeology.pdf.

Another limitation is that there is no scientific way to determine the time a latent print was deposited on a surface. An examiner cannot tell how long a print has been on a surface or under what circumstances it was placed there. For example, if a suspect's print is found in the kitchen of a murdered acquaintance, the print may or may not be tied to the murder, especially if the suspect claims to have visited the victim's house fairly recently.

11. The fingerprints of identical twins might be identical

There are three levels of fingerprint comparison: the first is the type of the print (loop, whorl, arc), the second – the Galton details, and the third – the microscopic details. Since the first level represents the general shape of the fingerprint, there can are many similarities and, consequently, no identification can be made at this level. In the second level, there are also some similarities between the characteristic points such as ridge beginning, ending, and bifurcation, but in the empirical approach of the fingerprint comparison, the incident of having a sufficient amount of these similarities from the same types at the same places is impossible. In the third-level details, represented by edgeoscopy and poroscopy, the similarities become extremely rare. This level is used mainly in difficult traces, when there are fewer second-level details, or in very serious cases such as terrorism.

Furthermore, in each fingerprint there are between forty to one hundred minutiae of second-level details[41] where not one of these points is identical with the others, even though similarities may occur, namely with most frequently repeated details such as bifurcation and ridge ending. If they do occur, the third level provides the expert with the microscopic clarity that demonstrates the differences.

Lin et al.[42] concluded that "although fingerprints [of identical twins] may have a high degree of similarity […] variations in minutiae distribu-

[41] R. Bansal, P. Sehgal, P. Bedi, "Minutiae extraction from fingerprint images – a review", *International Journal of Computer Science Issues* 8 (5), 2011, no. 3.

[42] C.H. Lin et al., "Finger-print comparison I: Similarity in fingerprints", *Journal of Forensic Sciences* 2, 1982, no. 27, pp. 290–304.

tion still permit their differentiation", and the National Forensic Science Technology Center has stated that no two fingerprints have ever been found to be identical, from different sources, and this includes identical twins.[43]

12. It is impossible to determine sex from a fingermark

One of the most widespread myths is that determining sex from a fingermark is beyond the capacity of science. However, the perpetrator's sex can be established if there is a sufficient amount of biological traces within the constituents of the fingermark. A recent study based on a scientifically proven analytical method – which depends on Matrix Assisted Laser Desorption Ionization Mass Spectrometry Profiling mode as a forensic diagnostic tool to perceive and map molecular data of fingermarks, Partial Least Square Discriminant Analysis, and the employment of extensive statistical modelling – succeeded to determine a model with the highest sex predictive accuracy. The main negative effect on this accuracy is represented by the presence of polymers as external contaminants in natural fingermarks. To overcome this problem, the concerned study proposed using a specific type of scoring system with 86.1% predictive power to differentiate male and female fingermarks.[44] The major significance of the study is to provide the investigators and criminal intelligence analysts with critical intelligence information, which positively influences the effectiveness of criminal justice.

13. A fingerprint will disappear when it is exposed to direct sunlight

The sun emits a wide range of wavelengths in the form of visible and invisible electromagnetic radiation. In fact, invisible ultraviolet radiation blocks the short-wavelength UVC radiation as much as the atmosphere,

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[43] National Forensic Science Technology Center, *A simplified guide to fingerprint analysis*, 2013, http://www.forensicsciencesimplified.org/prints/Fingerprints.pdf.

[44] C. Heaton et al., "Investigating sex determination through MALDI MS analysis of peptides and proteins in natural fingermarks through comprehensive statistical modelling", *Forensic Chemistry* 20, 2020, https://doi.org/10.1016/j.forc.2020.100271.

and the earth receives the two other longer wavelength UVB and UVA. However, indoor exposure to these types of UV radiation has a lesser effect, as window glass plays the role of an additional filter. The infrared wavelength extends beyond 2000 nm, which has a considerable effect since it warms the substrates that absorb a significant dose of these wavelengths.[45]

Despite the fact that the sunlight speeds up the evaporation process of water and water-soluble molecules, as mentioned above, it will have a very small effect on solid and non-evaporative materials, even if these are fingermark traces of very tiny quantities that cannot be seen by the naked eye. Furthermore, the thermal process of fingerprint development from many surfaces has distinctive results whether the surface is made of textiles, paper, cotton, banknote, or any other materials. The Thermal Fingerprint Developer TFD-2 is used to develop fingerprints from different surfaces just by heating, i.e. without using any reagents, and it provides satisfying results. Hence, the fingerprint deposited on a thermal paper will be developed automatically when it is exposed to sunlight or warm air. Nevertheless, when the deposited surface is exposed to sunlight, fingerprint development specialists at the forensic laboratory have to study all the influencing factors of the case and identify all the relevant conditions to design the proper plan for fingerprint development.

14. The fingerprint will disappear when it is exposed to water flow, rain, or humidity

In fact, water is a major ingredient of sweat glands secretions that has the potential to evaporate immediately after the deposition, unlike other ingredients such as amino acids and lipids. Hence, for this kind of fingermarks water plays a critical role in determining the other insoluble ingredients, assuming that low humidity levels accelerated the drying process, whereas high humidity levels extended the water preservation.[46] However, Barnett and Berger studied the influence of humidity, temperature, and time on the clarity of fingerprints. They stored finger-

[45] S.M. Bleay, R.S. Croxton, M. de Puit, op. cit.
[46] Ibid.

marks with humidity ranging between 32 and 93% and found that its influence on determining the fingermark clarity was minimal. They also concluded that the main influencing factor affecting the fingermark is the primarily originated print quality and not humidity and temperature. Additionally, they experimentally proved the persistence of fingermarks for weeks in rather extreme storage conditions, and their development still gave detectable results.[47]

The non-soluble contents of eccrine sweat, sebaceous, and apocrine glands as well as other contaminating materials are less affected by water and humidity. For instance, sebum, triglycerides, and fatty acids need direct effort and/or detergents to be swiped from non-porous substrates, contrary to the porous and semi-porous substrates, which absorb the majority of fingermark compositions and motivate amino acids to adhere with the cellulose molecules of paper-based substrates.[48] However, extreme rain or water immersion may cause corrosion on metal substrates and the dissolving of water-soluble constituents, causing their collapse.

Heavy rain conditions might have an impact on some components of the fingerprint, but the question remains who can confirm whether the fingermark has disappeared or not. The crime scene investigator has no right to assume that the fingerprints have disappeared – this myth may lead to dismissing important evidence which might solve the crime and strongly support the investigation. It is easy to develop a fingerprint in normal conditions, but in such challenging cases the procedures are different and the interference of a laboratory technician is crucial. At the same time, the small particles reagent (SPR) is an ideal way to reveal fingerprints from wet surfaces, even after rain, knowing that the rain has less effect on the fatty components as well as others, such as sebum, squalene, or oleic acid.

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[47] P.D. Barnett, R.A. Berger, "The effects of temperature and humidity on the permanency of latent fingerprints", *Journal of the Forensic Science Society* 16, 1976, no. 3, pp. 249–254.

[48] K. Wertheim, "Fingerprint age determination: Is there any hope?", *Journal of Forensic Identification* 53 (1), 2003, pp. 42–49.

A new experimental study by Kapoor et al. involved submerging objects of eight different substrates for a different period of time, ranging from 0.5 up to 120 hours. The results showed the efficacy of using the brushing method of Robin powder blue and silver magnetic dual powder, which gave notable clarity of fingermarks. Accordingly, the authors emphasize the importance of enhancing fingerprints from recovered items regardless of the time they spent underwater.[49]

Conclusion

To summarize, the fingerprint evidence procedures consist of nine essential and complementized steps: collection, development, analysis, comparison, evaluation, verification, reporting, quality control, and interpretation. However, the interpretation step is the most critical and crucial one as it evaluates the whole adopted procedure and presents the real meaning of the evidence, not the superficial meaning that might contradict the facts. As a result of wrongful ideas about fingerprint evidence, some scientists have claimed the fingerprint science is unreliable, instead of admitting the fact that what leads to wrong results are preconceptions and individual mistakes. This, however, does not make forensic science itself unreliable. Knowing the scientific side of these myths is likely to result in a perfect interpretation of the fingerprint evidence – and accordingly, ignoring those facts may lead to a bad interpretation of the fingerprint evidence, due to which an innocent person will be convicted and the criminal will walk free.

Ultimately, as much as forensic scientists should conduct more in-depth research on fingerprints, crime scene technicians, investigators, prosecutors, and judges also ought to change their preconceived ideas and cooperate more with forensic scientists and specialists. In this way, the justice system can benefit from the new developments, techniques, advances, and innovations that are occurring in fingerprint science.

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[49] N. Kapoor et al., "Development of submerged and successive latent fingerprints: a comparative study", *Egyptian Journal of Forensic Sciences* 9, 2019, https://doi.org/10.1186/s41935-019-0147.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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How to account for the possibility of disguise when assessing signature comparisons

Raymond Marquis

School of Criminal Justice, University of Lausanne, Switzerland

Tacha Hicks

ORCID: 0000-0002-0114-5258
School of Criminal Justice, University of Lausanne, Switzerland

Williams Mazzella

School of Criminal Justice, University of Lausanne, Switzerland

Abstract

Following the recommendations of the ENFSI guideline for evaluative reporting, forensic handwriting examiners should assign a LR to evaluate their results. But when evaluating the results of a signature analysis, how should one account for the possibility of disguise? The present paper explores three possible solutions. The first option could be to assign two LR values, one assuming that the questioned signature was disguised, and the other that it was sincerely written. The authors show that this option is not optimal, since propositions ought to be exhaustive in the context of the case. It is the expert's task to take into account all the relevant information to assess results in a meaningful way. The second option suggests partitioning the proposition of a genuine signature based on the event of disguise and non-disguise. This requires assigning probabilities of disguise and non-disguise and could impact the value of the results. The third option is to

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consider only the events that have an impact on the case and not formalising those that do not solely for the sake of exhaustiveness. These developments will hopefully help forensic handwriting examiners to cope with the possibility of disguise when assessing the value of signatures in casework.

Keywords: handwriting examination, signature analysis, forensic interpretation, likelihood ratio, Bayesian framework

Introduction

In 2015, the European Network of Forensic Science Institutes (ENFSI) published a guideline for evaluative reporting in forensic science.[1] This guideline recommends following the likelihood ratio (LR) approach for assessing the value of forensic results. This method typically should be adopted in cases where an evaluation needs to be carried out by a forensic scientist after having compared a questioned item and reference material from a known source.

More and more laboratories in Europe and abroad are moving towards the LR approach, which is now well documented and developed in many forensic disciplines, such as forensic genetics, micro-traces, fingerprints, firearms, and handwriting analysis. The method provides a standardized basis and a common language between experts, which is in agreement with scientific requirements. The desired properties of forensic scientists' statements, which include balance, logic, robustness, and transparency, can be met by following the principles of forensic interpretation,[2] also highlighted in the guideline.

The guideline introduces the framework in which the method is applied, exposes principles[3] and concepts, gives advice on communicating

[1] S. Willis et al., *ENFSI guideline for evaluative reporting in forensic science*, 2015, http://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf.

[2] I.W. Evett et al., "The impact of the principles of evidence interpretation on the structure and content of statements", *Science and Justice*, 40, 2000, pp. 233–239.

[3] According to these principles, the assessment is always carried out in a set of circumstances (and relevant information must be taken into account), it is based on two propositions at least (which generally represent the views of the parties at trial), and the forensic scientist evaluates the results (in the light of the propositions) and not the propositions themselves (in the light of the results).

the value of forensic results. It also provides some examples in various disciplines of forensic science to help readers understand the method. However, the guideline is not designed to help forensic scientists assign a LR given case specifics, nor to assist forensic scientists in eliciting probabilities that take part in their LR. Without appropriate education it is therefore difficult for forensic scientists to apply the approach in practice. This difficulty lies not only in misunderstanding what uncertainty is and how to measure it (i.e. probabilities), but rather in the degree of detail that must be reached in the LR formula development. This is especially true in regard to what factors need to be accounted for and how.

