The Modular Forensic Handwriting Method 2016 Version

Edited by: Bryan Found[1] and Carolyne Bird[2]

Overview: *This document provides a summary of a practical method that can be used to compare handwriting (whether text-based or signatures) in the forensic environment. It is intended to serve as an approach to forensic handwriting examination for practitioners actively involved in casework, or for those interested in investigating general aspects of the practice of forensic handwriting examination (for example researchers, academics and legal professionals). The method proposed does not cover in detail all aspects of the examination of handwriting. It does, however, form the framework of forensic handwriting methodology in the government environment in Australia and New Zealand as represented by the Document Examination Specialist Advisory Group (DocSAG).*

It is noted from the outset that handwriting is examined using complex human perceptual and cognitive processes that can be difficult to accurately and validly describe in written form since, for the most part, these processes are hidden. What is presented here is the agreed general approach that DocSAG practitioners use in the majority of the comparisons that they carry out. The method is based around a flow diagram which structures the comparison process and provides the reader with a guide as to the significant landmark stages commonly worked through in practical handwriting examinations. Where decision points occur within the course of the method flow diagram a series of modules have been developed which describe the nature of the decision under consideration and address relevant theoretical and practical issues. Each module is, as far as is practical, independent of other modules in the method. This assists in facilitating changes in the process over time that may result from theoretical, practical or technological advances in the field.

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Key Words: Handwriting method, handwriting theory, handwriting complexity, simulation, disguise, traced signatures, evidence evaluation, reporting procedures

Introduction to method

Forensic Document Examiners (FDEs) are specialists that are called upon to provide their opinions regarding a wide range of issues associated with questioned documents (ink comparisons, print process identification, indentations, alterations, obliterations, erasures, typewriting etc.). One of the most commonly sought after examinations is the comparison of handwriting (which can either be text-based or in the form of signatures). It is recognized that some individuals specialize in the forensic examination of handwriting and do not claim particular expertise around all aspects of document examination commonly associated with the title of FDE. In recognizing this, the method refers to professionals undertaking forensic handwriting work

1,2. Direct correspondence to Carolyne Bird, GPO Box 2790, Adelaide SA 5001. Telephone: +61-8-8226-7700. Email: carolyne.bird@sa.gov.au

simply as Forensic Handwriting Examiners (FHEs). FHEs express opinions not only relevant to the authorship of writings but also to the process by which writing is produced (for example whether a signature is the product of a copying process). FHEs draw their skill and expertise from a wide variety of sources. These include training programs within laboratories or specialist society meetings, the scientific literature relating to the discipline and a number of dedicated textbooks (see for example Caligiuri & Mohammed, 2012; Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1982; Huber & Headrick, 1999; Kelly & Lindblom, 2006; Osborn, 1929 and the journals cited in the reference section of this document). In addition, most FHEs subscribe to independent testing programs which provide them with feedback regarding the probative value of the skills that they claim and utilise in day to day casework. When reading the method it should be noted that this document is brief and sits at the front of a significant quantity of detailed specialist information, research and FHE experience. This document remains dynamic with regular amendments based on both feedback from those choosing to subscribe to it, and changes to the paradigm arising from scientific research. The document is not intended to be used in isolation, but does provide a framework and summary of the authors' perceptions of the most recent relevant philosophies within the field.

Handwriting is a complex learned motor behaviour that is carried out, at least to some extent, by most members of the population. Individuals are generally taught a copy-book system of writing (one which through formal education is considered to be the model for the handwriting that they are to produce.). There are many copy-book systems taught throughout the world. Huber and Headrick (1999) list 76 different systems in North America alone. What makes skilled handwriting a useful form of evidence in the forensic environment is that it is found to be a relatively stable behaviour within the writer, but the features of written characters do vary markedly among writers, even when people are taught exactly the same copy-book system. The extent of inter-writer variation was illustrated by Srihari and his colleagues (2002). Using computer algorithms these researchers were able to validate handwriting individuality in a sample population of 1500 individuals with a 96% confidence. Using additional features the authors suggest that this conclusion could be reached with a near 100% confidence. A qualitative approach was used by Huber (2000) on nearly 1000 samples of writing. This author found that for all, bar two, of the samples the balance of the samples could be discriminated. Studies on homogenous groups of writers (taught the same copy-book system in the same schools) show that these writers introduce different class-divergent features to the extent that they can be discriminated with a high degree of accuracy (Durina & Caligiuri, 2009; Savoie, 2011). Perhaps the most compelling evidence of the extent of inter-writer variation are those studies dealing with the handwriting of twins and triplets (Beacom, 1960; Boot, 1998; Gamble, 1980; Ramsey Lines & Franck, 2003; Srihari, Huang & Srinivasan, 2008). Across all studies researchers report that there were no instances where the handwriting of one sibling could be mistaken for the handwriting of another.

As with most forms of forensic identification evidence, it is this 'inter-individual' variation that provides us with a useful parameter to assess whether there is evidence to support the proposition that a particular sample of writing was written by the writer of another sample. Handwriting as a learned behaviour is, however, subject to a number of variables that can make the examination process quite complex. Examples of these variables are intra-writer variation (the variation in the handwriting within an individual which is observable as variations in the handwriting patterns each time a sample is produced) and the reality that people can change their handwriting purposefully (disguise behaviour) or copy the handwriting of others (simulation behaviour). This document summarizes the interaction between these methodological elements.

There are a large number of variables that can impact on an individual's ability to produce handwriting in a consistent fashion in relation to the model that they were taught. These include the complexity of the original copy-book system, the writer's propensity to consciously modify the characters or connections diverging from the copy-book system (see Simner [1998]) for an interesting study on copy-book divergence), subconscious modifications to the movements (which may occur in order for them to increase the efficiency of their movements), the writer's

motor skill level and capacity, and bio-mechanical/ postural restrictions which may be associated with any given writing event (see for example Equey, Marquis & Mazzella, 2007; Sciacca, Langlois-Peter, Gilhodes, Margot & Velay, 2008; Sciacca, Langlois-Peter, Margot & Velay, 2011). Complicating the system is that individuals can purposefully change their motor output, and therefore the handwriting that they produce, and can therefore attempt to disguise their own handwriting characteristics or attempt to imitate (simulate) the images produced by others.

In the very simplest of forms the process of handwriting comparison can be described as follows. Examiners are provided with a handwriting sample (whether text-based or signatures) whose author is considered unknown or disputed. This sample is termed *questioned*. The features of the questioned writing are analyzed and compared to another sample of writing (a *comparison sample*). This comparison sample could be writing submitted as having been written by a particular person (a *specimen* or *exemplar*) or it could be another sample of questioned handwriting (termed a *common authorship* examination). Specimen writings are the most frequently encountered form of comparison sample. These may be either *requested*, where the content of the handwriting is dictated to the individual or a sample text provided, or *collected*, where the investigator, or client, locates samples of an individual's day to day writing. The questioned sample is examined and pictorial and structural features that the examiner believes characterize the handwriting are assessed. These features are compared to the features associated with the comparison sample. The examiner assesses the probability of the observations given the proposition that the writer of the comparison material wrote the questioned material against the probability of the observations given the proposition that someone other than the writer of the comparison material wrote the questioned material. Based on this assessment an opinion may be formed as to the extent of support for one of the propositions over the alternate proposition. In some instances where similarities are observed, the examiner will be of the opinion that there is evidence to support the proposition that the handwriting was written by the writer of the comparison material, rather than forming an opinion for the alternate propositions. Alternatively, if the features are found to be dissimilar to the questioned images, the examiner may be of the opinion that the evidence favours the proposition that the handwriting was written by someone other than the comparison writer over the proposition that it was written by the comparison writer.

There are limitations associated with the comparison of handwriting for use in forensic science. Handwriting is a behavioural artifact. As a behaviour, handwriting evidence is subject to a number of potentially limiting factors which include:

- There is not an amount of handwriting which will fully characterise the extent of the variation in the behaviour within an individual or describe precisely the characteristics of the process which controls its generation.
- It is still not possible to determine objectively the relative frequency of any particular handwriting feature in the population although approaches to this issue have been reported (Bishop, 2012; Johnson, Vastrick, Boulanger & Schuetzner, 2015; Saunders, Davis & Buscaglia, 2011). Although handwriting databases may be used in the future, assessment of feature chance match frequencies, or assumptions regarding these frequencies, remains within the domain of practitioner specialized knowledge.
- The features of writing may change naturally over time (particularly in response to aging, (Caligiuri, Kim & Landy, 2014; or cognitive impairment, see Balestrino, Fontana, Terzuoli, Volpe, Inglese & Cocito, 2012) or may change as a result of internal or external factors. See, for example, research reports into the effect of alcohol consumption on handwriting features (Asicioglu & Turan, 2003; Beck, 1985; Philips, Ogeil & Rogers 2008), the work on motor disorders (Harralson, 2008) and handwriting and dementia (Caligiuri, 2013).

Added to these considerations is the reality that the instrument performing the examination

and comparison of handwriting in the forensic environment remains the FHE's brain. The technique is therefore subjective as it is based on the perceptual and cognitive processes of an examiner or a group of examiners. Issues around human factors in forensic decision making processes and in particular the potential for bias in these processes has attracted considerable interest in recent times (Dror, 2013, 2015; Found, 2014; Stoel, Berger, Kerkhoff, Mattijssen & Dror, 2015; Stoel, Dror & Miller, 2014). To protect against potential cognitive contamination of evidence, some practitioners are now turning their attention to changing procedures to avoid exposure to potentially biasing domain irrelevant information (Found & Ganas, 2013). In addition, the relationship between forensic cognitive processes and the structure of examination approaches, quality management factors (such as peer review) and reporting frameworks are being reassessed in light of the new field focused on human factors coined *cognitive forensics* (Dror, 2012; Dror, Thompson, Meissner, Kornfield, Krane, Saks & Risinger, 2015; Dror & Stoel, 2014; Found, 2014).

The results of handwriting examinations are expressed as opinions which are the examiner's subjective belief in the extent to which the examination findings support that the writer of the comparison sample did or did not write the questioned writing. Although research into computational approaches to the examination of handwriting and signatures continues, such approaches are still not sufficiently developed and validated for use in casework (see for example Al Haddad, White & Cowell, 2011; Malik, Liwicki, Dengel & Found, 2014; Marcelli, Rendina & De Stefano, 2011; Parodi, Gomez, Alewijnse & Liwicki, 2014; Srihari, 2010).

Handwriting examination involves more than solely the assessment of evidence to determine if it supports one proposition over another. FHEs' expertise also encompasses skills associated with the determination of handwriting processes. Handwriting processes are behaviours that can be inferred from features within the images. Examples of the processes that FHEs form opinions on are disguise behaviour, simulation behaviour (whether performed unassisted or as a tracing), and the production of machine-generated handwriting. These issues are also addressed within this document.

What is not addressed in this method is the extraction of writer demographic features such as age and gender. Although there has been some controlled research conducted into the determination of these characteristics (Bandi & Srihari, 2005; Haines, Phillips, Rogers & Found, 2001) the results either do not support that the techniques employed are sufficiently reliable for application in forensic science, or the techniques themselves can not be applied to casework samples due to the limitations associated with the format of commonly encountered writing samples. Issues regarding the production of handwriting using machine automation are also not discussed (see Kruger, 2010).

In some countries (for example the US) there has been significant investment in technologies that capture signatures digitally. In the Australasian environment some industry sectors have invested in this technology (for example the postal system). These technologies result in the characteristics of signatures being stored as digital files (which may or may not contain dynamic information). Although requests to examine electronic data files of questioned signatures that are the product of these technologies are rare in the DocSAG environment, demand may increase into the future. Further information regarding forensic aspects of electronic signature examination can be found in Flynn (2012), Harralson (2013) and Nicolaides (2012).

Peer review

Opinions formed using this method should be exposed to a process of peer review. Peer review in most forensic laboratories is not blind but rather a system by which the case is checked against the technical requirements of laboratories and the direction of the opinion verified by another qualified FHE. Should there be any corrections made to technical aspects of the examination or should there be a change in the direction of an opinion, laboratories will usually record this using their quality systems to manage the process.

Validation of method

Given that the forensic examination of handwriting is based on cognitive and perceptual processes, the validation of the strategies used to examine and

compare handwriting is centered on blind testing of FHEs. This is achieved through quality assurance systems and independently conducted trials where the ground truth of the trial is known. This will ensure that, although the written method is difficult to directly validate, the skills claimed by FHEs with respect to the examination and comparison of handwriting and opinions regarding the attribution of authorship or process can be directly investigated and appropriately characterised. This is further explored in the annexure.

Endnotes:

Specialist Advisory Groups (SAGs) were established under the auspices of the Senior Managers Australia and New Zealand Forensic Laboratories (SMANZFL). The SAGs are managed by and report to the Australia and New Zealand Policing Advisory Agency National Institute of Forensic Science (ANZPAA NIFS) Forum. The structure of ANZPAA NIFS has recently changed, and reporting of SAGs is now to the Australia New Zealand Forensic Executive Committee (ANZFEC). The SAGs are designed to put in place mechanisms to encourage collaborative behaviour and innovative thinking with a core focus on maintaining a national outlook and promoting continuous improvement in the application of forensic disciplines. The purpose of each SAG is to promote science excellence in the SAG discipline by influencing decisions on the following key priority areas: technical systems/advice; research and development; training; quality; legislative policy/framework; and communications/representation.

Dictated specimen writings are preferred over a sample of written or printed text as the presentation of a visual model may provide undesirable cues as to sentence/paragraph formatting, and allow a greater opportunity for the writer to introduce disguise elements into the sample.

Authors:

The current form of this document is based on the contributions of a large number of practicing forensic handwriting examiners and academics both nationally and internationally. Significant contributions have been made by;

- Bryan Found (Victoria Police, La Trobe University, University of New South Wales)
- Doug Rogers (La Trobe University); including the role of previous co-editor
- Carolyne Bird, Sharon Birchall, Ian Riebeling (Forensic Science SA)
- Allan Herkt, David Boot, Delwynne Walsh (New Zealand Police)
- James Hofstee, Richard Troncone, Brett Nicholson (West Australia Police)
- David Dick, Kirsten Lacey, Virginia Rowe, Hermann Metz (Australian Federal Police)

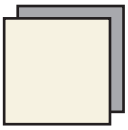
Module 1

The Method Flow Diagram

The method flow diagram provides the backbone for the practical forensic examination of handwriting and signatures. To structure the comparison process the background of the flow diagram has been pattern coded. The explanations for these pattern codes appears below.

