Methodological Aspects Of Handwriting Identification

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Abstract: *Signature authentication and identification of writing or printing is one of the most common issues presented to forensic document examiners. Handwriting is a complex motor skill expressed individually as a result of learned symbols that are stored in long term memory. This paper discusses the stages of memory retrieval that begins the writing process through the muscle joint systems that execute the movements that result in the graphic expression.*

The authors discuss in detail the identification process and comparison of handwriting characteristics used in the Forensic Science Laboratory, the Netherlands. The process includes discussion of general characteristics, micro-characteristics, spacing characteristics, and variation, as well as touch-ups and disguise. References are made to literature and research projects that support the principles and methodology. The paper concludes with a discussion about the levels of opinions expressed by forensic document examiners.

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1. Introduction

Forensic handwriting examination is for the most part an empirical science. It is sustained through the experience and knowledge of individual practitioners. The knowledge is transferred during case studies carried out by apprentices under the guidance of an experienced handwriting expert. In this type of system, the practice of science is dependent upon the quality of the trainers and training.

It has become clear through participating in workshops, congresses, intercollegiate exchanges and proficiency testing that there are clear parallels in the working methods of experts from various countries. Moreover, trained, experienced handwriting experts tend to come to identical conclusions when assessing the same material.

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When experts do not disagree, a lawyer in defending his client will not direct his attack so much on the conclusions of the handwriting identification, but on the methods and techniques applied. In this area, forensic handwriting identification is definitely vulnerable. The first signs of this vulnerability are already visible. At the recent congress of the International Graphonomics Society and Association of Forensic Document Examiners held in London, Ontario, Canada (August 1995), a lawsuit was discussed in which the scientific character of handwriting identification was successfully challenged.

Issues such as unambiguous definitions of handwriting characteristics, rules for decisions regarding concordance between characteristics, and values awarded to similarities or differences are rarely discussed in this literature. The search for underlying principles or theoretical bases which explain observed phenomena is also rarely discussed in this literature.

In short, an improvement to the methodological structure of hand writing identification is definitely possible. In the future it is expected that forensic

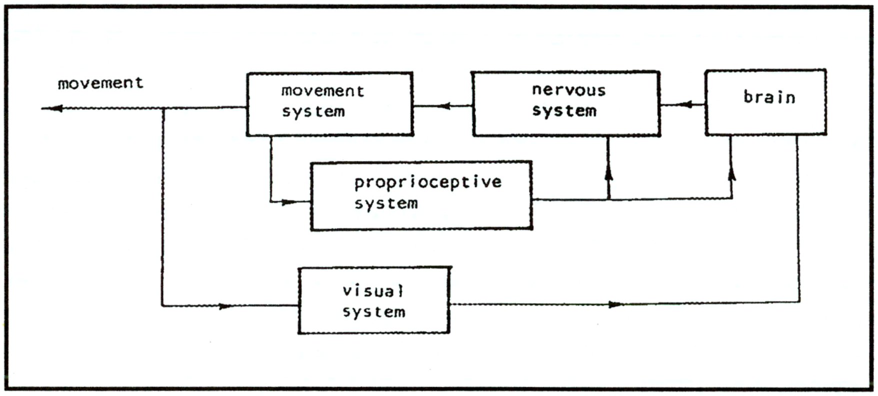

Figure 1. The writing system .

handwriting examination will be confronted more frequently with methodological questions, especially now that scientists from related areas of research such as graphonomy are called upon by the courts and lawyers to help ask these questions. Graphonomy, not to be confused with graphology, is the study of the psychological function and motor aspects of handwriting.

The publication of and comment upon methods and techniques are some of the most important traditions in scientific research. By publishing his work, a scientist is accountable to his colleagues and he allows colleagues and others to test the reliability of his results, deliver comment, spot mistakes and suggest improvements.

This article is aligned with the aforementioned scientific tradition. It describes the methodology used by The National Forensic Science Laboratory of the Netherlands in forensic handwriting identification. It comprises analyses rules and procedures that are aimed at reliable and reproducible examination results. Furthermore, use is made of findings and results from graphonomic research, supplemented with those from in-house experiments, as well as physical. mathematical, statistical and anatomic physiological views.

The comparison method presented here has already been partly published (see Hardy and Fagel 1986). Consequently, a number of literary references relate to the previous period. More recent views have farther confirmed or broadened the picture but have not given rise to any essential modifications. For the implications of more recent graphonomic research on handwriting comparison refer to Hardy (1992).

Theoretical Background

In this section, attention is paid to a number of aspects of the dynamic writing system, insofar that they are of importance to the analysis system described later.

2.1. The Handwriting System

Figure 1 shows the writing process as a control system. Three levels can be distinguished. Activity at the central or brain level ultimately results in motor or action programmes that are sent via the nerves. They activate systems of muscles and joints that in turn move the pen connected to them.

In the system illustrated in figure 1, the feedback mechanism is also pictured. Two types of feedback, visual and proprioceptive, are distinguished. The proprioceptive messages come from receptors in the muscle and tendon which relate to touch.

Denier van der Gon and Thuring (1965) pointed out an important aspect of handwriting. It is well-known that the visual system introduces a certain delay that lasts around 100 to 200 milliseconds (ms). On the other hand, during writing the pen tip often reaches speeds of more than 5 to 10 cm per second. This may seem extraordinarily fast, but these are actually measured values frequently reported in literature. The data in figure 4 show an example. The actual total length of the writing trace of the letter 1 in that figure is about 2 cm. As can be seen from time measurement, it takes about 230 ms (=0.23 s) to finish the movement. This gives a mean velocity of about 8.7 cm per second. Peak velocities are even faster. If the writer observes visually that something is wrong while a letter is being written, the letter will be completed or nearly completed before a correction to the writing movement can be made effectively. The production of a letter takes between 100 to 500 ms. It can, therefore, be concluded that visual feedback has no influence on the writing movement within a certain unit of handwriting such as a letter, part of a letter or a combination of letters.

For the same reasons Denier van der Gon et al state that proprioceptive feedback is also not a workable instrument in the production of a handwriting unit either. The reflex-delay time lies in the order of 25 ms. Therefore, correction would also be too late. Denier van der Gon carried out experiments that appear to confirm this assumption. Experiments using other relatively quick movement forms also indicate a suppression or switching-off of the reflex mechanisms (Denier van der Gon and Wieneke, 1969; Wadman et al, 1979). This brings Denier van der Gon to the assumption that writing movement is a preprogrammed action. The action programmed is formed at the central level and is not influenced by feedback. General programmes are thus established, as well as variations in handwriting that partly mirror information from the central level.

Dooijes (l984) attempted to reconstruct the underlying motor programme from the registration of the writing movement. A further elaboration of his idea could be of importance to handwriting examination, because at least to a certain extent motor programs have to be considered as invariable properties of someone's handwriting. There are indications that the writing system has a different arrangement at slower speeds (Denier van der Gon and Wieneke 1969).

It cannot be concluded from the above that visual and proprioceptive feedback are not important in the total writing process. Obviously if the writing space becomes restricted, the action programmes are adapted during the course of the movement. However, they are fixed until the next adjustment

The next section deals with some of the features of the central and execution levels.

2.2 The Central Level

Anyone who practices the art of writing, (not in a literary fashion) in fact, practices a complex motor skill which was acquired with considerable effort. Information necessary for the manifestation of an acquired motor skill must be held in the memory in one form or another. The questions to be asked now are: what information about movement is held in the memory, (central level) and how is the information processed from the moment that someone intends to write something to the actual writing act?

The word *something* in the previous paragraph can be interpreted as an item, i.e. a word or letter created by the writer or another person. The cognitive processes associated with devising a word or letter are not a matter for concern here. Also, whenever the intention to write is addressed in this text, it must be read in the limited sense of the complex motor skill described above.

Research in the areas of neurophysiology and functional psychology has led to the conclusion that at least two sorts of memory must exist: the long-term memory (LTM) for information that is or must be remembered for long periods, and the short-term memory (STM), also called the working memory. The working memory has a limited capacity to absorb information. At any moment, the information present in the working memory is retrieved from the long-term memory or from the outside world via sense perception, for example a telephone number from a telephone book. According to this theory, all information first enters the working memory. Only a part of this information (coded) will be entered into the long-term[1] memory, either through conscious effort or for other reasons, such as repeated observations, emotional tension, etc. Although both types of memory are seen today more as two sides of the same memory process which contains more levels, long-term memory and working memory are still considered as active notions. In addition, it is considered very probable that there are various sorts of memories for various types of material, for various modes of senses. *Motor memory* is thus mentioned to indicate the information in the central level needed to carry out various acquired actions such as walking, writing, playing tennis or playing the piano. It is believed that every ordered succession of movement elements is represented in the long-term motor memory by a motor programme. Research by Keele (1981) indicates that such motor programmes are abstract, i.e. not muscle-specific. This is true whether the left or the right hand is used or whether the handwriting is small or very large; i.e. written on a black board or with an aerosol on a wall (where the arm is moved from the shoulder). In unusual ways of writing, such as with the mouth or foot, the same abstract motor programme is supposed to be used.