In short, challenges may be faced when turning theory into practice and assigning LRs in casework. This paper deals with one problem commonly encountered by the authors in the area of forensic handwriting examination, more specifically – cases where there is a chance that the true writer has disguised the questioned signature. It may indeed be challenging to know how to properly handle such a possibility (i.e., to logically take into account this event in the assessment of the comparison of signatures). This drawback will be addressed through a fictive case, and solutions will be proposed.

It is worth noting that the present article will not explain how to elicit probabilities that take part in the LR. The values given will serve as a basis for discussion. Interested readers may find relevant information on elicitation of probabilities in the context of signature analysis in Köller et al.[4] and Marquis et al.[5]

The case

Let us consider a signature case where a lot of similarities and no differences are observed between the questioned and reference signatures. Let us denote our comparison results by the letter 'E', for evidence. To evaluate our results, in agreement with the ENFSI guideline, we con-

[4] N. Köller et al., *Probabilistische Schlussfolgerungen in Schriftgutachten* [Probability conclusions in expert opinions in handwriting], München 2004;

[5] R. Marquis et al., "What is the error margin of your signature analysis?", *Forensic Science International* 281, 2017, e1–e8.

sider two mutually exclusive propositions, exhaustive in the context of the case at hand.[6]

H_1 – the questioned signature was written by Mr. Jones.

H_2 – the questioned signature was simulated by an unknown person.

In its usual simple form, the LR formula can be written as follows: $LR = P(E|H_1, I) / P(E|H_2, I)$. Let us assume the results are very likely if Mr. Jones wrote the questioned signature, and consider a value close to 1 for the numerator of the LR. At the same time, let us assume the results are very unlikely in the case of a simulation, given the signature's complexity. Let us consider a value of 0,001 for the denominator of the LR. The LR value is therefore 1000 (= 1/0,001). Disguise was not considered in this evaluation.

Taking disguise into account

Let us consider that a new piece of information has been delivered in the case at hand and the expert is now required to take into account the possibility that the questioned signature was disguised. How does one include the possibility of disguise in the assessment of the results? Three options are proposed hereafter.

First option

The first solution involves assuming that it is not the role of the expert to consider the intentions of the writer. In this view, the results may be assessed separately under two sets of propositions. The first set assumes that the questioned signature, if written by Mr. Jones, has been sincerely written (i.e., without disguising it):

H_{1a} – the questioned signature was sincerely written by Mr. Jones.

H_{2a} – the questioned signature was simulated by an unknown writer.

The second set assumes that the questioned signature, if written by Mr. Jones, has been deliberately modified (i.e. disguised).

H_{1b} – the questioned signature was disguised by Mr. Jones.

H_{2b} – the questioned signature was simulated by an unknown writer.

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[6] A. Biedermann et al., "On the use of the likelihood ratio for forensic evaluation: Response to Fenton et al.", *Science & Justice* 54, 2014, pp. 316–318.

Two separate LR values would be provided and the responsibility of deciding which one is relevant in the case at hand would be left to the decision maker (e.g. the judge). If this solution was adopted, the meaning of these two values would need to be stated in a clear and transparent way, so that the judge could use them properly. However, one can wonder whether it is relevant to report two different LR values in a case and whether it is realistic to expect a coherent use of the expert's conclusions from the judge, since the task is already not straightforward with a single LR value.

Depending on the case, it may, of course, happen that the two LR values differ significantly. Such a potential difference demonstrates that the possibility of disguise can be a valuable information to take into account. Any information that strongly impacts the LR value should be considered as an important factor that needs to be taken into account when assessing the results in the case. Otherwise, one may consider the situation where the expert may deliver one LR value for each separate important factor, which is definitely not acceptable. It is the role of the expert to consider all the relevant information to express the strength of the results.

Second option

The second option is to formulate the propositions slightly differently, by partitioning the proposition appearing on the numerator based on disguise.[7]

H_1 – the questioned signature was written – with or without disguise – by Mr. Jones.

H_2 – the questioned signature was simulated by an unknown person.

The formal inclusion of the possibility of disguise in the LR numerator requires one to apply the law of total probability, also called the law of extension of the conversation.[8] The LR can therefore be written as follows (here we omit the information for ease of notation in the formula and we denote disguise by D and non-disguise by $\bar{D}$).

[7] N. Köller et al., op. cit.; A. Biedermann, R. Voisard, F. Taroni, "Learning about Bayesian networks for forensic interpretation: an example based on 'the problem of multiple propositions'", *Science & Justice* 52, 2012, pp. 191–198.

[8] C. Aitken, F. Taroni, *Statistics and the evaluation of evidence for forensic scientists*, Chichester 2004.

$$LR = \frac{P(E|H_1, D) \times P(D|H_1) + P(E|H_1, \bar{D}) \times P(\bar{D}|H_1)}{LR = P(E|H_2)}$$

The probability of the results if H_1 holds is now the sum of two terms: (1) the probability of the evidence conditioned on disguise multiplied by the probability of disguise, and (2) the probability of the evidence conditioned on non-disguise multiplied by the probability of non-disguise. These conditioned probabilities of the results must thus be respectively multiplied by probabilities $P(D|H_1)$ and $P(\bar{D}|H_1)$ that Mr. Jones did – or did not – disguise his signature. We know that these two probabilities add to 1, because the events are mutually exclusive and exhaustive. The forensic handwriting examiner, who may have no information about such probabilities, could suppose that disguise is just as likely as non-disguise, and assign values of 0,5 to each of the probabilities. In the case at hand, since the findings are not expected in the case of disguise, a value close to zero is assigned to the probability of the results under disguise $P(E|H_1, \bar{D})$. As the findings are very likely if Mr. Jones wrote the questioned signature without disguising it, a value close to 1 is assigned to the probability $P(E|H_1, \bar{D})$. The LR finally approximately becomes:

$$LR = \frac{0 \times 0{,}5 + 1 \times 0{,}5}{\text{LR} = 0{,}001 = 500} = 500$$

Remember that if disguise was not considered at all, a value of 1 would have been assigned to the numerator of the LR. In other words, by partitioning the proposition of the numerator based on disguise, a level of uncertainty that is difficult to handle quantitatively has been introduced, and a decrease of the LR value is observed (from 1000 to 500) due to the probabilities of the considered sub-propositions. Therefore, adding uncertainty about the writing conditions of the signature has an impact on the LR value, though it can be argued this effect is only moderate in this case since the LR value remains within the same order of magnitude. It is worth mentioning that the same kind of inconvenience would arise if uncertainty were to be formalised regarding the type of simulation (free hand, tracing, and so on) and taken into account in the denominator of the LR.

It is also worth mentioning that the features of the questioned signature (i.e. without comparing it with the reference signatures) may inform the forensic handwriting examiner about the probability of disguise. An example of this would be the presence of hesitation or retouching.[9] Taken into account formally, this element would make the LR formula more complex – however, this will not be developed here.

Third option

Finally, it may be assumed that there is no need to formalise uncertainty about the writing conditions in the LR. Unless this was explicitly requested by the mandating authority or known to be important for the decision making, no sub-propositions would be specified. But of course, the possibility of disguise may be taken into account to assign a value to the LR numerator, exactly in the same way other information would be taken into account, such as the writer's health status, whether they were sitting at a table, whether they take abusive substances, etc. All of this information is necessarily taken into consideration during the evaluation process, though not necessarily made explicit in the propositions. However, one should bear in mind that assumptions made in the evaluation stage should be disclosed in the statement. The recipient of information should know, for example, whether disguise was taken into account or excluded based on the case circumstances. Following this third solution, the propositions are left unchanged compared to the initial set (i.e. "the questioned signature was written by Mr. Jones" vs "the questioned signature was simulated by an unknown person"). On the one hand, this could mean putting a weight of one or zero on disguise, whether disguise is respectively taken as true or not. In this case, the assumptions regarding (non-)disguise must be disclosed in the expert's statement. On the other hand, this could mean that the probability of the results is globally assessed given both disguise and non-disguise, but without formally extending the conversation. The authors argue that for transparency and robustness, if the probability of disguise is not close to zero or one, then the second approach proposed in this paper is recommended.

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[9] R.A. Huber, A.M. Headrick, *Handwriting identification: Facts and fundamentals*, Boca Raton, FL 1999.

Conclusion

In the future, forensic laboratories may be requested to deliver the strength of forensic results in the form of an LR in their evaluative statements. This is supported by a recently published guideline on the matter by the ENFSI. While the LR approach is theoretically appealing, its application in practice is challenging, as any scientifically sound evaluation would be. One major issue was addressed in the present paper to help handwriting examiners who may face a problem typical for their discipline: how to incorporate the possibility that a questioned signature was disguised into the LR. The first option proposed is to deliver two LR values, one assuming that the questioned signature was disguised, and the other assuming it was sincerely written. The authors argue this option is problematic because disguise may significantly affect the LR, and it is especially the expert's task to account for all the relevant information when assessing the value of the results. The delivery of two LR values may furthermore be embarrassing for the recipient of information. A second option would be to partition the proposition of a genuine signature (on the numerator of the LR) based on the event of disguise vs. non-disguise. This procedure requires the assignment of probabilities of disguise and non-disguise, which may be logical, but also laborious. This procedure will impact one's LR – although in a limited way – compared to the situation where disguise is not made explicit in the propositions. In the third option, in cases where disguise can be either admitted or excluded (based on case circumstances), there is no need to explicitly mention disguise in the propositions. However, the assumption about (non-)disguise should be disclosed in the expert's statement. These developments will hopefully help forensic handwriting examiners to cope with the problem of taking disguise into account in their evaluation. While the task may be challenging, we encourage forensic handwriting examiners to adopt the logical approach recommended by the ENFSI, which will certainly contribute to harmonising and structuring the assessment of findings to strengthen conformity to scientific requirements.

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Forensic examination of electronic signatures: A comparative study

Priya Sharma

ORCID: 0000-0003-4986-8022
Chandigarh University, Chandigarh, Punjab, India

Mohinder Singh

ORCID: 0000-0002-2649-1616
Formerly Government Examiner of Questioned Documents
Central Forensic Science Laboratory, Hyderabad, India

Om Prakash Jasuja

ORCID: 0000-0002-2221-1242
Department of Forensic Science, Chandigarh University
Gharua, Punjab, India

Abstract

The writing of names or signatures has great importance due to its use in authentication, validation, and authorization of documents. Moreover, handwritten signatures present an aura of personality and make an impression on many people. But now, with the emergence of new technologies, a variety of electronic writing media such as digital tablets and pens are being used to produce writings and signatures; and the conventional way to produce the writing using pen and paper is waning. With the changing ways of writing and signature production, the means of producing forged writing or signature are also bound to change. This has brought new challenges for handwriting examiners. In the present study, a comparative analysis of electronically captured signatures with pen-paper signatures has been performed to study the effect of changes in writing media. Signature samples were taken from the same subjects on paper and electronic

pads. The similarities and differences with respect to class and line quality features between both signatures were analysed. It was observed that despite differences between the signatures produced by the same author, it is still possible to establish the authorship of signatures in the case of electronic signatures.

Keywords: forensic science, handwriting, signature, authorship, electronic signature, digital tablet

1. Introduction

With the advancement in technology, the world is becoming paperless. Digital and electronic devices are in widespread use, replacing the conventional pen and paper. This advancement has brought the use of electronic signatures instead of the pen-paper signatures in various areas. Electronic signatures are the handwritten signatures produced by using electronic pads and a stylus.

Electronic signatures are mostly confused with digital signatures, but the two differ from each other. Electronic signatures are handwritten signatures captured on digital tablets; digital signatures are not only handwritten, but appended with a sort of mathematical data which is an algorithm consisting of a private key and a public key which is used for authenticating an electronic document.