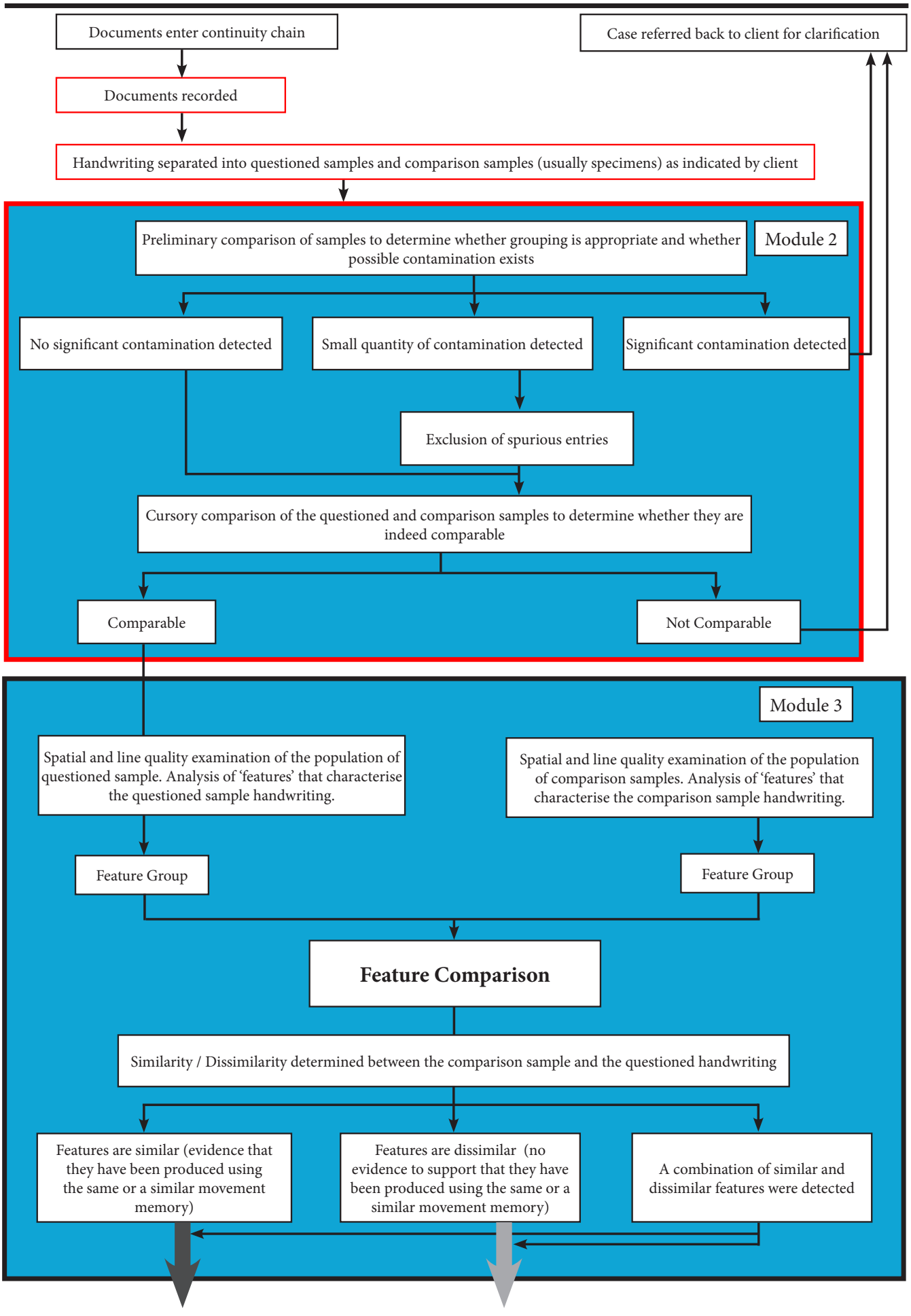
This pattern highlights a stage where there is a written module within the method specifically dealing with this issue.

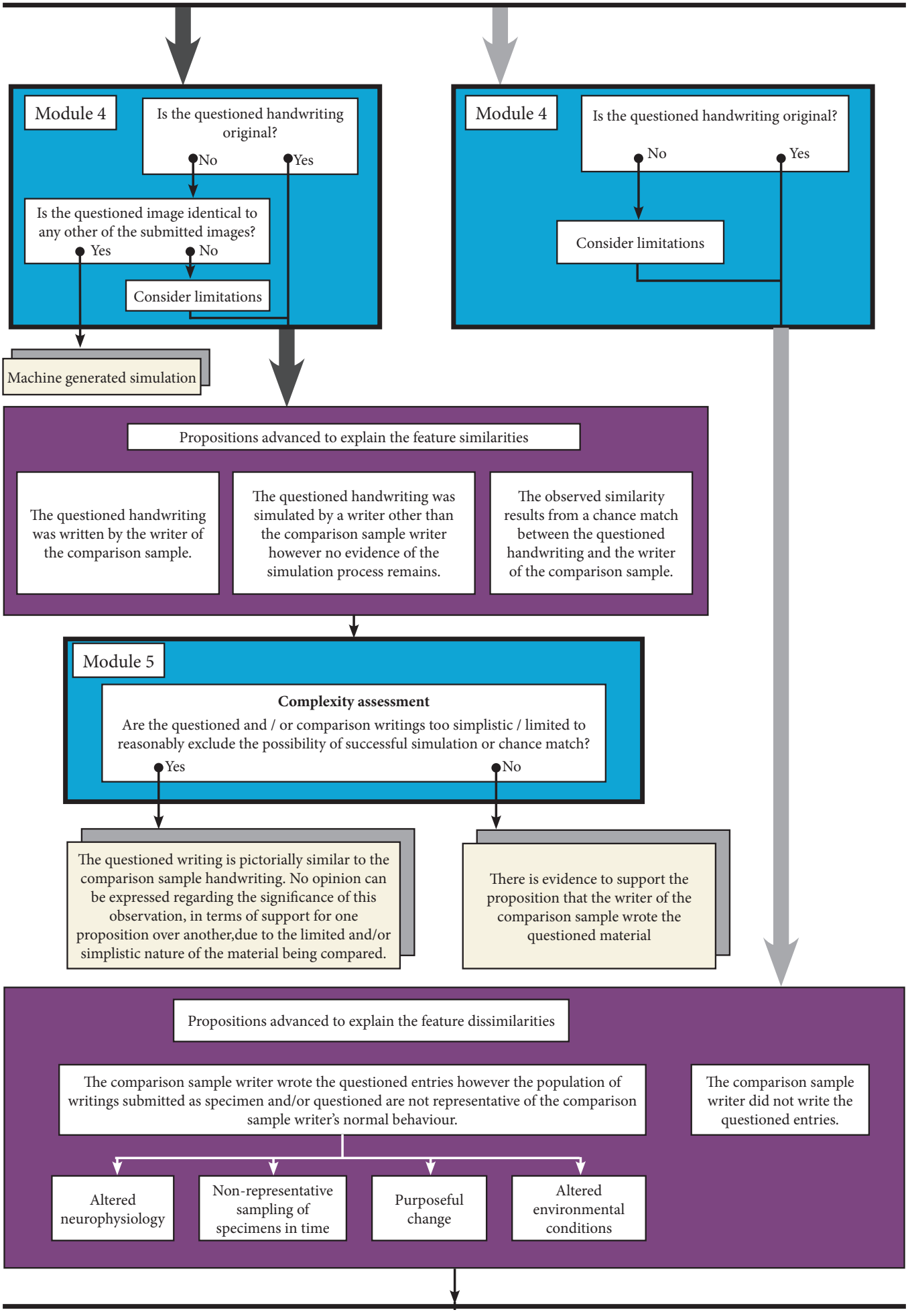
This pattern highlights a stage where alternative propositions are being considered by the examiner.

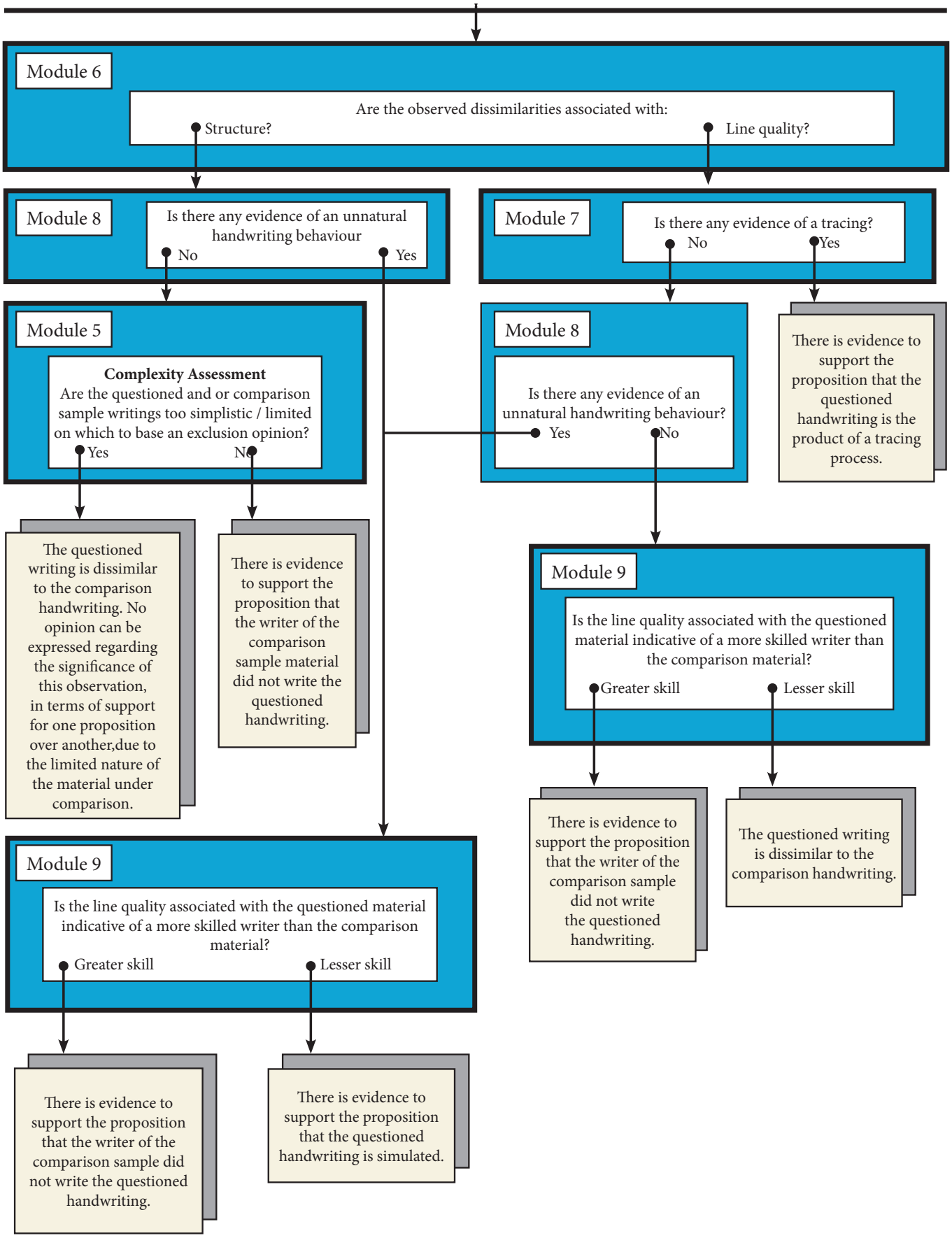


This pattern highlights an opinion formation stage.

Red boxes indicate stages that may be substantially carried out prior to the FDE examining the case. For example, in laboratories that have context control procedures in place, the FDE's examination would commence at Module 3 and the examinations described in Module 2 would be repeated once the questioned sample is analysed.


Documents enter continuity chain
Case referred back to client for clarification
Documents recorded
Handwriting separated into questioned samples and comparison samples (usually specimens) as indicated by client
Module 2
Preliminary comparison of samples to determine whether grouping is appropriate and whether possible contamination exists
No significant contamination detected
Small quantity of contamination detected
Significant contamination detected
Exclusion of spurious entries
Cursory comparison of the questioned and comparison samples to determine whether they are indeed comparable
Comparable
Not Comparable
Module 3
Spatial and line quality examination of the population of questioned sample. Analysis of 'features' that characterise the questioned sample handwriting.
Spatial and line quality examination of the population of comparison samples. Analysis of 'features' that characterise the comparison sample handwriting.
Feature Group
Feature Group
Feature Comparison
Similarity / Dissimilarity determined between the comparison sample and the questioned handwriting
Features are similar (evidence that they have been produced using the same or a similar movement memory)
Features are dissimilar (no evidence to support that they have been produced using the same or a similar movement memory)
A combination of similar and dissimilar features were detected


Module 4
Is the questioned handwriting original?
No
Yes
Is the questioned image identical to any other of the submitted images?
Yes
No
Consider limitations
Machine generated simulation
Module 4
Is the questioned handwriting original?
No
Yes
Consider limitations
Propositions advanced to explain the feature similarities
The questioned handwriting was written by the writer of the comparison sample.
The questioned handwriting was simulated by a writer other than the comparison sample writer however no evidence of the simulation process remains.
The observed similarity results from a chance match between the questioned handwriting and the writer of the comparison sample.
Module 5
Complexity assessment
Are the questioned and / or comparison writings too simplistic / limited to reasonably exclude the possibility of successful simulation or chance match?
Yes
No
The questioned writing is pictorially similar to the comparison sample handwriting. No opinion can be expressed regarding the significance of this observation, in terms of support for one proposition over another,due to the limited and/or simplistic nature of the material being compared.
There is evidence to support the proposition that the writer of the comparison sample wrote the questioned material
Propositions advanced to explain the feature dissimilarities
The comparison sample writer wrote the questioned entries however the population of writings submitted as specimen and/or questioned are not representative of the comparison sample writer's normal behaviour.
The comparison sample writer did not write the questioned entries.
Altered neurophysiology
Non-representative sampling of specimens in time
Purposeful change
Altered environmental conditions


Module 6
Are the observed dissimilarities associated with:
Structure?
Line quality?
Module 8
Is there any evidence of an unnatural handwriting behaviour
No
Yes
Module 7
Is there any evidence of a tracing?
No
Yes
Module 5
Complexity Assessment
Are the questioned and or comparison sample writings too simplistic / limited on which to base an exclusion opinion?
Yes
No
Module 8
Is there any evidence of an unnatural handwriting behaviour?
Yes
No
There is evidence to support the proposition that the questioned handwriting is the product of a tracing process.
The questioned writing is dissimilar to the comparison handwriting. No opinion can be expressed regarding the significance of this observation, in terms of support for one proposition over another,due to the limited nature of the material under comparison.
There is evidence to support the proposition that the writer of the comparison sample material did not write the questioned handwriting.
Module 9
Is the line quality associated with the questioned material indicative of a more skilled writer than the comparison material?
Greater skill
Lesser skill
There is evidence to support the proposition that the writer of the comparison sample did not write the questioned handwriting.
The questioned writing is dissimilar to the comparison handwriting.
Module 9
Is the line quality associated with the questioned material indicative of a more skilled writer than the comparison material?
Greater skill
Lesser skill
There is evidence to support the proposition that the writer of the comparison sample did not write the questioned handwriting.
There is evidence to support the proposition that the questioned handwriting is simulated.

Module 2

Determination of the suitability of questioned and comparison samples: issues of comparability and contamination

Overview. *The primary focus of this stage of the examination is to determine whether any meaningful comparison will be possible based on the samples of handwriting submitted. This stage is normally carried out as a vetting function, where ideally the judgements are made by an FHE that will not carry out the balance of the examination task (a vetting officer). For example, in laboratories that have context control procedures in place, the vetting officer will undertake the assessment for comparability and contamination outlined in this Module. The reporting FHE's examination would commence at Module 3 and the examinations described in this Module would be repeated once the questioned sample is analyzed. In order to proceed through the method, the samples (whether specimen and questioned, or questioned alone) must be comparable. Normally comparison samples are in the form of specimens (where someone other than the FHE has attributed writings to a particular individual). One of the most critical aspects of any comparative and evaluative process is the internal validity of the comparison sample as it is important from the outset that only one writer is represented within it. Since requested handwriting is witnessed, it is assumed to have been written by the nominated person. Collected handwriting is however subject to potential contamination by more than one writer. Although it is not the task of the FHE to prove the validity of the specimen material, writings are assessed, both by the vetting officer and later in the method by the FHE, to determine whether there is any evidence of more than one writer having been responsible for the entries.*

Comparability

Handwriting is a product of the motor system's control over movements of the arm and fingers. The information required to produce these complex movements stems from generalized motor programs or motor memories within the brain. During the comparison of handwriting samples, the examiner is effectively studying the product of motor memories executed by the writer/s in authoring a sample. For the comparison process to proceed, the same characters and forms of characters are required to be present.

Letters can be thought of as either graphemes (such as the images representing the letter "g", which may be uppercase, lowercase, cursive or printed) or allographs, which are specific forms of graphemes (such as the printed character "g"). Different allographs for a particular letter grapheme are usually not comparable. This is because to compare a "G" with a "g" , for example, FHEs are not comparing the same motor memory for the formations. What is required is that the two samples being compared contain common allographs; as these allographs represent the same form of motor memory they can be directly compared. The relationships of allographs to handwriting production and the comparison process are represented in Figures 2.1 to 2.3.