Although motor programmes possess a certain abstraction, it is believed that various collections of programmes exist in the motor memory for various acquired sorts of handwriting, particularly for cursive writing, handprinting and block capitals. In practice, a certain exchange seems possible through which mixed forms can arise.

Research in the psychomotor area has lead to the model described by Van Galen and Teulings (1983) of the writing process as a cognitive activity. In this model, between the intention to write something down and the actual movements of the pen, three stages of motor preparation are distinguished. The first stage in the preparation process, the programme stage, is concerned with the retrieval of the motor programme from the motor long-term memory for a certain writing element such as a letter. In the second or parameter stage, the programme retrieved is placed in the motor working memory where it is made more concrete because from that moment a number of parameters are, in a manner of speaking, 'filled in'. These parameters include the size, speed, and accuracy of the writing. The third and last psychomotor stage is the motor initiation stage, in which the filled-in motor programme is translated into motor commands which activate the correct muscle group at the right moment.

Van Galen and Teuligs found empirical support for the actual existence of the stages in their own reaction time experiments. In these experiments the associated variables of the different stages were systematically varied and the effect of this on the reaction time (the time between the instruction to start the writing process and the actual writing movement) was measured. Some experimental results, however, could only be explained by assuming that during the normal writing process the various stages run simultaneously; during the writing of a completed programmed element, the next element is already being retrieved from the motor memory. Evidence for this parallel processing is given by Hulstijn and Van Galen (1983).

Other research indicates that at most 1 or 2 letters can be prepared simultaneously with the execution of a given motor programme (Teulings, Thomassen and Van Galen, 1983). This number is probably dependent on the limited intake capacity of the working memory mentioned earlier. Kalsbeek (1967) carried out experiments in which he told his test subject to press down on a left or right pedal while writing whenever they could hear a high or low bleep. The working memory was thus loaded even more by this instruction. The resulting handwriting appeared to be more slowly and more spaced as the bleep increased in frequency. Moreover, letters and syllables were unnecessarily repeated. The extra load on the working memory, therefore, seemed in the first instance to influence the parametrization and, depending on how heavy it became, perhaps also the retrieval in the programming phase. Kalsbeek refers here to a limited capacity of the information channel.

With regard to the motor programmes proposed above, one may wonder to which basic units they are related. In other words, how big are the writing elements for which separate programmes exist in the motor memory? Do the handwriting movements psychomotorially consist of a series of programmes for single strokes, combinations of strokes, whole letters or even combinations of letters? On the basis of their research, Teulings, Thomassen and Van Galen (1983) concluded that complete letters form the most probable units in handwriting movement. The research results leave sufficient questions unanswered for alternative interpretations not to be ruled out. The question may be asked whether motor programmes for certain letters can be built up again from separate subroutines, so that various levels of programming exist. In actual practice, it is well-known that some letters or parts of letters have a correlated course of movement. The correlations arise from the copy book that served as a starting point. For example, in Dutch handwriting the upper lengthening of the letters *b, f, h, k* and *l* are often correlated, as are the lower lengthening of the letters *g, j, ij,* and *f*, the ovaling of

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the letters *a, d, g, o* and *q*, and the bridge and/or base formation of the letters h, k, m, n and p. These are the most striking correlations between letters. On careful examination there is a great deal more to distinguish. In an efficiently set up model which concerns the preparation of the writing action, it must be assumed that separate subroutines exist for these corresponding parts. In this way, a motor programme to write the letter "*h*" can be built up out of the subroutines *upper loop* and *foot forming*. Subroutines can exist for smaller parts of letters which are smaller than the aforementioned more or less rounded sections of letters. In certain handwriting, therefore, the feature can sometimes be observed where letters at the end of a word display a similar curved finishing stroke (for example, the letters *r* and *n*).

According to the above-mentioned view, motor programmes are built up out of various subroutines. In the main section of the motor programme the specific concatenation of the sub routines is specified. It is not necessary to assume that motor programmes only relate to a single letter. Separate motor programmes can exist for certain sequences of letters or words and the connections between them. From the view of efficiency, it seems plausible that such ready-made motor programmes should exist for very frequent letter combinations . It can be assumed that a prolific writer will develop motor programmes for long letter combinations sooner, and in particular for letter combinations that he regularly uses, than someone who rarely writes. This includes Dutch handwriting examples such as the short words *is* (is), *en* (and), *de* (the), *het* (the) and *van* (of/from), frequently used suffixes such as -*ing*, -*lij*, -*en*, as well as words individual to the writer in connection with his job or other frequently used words (jargon). In addition, initials, or signatures that are not too long can be considered as being one motor programme in the sense described above. In normal handwriting, however, the size of the motor programme is limited to, at most, a few letters.

2.3 The Execution Level

The writing movement comes about physically through a number of muscle joint systems that set a writing instrument in motion. Normally the muscle joint systems in the hand-wrist area are active, but

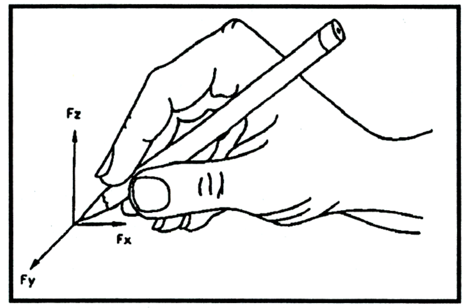

Figure 2. Interaction of forces during the writing action.

the elbow and shoulder joints can also take over parts of the movement. The movement of the tip of the writing instrument describes a trajectory that is the result of all the individual movements. The trajectory laid down is registered because a ball pen, for example, leaves behind an ink trail. The movement generated can be physically divided into three components, two of which lie on the writing surface and the third which is perpendicular to the writing surface (see figure 2). This last movement component experiences the counteracting force of the writing background. The force working perpendicular to the writing surface is also called the writing pressure.

It is worthwhile to consider the freedom of movement of the various joints (see also Hardy 1992). The interphalangeal joints have only one degree of freedom. Each separate joint can only rotate on one axis, resulting in a pen movement along a fixed working line. When two or more interphalangeal joints work together, the movement along the separate working lines is combined, resulting in a curved writing trace. Other joints have two degrees of freedom. They can move along two axes. For some joints, for example the metacarpophalangeal, the second degree of freedom is practically disconnected during the writing act.

The limited freedom of movement of the joints has important consequences for the writing movement. Figure 3 shows an enlargement of a looped letter "l". At point A there is a reversal in the direction of movement. The initial movement to the right changes to a movement to the left. Points B, C and D are also points where the direction of movement is reversed. If the movement to the right at point A is caused by a joint with one degree of freedom, then the reversal in direction is only possible when:

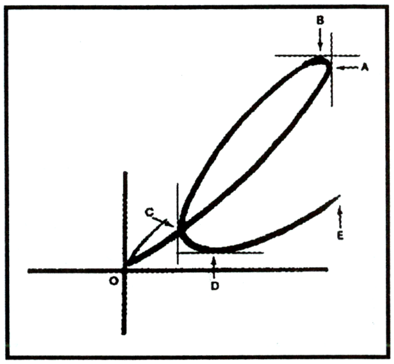

Figure 3. Reversal points in movement.

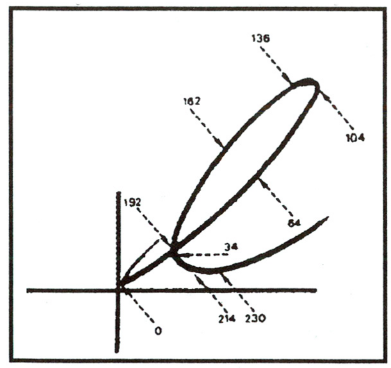

Figure 4a. Length of time in milli seconds pen point takes to reach the marked point.

A. another joint is involved so that the pen point is pushed or pulled in another direction,

or

B. the same joint remains operational, but is now empowered by the opposing muscle group.

In both cases, information or stimulation is necessary from the central level for the working of another muscle group. In principle, a reflex mechanism could also cause the reversal described in A. above. If the reflex is restricted to the same joint, the movement continues to work only in the opposite direction. The joint movement described in B. above is not very common. Denier van der Gon et al (1969) also found suppression of the reflex mechanism with (quick) writing movement.

Using high speed film recording, Hardy et al (1985) measured activity of the muscle-joint system during the writing act. Figure 4a, and 4b shows a picture of their results. In graph 4b, *d* is a measure for the joint activity. The time-dependent change of the activity in the joints of the middle finger is represented, and the joints are shown in the figure by R3-R2 (distalinterphalangeal), R2-R1 (proximalinterphalangeal) and R1-W-2 (metacarpoplangeal).