In electronic signatures, the signer employs conventional methods by physically signing a document, except using traditional ink and paper. The signer writes on the surface of an electronic device with a stylus. There is a number of devices which are used for capturing electronic signatures, such as tablet PCs, Personal Digital Assistants (PDAs), and mobile telephones. Digital tablets are commonly used to capture signatures. These tablets depend on electromagnetic induction to transmit and receive information to and from the stylus. The stylus also consists of electronics for receiving and transmitting information by signals which help to locate the position of the stylus on the tablet. The use of electronic signature has simplified many tasks, for instance printing, signing, and scanning or faxing the document – one does not have to go through all the time-consuming steps to sign the documents. Other applications of electronic signatures are network access control, client identification, document workflows, electronic transaction security, contractual agree-

ments, delivery verification, biometric security checkpoints, bank signature cards, and point-of-sale transactions.[1]

The signatures can be characterized by using their various features, namely class and individual ones. Class features are common to a specific group or class of writers. These features include a particular copybook form or style of letters, and the individual features are the result of diversion from the copybook form. Class characteristics have little weight in identifying a writer, as they can easily be seen in other people's writing. Individual characteristics, however, constitute the backbone of identification. If two writing samples were not prepared by the same author, then this can be established through a significant difference in either individual or class characteristics.[2] The fundamental or significant differences are those beyond the range of natural variations. They cannot be accounted for by external and internal factors such as age, illness, mental state, the writing instrument, and writing support.[3] Hilton states that "hesitation, unnatural pen lifts, patching, tremor, the uncertainty of movement as portrayed by abrupt changes in the direction of the line, and a stilted, drawn quality devoid of free, normal writing movements combine to reveal the true nature of a forgery."[4]

The way of writing or signing depends on the combined effect of both external and internal factors, which cause variations in handwriting or signatures. Variation is an essential part of genuine handwriting and no two samples of writing made by one and the same person are identical in every detail. The extent of natural variation is different for every writer, so it is an important element in the identification of handwriting. In some cases the variation occurs only in few details of the writing, but in others the formation of letters and words may differ to a great extent. The variation is due to not only the lack of machine-like precision in human activities, but also to external factors such as writing position, the type of writing instrument used, and the amount of care given to the writing.

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[1] H.H. Harralson, *Developments in handwriting and signature identification in the digital age*, UK 2013.

[2] O. Hilton, *The scientific examination of questioned document*, New York 1982.

[3] R.A. Huber, A.M. Headrick, *Handwriting identification: Facts and fundamentals*, Boca Raton, FL 1999.

[4] O. Hilton, op. cit., p. 185.

The variation may also be influenced by the physical or mental condition of the writer: fatigue, intoxication, drug use, illness, and nervousness. The degree and intensity of these conditions affect the extent of variation in the writing. The variation does not affect the identification of handwriting, but indicates its genuineness. Handwriting is influenced by the nature of the writing instrument and the writing surface. It is a fact that handwriting is a product of neuromuscular coordination, so irrespective of the writing instrument (i.e. electronic pad and stylus), the brain which controls the movement of the hand remains the same. Therefore, the structure of handwriting remains unaltered and consistent, and it is only the general appearance of the writing which is affected by the nature of the writing instrument. We may encounter many cases in which we have to compare the questioned electronic signatures with pen-paper signatures or vice versa.

The present work is a comparative study of the electronic signature with conventional pen-paper signatures. A signature captured on an electronic pad was compared with a signature handwritten on paper with a ballpoint pen. The similarity and differences between an electronic signature and a pen-paper signature have been studied.

Galen and Gemmert[5] examined the differences between natural and simulated handwriting on the basis of spatial and dynamic variables using a digitizer tablet. Wright[6] discussed the use of electronic signatures for the authentication of legal documents. Plamondon and Srihari[7] described the automatic handwriting recognition models and discussed the algorithms for on-line (digitally captured) and the off-line (scanned images) handwriting recognition. Bharvada[8] reviewed the various types of electronic signatures and their advantages. Mason illustrated the evi-

[5] G. Galen, A. van Gemmert, "Kinematic and dynamic features of forging another person's handwriting", *Journal of Forensic Document Examination* 9, 1996, pp. 1–25.

[6] B. Wright, "Making electronic signatures a reality", *Computer Law & Security Review* 15, 199, no. 6, pp. 401–402.

[7] R. Plamondon, S.N. Srihari, "On-line and off-line handwriting recognition: A comprehensive survey", *IEEE Transactions on Pattern Analysis and Machine Intelligence* 22, 2000, pp. 63–84.

[8] K. Bharvada, "Electronic signatures, biometrics and PKI in the UK", *International Review of Law, Computers & Technology* 16, 2002, pp. 265–275.

dential issues related to electronic signatures[9] and presented a comparison of the risks between the use of electronic signature and manuscript signatures.[10] Richiardi et al.[11] examined 39 local (based on single data point) and 46 global (based on the entire signature unit) features for online systems to find out the most efficient and most discriminating power for signature verification. Tariq et al.[12] evaluated the strong and weak features in an online signature verification system.

Harralson et al.[13] examined the temporal (dynamic) and spatial (static) differences between online and offline signatures. The signature samples in three different conditions, that is, on paper using a ballpoint pen, on Wacom Intuos3 tablet, and using a mouse, were collected. He observed the difference in features such as a change in size, simplification of signatures, slow movements, and a change in the spacing of signatures. Harralson[14] stated that the electronic signatures are digitized and the this process leads to some common differences, for instance in the shading of ink traces, feathered beginning and ending strokes converted into blunt strokes. Smooth air strokes and lifts in the signature appeared to be cut off or blunt after digitization. These differences may lead to erroneous opinions when comparing electronic signatures captured on digital tablets to pen-paper signatures.

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[9] S. Mason, "Electronic signatures – Evidence: The evidential issues relating to electronic signatures", part 1 and part 2, *Computer Law & Security Report* 18, 2002, no. 3, pp. 175–180, no. 4, pp. 241–248.

[10] S. Mason, "A comparison of the risks between the use of manuscript and electronic signatures", *Amicus Curiae* 50, 2003, pp. 11–13.

[11] J. Richiardi, H. Ketabdar, A. Drygajlo, "Local and global feature selection for online signature verification", *International conference on document analysis and recognition*, 29 August–1 September 2005, pp. 625–629.

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[13] H.H. Harralson, H.L. Teulings, S.L. Miller, "Temporal and spatial differences between online and offline signatures", *15th International Graphonomics Society Conference*, 12–15 June 2011, pp. 34–37.

[14] H.H. Harralson, op. cit.

Kaźmierczyk and Turner[15] differentiated between the electronic signatures and handwritten signatures. They also observed changes in features such as dimension, loss or addition of details, blunt strokes instead of feathered strokes, expansion, pen lifts, simplification, and abrupt change in direction. It was concluded that writers alter their signature in order to meet the requirements of the software.

Mohammed et al.[16] observed the dynamic features (duration, size, velocity, jerk, and pen pressure) between genuine and simulated signatures with the effect of stylization. Stroke duration, velocity, and pen pressure were found to be inconsistent between genuine and simulated signatures. This indicated that the style of the simulator's own signature and the style of the simulated signature can impact the characteristics of handwriting movements.

All these studies were about differentiating between genuine and forged signature captured on electronic pads based on their dynamic features such as speed, pressure, duration, etc.

But before studying about differences between forged and genuine writings on electronic media, one should be aware of the differences that occur within the genuine signatures depending on whether they were written on paper or on an electronic device. Therefore, in the present study, an attempt is made to determine if due to a change in the medium of writing fundamental differences are affected or if they remain within the range of natural variations.

2. Material and methods

The aim of this study was to identify the differences, if there are any, among the two sets of signatures written by the same individual on a digital writing pad with the help of a stylus and on paper with a conventional writing instrument (the ball pen).

[15] Z. Kaźmierczyk, I. Turner, "Is your electronic signature really yours?", https://www.academia.edu/6630002/Is_your_electronic_signature_really_yours (accessed: 18.11.2016).

[16] L. Mohammed et al., "Dynamic characteristics of signatures: Effects of writer style on genuine and simulated signatures", *Journal of Forensic Sciences* 60, 2015, no. 1, pp. 89–94.

Selection of the subjects

The samples for the present research work were collected from fifty subjects, all of whom were skilled writers, well-educated (with graduation as a minimum qualification), and users of online shopping websites. The subjects were randomly selected. Nineteen of them were fully familiar with digital tablets and had used them or cell phones for delivery verifications. Informed consent was obtained along with the subjects' names, ages, and qualifications. Additionally, it was recorded whether the subjects had used these devices earlier, including for signing purposes.

Writing conditions

Since usually signatures are made in a standing position, for instance during delivery verifications, in shopping stores and banks, the subjects were requested to sign in that very position to simulate the actual position of writing in both the cases, that is, electronic devices as well as paper.

Writing instruments

The signatures were collected on white A4 sheets using a blue ballpoint pen and on a digitalizing tablet – Bamboo™ Pad, a USB model by Wacom Company – using a stylus. The general specifications of the device are as follows:

- physical size: (W × D × H) 141.4 × 166.5 × 4.5 mm;
- pen technology: electromagnetic resonance technology;
- pen active area: (W × D) 107 × 67 mm;
- readable height: 16 mm;
- communication interface: USB;
- operation: the blue LED lights up after powering the units on. Brighter blue when touch is used. Amber when the pen is used. The pad is pressure sensitive when used with a stylus. It only produces writing when the stylus is touching the surface with a certain pressure and an amber light turns on.

Sample collection method

The Bamboo™ pad was connected to a PC using its USB. Then the signatures were captured in a computer graphics application Microsoft Paint (MS Paint) and the image was saved in TIFF format. Unlike other formats, TIFF has the ability to store image data in a lossless compression and makes a TIFF file in a useful image archive. A TIFF file can be edited and re-saved without losing image quality. The subjects were allowed to look at the desktop while signing for proper device positioning on the tablet surface. Four signature samples were collected both on the digital tablet and on paper to find the natural variation in the subjects' writing. All samples from one subject were within their range of variation. So out of four samples one signature was randomly chosen and used for detailed examination (in results).

Sample analysis

The pen-paper signatures were analyzed using a magnifying glass and scale. The electronic signatures were analyzed in MS Paint by magnification, ruler, and gridlines available in it. The features with their respective significance mentioned in previous studies and literature which were selected to compare the pen-paper signatures and electronic signatures include:

1. dimensions: vertical and horizontal,
2. spacing,
3. alignment,
4. arrangement,
5. initial and terminal strokes,
6. connecting strokes,
7. pen lifts,
8. diacritics,
9. embellishments,
10. tremors,
11. simplification,
12. forms and formation.

3. Results and discussion

The differences and similarities were observed in the pen-paper signature and electronic signature of 50 subjects. The percentage of the observed feature was calculated.

3.1. Dimensions: vertical and horizontal

A comparison between the horizontal dimension (i.e. length of the signature) and vertical dimension (i.e. height of lowercase and uppercase letters) showed that all the subjects increased the horizontal dimension – that is, the measured parallel to the baseline using scale from the first letter to the last letter of the signature – and vertical dimension of signature – that is, the height of uppercase and lowercase letter on digital tablet were also measured (Figure 1a and 1b, Figure 2a and 2b). Then the total percentage increase in the length of the signature the height of uppercase letters, and height of lowercase letters, were calculated.