Ideally, it is not only the allographic forms that should be the same. Often, individuals utilize a number of different forms of a particular allograph depending on such factors as its position within the word. Although not a requirement for an examination

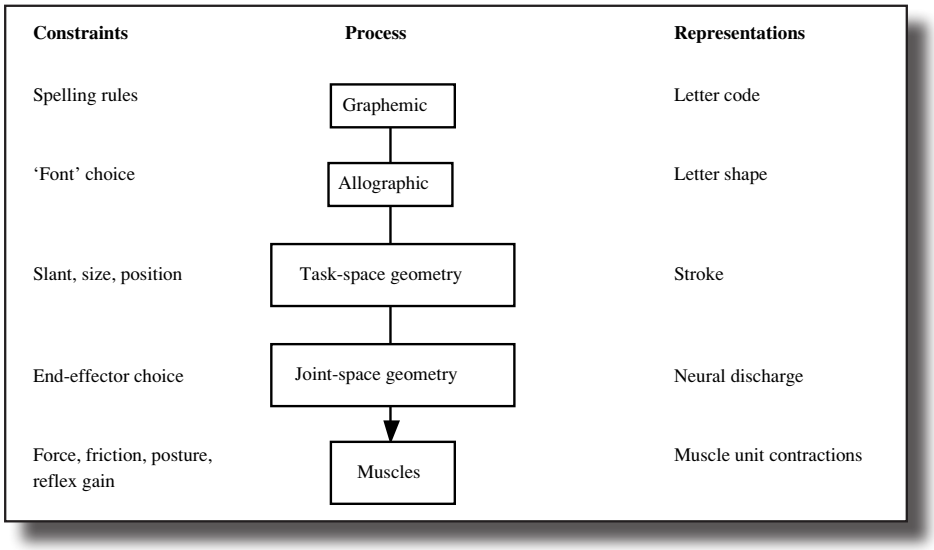


Figure 2.1. Model of handwriting production stages (modified from Schomaker & van Galen, 1996).

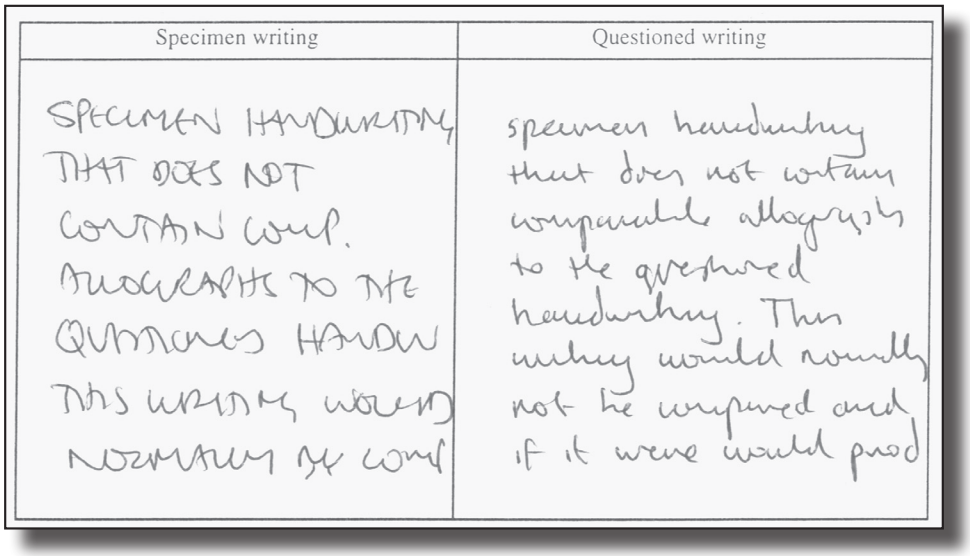


Figure 2.2. Specimen handwriting that does not contain comparable allographs to the questioned writing. This writing would not normally be compared.

to proceed, additional information can be gained from having comparison material that contains common words, or common sentences. This can provide information regarding the feature relationship between combinations of characters and words (see Figure 2.4) and the relationship of the allographs to layout features within the document itself including baselines and margins (see Figure 2.5).

The comparison of signatures adheres to the same principles that pertain to handwriting; however, signatures may bear no recognizable text characters. For this reason, the stylized forms, or features that comprise a signature sample must be comparable with the sample to which it is being compared (see Figure 2.6). Usually stylized signatures can not be compared to handwritten text (see Figure 2.7). Signatures that are legible or are text character based may be compared to handwritten text (see Figure 2.8).

To progress into the next section of the method the vetting officer performs a gross assessment of the

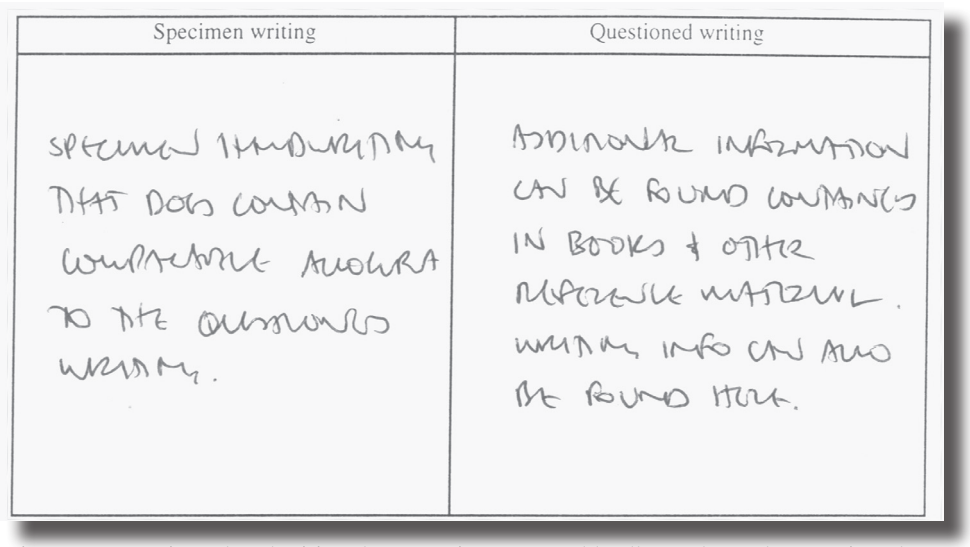


Figure 2.3. Specimen handwriting that contains comparable allographs to the questioned writing. This writing can be compared.

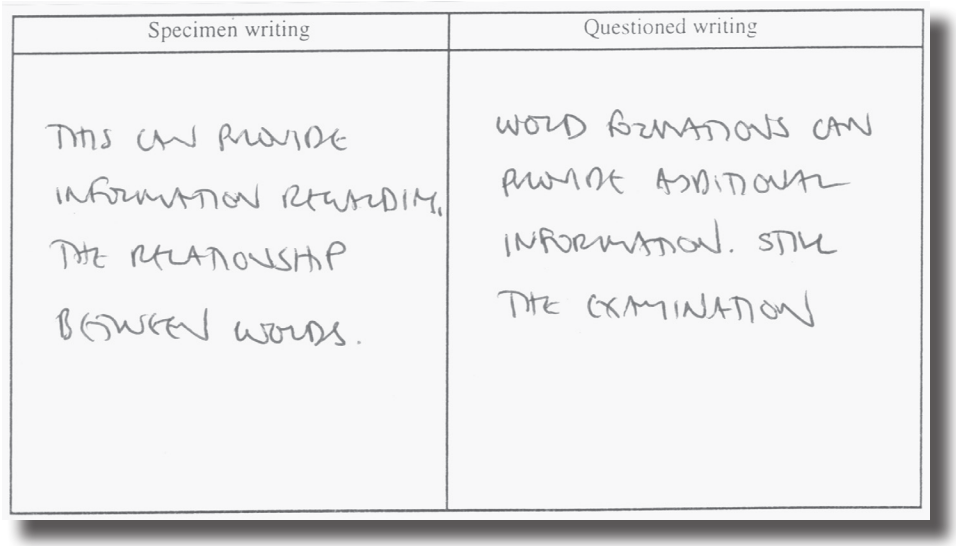


Figure 2.4. Specimen handwriting that contains words in common with the questioned material.

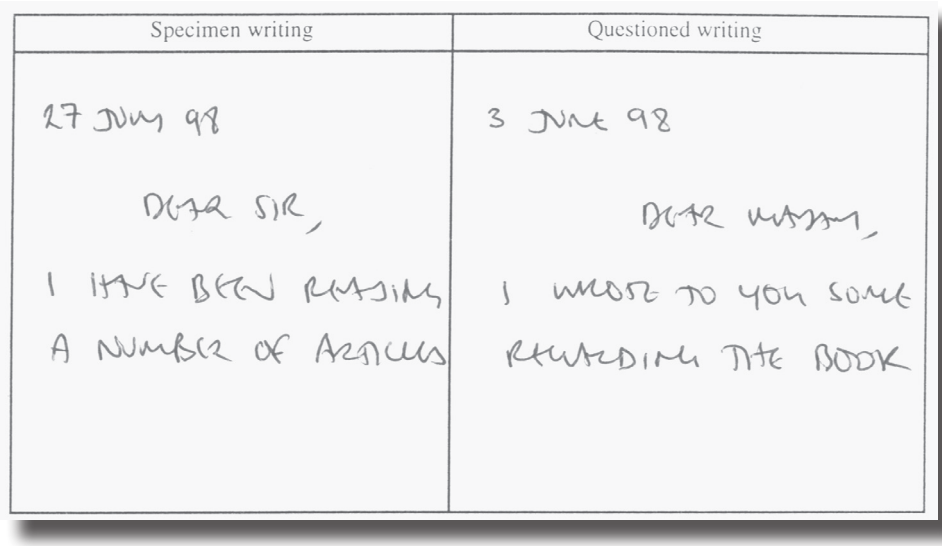


Figure 2.5. Specimen handwriting that contains common text layout features to that of the questioned material.

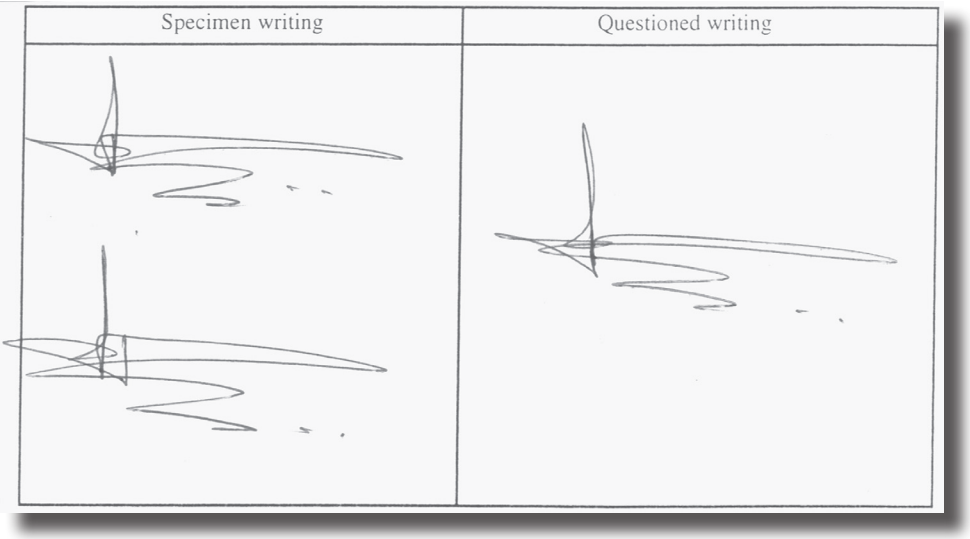


Figure 2.6. Specimen signatures that contain features in common with the questioned material.

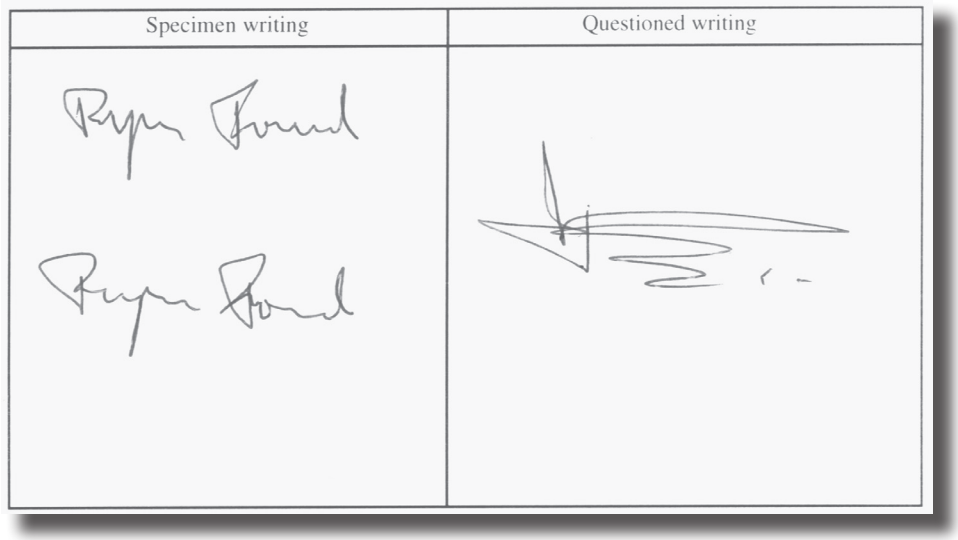


Figure 2.7. Examples of specimen signatures that do not contain features in common with the questioned material. The questioned signature is not comparable to the comparison sample.

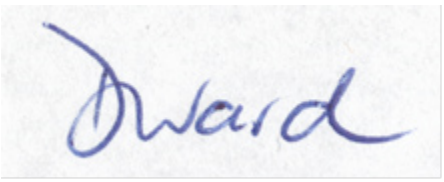


Figure 2.8. Example of a questioned text-based signature that may be able to be compared to specimen handwritten text.

comparability of the submitted samples. Within the body of the method, the examining FHE will normally perform a more detailed analysis of the comparability of the presented samples.

Contamination

The handwriting has been separated into sample groups which the vetting officer considers to be comparable. These groups comprise either comparison or questioned handwriting. In most circumstances the comparison will be between specimen and questioned handwriting.

Once the comparability of the samples is established, the questioned material is set aside and the vetting officer undertakes a preliminary intra-comparison between the populations of handwriting forming the comparison sample(s). This examination is a modified form of the steps shown on the flow diagram of Module 1. The aim of this preliminary examination is to determine whether there is any indication that the comparison samples may contain writings from more than one individual. A more detailed analysis of this possibility is performed by the FHE in the conduct of the full examination process.

A comparison sample document containing a quantity of handwriting that can establish features that the examiner believes characterize this writer is selected. This sample is used to compare with the other comparison sample documents. A preliminary examination of the material can reveal whether or not the writings are similar when an inter-sample comparison is conducted. The importance of this preliminary examination is discussed in the general texts on the subject (Ellen, 1989: Harrison, 1958; Hilton, 1982).

Any inconsistencies observed in the comparison sample handwritings are referred to by the authors as *potential contamination*. The type of characteristic considered as a dissimilarity is covered in detail in Modules 5 and 6. The treatment of handwriting as potential contamination of comparison sample material may result from any of the following realities:

- The comparison sample entries have been written by more than one writer.
- The comparison sample writer may have more than one style of handwriting (excluding dissimilarities that invariably result from uppercase, lowercase and cursive formats of writing).
- The comparison sample entries may have been generated at significantly different times, using various writing implements. This may result in material that the examiner considers too unreliable for inclusion.

Excluding spurious entries

Should the vetting officer or examining FHE have any doubts as to the reliability of spurious entries (which appear in minority) then those entries are excluded from the sample group. When a significant quantity of potential contamination is detected the vetting officer or FHE should contact the investigator to clarify the proof of authorship of the sample material.