From the graph in Figure 4b it can be seen that the periods of inactivity (*d* is constant) of the separate joints alternate with the active periods. The letter *1* produced during the registration is shown in figure 4a. A number of positions which were made by the pen point after the allotted period of time had elapsed have been marked on this letter. The time duration is shown in milliseconds.

The reconstruction of the dynamic processes in completed writing will be discussed in more detail later. Here it will be confined to the statement that *the writing movement within a letter, for example. is a result of a combined action o(the muscle-joint systems alternating active periods with inactive periods.*

3. Handwriting Characteristics

In forensic science, a number of techniques such as the identification of people by fingerprints, blood, hair, teeth, etc. are well-known. Identification is carried out more indirectly using objects and materials that can be connected to the person. These include the identification of tool marks, firearms, paint and fibres. Traces are compared in the identification process in order to determine whether the traces could have come from the same source.

The following phases can be distinguished is the Identification process:

- *Analysis* of traces or objects.
- *Comparison of the analysis results* and formation of a decision as to whether they are in complete agreement. In handwriting identification the question to be answered is whether the characteristic of one piece of handwriting corresponding with those of another piece
- *Determination - the relative individuality* of the characteristics

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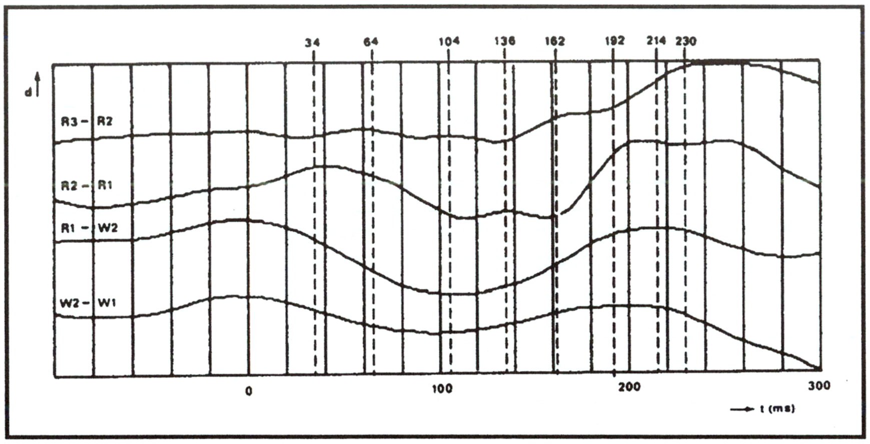

Figure 4b. Activity (d) from various joints as a function of time during the production of the letter I, represented in 4a.

- Are the writing characteristics found among a relatively large group of people or are the) characteristics that occur among only a few people?

Handwriting is a variable product. On the one hand this is because in the programming phase, direct action can to a certain extent be taken either consciously or unconsciously and on the other hand, because the execution of the same movement programmes can differ from production to production, for example, as a result of other muscle reactions.

The description above is limited to so-called short-term variations. Changes that take place in the long-term, for example in the development phase of handwriting as a result of sickness or the aging process, as well as the result of activities connected to one's profession, with the exception of a few examples, are not considered here.

In light of the short-term variation, also called natural variations, which arise during the programming and execution phases of the writing trajectory, the intrinsic possibilities of handwriting as a means of identification can be considered here. If handwriting is variable, is it then a suitable means of identification? There are arguments which suggest these possibilities must be placed at a premium. An individual can recognize his own handwriting and that of people in his direct environment almost in a glance. In addition. clear differences can already be observed by studying the handwriting of children who have completed the first learning phase of handwriting education. On the other hand, the fact that writers have some ability to consciously disguise their handwriting might be given as an objection to the use of handwriting as a means of identification. Moreover, handwriting examination practice docs not always inspire confidence for within the Netherlands and abroad there are familiar examples of conflicting experts. However, this last example confuses the problem posed here to a certain degree. for there is a distinction to be made between the principal identification possibilities and the manner in which they are utilized by the collective practitioners.

The axiom that no two people possess exactly the same handwriting is often used as an argument in the discussion of identification possibilities offered in handprinting examination. In actual practice, the investigator is rarely confronted with the total writing repertoire of an individual. Usually he only has to deal with a sample from that repertoire, for example, in the form of a short writing statement a letter in disguised handwriting, or a signature. Tests like those done by Conrad (1975) show that in such a situation, handwriting examination can be a reliable means of identification indeed. In these types of tests, handwriting examiners are confronted with maternal that has been produced under well-defined experimental conditions. If the results of the examinations are compared with the correct ones, then a picture could be obtained of the competence of the experts and to a certain extent the reliability of the means of identification. Skilled experts seem to be capable of very reliable judgment. They distinguish themselves from their less capable brothers taking part in the same tests. Michel (1982) underlines the importance of a well-defined analysis system in this context.

Practitioners of identification techniques which are considered scientific are, on the whole, in agreement about the analysis system used. In paint analysis the elementary composition of the pigment is determined using x-ray fluorescence and the chemical properties of the binder are determined using pyrolyse-gas chromatography. Forensic serologists, without exception, characterise blood on the basis of a number of systems. Handwriting examiners are, in this respect, less unanimous. While there is little difference in opinion concerning a number of well-defined and measurable characteristics such as word spacing, line spacing, left and right margins and angle of inclination, the consensus lessens for characteristics, where a clear definition or degree of measurability is lacking. Michel(1982) handles the idea of ‘’Strichspannung”, for example, without giving a definition of it. The idea can be verbally described in terms of elastic buoyant tense versus slack tense. Similar scales are frequently and successfully applied in psychometry. The minimum condition is that as many investigators as possible make use of the same Scale of reference. In handwriting examination, the latter is unfortunately not always the case.

In the German language area Michel’s (1982) proposed analysis system has been frequently applied, although sometimes differing views are heard (compare with Lamp’l 1983). In spite of the objections attached to the system, its wide acceptance can be considered as an improvement. In the Netherlands the situation is similar. The Forensic Science Laboratory uses a system discussed below, which in technical circles has been discussed in detail and accepted by a majority of the Dutch forensic handwriting examiners.

In forensic handwriting identification literature, the concept of range of variation is frequently handled in the comparison of writing characteristics. Hilton (1982, p. 174) states “Thus the identification of a signature consists not only of matching it exactly with a particular known signature , but of determining that it contains the characteristics of and is written in the same way as the standards and also fits within the extremes of variation established by the collection of known signatures”. A definition of what varies and bow the variation is described is missing .

The analysis and comparison systems used by the Forensic Science Laboratory in the Netherlands will now be discussed in greater detail.

3. Analysis of Handwriting

The analysis of handwriting in the Forensic Science Laboratory the Netherlands is carried out on the basis of the following four main groups of characteristics:

1.Micro-characteristics

2.Characteristics that deviate from the norm

3.General or derived characteristics

4.Spacing characteristics

3.l. Micro-characteristics

The original movement can be described using these characteristics. The theoretical background shows that the units in which writing is stored and processed at central level are letters, finished parts of letters or letter combinations.

Moreover, it has been shown that the execution of these types of units occurs without visual feedback and probably without proprioceptive feedback. It seems an obvious step to describe the movement within the units referred to here. In the discussion of the execution level, the movement within a letter is described as a combined action of movements of muscle-joint systems that alternate between active and inactive periods. It has been shown that the points of reversal in direction reflect the engagement of a system. For initiation of a system, a command from the central level is necessary. The action programme must contain this instruction. However, activation and deactivation also occur between two successive points of reversal. It will now be shown that the points in the written form that correspond with this can be reconstructed. The starting point is to accept the fact that by engaging a new system, the pen is pushed or pulled in a different direction from the original. Again the cause is the restricted degree of freedom of the joints, which is also addressed.

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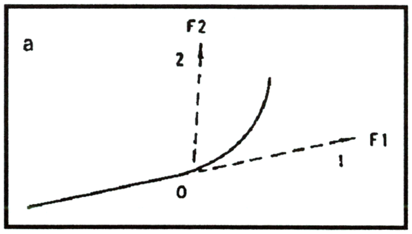

Figure 5a. Schematic representation of the localisation of an interaction point.

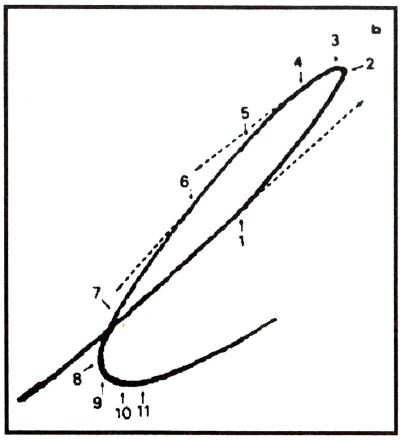

Figure 5b. Determination of definition of the notion of interaction points in a written interaction point is given by Hardy letter I.