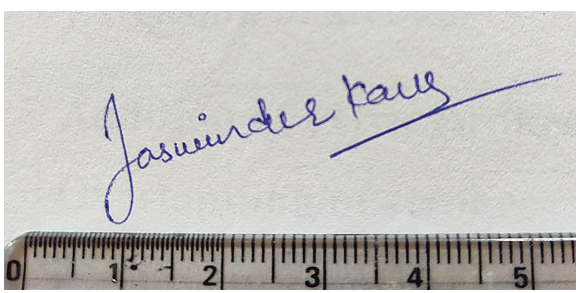

Figure 1a. The horizontal dimension of pen-paper signature with a ruler in cm

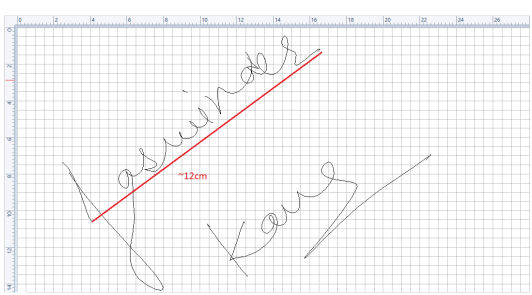

Figure 1b. The change in horizontal dimension of electronic signature

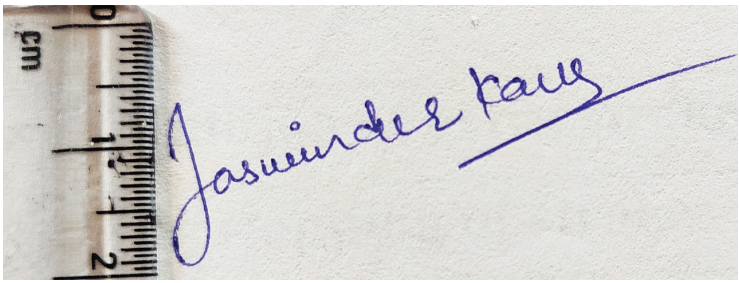

Figure 2a. The vertical dimensions of pen-paper signature and electronic signature

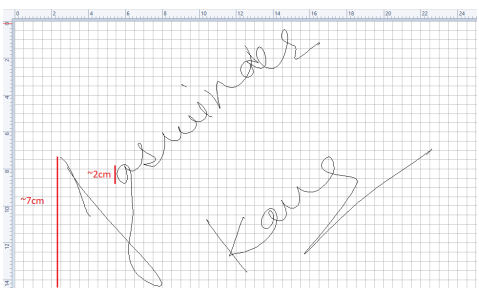

Figure 2b. The change in vertical dimension

It is clear from Table 1a–c that the increase in the signature size with respect to the length and height remains almost constant, indicating that the writer's neuromuscular impulse remains unchanged irrespective of the writing surface. The height and width ratios also remain the same in both cases, indicating that a skilled writer's writing habit cannot be changed depending on the writing surface. Jasuja et al.[17] reported similar findings in their study of wall writings – the writing size may increase with the change in writing surface and instrument, but the height and width ratios remain almost the same. These observations make it evident that the same method of examination can be applied to examine and compare the electronic signature and pen-paper signatures.

[17] O.P. Jasuja et al., "Spray paint writings on vertical surfaces executed by spray paint cans: A preliminary forensic study", *Z Zagadnień Nauk Sądowych* (Problems of Forensic Sciences) 98, 2014.

Table 1a. Length of the signature

Average length of the pen-paper signature (initial average value)	Average length of the electronic signature (final average value)	Total percentage increase in length of the signature
2.584 cm	13.104 cm	(13.104 - 2.584) / 2.584 × 100 = 407.12%

Table 1b. Height of uppercase letters

Average height of uppercase letters in the pen-paper signature (initial average value)	Average height of uppercase letters in the electronic signature (final average value)	Total percentage increase in height of uppercase letters in the signature
0.974 cm	4.548 cm	(4.584 - 0.974) / 0.974 × 100 = 366.94%

Table 1c. Height of lowercase letter

Average height of the lowercase letter of pen-paper signature (initial average value)	Average height of the lowercase letter of electronic signature (final average value)	Total percentage increase of lowercase letter of the signature
0.24 cm	1.232 cm	(1.232 - 0.24) / 0.24 × 100 = 413.33%

The reason for enlargement may be the device itself – during the present study an experiment was conducted in which 1 cm line was drawn on paper and the paper was put over the surface of a pad, which was sensitive enough to locate the stylus while the paper was put over it. The stylus was moved over the pre-measured line and the line was drawn in "paint." The approximate length was found to be 3 cm.

Kaźmierczyk and Turner[18] also conducted an experiment in which a 1 cm long line was drawn on a tablet. It was observed that the line which appeared on a screen was 1.8 cm long, which means that most signatures written using this device might become bigger automatically.

[18] Z. Kaźmierczyk, I. Turner, op. cit.

The study by Harralson et al.[19] showed an increase in the size of electronic signatures in 75% of the writers, and a decrease in size in 25%. In the present study, no decrease in size was observed.

3.2. Spacing between letters

The change in spacing between letters was observed in electronic signatures (Figure 3a and Figure 3b).

Figure 3a. The narrow spacing between letters in pen-paper signature

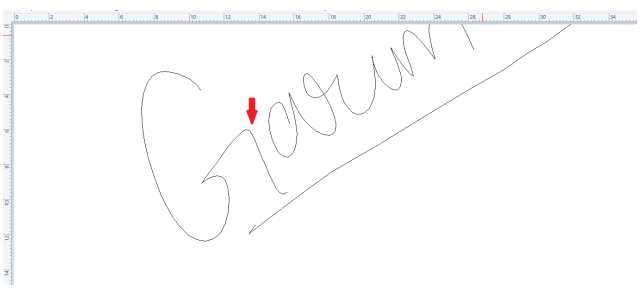

Figure 3b. The increase in spacing in electronic signature

There were 9 subjects who changed the spacing from narrow to wide, 10 subjects from uniform to wide, 16 subjects from irregular to wide, 5 subjects from wide to wider, 5 subjects from narrow to irregular, 2 subjects from uniform to irregular, and 3 subjects did not change the uniform spacing.

[19] H.H. Harralson, H.L. Teulings, S.L. Miller, op. cit.

In 6 samples, the spacing increased so much that the subjects ran out of the available space to complete the signature. In 4 samples the spacing was irregular and decreased only between a few letters, leading to the overlapping of letters.

The wide spacing between letters was observed in the writings of most subjects. This could be due to the increase in the signature's dimensions. The overlapping could be caused by the lack of visual feedback on the tablet surface.

3.3. Spacing between words

People generally develop their signature as per their choice; once it is developed, it remains the same. Some people may write their signature as a single pen operation, while many may have pen lifts. When a writer includes their second name (surname) in their signature, then most likely they have to lift the pen and then write the second name. In the present study, the surname and first name were present in 34 samples of pen-paper signatures, while in 16 samples no surname was present.

The change in spacing between first name and surname in 34 subjects was observed (Figure 4a, Figure 4b, Figure 5a, and Figure 5b). The increase in spacing was observed in 19 samples, decreased in 3 samples, and no change in 12 samples.

The increase in spacing could be due to the change in dimension, the decrease – to the lack of visual feedback. It also may be the case that as the dimension increased, the spacing was decreased to adjust the signature in the limited space.

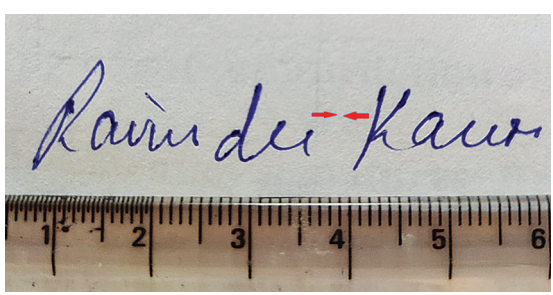

Figure 4a. The spacing between words in pen-paper signature

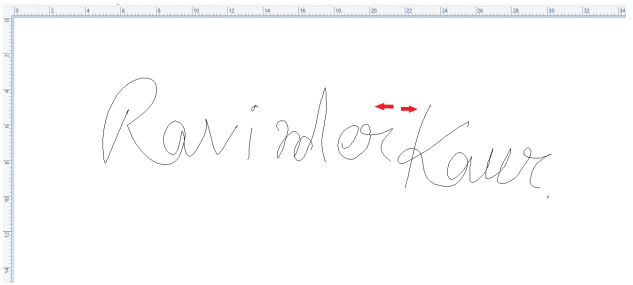

Figure 4b. The decreased spacing between words in electronic signature

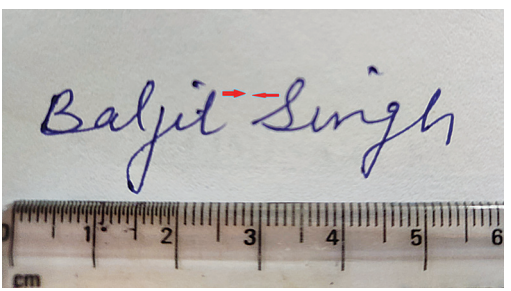

Figure 5a. The space between words in pen-paper signature

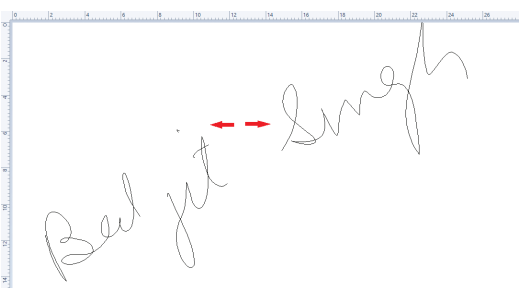

Figure 5b. The increased spacing between words in electronic signature

3.4. Alignment

The most common way used by criminals to alter the appearance of writing is by changing alignment and slant. These changes can be identified easily in a long passage of writing, but not in the case of signatures – only very small writing is available and it can mislead the forensic handwriting examiners. In the case of writing with a pen on paper and writings on a digital tablet, a change in alignment was observed. A tendency to shift towards ascending was observed – in the present study 7 subjects changed the alignment from straight to ascending, 9 changed the alignment from irregular to ascending, and 3 from arched to ascending. In 10 samples the alignment was ascending and remained so, but to a higher degree (Figure 6a and Figure 6b).

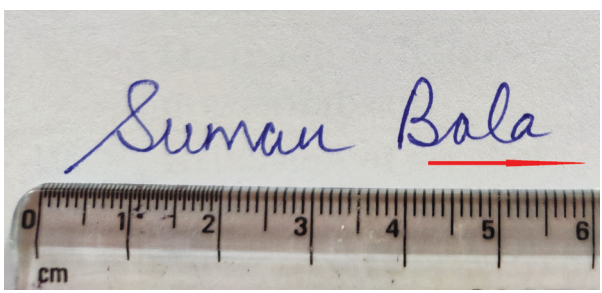

Figure 6a. The straight alignment in pen-paper signature

Figure 6b. The ascending alignment in electronic signature

Most of the subjects signed in an ascending way. This could be due to the limited area to sign on the tablet. So, to complete the signature in the available area, subjects may have changed the alignment. No remarkable change in alignment was observed in 21 samples.

3.5. Arrangement

Since the writing samples were in the form of signatures in the present study, the arrangement was not found to be affected. There was no difference in the arrangement of signatures written conventionally and on a digital pad. There were 39 cases where there was no change observed, while 11 subjects changed the arrangement from one line into two lines (Figure 7a and Fig 7b). The reason for this might be that the increase in size and spacing of the signature caused the writer to move half of the signature into the second line. The other explanation may be the small area of the tablet due to which the subjects might have been unable to complete the signature in one line. Finally, it may be a case of first-timers using the digital pad for signatures.

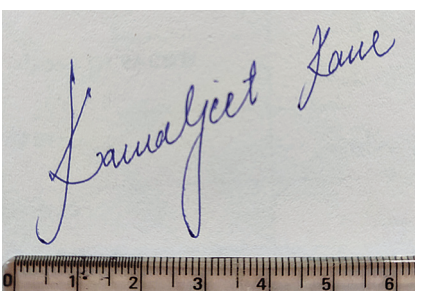

Figure 7a. The arrangement of pen-paper signature

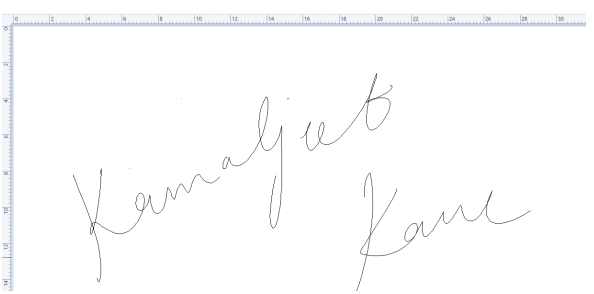

Figure 7b. The changes in arrangement in electronic signature

3.6. Initial and terminal strokes

One of the most important features of one's writing are the flying or tapered initial and terminal strokes. Due to high skill and fluency, the writing will be executed with more speed and less pressure. In the present study, all the writers were skilled and it was supposed that their writings – particularly signatures – were written with more speed than a typical text, thus making it a very important feature for studying the difference between writings created using various media. The present study noted changes in writing strokes with respect to initial and terminal strokes. All these changes could be classified into the following categories: 1. hooks present or not, 2. stroke eyelet modified into retrace, 3. length of the terminal stroke increased or decreased. It was observed that in 9 electronic signature samples hooks were absent from the initial strokes (Figure 8a and Figure 8b). The absence of initial or terminal strokes with hooks could be due to the improper positioning of the stylus over the tablet surface, which may have led to the omission of strokes.