Collected specimen documents such as address books or diaries frequently contain entries by more than one writer. The small quantity of discrete writing events that may appear on the pages of these documents can make it difficult to determine whether or not all of the entries are by a single writer. The entries may be limited to such an extent that the whole specimen document is excluded due to its unsuitable or unreliable nature, or sections of it are highlighted for exclusion (see Figure 2.9). In general, inconsistent entries that may be attributed to another writer, overwritten entries, and obliterated entries are excluded from the examination.

At the end of this process the FHE aims to have at least two samples of writing that are comparable and an internally consistent comparison sample.

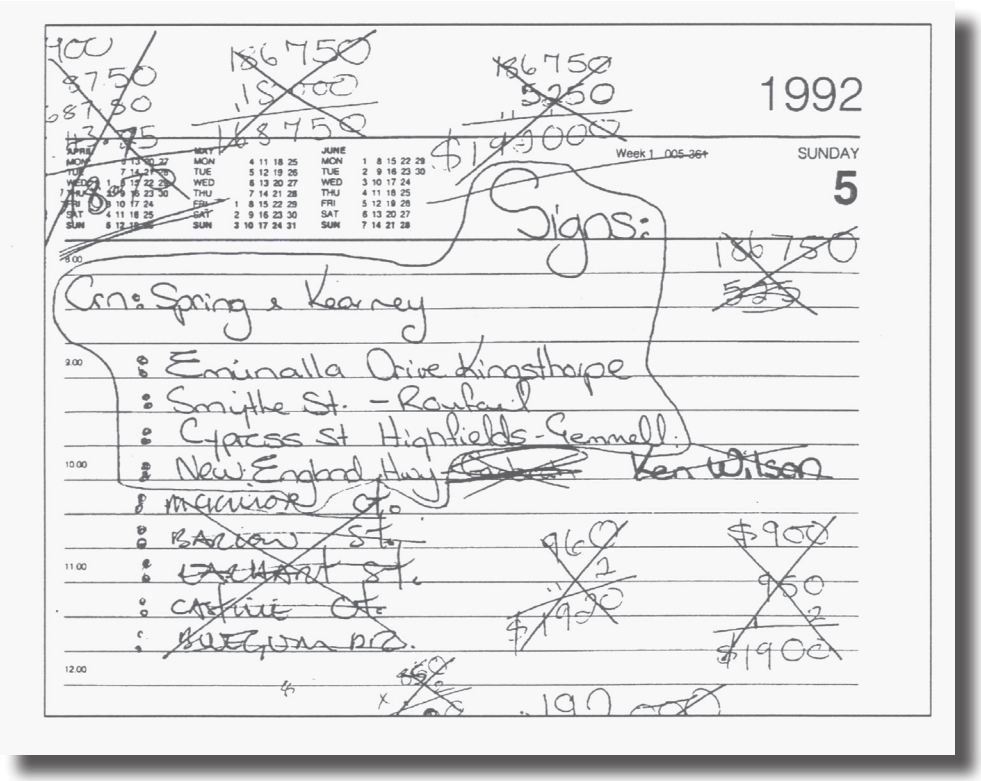


Figure 2.8. Example of a questioned text-based signature that may be able to be compared to specimen handwritten text.

Module 3

Comparison of handwriting samples

Overview: *The FHE is provided with two samples of handwriting that are comparable. This stage of the method deals with aspects of what is being compared and documented. One of the most difficult concepts when reflecting on visual comparison processes is to explain exactly how it is that the brain is processing the information it is provided with. There is a great difficulty in verbally describing all features that the brain judges to be similar or dissimilar over entire samples of handwriting. When dealing with a visual phenomenon, in the absence of quantitative comparison techniques, sense can only be made of opinions regarding similarity or dissimilarity, according to visual illustration. A decision as to overall similarity or dissimilarity involves all of the elements of the image from line quality details, character constructions, character combination constructions, word constructions and features associated with the overall text. For the purpose of the written methodology, no 'significance' in terms of support for one authorship proposition over another is, at this stage of the method, attached to the opinion resulting from the comparison.*

Discussion

In Module 3, the FHE, when possible, expresses an opinion as to whether there is evidence to support the proposition that the questioned writing is similar or dissimilar to the comparison sample. In doing so, the FHE is making a decision whether there is evidence to support the proposition that one sample of handwriting has been produced by the same or similar set of motor instructions as the comparison sample of writing and vice-versa: the questioned samples were produced by different motor instructions than the comparison samples.

To form an opinion, FHEs focus on *feature detection*. Feature detection is based on the rationale that, under normal conditions given a sufficient amount of writings, different skilled writers are unlikely to produce handwritten images that are the same in terms of the combination of construction, line quality, formation variation, and text formatting. The underlying principle associated with this inter-writer variation theory is qualified because if we were to select at random any number of extended handwriting samples from the general population, the incidence of samples that share exactly all combinations of features would be extremely low. Although there is some criticism that there is a lack of empirical support for this notion (Found & Rogers, 1995, 1996; Found, 1997; Risinger, Denbeaux & Saks 1989; United States v. Starzecpyzel, 1995) there is evidence to support the proposition based not only on the experience of individual examiners, but also on a number of formalised studies (Beacom, 1960; Boot, 1998; Durina & Caligiuri, 2009; Gamble, 1980; Huber, 2000; Li, Poon, Fung & Yang, 2005; Marquis, Schmittbuhl, Mazzella & Taroni, 2005; Ramsey Lines & Franck, 2003; Savoie, 2011; Seaman Kelly, 2002; Srihari, Cha, Arora & Lee, 2002; Srihari, Huang & Srinivasan, 2008; Ueda & Matsuo, 2005).

To some extent the *inter-writer* variation phenomena is complicated by *intra-writer variation*. Intra-writer variation results from variable motor outputs due to the interaction between the way that the information for the movement is stored in the

brain (van Galen, 1980, 1984), variation in personal tolerances for movement events, differences in the relative position of the movement system when the entry is to be executed and influences caused by environmental variables in which the writing act takes place.

Given the variation which exists between writers, it is not surprising that persons in the general population easily recognize their own handwriting and even samples from family and friends where the features are familiar to them. It could be argued that it is elements of the pictorial features of the writing that lay-persons are comparing with those stored in visual memory. In this case, the pictures of familiar writings have been ingrained by constant exposure to the handwriting of others. For this recognition to be achieved, the brain must be making a decision based on pictorial features. It may be that the brain is excluding alternate pictorial memories, where the features do not match to the sample being viewed in favour of those that do. The brain, therefore, is making decisions based on features that pictorially characterize the writing.

This process is relatively straightforward for a member of the general population as only a limited number of pictorial memories are referred to and an incorrect judgment may have no implications. FHEs are faced with a dissimilar situation in that every sample of handwriting submitted to them is in effect unknown. Examination of the questioned sample is first conducted by the FHEs to form a working knowledge of the features for comparison purposes.

Feature detection rationalizes that, given an adequate quantity of skilled comparable writings, the brain can perform an analysis and comparison to determine spatial and line quality features that contribute to the questioned sample's pictorial character. It is these features that are being compared to the comparison sample. It is on the basis of these features that the primary opinion is made as to whether one sample of writing is similar or dissimilar to another.

Investigating handwriting features

A detailed description of the characteristics that can be considered to make up the population of features is provided in Huber and Headrick (1999). Their classification divides features into four general types: elements of style; elements of execution; consistency or natural variations; lateral expansion; and word proportions. The following provides feature examples from their classification:

- placement of text
- uniformity of margins
- interline spacing
- parallelism of lines
- character, position and frequency of interlineations
- depth of indentations
- paragraphing format
- use of numerals and symbols in monetary amounts
- location of handwriting in relation to the printed document
- class of allograph (cursive, manuscript (disconnected), printing and composites of cursive and printing)
- connections (between characters and words)
- allograph design and construction
- feature proportions
- writing size
- slant
- intra and inter-word spacing
- use of abbreviations
- real or imaginary baseline alignment
- length, direction, path and taper of commencement and terminations in the line trace
- presence, style and location of diacritics and punctuation
- presence of embellishments
- legibility (quality of the writing)
- presence of pen stops and pen lifts
- line quality, and pen control characteristics (as evidenced by pen pressure differentials in the line trace)
- the imprecision with which the writer executes the movements, and therefore the writing features, on repeated occasions
- horizontal dimensions of a group of successive letters and words
- relative horizontal to vertical character of the writing
- size and spacing of the writing components.

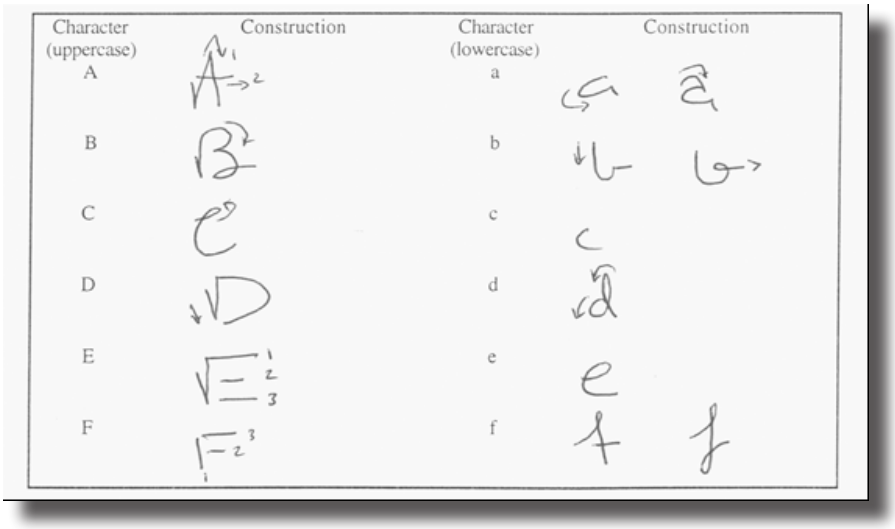


Figure 3.1. An example of a summary sheet for the questioned writings illustrating notes on character construction.

There are many ways that these features can be documented in the first stage of the comparison process. Typically, FHEs draw out and describe the stroke order of character constructions and line directions in the questioned material. Pen direction is determined by stroke connections, striation marks in the line, or even by observation of the ink interaction with the paper fibres. It should be noted that depending on the writing implement used, the writing medium, the size of the writing and whether the handwriting sample is original or non-original (see Module 4), some of the finer details of the writing strokes or features may not be able to be determined. A summary sheet may be prepared of these stroke orders and directions and other features (see Figure 3.1). Additional symbols such as punctuation marks or embellishments are added to the sheet if these symbols are present. At the end of this descriptive process the examiner should have gained a detailed knowledge of the questioned handwriting features.

Once the questioned sample(s) has been examined, for the features described above, the features in subsequent samples (other questioned or specimen samples) can be compared. Although all the features of the writing in each sample are compared, the form the notes take can vary according to the way that the writing manifests. Some general examples are as follows:

- Features detected in the questioned handwriting can be numbered and visual or microscopic examination can confirm (or not confirm) their presence in the sample being compared. These features can simply be highlighted, or numbered or noted on a copy of the sample under examination.
- Should a large number of comparison sample entries be present, then a similar sheet to that used to summarise the feature characteristics of the questioned writings may be used to structure the comparison process and facilitate future revision of the case.

Examiners at this stage are forming opinions as to what features are similar between the questioned and comparison material and what features are dissimilar.

Defining similarity and dissimilarity

Perhaps one of the most difficult concepts to describe in this field is what features in handwriting constitute a similarity or dissimilarity when comparing one sample of writing to another. We define these in general terms as follows (Found, 1997):

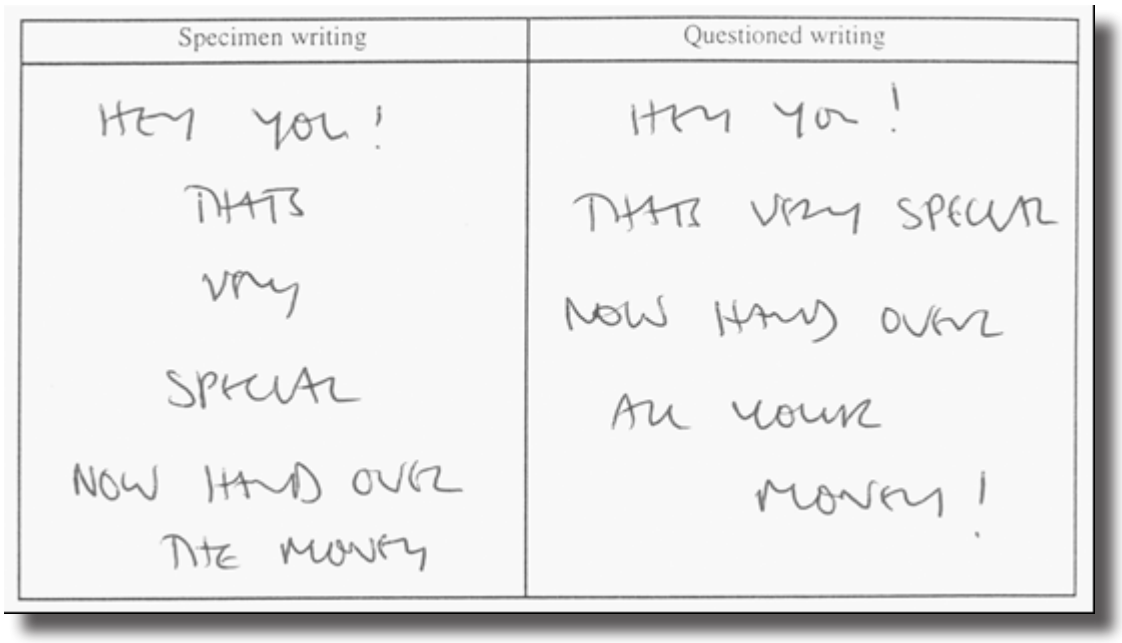


Figure 3.2. An example of specimen and questioned writings where the features are similar. The conclusion would be that there is support for the proposition that the writings were formed by the same or similar motor memories.

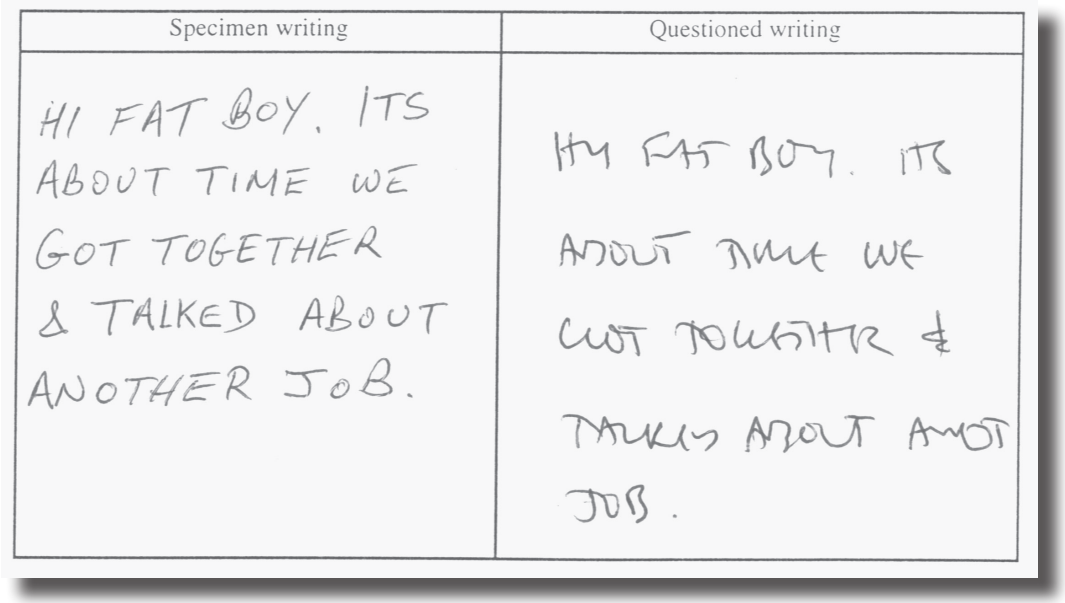


Figure 3.3. An example of specimen and questioned writings where the features are dissimilar. The conclusion would be that there is support for the proposition that the writings have not been formed by the same or similar motor memories.