In figure 5a the principle is shown schematically. An initial straight line undergoes deflection, which becomes clearer if the original trajectory is extrapolated. Figure 5b shows the result of this extrapolation principle in an actual written form.

The points where activation and deactivation take place are called *interaction points* It should be noted that when more systems are active, a change in the angle of inclination also arises if one of the participating systems is disconnected or deactivated.

The principle of reconstruction of interaction points has been demonstrated in its simplest form. In practice, more complicated interactions take place. In this way, more systems can be active while a new combination of systems is connected. The trajectory that is initially bent gets another curve. These interaction points are sometimes not accurately localised. A more scientifically founded definition of the notion of interaction point is given by Hardy et al (1985).

In summary it can be said that within the written form, activation or deactivation of muscle-joint systems occurring during the original movement can be reconstructed. These points are called interaction points .

They represent the original movement and the underlying action programme. A series of successive interaction points and the curvature of the writing trace around these points are together referred to as a micro characteristic. So one has to distinguish between the carrier of a characteristic (a letter, part of a letter, etc.) and the properties of that carrier (interaction points and curvature together named micro-characteristic).

3.2 Characteristics that deviate from the norm.

The previous section was concerned with the production of handwriting. In many cases, writing must also be read. The latter is only possible if the producer keeps within certain boundaries of specified norms. For example, in Dutch handwriting a letter *p*, is recognized as a *p* in a word or sentence if it corresponds with one of the sketched models in Figure 6a,b,c. A large number of writers make use of one of the visible forms in Figure 6a,b,c, or natural variations of them, which have only minor deviations. A relatively small number of people display more or less extreme deviations from the prevailing norm. An example is shown in Figure 6d. This is a characteristic that deviates from the norm, and in trade literature is also referred to as an individual characteristic.

These characteristics are used by experienced examiners to form a very efficient and effective means of identification. Deviation from the norm is not established in every case because obvious criteria are missing. It is true that deviation from the norm can be verified with the help of a representative sample, but the problem is then shifted to the representativeness of the sample. The absence of practical, manageable criteria causes some examiners to call on their experience as a source of reference. It is obvious that this holds several risks. In particular, beginners are inclined to see characteristics that they encounter for the first time in their short careers as deviating from the norm. The same problem exists when a more experienced examiner has to judge handwriting that is

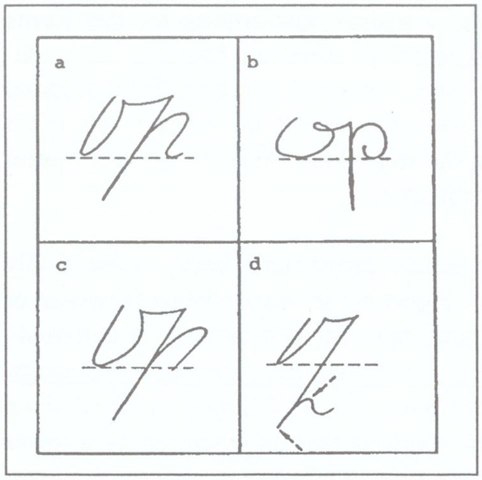

Figure 6. “Normal” letters p and letter p deviating from norm.

relatively unfamiliar to him, for example, handwriting produced by a foreigner.

Trade literature has until now shown an absence of such practical criteria for the establishment of deviation from the norm. On the basis of the previous section, however, some criteria can be given. It is necessary to come to a further sub-division of the notion of deviation from the norm.

On the basis of the action prorate, deviation from the norm increased by:

1. The whole action programme being different than the usual programme for the letter, letter combination, etc.

2. The sequence of movement deviating from the usual. Figure 7 gives an example of this. The top of the number 2 has an anti-clockwise tum. In the Dutch system the turn is normally clockwise. Foreign systems can show other norms.

3. The action programme consisting of more or less than the usual number of programme steps. A manageable criteria for this forms the number of points of reversal in direction because, as is described in paragraph 2.c., a new command is needed for a reversal in direction. Figure 8, for example, shows the letter *I*. An extra *eye* is stuck obviously on the small loop At least one extra point of reversal is introduced by this *eye*.

4. One or more steps of the action program being considerably longer or shorter than usual. Figure 6d

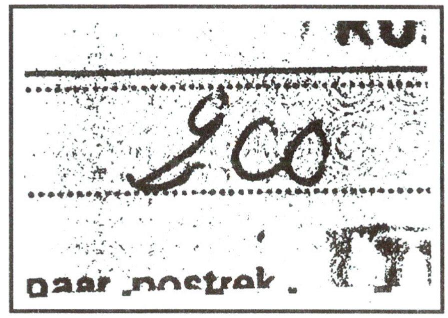

Figure 7. A number 2 that deviates from the norm (with respect to the Dutch system). The turn in cap is anti-clockwise.

shows a writing fragment of a letter *p*. The movement step, marked with arrows, is extremely short, so the base of the letter is not positioned at or near the imaginary base line as usual. In this case, a rule of thumb can be derived for deviation from the norm which is that an extension of a lower loop is not longer than about three times the length of an upper loop Conversely. It is rare that an extension at the bottom is shorter than a third of the length of an upper loop. Using approximation, assuming a normal distribution, it can be deduced that vertical length changes are rarely longer than four times the average length of the upper loops and also that they are rarely shorter than a quarter of that average length.

5. One or more angle changes that are different from the usual.

Although using these rules of thumb is a more practical approach for handling deviations from the norm, care should be taken. The risk of false analysis of these deviations, and even worse, the risk of a completely incorrect analysis is higher when the examiner increasingly bases his case on a supposed deviation. Comparison with micro-characteristics, including possible elements which deviate from the norm, will decrease the risk.

3.3 General derived characteristics

In trade literature the term *general* is interpreted in different ways. For example, as a class characteristic the term issued to indicate that certain characteristics are found within large groups of the population. Individual characteristics are the opposite of class characteristics.

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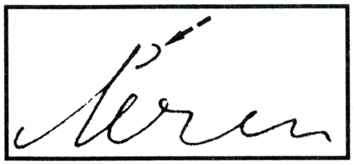

Figure 8. Letter I deviating from the norm, with added loop.

In the Foresic Laboratory's terminology, general characteristics are characteristics that describe the general image or impression of the handwriting. In trade literature the term global characteristic is also used in this context.

The following characteristics belong to the category of general characteristics:

- The style of handwriting (cursive writing vs hand printing).
- The slant measured between the upper and lower extensions and the imaginary baseline.
- The degree to which writing is disconnected.
- The proportion between the lengths of the upper extensions, the letters of the middle-zone (including man) and the lower extensions.
  The width proportion of the middle-zone.
- The writing pressure and the variations in this pressure.
- The line quality (fluent vs hesitating).
- The variation in all of the above-mentioned characteristics. In this context, variation can be interpreted broadly. For example. hand writing with a highly varying slant can give a very irregular image. Also, the style of handwriting can vary. Figure 9 shows that an uppercase block letter R also occurs with cursive writing.

A number of general characteristics can be deduced from micro-characteristics. If a detailed curve trajectory is compared within an upper loop for example. the average angle of inclination is also determined. These characteristics are referred to as derived characteristics.

General characteristics are most important when handwriting has to be compared with deviated style of writing. The comparison of micro-characteristics can, in fact only take place within an identical letter model. If a letter, written completely in block letters displays very angular links while another in cursive writing has a definite round character. then in this respect there is a difference in general characteristics. These types of differences in general characteristics are, in examination practice however, rarely of overriding importance.

3.4 Spacing characteristics

The following are included in this category:

- The positioning of the handwriting with regard to the edges of the paper. This positioning is determined by the width of the left and right margins and the upper and lower edge.
- Line spacing.
- Word spacing.
- Spacing between free-standing parts of words.
- Variations in these characteristics .

These characteristics can simply be determined using length measurement. Some characteristics of this category, for example the spacing between two successive words, are not affected by visual and proprioceptive feedback. When the writing of a word is interrupted, proprioceptive feedback can play a role. When the hand is in a fixed position on the paper for example, continuous movement will build up a greater strain in the wrist system. Feedback through the receptors in the tendon or muscle can lead to the displacement of the hand, thus relieving the increased tension. The process can repeat itself.

The width of the left and right margins and the line spacing can, in principle, be influenced by visual feedback. If a straight left margin is held as a norm, deviations from this norm can be signaled visually, so that corrections can be made. The delay time in the visual feedback does not constitute an impediment for effective correction.