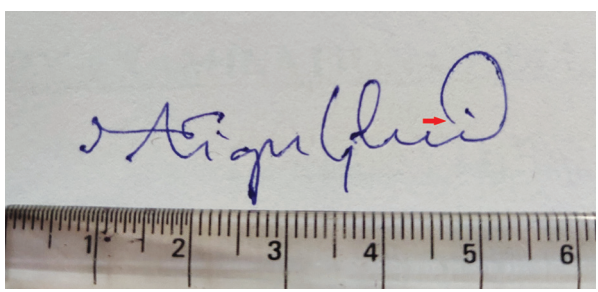

Figure 8a. The initial stroke with tapering end and terminal stroke at letter 'r' in pen-paper signature

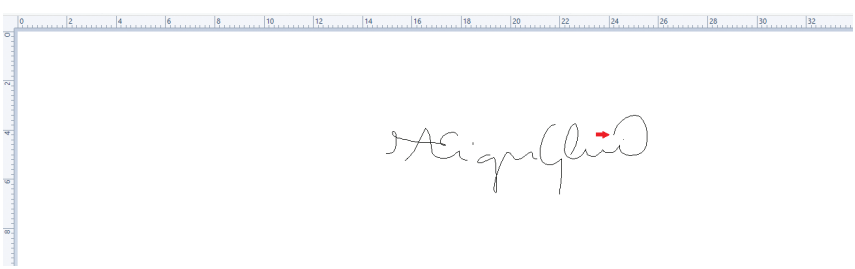

Figure 8b. The absence of initial stroke at letter 'p' and extension of terminal stroke at letter 'r'

In 7 conventional writing samples retracing was modified into eyelets. The modification in the forms of the initial stroke (eyelets instead of retrace) and the terminal stroke may be due to a lack of visual feedback on the tablet surface. In 18 electronic signature samples the length of terminal strokes was increased. The prolonged touching of the stylus over the tablet surface maybe led to the extension of strokes. In all the electronic signatures tapering ends were converted into blunt endings (Figure 9a and Figure 9b). Harralson[20] mentioned that there is no grayscale available in digitized signatures, so all tapered endings were converted into blunts strokes.

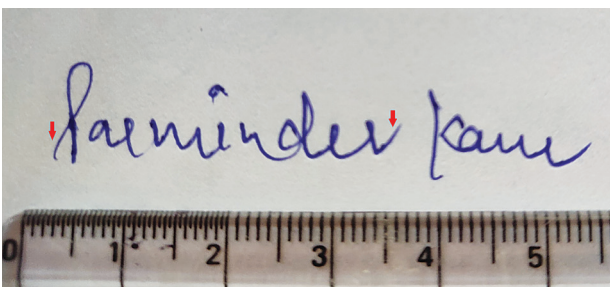

Figure 9a. The tapered ending in pen-paper signature

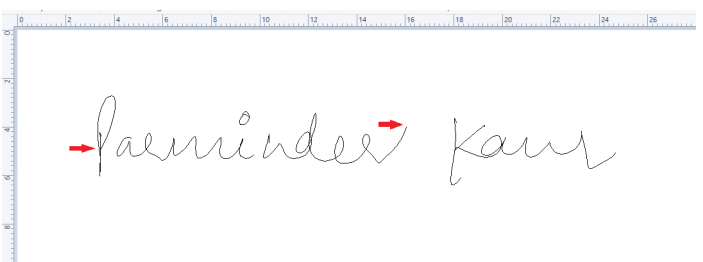

Figure 9b. The blunt ending in electronic signature

[20] H.H. Harralson, op. cit.

3.7. Connections

Skilled writers are supposed to write in cursive form and therefore most of the letters in one word are connected with each other. Letters of a word are connected with the connecting strokes which have a characteristic feature with respect to their form and formation. The present study aimed to observe if the form and formation of these strokes were similar in both signature sets. The observations were made in accordance with the following questions: were the connecting strokes are present in both signature sets? If so, is the placing of these strokes also similar? Was there any addition or subtraction in the connecting strokes? What was the form/formation of the connecting strokes? Connecting strokes were observed in 44 samples of pen-paper signatures, and they were absent in the other 6 samples. In 9 samples some connecting strokes were added which were absent in pen-paper signatures (Figure 10a and Figure 10b). The addition of connecting strokes in unusual places could be caused by the contact of the stylus with the surface if the subjects did not raise the stylus. The connecting strokes in 34 samples were in the retraced form and were modified into the eyelets. The surface was not as smooth as in pen-paper signatures, so retracing was rarely present in electronic signatures. The length of connected strokes was increased in signatures of 37 subjects (Figure 11a and Figure 11b). Spacing was also increased – the reason could be the lack of visual feedback.

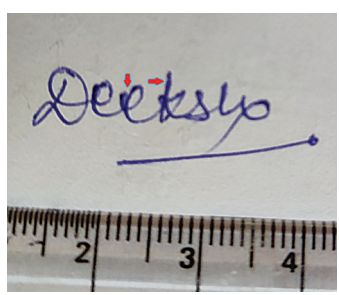

Figure 10a. The retraced connecting strokes in pen-paper signature

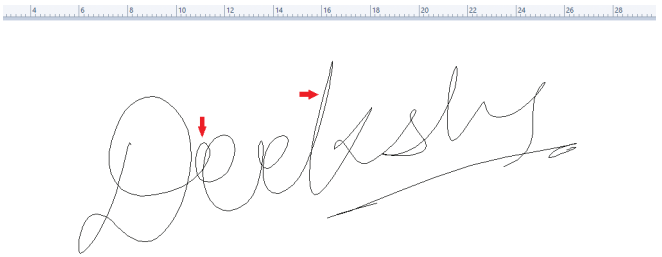

Figure 10b. The eyelets formed in electronic signature

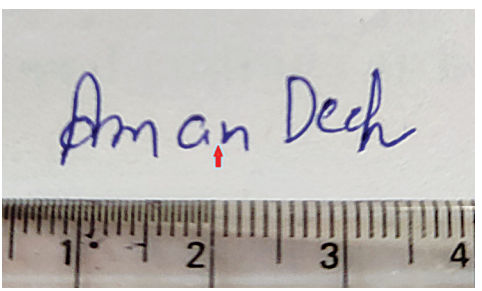

Figure 11a. The absence of connecting stroke and length of connecting stroke in pen paper signature

Figure 11b. The addition of connecting strokes and extension of connecting strokes in electronic signature

3.8. Pen lifts

In the present study, pen lifts indicated a very important point while comparing signatures on paper and on the digital pad. It seemed obvious to presume that whatever pen lifts were present in pen-paper signatures, the same should also be present in digital pad signatures. But it was not so – in 21 digital pad signature samples pen lifts were present in unusual places. Most of such pen lifts led to the omission of strokes, as is evident from Figure 12a and Figure 12b. However, in 19 samples there was an absence of pen lifts in electronic signatures while they were present in the pen-paper signature sample provided by the same subject. As evident from Figure 13a. and Figure 13b, the absence of pen lifts leads to the addition of extra strokes. It is thought that these changes may be due to improper positioning of the stylus over the tablet surface, but it cannot be said with certainty.

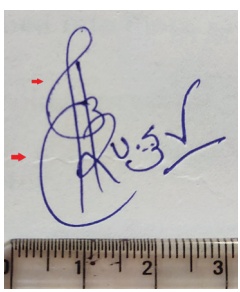

Figure 12a. The pen-paper signature

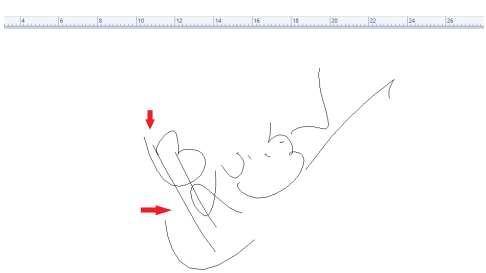

Figure 12b. The omission of strokes due to pen lifts in electronic signature

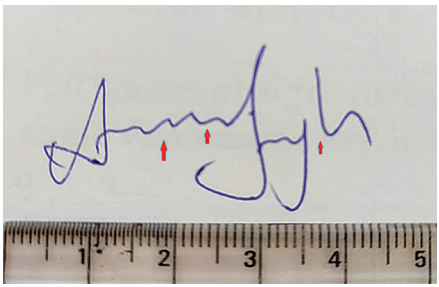

Figure 13a. The pen lifts in pen-paper signature

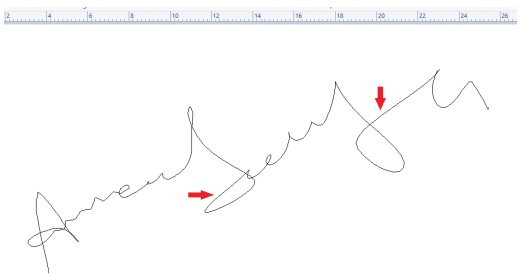

Figure 13b. The absence of pen lifts in electronic signature

3.9. Diacritics

In the present study, 'i' dots, 'j' dots, and the crossbar of 't' were considered for the comparison of two sets of signatures from different media. The changes were observed but not significant, and the increase or decrease in the positioning of the dots or the length of the crossbar can be considered a result of natural variations. Figures 14–15 indicate changes/variations in diacritic marks in these two sets of signatures. In all samples the 'i' dot was observed in 24 cases, and out of these 24 the shape of the 'i' dot was modified in 13 samples, while in 11 samples it was omitted. At the same time, 10 subjects changed the position of the dot. In case of the 't' crossbar, out of 16 samples the crossbar was completely omitted in 2, while 6 subjects extended its length. The prolonged touching of the stylus may have caused the extension of the 't' cross.

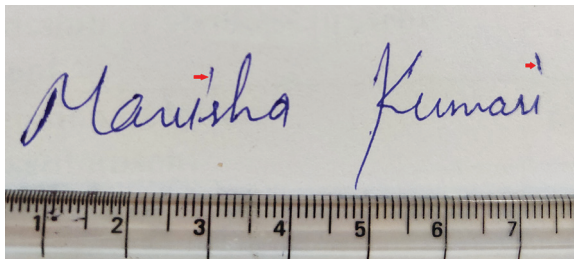

Figure 14a. The pen-paper signature

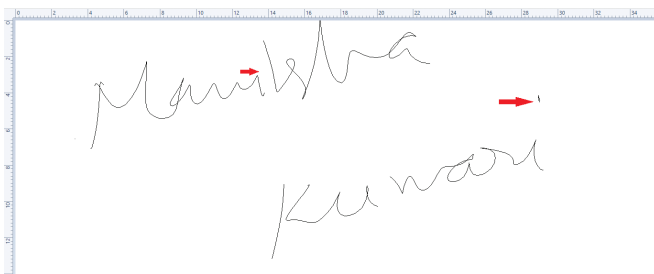

Figure 14b. The omission of 'i' dot and change in shape of 'i' dot in electronic signature

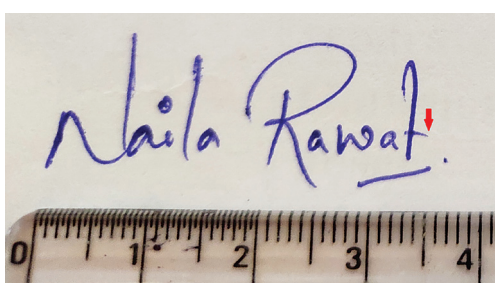

Figure 15a. The length and position of t-cross in pen-paper signature

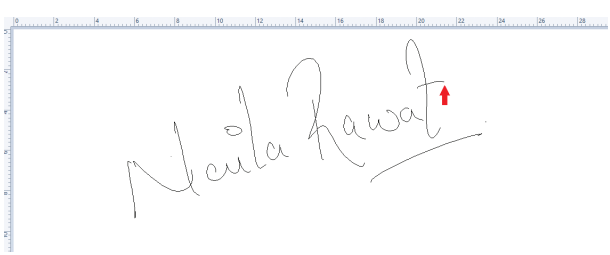

Figure 15b. The change in length and position of t-cross in electronic signature

3.10. Embellishments

Embellishments are not necessarily present in everyone's writing, but when present, they may indicate certain individuality as well as a sort of idiosyncrasy. A person who adds embellishments in the writing will certainly keep those come what may. Therefore, in the present study, it was an important observation if embellishments did vary with the change of the media of writing, and if so, in what way. Embellishments were observed in the writing with respect to their presence or absence, their position, they were modified, and if so, whether there were some additions or omissions.