- *Similarities:* the same pictorial, line quality or structural features found in both the population of questioned and comparison writings. Similarities can be observed in terms of the fluency of the strokes, the way the strokes are connected into allographs, allograph combinations, word formation and the relative placement of images (see Figure 3.2).
- *Dissimilarities:* different pictorial, line quality or structural features found in the population of questioned and comparison writings. The dissimilarities can be observed in terms of the fluency of the strokes, the way the strokes are connected into allographs, allograph combinations, word formation and the relative placement of images. The criteria for dissimilar features to be described as significant is that they are generally repeated, fundamental to the pictorial or structural character of the writing, and are not shared between the bodies of writings being compared (see Figure 3.3).

Dissimilarities, which the examiner does not consider to be significant, may also be noted. These are usually considered to be minor variations or accidental features in the writing, which are not fundamental to the writing behaviour and do not typically involve differences in pen direction. Dissimilarities which are not significant are usually associated with the dynamic or behavioural nature of handwriting production. A good example of this is where an increase in speed of writing may result in a reduction in the vertical component of the pen movement, which may also manifest in an increase in internal connections within and between characters. In addition, initial or terminal ticks may be detected which may not be evident in more slowly written comparison material.

Clearly, these definitions do not address authorship propositions. What they do, however, is focus the examination on the appropriate set of propositions that could account for the observed similarities or dissimilarities described. Consideration of the proposition sets under the differing similarity/dissimilarity conditions are discussed in Module 5.

In some instances the examiner will find questioned writings that contain a combination of similarities and dissimilarities. Under these circumstances it may not be clear which of the two proposition sets in the method flow diagram to consider. The examiner will consider all propositions (those that explain both dissimilarity and similarity (see Module 1)). This will be further explored in Module 8.

Module 4

Non-original handwriting

Overview: *At this stage of the methodology, the FHE considers issues around whether one or more of the handwriting samples being compared is non-original. Non-original handwriting is commonly encountered in the forensic environment. FHEs are required to take into account a number of limiting factors when expressing opinions regarding apparent similarities and/or dissimilarities when examining non-original samples of writing. This module overviews the rationale for the special treatment afforded to non-original handwritten images.*

Discussion

Document examiners may be requested to perform handwriting examinations on non-original documents. Non-original handwriting refers to images appearing on documents that are not produced directly by the interaction between the human movement system, the writing implement and the writing surface. Examples of processes producing non-original images include photocopying, microfilm, software-generated print-outs and facsimiles. As reproduction processes produce images that contain less feature information than original handwriting, many examiners are hesitant to express opinions on this type of material. However, a number of authors (Ellen, 1989; Hilton, 1982; Morton, 1989), while strongly emphasizing major restrictions when expressing opinions regarding non-original writings, consider that fruitful comparisons can often be made. Hilton (1982, p.384), regarding the examination of non-original writing, wrote that "…general handwriting can often be tentatively and sometimes be positively identified" and that this condition also holds for signatures. This author does, however, recognise that "…some workers refuse to examine all copies, but the practical examiner recognizes that it is necessary to rely on copies at times" (Hilton, 1982, p.385). Along similar lines Ellen (1989, p.62) has written "…although some of the detail will not be apparent, in many examples of good quality photocopies there will be adequate material for a useful comparison to be made", and that "…it is possible to identify photocopied writing as having been made by a known writer". Morton (1989, p.464) in another study on non-original documents concluded that "most of the copiers reproduced the signatures, genuine and forged, well enough for a fruitful examination".

A detailed study regarding experts' assessments of line quality features in non-original signatures was presented by Dawson and Lindblom (1998). These authors investigated the extent to which the photocopying process inhibits the ability of experts to assess a variety of line quality features and whether the non-original features impacted on the assessment of overall line quality. They found that although not all line quality features could be correctly identified by FHEs, this did not result in significant inaccuracies in the overall assessment.

A study by Found, Rogers and Herkt (2001a) compared the accuracy of examiners' opinions on 260 original questioned signatures and on the same signatures that had been photocopied. It was found that no errors regarding authorship were made for original or photocopied signatures, and there were no instances where an opinion supporting identification/elimination was reversed between a photocopy and its original. Only 2.3% of opinions relating to an original signature differed in any way from that offered for its photocopy. The high correct rates for questioned genuine signatures were similar for original (100%) and

photocopied signatures (98%). The correct opinion rate regarding the process of production of simulated questioned signatures, for original and photocopied samples combined, was 99.7%. A follow-up study by Found and Rogers (2005a) showed that there was strong evidence to support that examiners were able to express accurate opinions on photocopied signatures. These studies provide strong evidence that examiners are able to express valid opinions on handwriting with the same accuracy and similar sensitivity when using either originals or photocopies.

When undertaking an examination of non-original handwriting, the examiner must be aware that almost all reproduction processes result in a loss of fine detail which may make features such as striation marks, pen lifts, pen stoppages, retouching and line quality indeterminable or ambiguous (Dawson & Lindblom, 1998). Indicators of a tracing process such as traced guidelines, pencil guidelines and indented impressions may also be undetectable on the copy (Ellen, 1989). In addition, artifacts of the copy process (trash marks for example) may be difficult to differentiate from the handwriting being examined. However, in many instances handwriting comparisons can be made on non-original documents such as letter formations and their connections, size and height relationships, spacing and slant can often be extracted from good quality images. Although handwriting generated from indented impressions, carbon and non-carbon receipts are the direct result of the handwriting act, the process of their production may limit the extent to which features can be extracted and, as such, some of the limitations associated with common non-original handwriting may also apply to these writings.

Compounding the difficulty associated with potential modifications of the original handwriting by the copying process, itself, is that documents, and the images that appear on them, can be intentionally manufactured or manipulated from a genuine original document. Examiners must be aware of this as the validity of their opinions regarding the authorship of handwriting appearing on questioned documents may be unrelated to the validity of the questioned document itself. This section of the method aims to frame the possible limitations associated with these types of documents for the remainder of the examination process.

Manipulations to non-original documents

Production of non-original modified documents can be broadly divided into those that have been manually produced and those that have been electronically produced (Metz & Black, 1994).

Manually produced non-authentic documents

Techniques used to manually produce documents are commonly referred to as *cut-and-paste* methods (for example a genuine signature appearing on one document is physically cut out and placed onto another document, from which a copy is made). Types of features that may be observed that would indicate this process include:

- Shadowing caused by the cut-and-paste insertion of the paper on which the words or characters appear (Figure 4.1)
- Isolated entries which have no overlap with neighboring entries
- Unusually cramped or orientated entries (Figure 4.2)
- Incorrect syntax within a sentence or paragraph
- Artifacts, or smudges in the vicinity of the questioned entry that could indicate the chemical or physical removal of previous entries or the addition of an obliterating substance to the medium
- Missing portions of printed or written characters, printed backgrounds or baselines in the vicinity of the questioned entry that could indicate the removal of previous entries (Figure 4.3)
- Additional portions of printed backgrounds, baselines, characters or handwriting strokes in the vicinity of the questioned entry that could indicate the transference of these entries along with the subject of the cut-and-paste (Figure 4.4), or the incomplete removal of previous entries (Figure 4.3)
- Difference in image quality between one specific area on the document when compared to the quality of surrounding entries

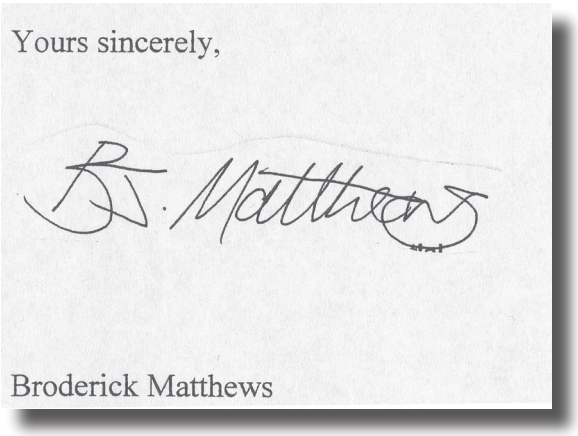


Figure 4.1. Shadowing around the top of the signature caused by 'cut and paste' insertion, and traces of original printed text overlapping the terminal portion of the inserted signature.

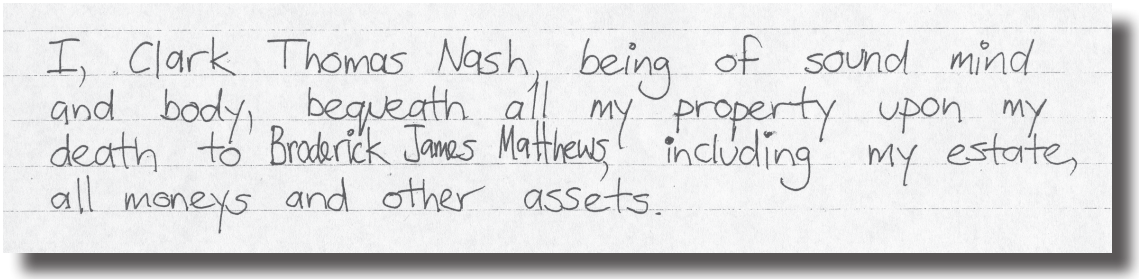


Figure 4.2. Unusually cramped entries "Broderick James Matthews".

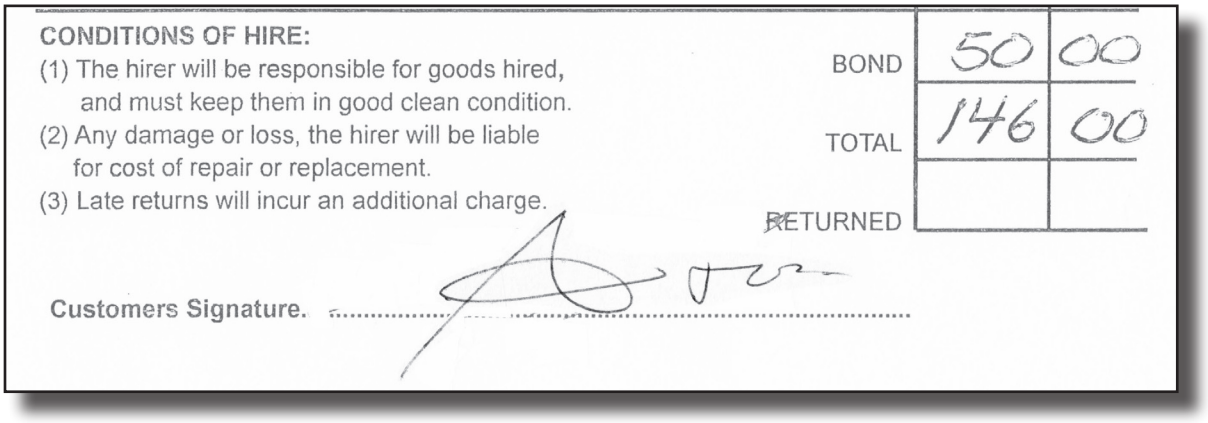


Figure 4.3. Missing portions of printed signature baseline caused by whiting out of the previous signature. Note also additional strokes near the start of the printed baseline and around the R of RETURNED, which are evidence of the incomplete removal of the previous signature.

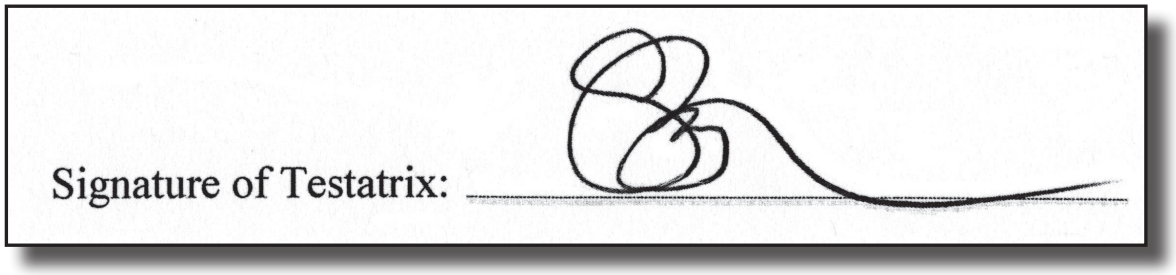


Figure 4.4. Additional portions of printed background in the vicinity of the questioned signature and signature line that indicates the transference of these features along with the subject of the cut-and-paste.

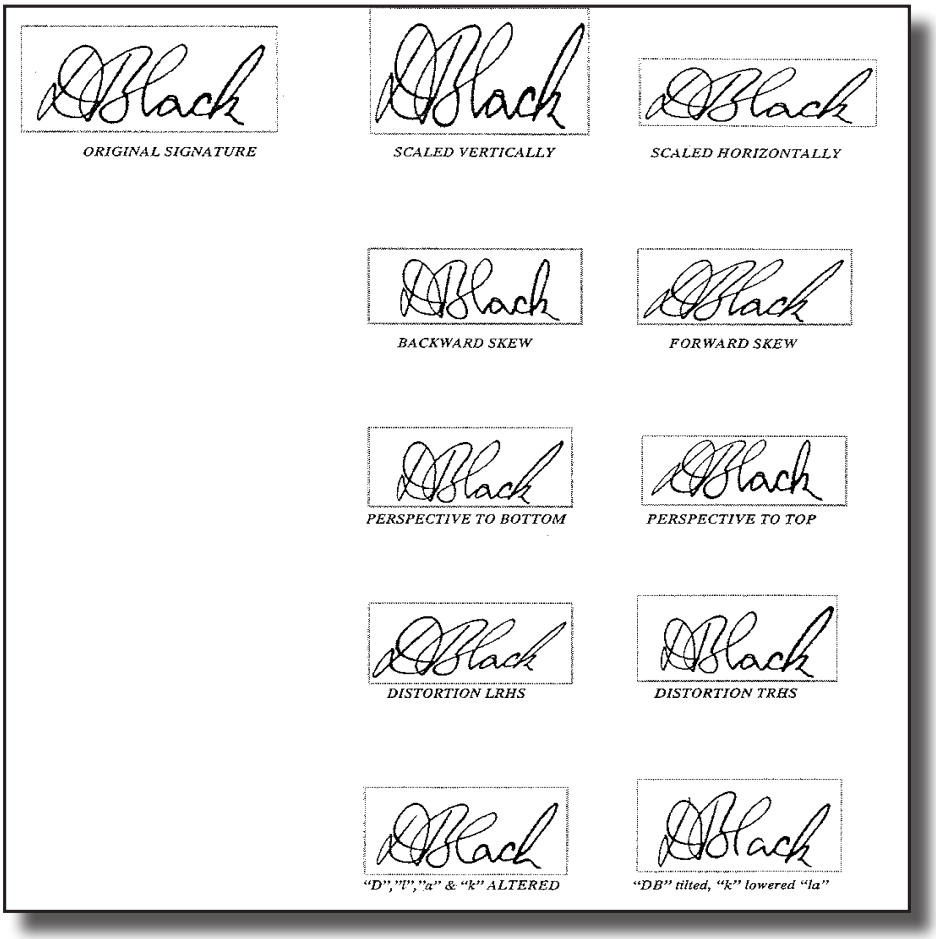


Figure 4.5. Computer generated manipulations of a genuine signature into ten new (non-original) signatures.