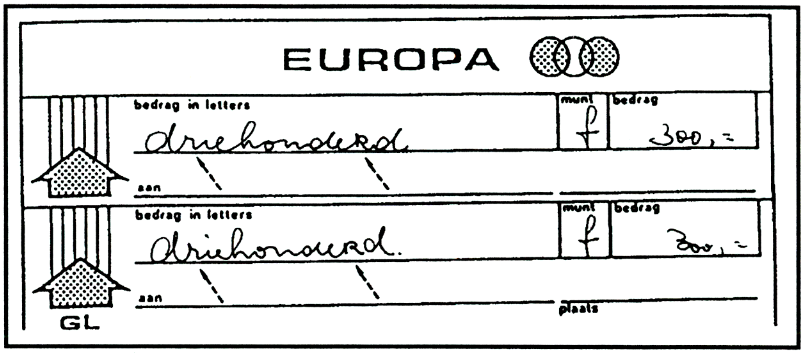

Figure 9. Cursive writing with the usual and the uppercase block letter R.

4. Comparison Of Handwriting Characteristics

4.1 Levels of Comparison

As was discussed earlier, an identification process can be divided into:

- The analysis of characteristics .
- The comparison of characteristics.
- The determination of the relative individuality of characteristics .

In the comparison phase discussed below, similarities or differences between characteristics are considered between the questioned handwriting and the standards. The so-called decision rules are handled here. The fact that handwriting is a variable product makes the decision rules complex. Two pieces of handwriting totally different in image, may after careful examination appear to be written by the same hand. There are practical examples, however, where a writing expert comes to the conclusion that two pieces of handwriting are not by the same hand, even though there are numerous correspondences. Purely statistically speaking, it seems to be a matter of a limited number of points of difference, known as inconsistencies, which can settle the matter in such cases. A consistent set of decision rules must be able to cope with the cases described. Insufficiently trained examiners run the risk of using an inconsistent (ad hoc) set of rules, or misinterpreting a correct set of rules.

In the following paragraph it is argued that the comparison process has a hierarchical structure that shows parallels with the programming of handwriting at central level. Furthermore, the conditions are given under which the statistical tests are applicable.

Handwriting is a pre-eminently variable product. There are natural or short-term variations which are observable in writing units produced in a short period of time, as well as changes that occur in the long-term. More over, handwriting can be disguised. The effects that these sources of variation have on the final product are only partly known or predictable. The effect of handwriting disguise is often over-rated by inexperienced examiners. More fundamental research is necessary to gain a better insight into the different variation mechanisms, but total predictability is impossible. The effects of handwriting disguise can be studied by using test subjects to carry it out within well-defined conditions. From this, general rules can be derived. It remains impossible, however, to predict with certainty the behaviour of an individual in specific situations.

The formal comparison and decision procedures applied in the Forensic Science Laboratory in the Netherlands will now be discussed.

A number of levels or phases are distinguished that are not easily recognisable in actual practice. An experienced examiner can pass through a number these levels in a glance without realizing it. In situations where this is necessary, the examiners can always rely on the formal procedures.

The comparison process has a hierarchical structure that appears to be parallel with programming of handwriting at the central level. The more levels of

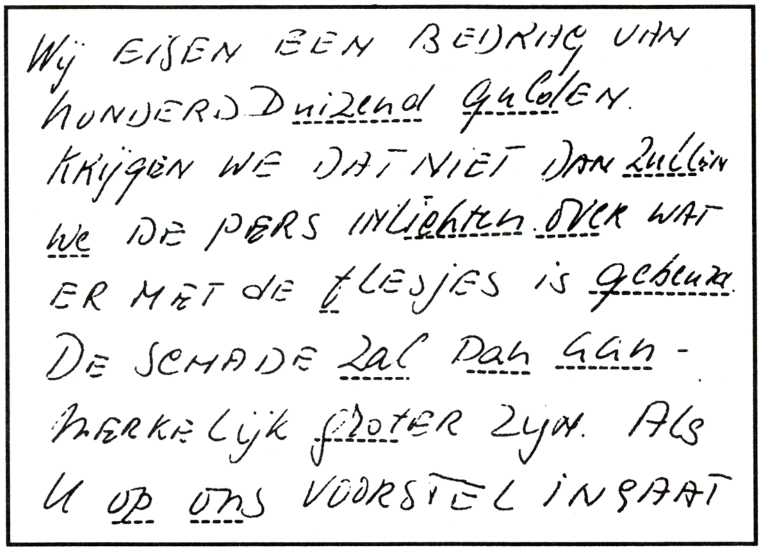
Wij EISEN EEN BEDRAG VAN
HONDERD Duizend gulden.
KRIJGEN WE DAT NIET DAN zullen
we DE PERS inlichten over WAT
ER MET DE flesjes IS gebeurd.
DE SCHADE zal dan aan-
merkelijk groter zijn. Als
U op ons VOORSTEL INGAAT

Figure 10a. Fragment from a blackmail letter in block letters. A number of fragments in cursive and (small) can be seen.

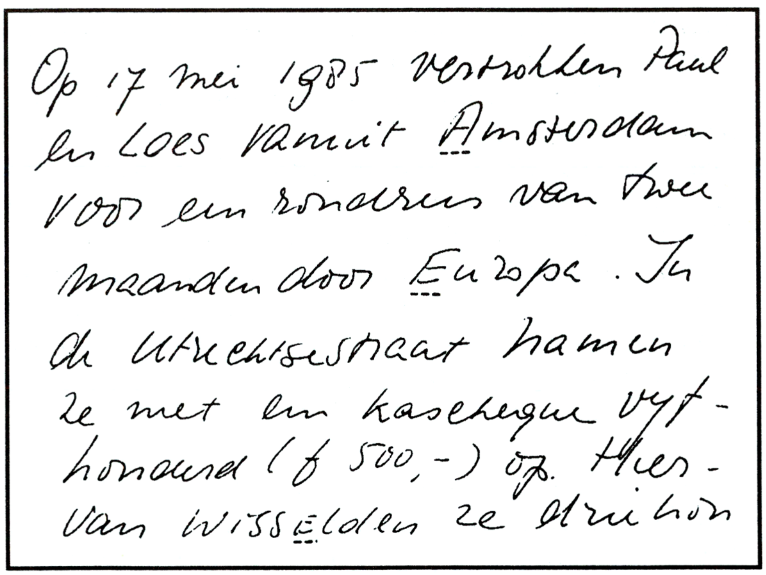
Op 17 mei 1985 vertrokken Paul
en Loes vanuit Amsterdam
voor een rondreis van twee
maanden door Europa. In
de Utrechtsestraat namen
ze met een kascheque vijf-
honderd (f 500,-) op. Hier-
van wisselden ze drie hon

Figure 10b. Writing sample, Uppercase block letters occur.

this hierarchy that can be passed, the more meaning the resulting similarities or differences present for the examiners. This is also referred to as the quality of the similarity or difference. The next levels or phases in the comparison process, as set out in this hierarchical model, are distinguished now.

- The handwritings to be compared are first examined to see if they are of the same style of writing. If this is not the case, the they are examined to see whether certain parts belong to one style of writing Figure 10 shows a more specific example of this principle. Figure 10a shows a fragment from a blackmail letter, and 10b shows a part of a writing sample. The style of writing in essence are different. In one case there are block capitals and in the other, cursive writing. In a number of places, however, similar handwriting is present. For these elements, a comparison on the next level can take place. If similar elements are missing, then the comparison is only related to the

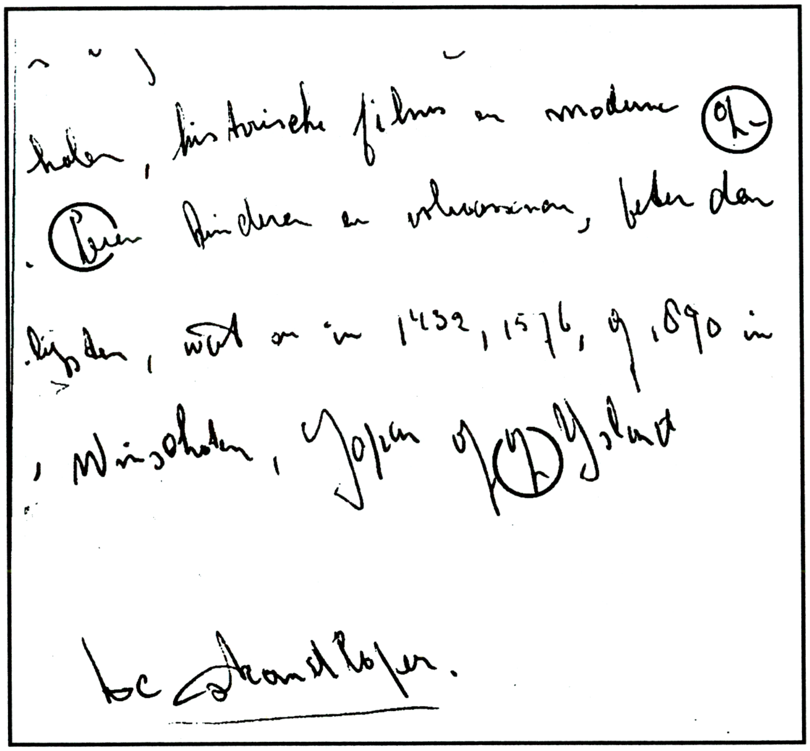

Figure 11a. Characteristics deviating from the norm in disguised writing. (l with extra loop and p with low-placed foot.)

spacing characteristics and some general characteristics (angular versus roundness, proportion of length, etc). In this phase an examiner investigates whether similar programme collections are present at central level. If this is not the case, then the comparison is restricted to the central information that is used in all collections such as word spacing and the arrangement of the writing.