In total, embellishments were present in signatures of 27 subjects. Embellished strokes were omitted in 9 samples while writing on the digital pad, and modified in 11 samples. No change in embellishments was observed in 7 samples. An addition of embellishments was observed in 11 samples, 2 subjects completely omitted the rubrics, and 12 subjects modified them. Furthermore, 2 subjects added the rubrics in the electronic signature while they were absent in pen-paper signatures (Figure 16a–b and Figure 17a–b). All these observations indicate an unorganized representation of this feature because of natural variation in the signatures. The writer may be more conscious during the process of forming their signature on the tablet than when signing on paper. So, if there were rubrics added or ornamentations modified in the electronic signature, this might be due to the lack of speed and fluency present in the pen-paper signatures.

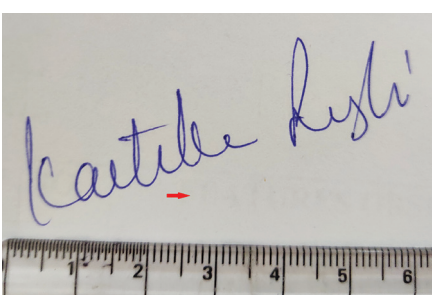

Figure 16a. The absence of rubric in pen-paper signature

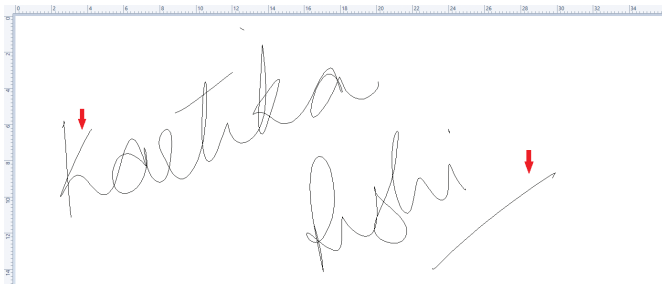

Figure 16b. The presence of rubric and addition of embellished letter ‘k’ in electronic signature

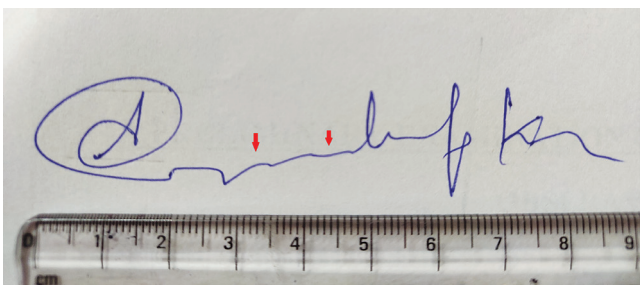

Figure 17a. The embellishment of letter ‘a’ in pen-paper signature

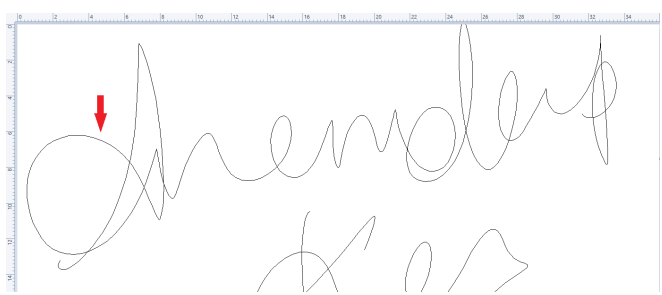

Figure 17b. The modification in embellishment in electronic signature

3.11. Tremors

Tremors in the handwriting are supposed to be the result of two factors: they are present either due to neuromuscular incoordination or to some kind of forgery. Therefore, it was unusual to observe that tremors were present in one's handwriting when written on the digital pad, while in the normal writing on paper no tremors were present. The strokes of the 36 samples of electronic signature were tremulous (Figure 18a–b). The awkwardness of signing on a digital tablet may cause the tremor in strokes. The other possible reason could be the lack of smoothness characteristic of paper on the tablet surface, which leads to a tremor in strokes.

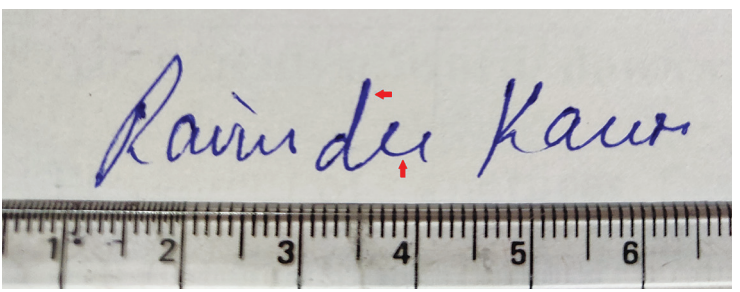

Figure 18a. The clear-cut strokes of pen-paper signature

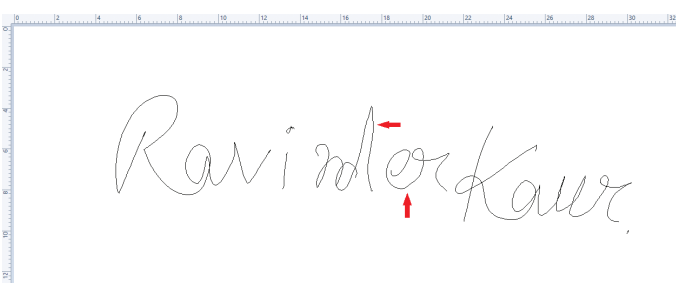

Figure 18b. Tremulous stroke in electronic signature

3.12. Simplification

Simplification of the strokes in handwriting or signatures may be caused by the tendency of the writer to write quickly because of overburdening with the task to produce more writing in a limited time. But in the present study, the writers were provided with enough time and no time limit. However, the occurrence of simplification was not very frequent – it was found only in 9 samples (Figure 19a–b and 20a–b). The possible reason, as mentioned above, may be the writer's casualness and the significance of the writing.

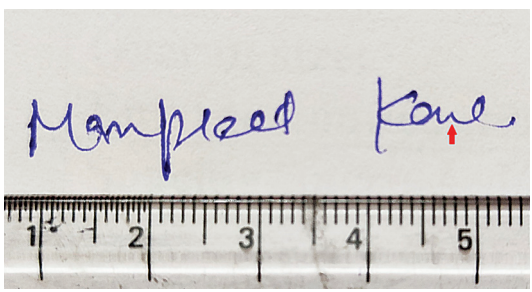

Figure 19a. The pen-paper signature

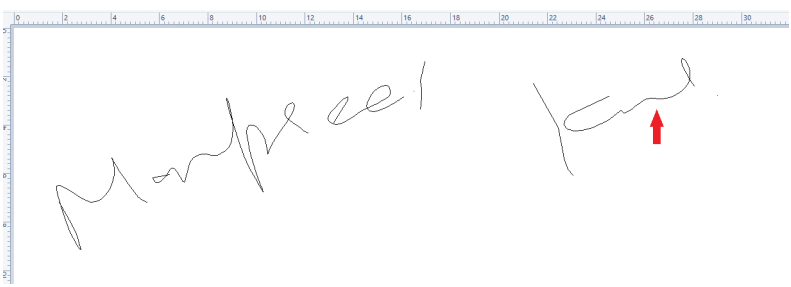

Figure 19b. The simplification of letters 'a' and 'u' in electronic signature

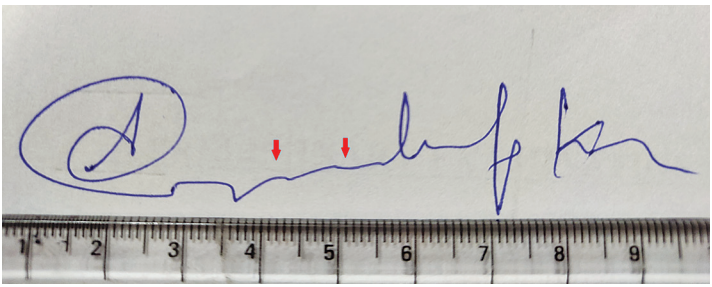

Figure 20a. The simplified letters in pen-paper signature

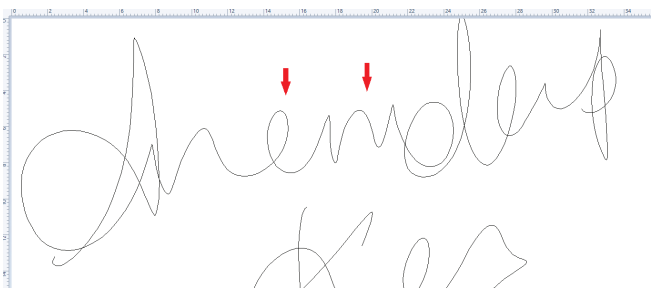

Figure 20b. The omission of simplification in pen-paper signature

3.13. Forms and formation of letters

It was observed that, despite differences in some letter forms, the direction of the stroke formation was the same. As evident from Figure 21a–b, Figure 22a–b, and Figure 23a–b, variations in the letter forms were found, such as eyelets instead of retracing, distorted letter forms, open ovals instead of closed ovals, but the direction of their formation remained the same. The differences in the letter forms were not remarkable enough to establish different authorship of the signature – they were found within the range of variation.

Harrison[21] mentioned that there may be considerable variation in the shapes of letters, since a writer may use various forms of one letter. But the range of variation is a highly individual characteristic of each writer.

[21] W.R. Harrison, *Suspect documents: Their scientific examination*, London 1958.

The differences in letter forms beyond the range of variation could be due to the lack of visual feedback in tablet signatures, which leads to distorted letter forms or the presence of retracing instead of eyelets or loops. But the letter formation of electronic signatures and pen-paper signatures was found to be similar in all the samples.