Electronically produced documents

Detection of electronically produced, fraudulent non-original documents has become more difficult as the technology for reproducing documents continues to develop. There already exists various types of electronic equipment that can capture, manipulate handwriting, and print a new document. Manipulations may be in terms of size, orientation, position, slant, insertions, deletions and distortions. Figure 4.5 shows a genuine signature that has been digitally manipulated into ten new non-original signatures. These signatures could then be digitally transferred onto a questioned document and printed. It is not uncommon to find genuine non-original signatures appearing on genuine documents (e.g. cheques). This can be achieved by printing a genuine signature from an electronic file onto a genuine document which is fed through the printing device. However, in cases where an opinion is expressed that a non-orignal signature is genuine, the examiner will generally not be able to express an opinion as to the veracity of the document itself.

Both manually produced and electronic forms of document manipulation open the possibility for a single handwriting or signature model being used repeatedly over a series of questioned documents. It may also be the case that the original model that has been used may appear in the documentation submitted for examination. Under these circumstances the questioned signature or handwriting will be super-imposable onto (although there may be some distortion to line quality or scale), and similar with respect to line quality features to, the original specimen or another questioned signature or handwriting that has been submitted. Given these observations it may be possible to express the opinion that the signature or handwriting is a *machine generated simulation* (see Module 1 flow diagram).

It is the case that with either manual or electronically produced non-authentic documents, part of, or entire passages of questioned text can be generated from a range of known writings by selecting characters and words, manufacturing a new non-authentic document. The sophistication of the approach to manufacture documents in this way will impact on whether any artifact of the process remains on the questioned document.

Considerations regarding the reporting of the results of non-original handwriting where no evidence of manipulation has been detected

Two schools of thought exist when it comes to the reporting on the examination of non-original documents. In both cases, the examiner draws the attention of the reader to features of comparison, which illustrate similarities or dissimilarities within the handwriting or associated with the documentation. Some examiners limit their opinions to observations regarding pictorial similarity or dissimilarity when compared to another sample. The significance of these observations is not addressed with regard to authorship to guard against the limitations discussed above not being fully appreciated by the client group.

Other examiners do offer an opinion to the client. These opinions are however, qualified by a statement that the opinion expressed is based on the assumption that the non-original(s) examined are a true and accurate representation of the original document, and that if this assumption is proven, by whatever means, not to be true then their opinion should be reviewed.

Conclusion

There are limitations when comparing non-original documents for the purpose of establishing with authorship. The standard basic criteria related to the quantity of material available for comparison and issues of complexity of material still remain relevant (see Module 5). In general, the examiner may be able to provide evidence that a non-original document has been altered in some way (i.e. insertions or deletions), or that the non-original document may be a composite or fabricated document (Hilton, 1982). In addition, an opinion in support of authorship may be expressed. In these cases the assumptions made and the limitations of the examination should be stated. When communicating opinions as to the authorship of non-original questioned handwriting (refer to Module 10), examiners must be careful to explain that although the handwriting may or may not indicate the involvement of the specimen writer, the document itself, or the message communicated by the handwritten text, may not be authentic. When the

examiner is dealing with non-originals produced by dynamic reproduction processes (such as is evidenced on carbon paper or through imaged indentations) it may be possible to express stronger opinions about a document's authenticity than that which would be given for a machine generated non-original.

Module 5

The assessment of handwriting complexity: addressing propositions regarding authorship

Overview: *At this stage the examiner has compared the features associated with the two or more samples of writing. An opinion has been formed that one sample is either similar or dissimilar to the other sample(s). The propositions that could account for the similarities and/or dissimilarities have been listed (see Module 1 flow diagram). The issue now under consideration is whether there is evidence to support one of these propositions in preference to the alternatives and what degree of support is appropriate. The complexity of handwriting is the critical element in this process. It is based on an FHE's judgement in relation to the ease of simulating a handwriting sample and whether there is sufficient material to subjectively assess the possibility of a chance match between two or more samples of writing that were written by different individuals. Although there currently exists no systematized global quantitative test to provide a guide to the complexity factor, the FHE's specialized knowledge which is used to assess this factor can be monitored through performance on independently administered blind trials.*

Discussion

Should the FHE's opinion, as a result of the processes considered in Modules 3 and 4, be that a questioned handwriting sample is similar to the comparison sample then a number of propositions are considered that could account for this observation:

- The samples were written by the same writer;
- The samples were written by different writers. However, one writer has simulated the handwriting features of the other without leaving behind in the writing trace evidence of the simulation process;
- The samples were written by different writers. However, the handwriting features are similar due to chance.

The authors note that although there has been a report of mechanical writing simulators, for the purpose of this document this proposition is not considered further (Kruger, 2010; Schneider-Pieters, ten Camps & Hardy, 1996).

Should the decision be that a questioned handwriting sample is dissimilar to the comparison handwriting sample (see also Module 6) then a number of propositions are considered:

- The samples were written by the one writer. However, the population of one or other of the sample writings is not representative of the writer's normal behaviour. This could occur for a large number of reasons such as illness, unusual writing position or conditions, purely non-representative sampling of the writing in terms of time, or the writer having purposefully changed their behaviour (see Module 8)
- The samples were written by different writers.

Methodologically the focus is now on forming an opinion as to the probability of observing the similar and/or dissimilar features for each of the propositions

if they were true. It is the complexity of the handwriting that is thought to underpin a decision at this stage. Chance match probability and the ease or difficulty of a person simulating the feature characteristics of another writer is referenced by this factor. In the simplest case a single horizontal or vertical line drawn on a page could constitute the entire signature of an individual. This line, if similar to the comparison material, may satisfy both spatial and line quality criteria of the comparison protocol and be similar to the known material. In this instance, however, the probability of observing the similar features if the specimen writer had written the signature would be similar to the probability of observing the similar features if the signature had been simulated, and the case circumstances may not warrant consideration of chance match (particularly with signatures). No probative finding would likely result. Assessments of complexity, either consciously or subconsciously, are routinely made by FHEs.

The assessment of the complexity of handwriting has been reported in related fields of research (Brault & Plamondon, 1993; Kao, Shek & Lee, 1983; Meulenbroek & van Galen, 1990; van der Platts & van Galen, 1990; van Galen, 1984; Wing, 1978). Complexity of handwriting is important not only in terms of assessing alternate authorship propositions, but also the probability of FHEs observations given a simulation proposition. Research in the forensic environment provides evidence that simulators are more likely to concentrate on eye-catching characteristics and therefore not successfully imitate inconspicuous features (Leung, Cheng, Fung & Poon 1993a). Reaserchers have found that simulators producing copied handwriting show prolonged reaction times, increased movement times, decreased fluency and evidence suggesting a high degree of limb stiffness (Caligiuri & Mohammed, 2012; Caligiuri, Mohammed, Found & Rogers, 2012; Mohammed, Found, Caligiuri & Rogers, 2015; van Gemmert & van Galen, 1996). Similar evidence of the neglect to faithfully reproduce fine features in handwriting can be found in case examples in forensic document examination texts (Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1982; Huber & Headrick, 1999; Osborn, 1929). Clearly these inconspicuous features contribute to the difficulty of the simulation process. It is not surprising, therefore, that as the amount of writing required to be simulated increases the more difficult the task is for simulators, and the more likely that disturbed writing behaviour will result. An interesting investigation into simulator strategy according to model complexity can be found in Pepe, Rogers & Sita (2012).

There are a number of parameters that have been or could be proposed that either singularly or jointly are likely to contribute to the perceived complexity of the final sample of handwriting and which can be measured on static handwriting. Examples of these are: the number of turning points in the line (Found, Rogers & Schmittat, 1997; Found, Rogers, Schmittat & Metz, 1994; Hardy, 1992), the total line length over which the turning points occur, the number of line intersections including retraced line sections, the number of pen lifts per unit line length, the number of line portions where superimposition of other line portions has occurred, the presence of feathering of the line (as an indicator of pressure differentials), the number of unique characters (e.g. signatures that are not composed of a single repeating unit), or even an assessment by FHEs regarding the extent of copy-book divergence. The rationale for regarding many of these parameters as contributors to complexity have been discussed and reviewed in a number of works (Brault & Plamondon, 1993; Found, 1997; Found & Rogers, 1996; Huber & Headrick, 1999).

Complexity relationships

Based on the research associated with complexity and simulation behaviour (Brault & Plamondon, 1993; Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1982; Kao, Shek, & Lee, 1983; Leung, Cheng, Fung & Poon, 1993a; Meulenbroek & van Galen, 1990; Osborn, 1929; van der Platts & van Galen, 1990; van Galen, 1984; van Gemmert & van Galen, 1996; Wing, 1978), two complexity relationships have been proposed which provide the foundations on which FHEs express opinions regarding the extent to which the examination findings support an authorship proposition. Empirical support for the relationships proposed under the complexity theory can be found in Alewijnse, van den Heuvel & Stoel (2011).

The complexity versus the likelihood of a chance match

If we were to choose random samples of handwriting (from different individuals) containing identical text and proceed through a stroke by stroke analysis of the concatenations, then as the complexity increases (as reflected in the number of strokes, for example), the likelihood that the samples will diverge in some way from each other would, in general, increase. This relationship is related to the class and individual characteristics theory that has been traditionally used to underpin forensic handwriting comparisons. The complexity theory articulated here accepts that, in general, the greater amount of writing that is examined, the more likely it is that the sample will contain features that deviate from other writers (class-divergent characteristics). Strong evidence to support the extent of inter-writer variation in the population has been reported (Ahola, 2000; Crane & Crane, 1997; Durina & Caligiuri, 2009; Horton, 1996; Huber, 2000; Savoie, 2011; Srihari, Cha, Arora & Lee, 2002).

The complexity versus the ease of simulation

As the handwriting becomes more complex it becomes more difficult for other writers to copy the features without leaving behind indicators of the copying process (for example tremor in the line,

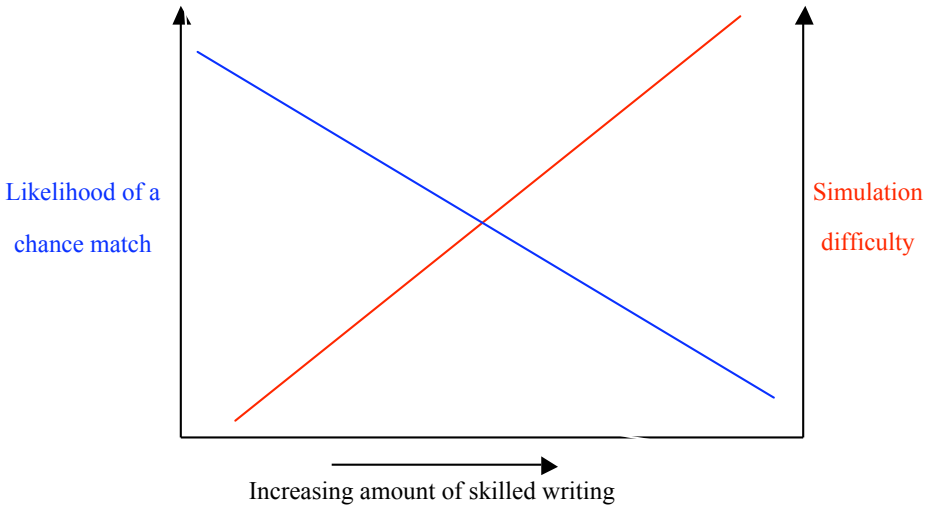


Figure 5.1. The generalized complexity relationships between the amount of skilled writing available in the sample, the difficulty a forger would experience in simulating the sample and the likelihood of a chance match between writers. The authors note that the precise shape of the relationships represented by the lines is not known and may be subject to a large number of variables (for example the variation in specific features in any given population and the variation in simulator skill level).

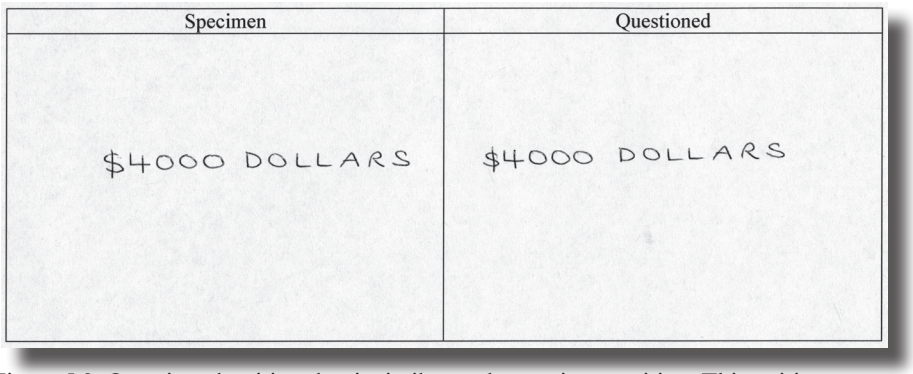


Figure 5.2. Questioned writing that is similar to the specimen writing. This writing is, however, not complex and therefore the probability of observing common features is similar under the same author/naturally written and different author/simulation propositions.

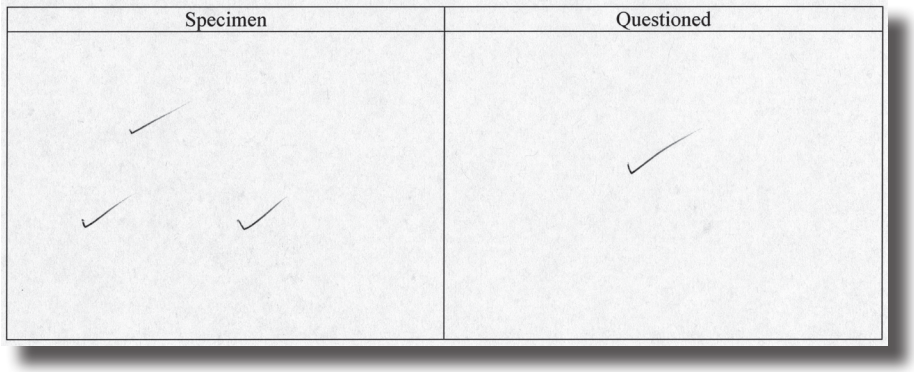


Figure 5.3. A questioned signature that is similar to the specimen signatures. However, this signature is not complex and therefore the probability of observing the common features is similar under the same author/naturally written and different author/ simulation propositions.

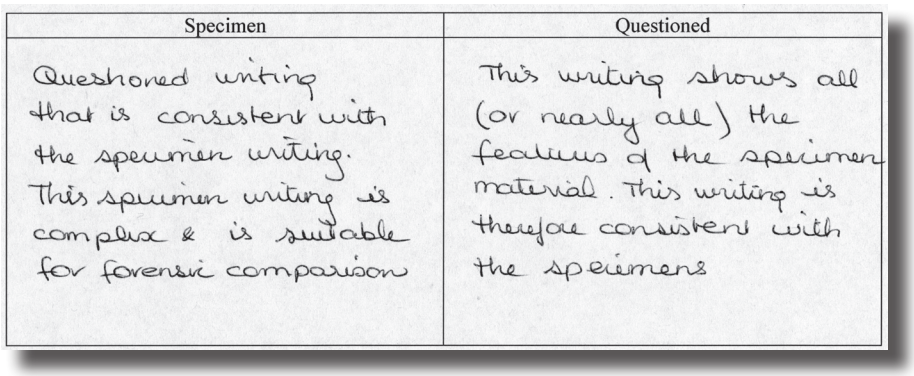


Figure 5.4. Questioned writing that is similar to the specimen writing. This writing is complex and similar and therefore the probability of observing the suite of similar features is high given the proposition that it is the same writer is true, is low given the chance match proposition is true, and low given the proposition that the writing has been simulated is true.

inappropriate pen lifts, spatial disturbances etc.). An example of this would be copying a straight line in comparison to copying an extended section of text.

The generalized complexity relationships are shown in Figure 5.1, with examples of complexity issues given in Figures 5.2 through 5.4.