- If there are fragments of identical writing styles in the first phase, the examiner then directs his attention to the parts that display a similar pictorial appearance. Examples of this include sections where the letter forms have roughly the same measurements and the same angle of inclination to the writing line. The image can be determined further by messy or sloppy handwriting, or conversely, neat writing. The speed at which the writing is completed determines this appearance of the writing. As in the central programming, the examiner searches for parts with an identical (central) parameter setting. If he finds such fragments, further comparison can take place. If they are not present, the examiner can concentrate on the comparison of characteristics that deviate from the norm, as well as the possibilities mentioned earlier. These characteristics are relatively independent of the execution conditions chosen. In Figure 11a and b, examples with such deviations from the norm have been circled. In spite of the difference in slant at which both fragments are written, the deviations from the norm remain. These are the added (small) *eye* in the upper loops, the low placement of the base of the letter *p*, and the long end stroke, not circled, of the letter *t*.

In addition to the comparison of deviations from the norm, the examiner can also, when a

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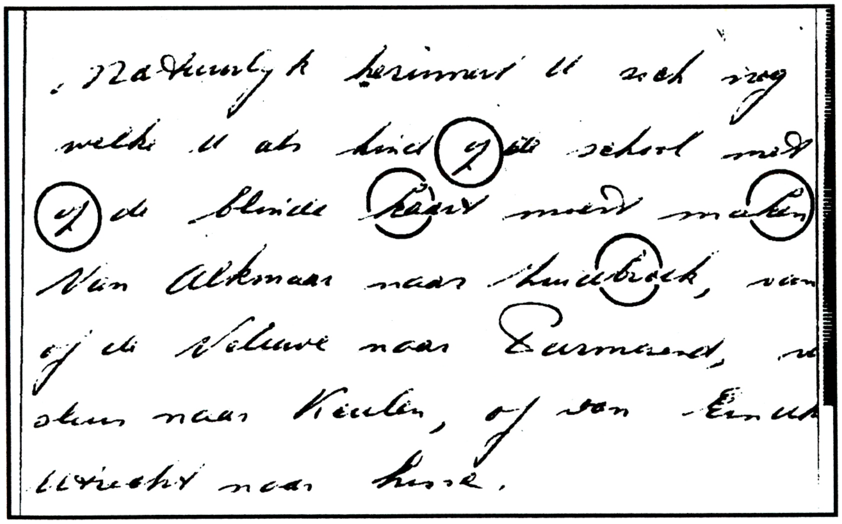

Figure 11b. Undisguised handwriting.

different parameter setting occurs, sometimes draw a comparison between micro-characteristics. If the slant of the writing to be compared is different, it can appear that the detailed course of the curve (micro-characteristics) is in agreement, for example, when rotated to a specific angle. If the size of the handwriting to be compared deviates considerably in a number of cases, it is simply a case of linear enlargement or reduction. Then a comparison of the micro-characteristics can also take place. Conversely, in some cases, enlargement or reduction has been known to lead to a totally different coordination of the writing movement.

- For the sections of the handwriting to be compared that eventually display a corresponding writing appearance, a comparison of the micro-characteristics takes place, (i.e., of the way in which the movement occurs within a writing unit). The movement is described using interaction points that correspond to points of steering, the principle of which is explained in paragraph 3.b. l.

Completely separate from the question of how a similarity or difference at micro-level is eventually established, it is suggested that similarities or differences have more meaning for the examiner if the decision is made on the basis of micro-characteristics. Not only the form or the model of the letter must correspond, but also the manner in which the writer concerned coordinates or steers the movement within the model.

Up until now, variability, a natural feature of handwriting, has not been dealt with. This will be discussed in more detail in the following paragraph which deals with decision rules.

4.2 Decision rules applied to the comparison of writing characteristics

4.2.1 The one-dimensional case

In their simplest form, decision rules can be defined for the characteristic "word spacing" for example. Comparison of this characteristic occurs using only one variable or one dimension . If all the word spacings in a large number of standards are measured, then a distribution of probability results. The next examination is whether the distribution of probability corresponds with that which is specific to the questioned writing. There are a large number of statistical tests for this purpose. In actual practice such a procedure would be very time consuming and of little effect. For this reason, most use is made of one of the following principles.

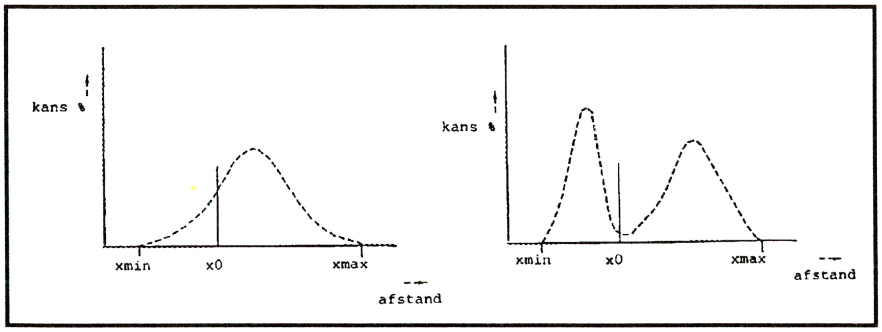

Figure 12. A. Probability distribution function. B. Bi-modal probability

4.2.2 The minimum-maximum principle

If word spacing is taken again as an example, the minimum and the maximum values of measured word spacing found in the questioned writing, for example, are checked to see if they lie in the minimum-maximum range of the word spacing of the standards. The "measurement" in practice is no more than a visual estimate; this is sufficiently accurate for this purpose.

4.2.3 The principle of visual equivalence

The questioned writing is examined to determine whether a word spacing arbitrarily chosen from the questioned writing can also be found in the standards, so that both spacings can no longer be visually distinguished from each other. These spacings are called *visual equivalents*. The accuracy of the visual estimation here, which mostly occurs with little or no enlargement, appears to be sufficient for this purpose. The procedure is repeated a number of times with other words to cover the whole spectrum of word spacings.

If one or both of the conditions (the minimum-maximum principle or principle of visual equivalence) are satisfied, then on a statistically grounded basis, the word spacing in the handwritings compared is in agreement. If the conditions are not met, then the word spacing is different.

For theoretical and practical reasons, the application of the principle of visual equivalence is preferred by the Dutch Forensic Science Laboratory. If the distribution of the word spacing has the form as sketched in figure 12, then the minimum-maximum principle could be applied without any problems. The value measured x0 lies within the range xmax-xmin, so x0 lies within the distribution of probability. In a form of distribution like that shown in Figure 12b, a so-called multi-modal distribution, the probability of x0 being among the collection is greatly reduced. Whether multi-modal distribution applies to handwriting characteristics has never been critically investigated. In practical applications it is sometimes suspected that this type of distribution does appear, especially in the comparison of the multi-dimensional characteristics described below. The actual existence of such a distribution would imply that a limited set of (motor) subroutines is made use of at central level in the motor initiation phase.

4.3 Multi-Dimensional case

The placing of a dot over the letter i can be used as a simple example of a two-dimensional characteristic. The position of the dot can, in principle, be described by the distance measured from the dot to the top of the letter, and also the angle under which the dot is placed in regard to the top (leading or trailing dot). The values found can be represented in a two dimensional graph. (See Figure 13). The distance measured is represented on the x-axis and the angle is represented on the y-axis. From a mathematical viewpoint, the characteristics of the i-dot are represented in a two dimensional space. A number of i-dots from writer A can be measured and when represented in the two-dimensional space produce a cloud of dots which represents the characteristics and the variation of the i-dot produced by writer A. The same can be done for writer B to produce another cloud of dots. When a

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writing expert investigates the characteristic i-dot of a questioned handwriting, it is then easy to decide if the *questioned* cloud is a better fit writer A or B

In reality, few. writing experts would carry out the measurement in the manner described above. The expert can judge at a glance the placement of the i-dot and, by taking the variation of position into consideration, decide whether this corresponding with writer A or writer B. In fact, the expert carries out the procedure described above in a glance and in this manner makes a decision which could be a workable alternative to statistical testing.

The description of an interaction-interval i.e., the section of a curve two successive turning points. is more complex. According to a model described by Hardy et al (1985), at least three variables are requested for the description of such an interval. A letter built up out of n such intervals (n=1,2,3…) is described scientifically as a point in a 3-n- dimensional space. Using this method to represent all the realizations of the same letters, a cloud of points arises in the 3-n dimensional space.