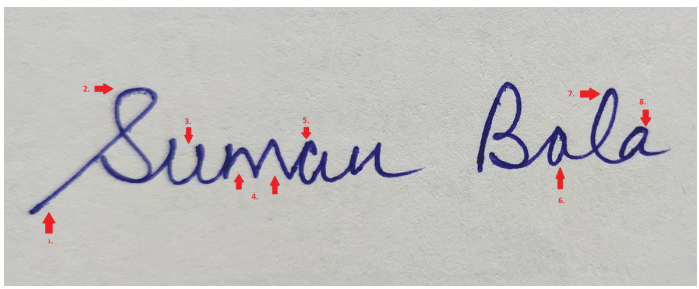

Figure 21a. Letter forms and formation in pen-paper signature

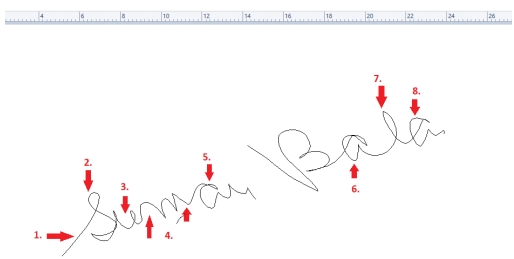

Figure 21b. The electronic signature

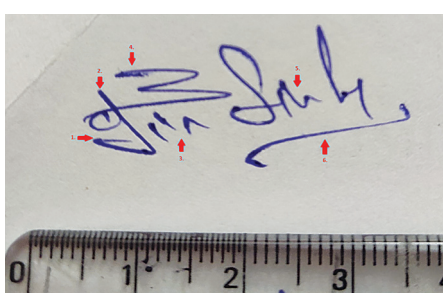

Figure 22a. Letter forms and formation in pen-paper signature

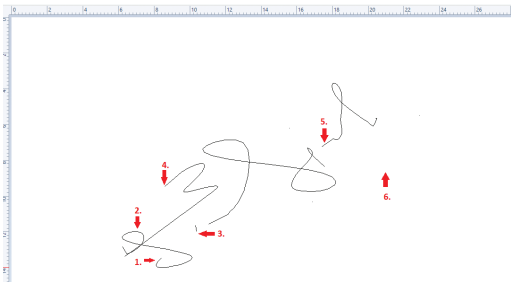

Figure 22 b. The electronic signature

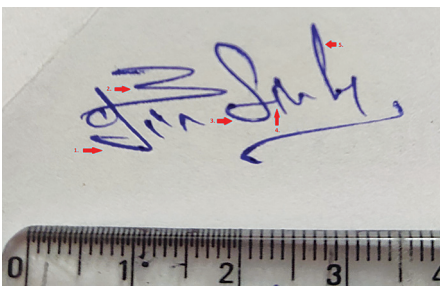

Figure 23a. Letter forms and formation in pen-paper signature

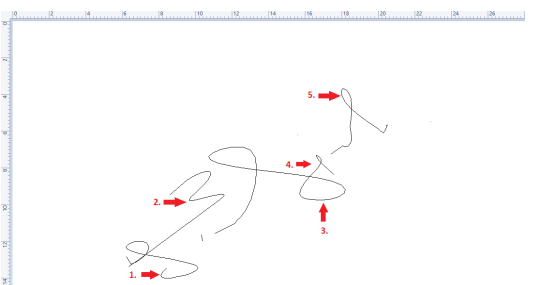

Figure 23b. The electronic signature

Table 2a. A comparison of forms and formations in pen-paper and electronic signatures

Feature no.	Feature	Pen-paper signature	Electronic signature
1.	Initial stroke	Starts from left downward to right upward	Starts from left downward to right upward
2.	Crest	Present (anticlockwise)	Present (anticlockwise)
3.	Trough	Present (anticlockwise)	Present (anticlockwise)
4.	Arches	Present (clockwise)	Present (clockwise)
5.	Oval	Closed (anticlockwise)	Open (anticlockwise)
6.	Oval	Closed (anticlockwise)	Open (anticlockwise)
7.	Eyelet	Present (anticlockwise)	Present (anticlockwise)
8.	Connected stroke	Retrace (downward to upward)	Eyelet (downward to upward)

Table 2b. Similarities between features of pen-paper and electronic signatures

Feature no.	Feature	Pen-paper signature	Electronic signature
1.	Hook	Present (anticlockwise)	Present (anticlockwise)
2.	Compound curve	Present (clockwise to anticlockwise)	Present (clockwise to anticlockwise)
3.	Eyelet	Present (anticlockwise)	Present (anticlockwise)
4.	Connecting stroke	Present	Present
5.	Eyelet	Present (anticlockwise)	Present (anticlockwise)

Table 3a. Differences between features of pen-paper and electronic signatures

Feature no.	Feature	Pen-paper signature	Electronic signature
1.	Stroke endings	Tapered ends	Blunt ended
2.	Retracing	Present	Absent (Eyelet)
3.	Omission of strokes	Absent	Present
4.	Hook	Present	Absent
5.	Simplification	Absent	Present
6.	Omission of strokes	Absent	Present
7.	Rubric	Present	Absent

Table 3b. Similarities between features of pen-paper and electronic signatures

Feature no.	Feature	Pen-paper signature	Electronic signature
1.	Hook	Present (anticlockwise)	Present (anticlockwise)
2.	Compound curve	Present (clockwise to anticlockwise)	Present (clockwise to anticlockwise)
3.	Eyelet	Present (anticlockwise)	Present (anticlockwise)
4.	Connecting stroke	Present	Present
5.	Eyelet	Present (anticlockwise)	Present (anticlockwise)

Table 4. Occurence percentage of various features in electronic signatures

Feature no.	Feature observed	Occurrence of features in electronic signatures
1.	Increase in horizontal dimension	100%
2.	Increase in vertical dimension	100%
3.	Increase in spacing between letters	80%
4.	Decrease in spacing between letters	8%
5.	Increase in spacing between words	38%
6.	Decrease in spacing between words	6%
7.	Alignment change	58%
8.	Arrangement change	22%
9.	Omission of initial stroke	18%
10.	Omission of terminal stroke	10%
11.	Modification of initial stroke	14%
12.	Modification of terminal stroke	6%
13.	Extension of terminal stroke	36%
14.	Addition of connecting stroke	18%
15.	Modification of connecting stroke	68%
16.	Extension of connecting stroke	74%
17.	Addition of pen lifts	42%
18.	Omission of pen lifts	38%
19.	Omission of i-dots	22%
20.	Modification of i-dot	26%

21.	Change in position of i-dot	20%
22.	Omission of t-cross	4%
23.	Extension of t-cross	12%
24.	Omission of embellishments	18%
25.	Addition of embellishments	16%
26.	Omission of rubrics	4%
27.	Addition of rubrics	4%
28.	Modification of rubrics	24%
29.	Modification of embellishments	22%
30.	Tremor	72%
31.	Addition of simplification	18%
32.	Omission of simplification	6%
33.	Change in forms	70%
34.	Change in formations	0%
35.	Blunt stroke endings	100%

Conclusions

In the present study, the comparison of pen-paper signatures with electronic signatures was performed to identify the differences and similarities between them and find out if they are limited to the range of variation or amount to fundamental differences. The signature samples from 50 subjects were collected on paper and a digital pad. The features were selected for comparison between both signatures. Then the percentage of features occurring in electronic signatures was calculated.

The comparison between the paper and electronic signatures showed many differences in features, most common of which were changes in the vertical and horizontal dimension and blunt stroke endings. According to the observations made, it was due to the inability of subjects to adapt to a new device as well as its limitations, which caused differences in

the features. The improper positioning of the stylus by the subjects led to pen lifts at unusual places and caused them to lose parts of the signatures, which may limit the examination of certain signature features. The prolonged touching of stylus on the surface of the electronic pad caused the addition of connecting strokes and extension of terminal strokes. Some samples lacked simplified forms of signature, which depicts that the writer might be more self-conscious while signing on a digital tablet. A tremor in strokes also appeared, which could be due to the lack of paper-like smoothness on the tablet surface. There were modifications in letter forms (such as retraces converted into eyelets), but the way of creating the forms (i.e. direction of formation) remained unchanged. In electronic signatures, unnatural pen lifts, abrupt change in direction, slow movement, a lack of tapered endings, and presence of tremulous strokes were observed, but these features should not be confused with the sign of forgery. The differences may mislead the examiners in terms of differentiating genuine signatures from forged signatures, but they were quite obviously caused by the device itself the writers' inability to adapt to it. The observed differences were almost the same in all the subjects and were not significant differences – letter formation, which is a very important feature for establishing the authorship, was found to be similar in both pen-paper and electronic signatures. It was concluded that despite differences, one can still establish the authorship from the comparison of electronic and pen-paper signatures.

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Document examination in criminalistics and forensic sciences: New approaches and modern technologies

Valery Shepitko

ORCID: 0000-0002-0719-2151
Criminalistics Department,Yaroslav Mudryi National Law University
Kharkiv, Ukraine

Mykhaylo Shepitko

ORCID: 0000-0002-7164-8037
Criminal Law Department,Yaroslav Mudryi National Law University
Kharkiv, Ukraine

Abstract

Document examination in criminalistics and forensic sciences is an activity required during the investigation and/or judicial proceedings. Using the full potential of investigative actions in document examination is an important source of evidence, which makes it possible to put the crime investigation on the right path. It is extremely important to resolve issues related with the expert examination of documents. Since the technical study of documents is the most common type of forensic studies, the article notes its transformation both towards expanding and restricting its volume. Moreover, the authors give indication of the new paradigm emerging in the examination of documents and their new forms, which highlights the need for developing new approaches and using different techniques and legal frameworks. Another important aspect is the protection of the judicial proceedings from false and erroneous forensic expert reports. To this end, forensic experts are warned of possible criminal liability and are sworn in. It is worth noting that these mechanisms are not always effective and the use of additional legal and managerial

decisions in this regard is required. Forensic experts' false and erroneous reports may be the subject of investigative actions and expert investigations.

Keywords: document examination, questioned document examination, forensic report, forensic scientist, expert witness

In the current context, the formation of forensic knowledge depends on the scientific and technological progress of humanity. The development of criminalistics and its trends are due to the impact of global information flow, the integration of knowledge about the capabilities of combating crime by way of scientific and technological achievements of the modern world. Informatization of the social environment has actually led to the "technologization" of criminalistics, the development and implementation of digital information, telecommunication, and other technologies. Modern technology is a permanent component used in the theory and practice of criminalistics and forensic sciences.

Forensic science is a form of using specialized knowledge (including criminalistic knowledge). It is considered to be professional knowledge and skills in the field of science, technology, art, craft, etc., necessary to resolve issues arising during the pre-trial investigation and evidence consideration in court.[1] In literary sources, specialized knowledge is defined as

> knowledge based on certain science having a theoretical basis, necessary for understanding the nature of phenomena, their properties, both obvious and hidden; in addition, this knowledge must be acquired during special training, the holder of this knowledge must not only be specially trained theoretically, but also possess practical skills in applying his knowledge in the given specialty.[2]

Specialized knowledge embodies the linkage between results achieved through research and practices requiring some preparation; it cannot be ordinary, widespread knowledge obtained in the general education process.[3] It is not a common set of information, but a dynamic entity that is constantly evolving, qualitatively and quantitatively increasing, since,

[1] Kochura O.O., "Definition of the concept of 'specialized knowledge' and its use in criminal proceedings", [in:] *Current trends in the development of criminalistics and criminal trial*, Kharkiv, 2017, p. 285.

[2] A.A. Korabliov, "Forms of using specialized knowledge in criminal proceedings", *Society: Politics, Economics and Law* 2016, no. 2, pp. 132–135.

[3] N.M. Kosmina, "Specialized knowledge of informed persons during the investigation of drug trafficking and its structure", *Forensic Bulletin* 19, 2013, no. 1, p. 25.

as is known, experience has the tendency to accumulate.[4] Specialized knowledge should contribute to the reliable establishment of evidence, not merely its study, and the person conducting the research (expert) should use proven methodologies, equipment, and materials to secure high accuracy of the results.[5]

In criminalistics and forensic sciences, document examination is given earnest consideration. In the field of "criminalistic technique", some of its branches, such as "questioned and criminalistic document examination," are traditionally regarded.

Questioned document examination is the most common type of criminalistic examination. Its principal focus are facts and circumstances related to the production of documents, the technique of introducing changes, identifying invisible records established on the basis of specialized knowledge in technical research (criminalistic technique research) of documents in the manner prescribed by law.[6] In accordance with the instructions on the designation and conduct of forensic examinations and expert studies (approved by order of the Ministry of Justice of Ukraine on 8.10.1998 No. 53/5), questioned document examination is divided into the examination of document details, printed forms, and document materials.

In the current context, attempts have been made to change the criminalistic document examination as a branch of criminalistic technique, replacing it with "criminalistic documentation" or "criminalistic records management." In particular, it is proposed to consider criminalistic documentation (document studies, document science, documentoscopy) as a system of scientific knowledge about the types of documents operating in criminal proceedings as well as the means, techniques, methods of their investigation, the use of this information for legal and criminalistic purposes.[7]

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[4] I.I. Kohutych, "Selected issues of the essence and forms of using specialized knowledge in criminal proceedings", *Bulletin of the Academy of Advocacy of Ukraine* 12, 2015, no. 2, p. 113.

[5] M.A. Maliutin, "Specialized knowledge as examination evidence", *OSU Bulletin* 139, 2012, no. 3, p. 96.

[6] O.V. Vorobey, "Forensic-technical examination of documents: Basic concepts, origin and prospects of development", *Judicial Practice* 2010, no. 11–12, p. 20.