Since quantitative measures are not used to assess the ease of writing simulation and the relationship between complexity, and chance match between writing samples, this stage in the method is not able to be numerically defined and remains in the realm of FHE specialized knowledge. Possibly the most important issue regarding investigations of this type is the determination of the relationship that exists between expert perceptions and case realities. A discussion of this issue was presented by Hecker (1996) and focused on the question of whether experts may be too conservative regarding their perceptions of the ease or difficulty that simulators experience in copying handwriting successfully. Additional research on the ease of simulation of simple signatures has been reported by Cadola, Margot & Marquis, (2013). The validity of opinions in support of authorship by FHEs ultimately can only be referenced through their participation in appropriately designed validation studies where the ground truth is known (see Annexure).

Module 6

Structural and line quality dissimilarities

Overview: *At this stage, the FHE is of the opinion that a questioned sample of writing is dissimilar to the comparison sample of writing. To focus on the implications that this may have in terms of evidence in support of an authorship proposition the primary nature of the dissimilarity is evaluated. This module describes the two major categories of dissimilarity that are observed in routine examinations.*

Discussion

The relationship between handwriting analysis and evidence in support of exclusionary opinions can become problematic as the signatures and/or handwritings become less complex (See Module 5). The lower end of the complexity scale, encompasses small amounts of writing. As well as writings that may be unskilled including samples displaying and or poor line quality, as well as writings that show a broad range of variation and or styles with little internal consistency. When FHEs consider the alternative propositions to explain an opinion of dissimilarity, then they are faced with a situation that the probability of observing dissimilarities can be high under a number of different propositions. For example, observed dissimilarities in the line quality and structure could provide approximately equal support for proposition A, the questioned sample was disguised, and proposition B, that the questioned sample was simulated. In an attempt to separate apart the propositions that can account for dissimilarity, a determination may be made regarding whether the primary dissimilarity is associated with either line quality or structural features. In some instances the dissimilarity will be a combination of both of these features. Dissimilarities are discussed in Module 3, and further detailed discussions of the interpretation of dissimilarities appear in the literature (Huber & Headrick, 1999; McAlexander, 1997).

For the dissimilarities to provide a reliable basis for an opinion in support of the proposition that the samples were written by more than one writer, there needs to be a reasonable body of complex handwriting. In this instance we reference the requirements in terms of the size of the population of features, the fluency of the writing, and the ideal time of sampling of the comparison material in relation to the questioned material. This allows for a number of dissimilarities or a recurring dissimilarity to be given the appropriate weight. If evidence in support of an exclusionary opinion cannot be found, this should not be seen to detract from the evidential power of handwriting examinations. Illustrating an opinion that one sample of writing is dissimilar to another provides the court with information that may be of use when supported by other evidence.

Structural dissimilarities

Structural dissimilarities can include such factors as dissimilar individual letter constructions, dissimilar relative feature size relationships and dissimilar writing slope or text formatting characteristics (Brewester, 1932; Conway, 1959; Ellen, 1989; Found, Dick & Rogers, 1994; Franks, Davis, Totty, Hardcastle & Grove, 1985; Harrison, 1958; Hilton, 1982; Huber & Headrick, 1999; McClary, 1997; Metz, Found, Dick & Rogers, 1994; Osborn, 1929). It is important however, to recognize at this point that a change in slope, the addition of a flourish or two, or a dramatic change in the size of a letter construction does not necessarily constitute what the examiner considers to be the type of dissimilarity which may provide support for the proposition that a questioned entry was not written by a particular writer. However a repeated dissimilarity with respect to the direction, or in the component

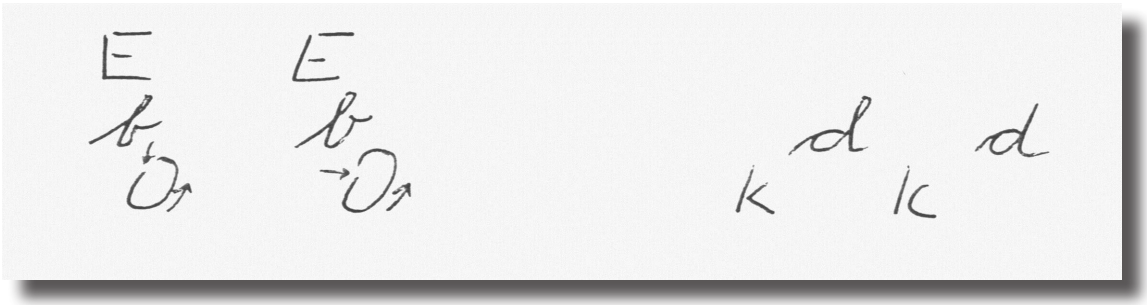


Figure 6.1. Structural dissimilarities with respect to individual letter constructions of little significance as these may be considered to be natural variations in handwriting performance.

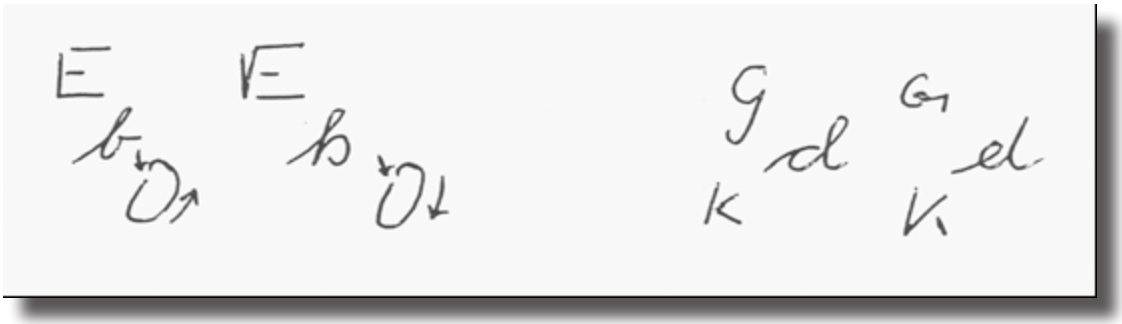


Figure 6.2. Structural dissimilarities with respect to letter constructions which may provide evidence to support the proposition that the writing was produced by two writers.

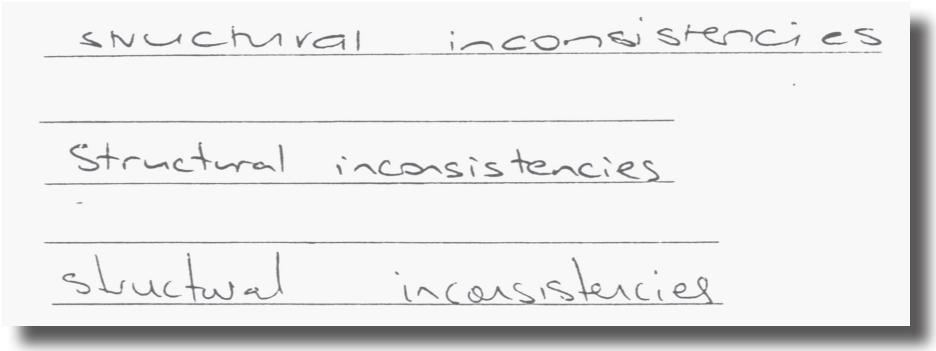


Figure 6.3. Structural dissimilarities with respect to size relationships. Note the height of the letter 't' compared to the surrounding letters for the three different writers.

strokes of a letter, could provide support for the proposition that a questioned sample was not written by a particular writer.

There are a number of explanations that can be advanced to explain why it is that a structural dissimilarity is observed. Examples are: deliberate disguise; accidental features resulting from disruption to the flow of the writing act (for example by interruption); the sampling of the specimen writings not covering changes in writing habits over time; the sampling of the specimen writings not capturing appropriate comparison material for individuals who have more than one writing style; natural variations that occur in writing structures and letter construction habits (Alford, 1970; Brewester, 1932; Conway, 1959; Ellen, 1989; Found & Rogers, 1992; Franck, 1988; Harris, 1953; Harrison, 1958; Herkt, 1986; Hilton, 1982; Kapoor, Kapoor & Sharma, 1985; Konstantinidis, 1987; Michel, 1978; Mohammed, 1993; Osborn, 1929; Thiéry, Marquis & Montani, 2013; Tsui, 1997; Webb, 1977; Wendt, 2000).

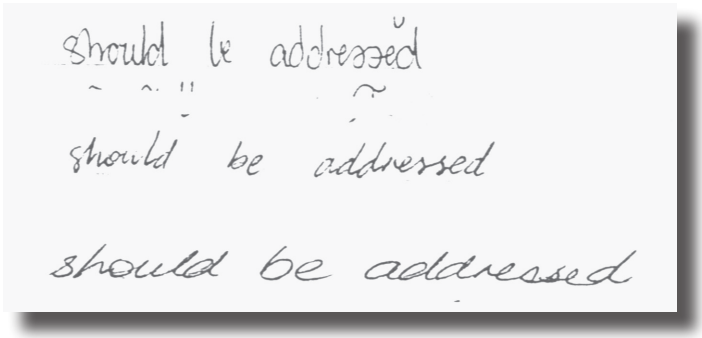


Figure 6.4. Structural dissimilarities with respect to writing slope.

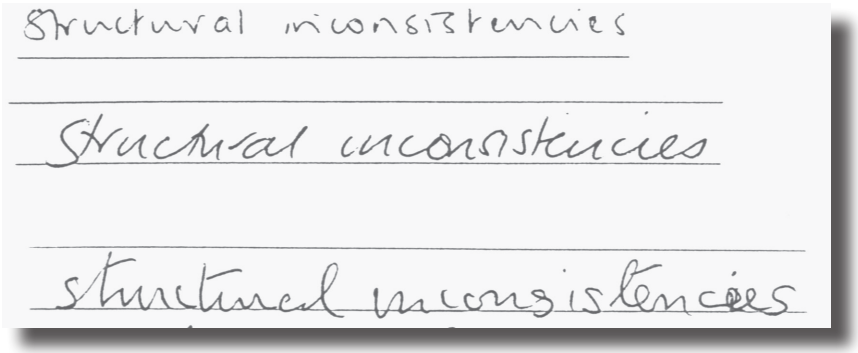


Figure 6.5. Dissimilarities between writers with respect to the alignment of the writing relative to the printed baseline.

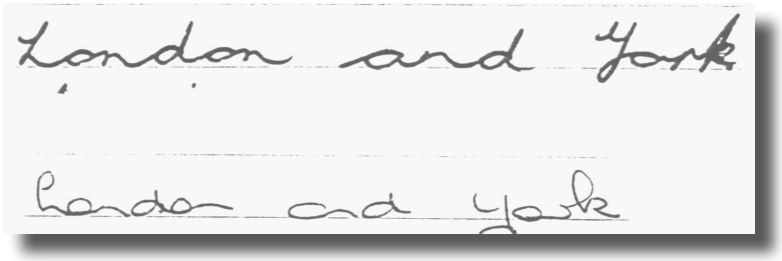


Figure 6.6. Structural dissimilarities in terms of style habits. Note the construction of the letters ‘o’ and ‘a’.

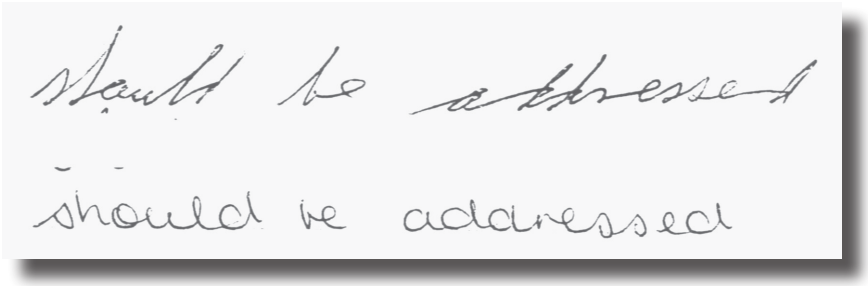


Figure 6.7. Structural dissimilarities in terms of writing angularity.

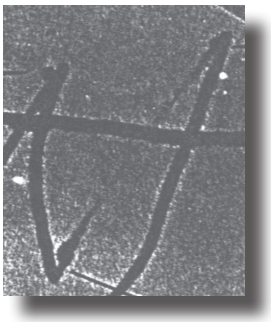


Figure 6.8. Line quality disturbance caused by ball point pen gooping.

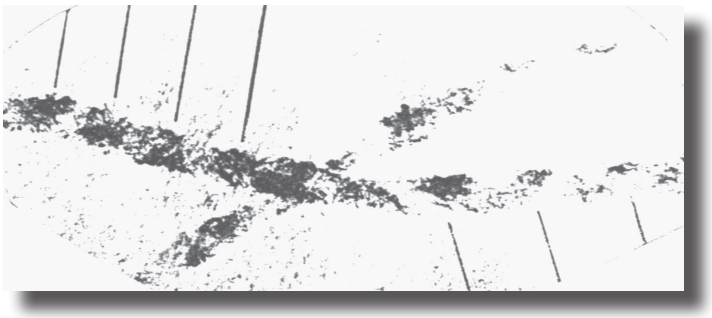


Figure 6.9. Line quality disturbance caused by ball point pen skipping.

Examples of structural dissimilarities

Figures 6.1 to 6.7 show examples of different classes of structural dissimilarity.

Line quality dissimilarities

Line quality dissimilarities may be observed in terms of writing pressure, fluency, speed and skill levels between the sample writings being compared (Brewester, 1932; Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1982, 1987; Huber & Headrick, 1999; Leung, Cheng, Fung, Poon, 1993a; Moore, 1983; Osborn, 1929; van Gemmert & van Galen, 1996; van Gemmert, van Galen, Hardy & Thomassen, 1996). Dissimilarities of this type result primarily from a different degree of motor control and therefore pen control.

The propositions that can be advanced to explain line quality dissimilarities can be generally divided into two groups:

1. Those line quality dissimilarities adjudged to be the result of disguise or simulation behaviour (see Module 8). The difference in this instance is where one sample is written slowly, or dysfluently, but shares some spatial features in common with the comparison material that are unlikely to result by chance (Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1952, 1982; Osborn, 1929; van Gemmert, van Galen, Hardy & Thomassen, 1996)

2. All other types of line quality dissimilarities associated with unnatural or disturbed writing processes. These may include, uneven backing surfaces on which writings are made, poor ball-point pen function and ball housing effects (see Figure 6.8), disturbances due to constrained writing spaces, and the effect of illness or drugs (Beck, 1985; Behrendt, 1984; Brewester, 1932; Conway, 1959; Ellen, 1989; Galbraith, 1986; Harrison, 1958; Herkt, 1986; Hilton, 1957, 1969, 1982; Huber & Headrick, 1999; Mathyer, 1969; Osborn, 1929; Simsons, Spencer & Auer, 2011; Vastrick, 1982).