Mathematically, it is not difficult to describe the properties of this cloud of dots.

An examiner who compares two pieces of handwriting and has to determine whether the handwriting is from the same hand, has to check whether for every separate characteristic a similarity can be distinguished. Focusing on the letter *1*, for example, a decision must be made as to whether the questioned letter *l* is similar to the one from the control hand writing. Statistically, it is necessary to test whether the cloud of dots which represents the questioned letters and the cloud of dots which represents the standard letters belong to the same distribution. Statistics provide an extensive series of tests to make this decision in a responsible way.

This testing can be translated into a relatively simple and, in examination practice, an easily manageable procedure. The procedure is based on the search for visual equivalents. The examiner checks whether for a randomly chosen letter *1* from the questioned handwriting, a visual equivalent can be found in the standards, (i.e., letters or parts of letters where the curving can no longer be distinguished visually.) Other productions of the letter l are then looked at in the same way, so that the whole spectrum

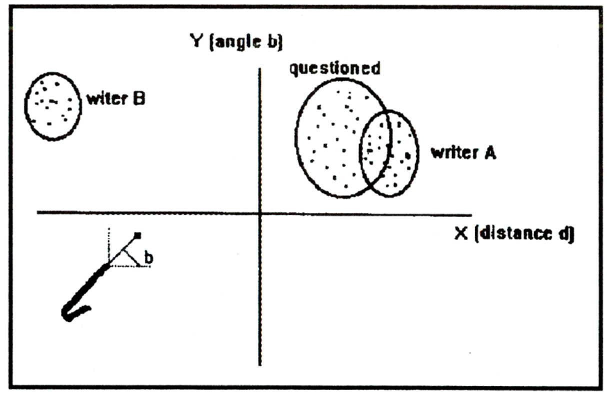

Figure 13. Clouds of dots in two-dimensional space.

of this letter is covered. If equivalents are found, then statistically it can be established that with respect to the letter l the compared handwritings correspond.

Figure 14 shows a practical example of the procedure. The productions are borrowed from the well-known handwriting of Anne Frank. A form from her standards can be seen, marked with number 1, and a visual equivalent form from one of her diaries, marked 2. In some cases, the way an interaction point can be established through extrapolation is illustrated. A selection has been made from all the upper loops in her hand writing, which are representative of the total variation in the upper loop formation. Visual equivalents were continuously sought and found. The characteristic "upper loop" is, therefore, in agreement. Likewise, examples of lower loops and ovals are given.

The essence of this procedure is that the examiner is satisfactorily trained in the observation of the curvature of the writing line, including the interaction points that occur there. The accuracy with which the trained examiner can compare the curvature visually or by using a microscope, is greater than the variation that normally occurs in handwriting. When close comparison is possible, well-trained examiners are able to see differences in length or position of 1mm or less. Even within quite uniform handwriting, a variation of 3 mm or more in the length of strokes, the position of interaction points or the curvature is quit normal. Let us suppose stroke length in a handwriting varies within the range of 8 to 11mm and the examiner should estimate a specific stroke to be equivalent to a stroke of 9 mm. Even when a maximum error is made and accurate measurement reveals a length of 10 mm, the examiner's decision that the stroke in question is

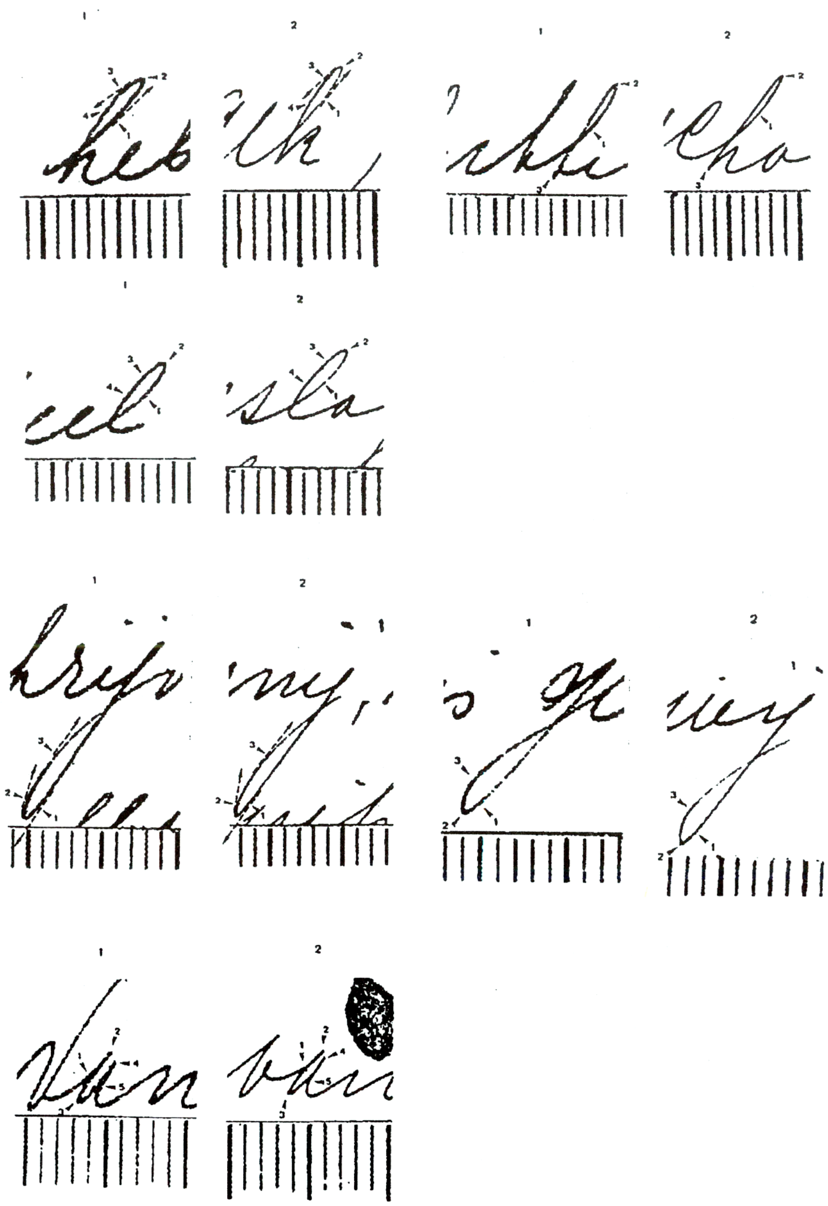

Figure 14. Visual equivalent characteristics from Anne Frank's handwriting. Illustrations marked with 1 are from the control handwriting. Those marked with 2 are found in the diary. Interaction points are shown in the characteristics.

within the range of variation turns out to be correct. To put it in more general measurement terms. The accuracy of the measuring instrument (the well-trained examiner) is in satisfactory relation to the, variables (length, position, curvature) to be measured.

If differences are established and the handwritings are not in agreement with respect to the letter *l*, this does not necessarily mean that the letter *l* is essentially different. It could be that the expert had to make his decision on the basis of a sample that is too small or on a non-representative sample. Eventually the examiner can ask for additional material in the hope the he or she can make a decision on the basis of this. A fundamental difference is only taken into consideration when the standards are sufficiently representative. The expert has to test the representativeness on a number of criteria. These criteria include: the amount of material, the variation and dating, the influence of production conditions, possible pathological processes, medicines, disguised handwriting, etc. The expertise and the experience of the writing expert determines the value or weight placed on these factors.

The procedure can be repeated for all other writing characteristics and writing units.

In practice, the following additional remarks can be made about visual equivalent writing units. In the forms illustrated, (Figure 14) the visual equivalent counts for the whole upper loop, the whole oval and the whole lower loop. However, if a small amount of handwriting has to be compared, the visual equivalent can be found for parts of the lower loop for example. The sections may not be too small in size. A complete upstroke or a downstroke is considered as a minimum unit to which visual equivalence can be applied in principal. Moreover , it is noted that visual equivalence can also be established between forms of unequal size or slant; for example, by an imaginary linear enlargement or reduction of one of the forms, or a rotation of it.

5. Handwriting disguise

A number of mechanisms arc discussed that make handwriting a variable product, and the notions of short-term[1] and long-term variations and handwriting disguise are introduced. In actual practice, the handwriting examiner usually encounters handwriting disguise when someone attempts to make his handwriting unrecognizable.

Research carried out by Pfanne (1971) and Etman and Hoogesteger (1971) has shown that the possibility of handwriting disguise is restricted for most people. Most handwriting disguise, particularly in situations where writing has to be produced at a sufficient speed, is reduced to:

- The choice of another style of handwriting. An anonymous letter is written in block letters, whereas the writing sample is in sloping cursive writing.
- The change in the slant and/or the size of the writing. Back slant writing is used when filling in a cheque, whereas the standards are written in forward slant.
- The change of the form of a limited number of letters.
- A combination of these possibilities .