[7] For more details see: M.V. Saltevskyi, *Criminalistics*, vol. 1, Kharkiv 1999, p. 416.

These proposals are not random, since the scope of the criminalistic technique document examination is expanding, the essence of the document itself as well as the objects and methodology of expert research are changing.

The transfer of information through documents is an important milestone in mankind's development. The documents themselves have also changed significantly: from rock art and images of ancient people to the use of papyrus, and from written documents to electronic ones.

In criminalistics, a document is defined as a material object which contains information about any past or alleged facts,[8] recorded using an artificial language or in the form of graphic images, by a person or using scientific and technological inputs intended for its transmission in space and time.[9] In accordance with the Ukrainian Law on Information, a document is a tangible medium containing information, the main functions of which are its storage and transmission in time and space.

In Ukraine, three document definitions are officially adopted:

1. SSTU[10] 2392-94. Document I. Recorded information which is considered to be a unit in the process of carrying out information activities;

2. SSTU 3017-95. Document II. A material object with information formalized by a human-made method for its transmission in time and space;

3. SSTU 2732-94. Document III. A material object that contains formalized information, drawn up in accordance with the established procedure and having legal significance in accordance with the legislation in power.

The document should include certain details, namely mandatory requirements for its execution. The State Standard of Ukraine (SSTU 4163: 20) establishes the requirements for document execution. In this case, when preparing documents it is necessary to use the following details: 1. a design of the State Coat of Arms of Ukraine; 2. a trademark image (a mark for goods and services) or emblem of the legal entity; 3. the name of the highest-level legal entity; 4. the name of the legal entity; 5. the name of the legal entity's structural unit; 6. the legal entity's reference data; 7. the code of the document form; 8. the code of the legal

[8] V.Yu.Shepitko, *Criminalistics: A course of lectures*, Kharkiv 2005, p. 92.

[9] *Criminalistics: Textbook*, vol. 1, ed. V.Yu. Shepitko, Kharkiv 2019, p. 149.

[10] State Standard of Ukraine.

entity; 9. the document type name; 10. the document date; 11. the document registration index; 12. the reference to the registration index and the date of the document to be addressed; 13. the place of document preparation; 14. a classification mark; 15. resolution; 16. crypto; 17. indorsement; 18. a control mark; 19. a title to the text of the document; 20. the text of the document; 21. a notice about the available annexes; 22. a signature; 23. a seal impression, etc.

Currently, various approaches for ensuring the security of documents against counterfeiting are offered. Special means of protecting documents include: 1. special security elements (e.g. holographic elements, protective tape or fibers); 2. special materials used for the manufacture of a certain document category (e.g. special paper, dye); 3. special technologies used for manufacturing documents that exclude their falsification (e.g. special design techniques, manufacture, and document decoration).[11]

Most developed countries have made the transition to a "new generation of documents" on a polymer basis back in the 1990s. In Ukraine, the manufacture of new generation documents is associated with the functioning of the Znak enterprise production complex, specializing in plastic cards.[12] Holographic security elements are used to manufacture various identification documents with special protection means against counterfeiting: pages for foreign passports; national driver's licenses; vehicle registration certificates; crew member certificates, etc. To manufacture these documents, the enterprise uses the following types of plastic: teslin and polycarbonate.[13]

The instruction on designation and conduct of forensic examinations and expert studies proposed an independent type of forensic examination, namely the examination of holograms. Its objects are holographic security elements, holograms used as a means of control, image, graphic holograms, intermediate products of holographic production, such as soft-

[11] O. Kobylianskyi, G. Trofimchuk, "Criminalistic analysis of special means of document protection against forgery", *Entrepreneurship, Economy and Law* 2017, no. 3, p. 282.

[12] V.I. Tikhonova, T.O. Zakharova, "Research of extremely advanced documents", [in:] *Theory and practice of judicial examinations and criminalistics*, Kharkiv 2010, p. 292.

[13] Ibid., p. 292.

ware, photo masks, and layouts, primary holograms, relief-phase original holograms, master hologram matrices, metal matrices for replicating holograms.

An independent branch of criminalistic technique related to document examination is the criminalistic examination of writing (in the narrow sense, forensic handwriting examination), a branch of science dealing with the laws of writing, the process of its study, the possibility of identifying a person by handwriting, and addressing other challenges of handwriting examination.[14] When examining a letter, the whole complex of handwritten text's characteristics is analyzed, that is, both semantic and graphic aspects, although they are used for various tasks: the author of the document is identified through the written language, and its executor through handwriting.[15]

Analyzing expert practice shows that there is a tendency to increase the number of examinations on the study of signatures and manuscripts created on behalf of persons of advanced and senile age. The accuracy of the criminalistic methodology used for determining the writer's gender can reach no more than 80%.[16]

A new trend in the development of criminalistic technique is forensic authorship identification, which provides scientific ways of establishing the author of a text using linguistics data (phraseology, grammar, etc.). Authorship examination is a type of criminalistic examination.[17]

The instruction on the designation and conduct of forensic examinations and expert studies recommended running a linguistic speech examination, which is divided into a linguistic examination of written language and a linguistic examination of oral speech. In turn, the framework of the written language linguistic examination includes authorship and semantic-textual studies.

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[14] V.Yu. Shepitko, op. cit., p. 103.

[15] I.N. Tetiuhin, K.H. Enhovatova, "Scientific basis criminalistic handwriting research", *Questions of Modern Science and Practice* 56, 2015, no. 2, p. 122.

[16] S.Y. Honhalo, O.H. Haiduk, L.S. Volchuk, "Unidentifying studies of handwriting: current situation and development prospects", *Journal of National University "Ostroh Academy". "Law" Series*, 11, 2015. no. 1, p. 5.

[17] *Great Ukrainian juridical encyclopedia*, vol. 20. *Criminalistics, forensic sciences, juridical psychology*, ed. V.Yu. Shepitko, Kharkiv 2018, p. 222.

In modern sources, attention is drawn to the need and prospects of conducting a graphological analysis for criminalistic purposes, as well as to the relevance of reassessing the attitude towards non-traditional methods of researching the handwritten speech – e.g. graphology and the psychological analysis of writing. In this case, through writing it is possible not only to diagnose (or even identify) the author or the executor of the written document, but also to perform a more complete and comprehensive analysis of the author's personality, highlight their character, abilities, mental disabilities, and even diseases.[18] Other researchers emphasize that the prospect of scientific research in graphology lies in creating an integrated approach to the study of personality through techniques that contribute to the possibility of changing the existing standards in the use of modern psychodiagnostic methods.[19]

The subject of document study, as a rule, is a competent person, namely a specialist or an expert. In some cases, the legislator allows other subjects to study documents within the framework of investigative (search) or judicial actions of other subjects (for example, investigator, judge, parties to criminal proceedings, etc.). In this case, it is not about conducting a forensic examination, but about studying the documents, inspecting them, or making them public.

Procedural legislation regulates investigative (search) actions such as inspection of documents, which is carried out in order to identify and record information regarding the circumstances of a criminal offense, and consists in studying and document examination to identify and capture the signs that attach to documents the meaning of physical evidence. The conduct of such an inspection is regulated by art. 237 of the Code of Criminal Procedure of Ukraine.

The term "document examination" in relation to the name of the judicial action is used in the criminal procedural law. In particular, art. 358

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[18] I.I. Kohutych, "Graphological analysis in criminalistics and its prospects", [in:] *Interdepartmental scientific-practical collection "Criminalistics and Forensics"*, ed. O.H. Ruvin et al., Kyiv 2017, p. 187.

[19] V.I. Kaiko, S.M. Matsyievska, "To the question of expert characterization of individual psychological features of the personality from the handwriting", *Bulletin of Alfred Nobel University. Series "Pedagogy and Psychology". Pedagogical Sciences* 16, 2018, no. 2, p. 58.

of the Code of Criminal Procedure of Ukraine regulates the conduct of the abovementioned judicial action. In part 1 of art. 358 it is indicated that the protocols of investigative (search) actions and other documents attached to the materials of the criminal proceedings – if they contain or certify information that is relevant for establishing the facts and circumstances of criminal proceedings – should be announced in court at the initiative of the court or on petitions of participants in judicial proceedings, submitted for review to participants in judicial proceedings, and, if necessary, also to other participants in criminal proceedings.

A survey on judges carried out by individual investigators revealed that they had to examine the following documents during the legal proceedings: written documents (98% indicated); graphic documents (43%); printing documents (16%); photo documents (85%); phonographic documents (45%); documentary films or visual documentation (71%); electronic documents (42%); other (2%).[20]

The investigation of the crime and the subsequent criminal proceedings requires the involvement of a forensic expert with the necessary expertise to conduct a forensic examination and provide answers to questions of interest to the investigation and/or the court. In Ukraine a guarantee of providing truthful answers to posed questions is a forensic expert's warning of criminal liability for a knowingly false expert report and a refusal to provide an expert report (art. 384 and 385 of the Criminal Code of Ukraine). It is an interesting fact that unlike other unprofessional participants in the proceedings (witness, victim), the forensic expert warns of the possibility of such criminal liability themselves (but not the judge, investigator or prosecutor), since the expert makes a corresponding note in the expert opinion (art. 102 of the Code of Criminal Procedure of Ukraine).

In accordance with art. 356 of the Code of Criminal Procedure of Ukraine, at the request from a party to criminal proceedings, a victim or on its own initiative, the court has the right to summon and question a forensic expert for the purpose of clarifying their report. Before the interrogation of a forensic expert takes place, the presiding judge will

[20] I.I. Shepitko, *Judicial examination in the system of judicial proceedings at first instance: A monograph*, Kharkiv 2018, p. 121.

establish their identity and they shall take the oath of the following content: "I (full name), swear in good faith to fulfill the duties of an expert, using all my professional capabilities." After being sworn in, the presiding judge (de facto once again) warns the forensic expert of criminal liability for providing a knowingly false expert opinion. Thus, the court considers these clarifications during the forensic expert's interrogation as part of the expert opinion, but not their testimony.

On the basis of the given study, as a part of this scientific paper the attempt to find a single forensic expert's knowingly false report for which they would be prosecuted (2009–2019) failed. At the same time, forensic experts are periodically subject to disciplinary actions for conducting forensic research that contains errors (but is not false). Evidence of the falsity of certain forensic experts' reports is also indicated by the fact that during a survey on judges and investigators it was established that in their practice they had encountered false forensic expert information – 6.6% (judges) and 5.3% (investigators). Thus, the information that is provided by a forensic expert in the form of an expert opinion, clarification, or consultation may have signs of falsity and be the subject of further investigation in criminal proceedings. In this situation, various investigative actions can already be carried out as well as expert studies on this document (expert opinion), with a view to establishing the authorship of the text, performing signatures, details, the order of their application, the fictitiousness of the studies themselves, etc.

A survey on forensic experts made it possible to reveal that they experienced unlawful influence in order to obtain a false opinion (24.3%). Moreover, this impact came from the suspect or accused's lawyer (7,75%), the suspect (accused) or their relatives (6,95%), from anonymous persons (5,1%), as well as from the heads of the expert institution (1,9 %). An example of such unlawful influence imposed on a forensic expert is a case that occurred in Kharkiv in 2007. Persons B. and D., wishing to evade criminal liability, forced the forensic expert (with the help of physical threats to him and his relatives) to form a deliberately false expert opinion. Thus, the criminal proceedings initiated in the case of a knowingly false expert report under art. 384 of the Criminal Code of Ukraine led to a criminal prosecution for an infringement on the life and health of the forensic expert and his relatives.

The means of counteracting such a negative impact on the forensic expert is minimizing the possibility of personal contact of the forensic expert with the expert service customer, conducting repeated expert investigations, selecting a forensic expert from the appropriate roster of judges, creating a market for forensic sciences services and their competition, as well as conducting internal and external review of the research conducted based on ENFSI instructions and guidance. In addition, the certification of experts and the accreditation of expert institutions are important, since monitoring the appropriateness of the applied methods and the forensic expert's knowledge in practice is an important component in providing a true and correct forensic expert's report to the prosecution, the defense, as well as the court.

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