These findings may well be surprising and seem incredible for some. However, seen in the light of the organization and the function of the writing system, they are easily explained. Within a letter, for example, feedback (visual and pro-prioceptive) is not effective. There are indications that the programming of writing units runs parallel, (i.e., information is processed simultaneously at different levels of the central system.) Interference in these programming cycles is therefore extremely difficult. However, the starting conditions can be changed, another writing style can be chosen or the parameter setting can be influenced by choosing a large or small script, and an usual writing posture can be adopted. Once initiated, the movement within these starting conditions cannot be affected without applying special strategies.

In a general sense it can be stated that the probability that handwriting disguise succeeds, i.e. the writing is not identifiable, decreases as more writing is produced.

A somewhat exceptional form of handwriting disguise appears in the imitation of signatures. A forger who has one or more examples of the signature he wishes to forge, will attempt to imitate them as closely as possible. The characteristics of his own handwriting are replaced by the characteristics copied.

6. The relative individuality of writing characteristics

If a conclusion is to be attached to the outcome of a comparison process, the examiner must pay attention to the relative individuality of the characteristics analyzed. The writing expert should ask himself how many other writers from a certain writing population would produce similar characteristics .

In principle, the relative individuality can be determined using a statistical sample. Methodologically speaking, extra attention must be paid to the representativeness of the sample. If the probability of relatively rare characteristics are

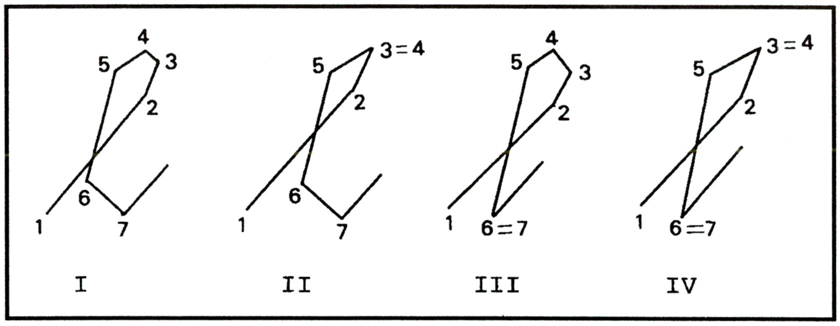

Figure 15. Schematic representation of variants of the letter I.

sought, the sample must be extensive and all examples of letter models used in the Netherlands, for example, should be proportionally represented. This procedure, as long as it is well executed, provides the examiner with valuable information. However, from a practical point of view it is very time-consuming.

It is insufficient to base the comparison exclusively on a restricted number of individual characteristics. It is better to have a large number of characteristics to analyze that are individually perhaps rare, but in combination make sufficient differentiation possible Thus, the problem of representativeness of the sample is avoided. For a comparison based on rare or supposedly rare characteristics, a considerable quantity of information that is locked in the hand writing is simply not used or is ignored. From a theoretical point of view, the question arises as to whether this reduction of information is legitimate; in practice this approach runs the risk of systematic differences being overlooked.

It is possible to gain insight into the relative individuality of characteristics via a theoretical model based on the position of the interaction points. If a number of writers each produce a series of straight lines, then many series would be executed in the same manner. Within the variation they cannot be distinguished from each other. If a second fragment of line is joined onto the first, then a certain part of the group of writers concerned choose a certain direction and length of that second fragment of line; another part of the group prefer another combination of direction and length. The probability of differences being displayed is greater on the grounds of the second addition. The number of interaction points is a measure for the differentiation possibilities or relative individuality. If we continue now this line of thought in order to arrive at the formation of the letter 1, this might result in the model outlined in Figure 15.

The differentiation in forms I to IV is a consequence of the coincidence or non-coincidence of the turning points 3-4 and 6-7 from model I. The model can be extended further by considering the variations of the points lying between 2 and 5. The models shown do not immediately make an impression natural letter forms; however, the interaction points drawn represent the most essential elements of the natural forms. Morasso and Mussa Ivaldi (1982) have carried out similar model simulation experiments that produced very natural handwriting.

On the basis of the model described, the letter forms in the handwriting for a group of 100 people were analyzed. The group was selected on the basis handwriting with the same pictorial appearance. In the analysis of the upper loop, for example, it appeared that after six successive interaction intervals, the loop formation of 44% of the participants did not differ. From this it can be calculated that on the basis of each interaction interval, on average 14% of the writers disappear from the original group. Their upper loop form deviates from the rest of the group.

Writing units that consist of six interaction intervals possess, according to this experiment, a minimal relative individuality of 44%. The term minimal is used here because in the experiment described, handwriting is sought that shows a corresponding image. If we consider, for example, the total writing population to which people who write in block letters belong, then the group referred to here form another section of the population.

The estimate obtained above opens up the possibility of calculating the minimal individuality of filling in "three hundred" in letters and numerals. This filling in occurs very often in the Netherlands, for example, in the case of cheques. Closer inspection shows that such a manifestation is built up from about 12 independent subroutines with about 45 interaction intervals in total. In this way the ovals of *d*, *o* and *g* form an independent subroutine that is built up out of 5 or 6 interaction intervals. The base formations of the letter *h* and the letter *n* are also often correlated. They consist of 4 or 5 interaction intervals. On the basis of the above, a minimal relative individuality of $(0.86)^{45} \approx 1.13 \times 10^{-3}$ can be calculated for this not unusually large piece of handwriting. In reality, this number is smaller for the reason stated above. The outcome of this calculation gives naturally only an order of magnitude estimation. We can continue the procedure and calculate the relative individuality of a text that consists of all the upper and lower case letters of the alphabet. We assume that the handwriting is reproduced according to a copybook frequently used until 1960 in the Netherlands. In this system there are about 25 independent subroutines to distinguish in the cross-section with a total of about 90 interaction intervals. On the basis of this, the total text has a relative individuality of globally $(0.86)^{90} \approx 1.27 \times 10^{-6}$.

The relative individuality of a combination of characteristics can be considerably increased, for example, by a factor of 10 or 100, if in the combination characteristics are present that deviate from the norm.

In summary, it can be said that a comparison carried out on the basis of the micro-characteristics described in paragraph 3.b.1. has a sufficient differentiation ability. A series of characteristics where each is independently not particularly rare can, as a combination, be very easily distinguished from a similar series produced by other writers.

7. The formulation of the conclusions of a handwriting examination.

ln previous paragraphs it has been explained that handwriting is a variable product. The decisions about the correspondence or non-correspondence of writing characteristics arc based on statistical rules. By using test subjects one can study how and to what extent people disguise their handwriting. From, this investigation another statistical element in the comparison process is brought into play. Statistics fill an important role in the determination of the relative individuality of writing characteristics.

Through this overall statistical contribution, from a methodological point of view, certainty of conclusion cannot be given. Nissen (1979) and Michel (1982) present a similar argument. In the case where two handwritings agree in the most optimal manner, these similarities are expressed in the probability formulation: "probability bordering on certainty" written by the same person. Optimal in this case means that all characteristics are qualitatively in agreement: (i.e., that agreement exists at the level of the micro-characteristics or the coordination of movement.) Moreover, the combination of similarities has to be sufficiently individual. It is also possible that the optimal agreement is not met because not all the characteristics arc comparable or the range of the writing is very limited. In these cases, a lower degree of probability exists. Thus, in decreasing value the probability scale includes:

- probability bordering on certainty
- highly probable
- probable
- very possible
- possible

This scale of probability is also used in a negative sense. The qualification "probability bordering on certainty not" written by the same person, indicates the most extreme difference that can be met between two hand writings that have been compared.

The use of probability conclusions occurs frequently in the reports of writing experts. Other European Forensic laboratories apply them as well. Some examiners extend the scale of probability mentioned earlier by introducing the qualification "certain". The distinction between both categories of examiners has a more theoretical than practical meaning. This does not arise from a difference in expertise. Even so, the use of the highest degree of probability instead of the qualification "certain" does not imply that any doubt exists about the correctness of the conclusion. Both categories of examiners differ in opinion when the question of whether scientifically certain conclusions are possible is addressed. In the view presented here, a writing expert conclusion is arrived at on the basis of statistical information. Thereby a small, but not exactly known, and therefore fundamental uncertainty remains. This leads on our part to the exclusive use of degrees of probability. Sometimes a counter argument is heard from laymen or even from handwriting experts. Probability conclusions as such would not be reasonable, because in real life someone has or has not written something. Therefore, the statement that someone has been involved for 90% in writing something, does not make sense. Clearly, probability conclusions are interpreted wrongly here. The objection is also heard that an expert must have the courage of his convictions and that actual practice is not served with probability conclusions. In our view, it is the task of the writing expert to show in a scientifically considered way that handwriting has or has not come from the same writer. To reiterate, the scientific, statistical approach only permits probability conclusions. In our experience, probability conclusions are accepted by the user and are assessed at their true value.

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