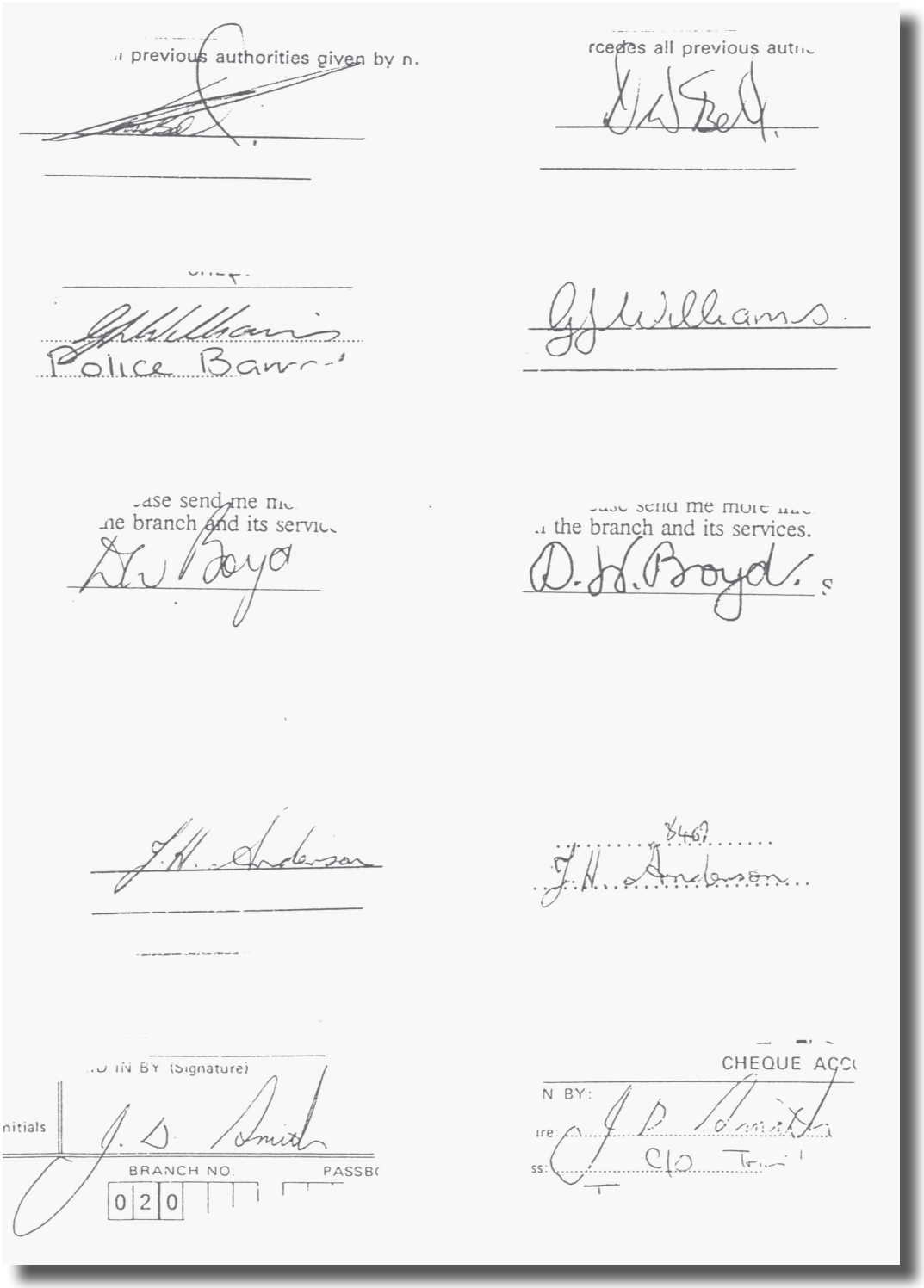


Figure 6.10. Line quality dissimilarities caused by disguise. The left-hand column provides the genuine signature of each of five subjects. The right hand column is an attempt by each subject to disguise their signature.

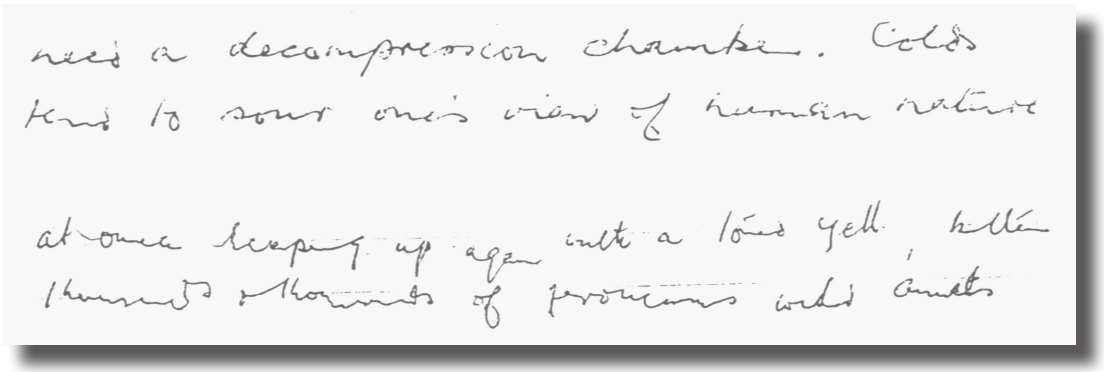


Figure 6.11. Line quality disturbance resulting from a stroke. The upper sample shows the subject's handwriting prior to the stroke.

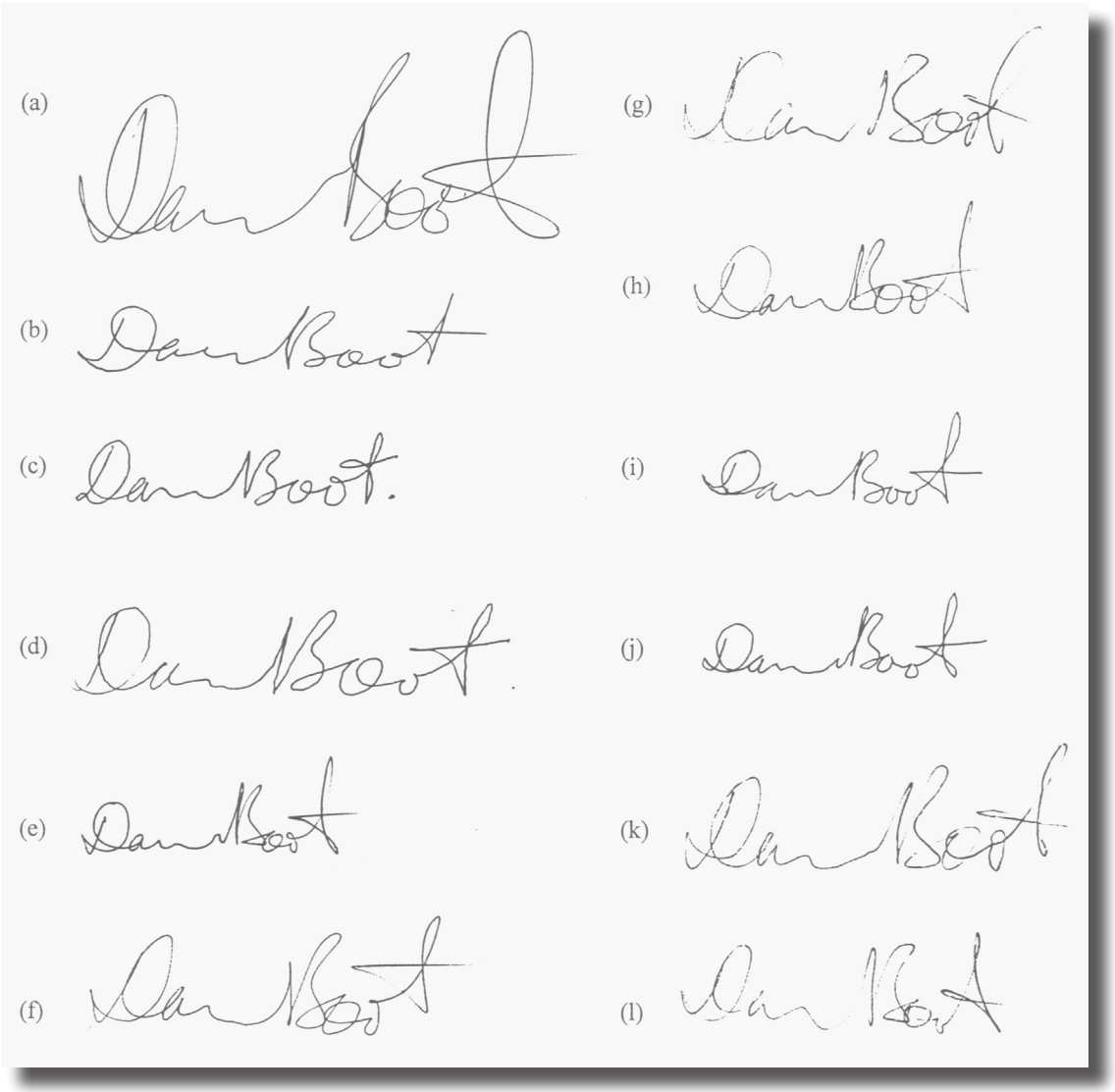


Figure 6.12. Line quality disturbances caused by a range of variables. (a) is a genuine signature affected by alcohol; (b) is a freehand copy; (c) and (d) are disguised signatures; (e) is a normal genuine signature; (f) is a genuine signature written standing up with the paper held in the hand; (g), (h) and (k) are genuine signatures written on rough backing surfaces; (i) is a copy completed with the aid of an indented guideline; (j) is a traced copy; (l) is a genuine signature affected by exercise.

Examples of line quality dissimilarities

A range of circumstances can result in line quality dissimilarities. Figures 6.8 to 6.12 provide examples of line quality disturbances and/or dissimilarities.

Conclusion

In some cases, the significance of the observed dissimilarities may be nebulous. In other cases, it will be clear and, if occurring repeatedly, potentially very useful in terms of addressing authorship propositions. When a dissimilarity is clearly regarded as a significant structural or line quality change not associated with variables such as writing instrument, writing medium, backing surface or space constraints, and where the comparison sample is representative of the behaviour (which can control for chronic and even acute handwriting disturbance associated with illness), then the method proceeds to consider disguise and simulation behaviours. Further reading around dissimilarities in handwriting features can be found in Brewester (1932) Conway (1959), Ellen (1989), Harris (2002), Harrison (1958), Hilton (1982), Huber & Headrick (1999), McAlexander & Maguire (1991) and Osborn (1929).

Module 7

Traced writings

Overview: *Tracing is a method of producing simulated signatures and handwriting. The detection of tracing indicators provides evidence of an assisted simulation process. The examination of documents for tracing indicators relies on well documented techniques and observations (Conway, 1959; Ellen, 1989; Harrison, 1958; Hilton, 1982; Huber & Headrick, 1999; Osborn, 1929; Totty, Hardcastle & Steele, 1996). An empirical study of traced signatures has also been reported (Leung, Cheng, Fung & Poon, 1993b). Although tracing behaviour is normally associated with the reproduction of signatures, which is the focus of this module, it is noted that handwriting text can also be copied using this approach.*

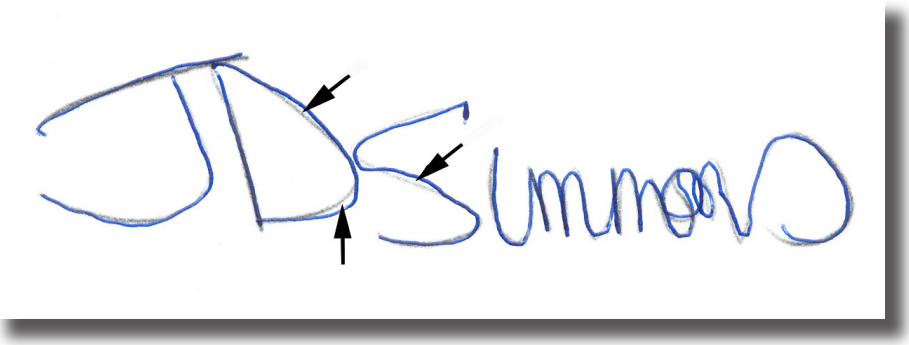


Figure 7.1. A traced signature where carbon paper was used to produce guidelines. Arrows indicate carbon lines.

Discussion

For a skilled writer, a legitimate signature is usually executed fluently. When a signature is copied, the simulator will attempt to reproduce the handwriting characteristics being copied. One of the simplest methods to achieve this is to transfer the features of a legitimate signature onto a fraudulent document through the process of tracing. A tracing will replicate the pictorial features of the genuine signature and, as a copy, is a member of the 'simulation' family.

Methods of tracing

A traced signature can be created using a variety of methods:

Carbon paper

An outline of the signature being traced is transferred by over writing an authentic signature using carbon paper beneath. The carbon image is then overwritten in such a way to reduce detection (see Figure 7.1).

Transmitted light

The receiving document is placed on top of the document on which an authentic signature appears. A transmitted light is then applied through the documents from the rear (using for example a window or illuminated light table). The genuine signature is then used as a guide

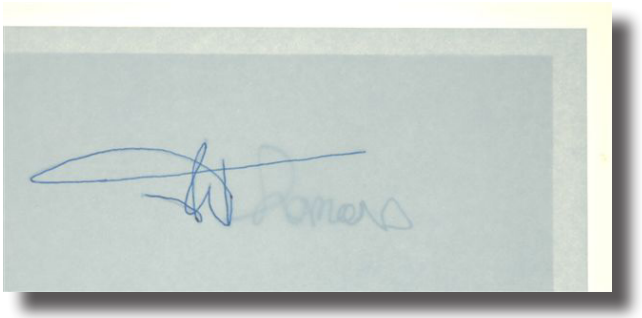


Figure 7.2. A traced signature using transmitted light.

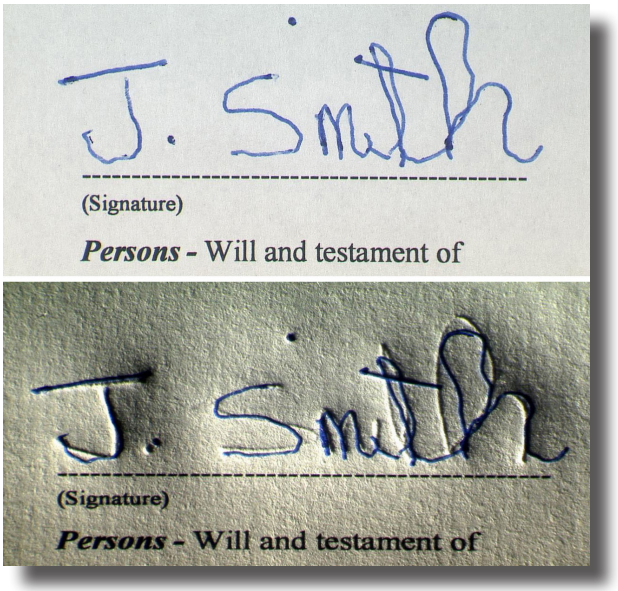


Figure 7.3. A traced signature where an indented guideline has been used. The top image is the questioned signature. The bottom shows the same signature viewed with oblique light. The indentations of the original traced guideline are clear.

to trace a new signature onto the uppermost document (see Figure 7.2). It is often difficult to detect clear evidence of this type of tracing from the questioned signature, however if the model used is submitted with the case materials, it may be possible to detect evidence of this process through indentation studies, or superimposition of the questioned signature over its model.

Tracing paper

An image is created under similar conditions as used when applying carbon paper, but the image is drawn on translucent paper, then coloured pencil or a similar soft tipped pencil is smeared on its back. The tracing is then transferred again by over writing the lines on the disputed document, which is then drawn in.

Direct transfer method

This technique requires the authentic signature to be overwritten with sufficient pressure to create guidelines onto a receiving document. These markings are then drawn in (see Figure 7.3). It is not usually within the skill of the simulator to accurately follow all the indentations, therefore additional marks and guidelines are often detected (Kullman, Sinke and Speckin, 2002; Totty, Hardcastle & Steele, 1996).

Conclusion

Tracing behavior does not normally result in features that would assist in the evaluation of the evidence regarding propositions relating to authorship. The opinion that an image is traced is therefore only an observation regarding the process of production of the handwriting.

Module 8

Unnatural handwriting behaviours

Overview: *Unnatural handwriting may be considered writing which is disguised, simulated, or modified by internal or external factors such as the writing environment, illness, medication or intoxication by drugs or alcohol. However, only simulation and disguise are considered in detail in this module. The term simulation is generally used to describe a process of replicating handwriting using a mental or physical model. Disguise is a process of attempting to suppress an internalized model of handwriting features (the motor memory) in order to cause physical changes to handwriting features. Although there are several methods of replicating and disguising writing (e.g. tracing (see Module 7) and machine generation (see Module 4)) this module will focus on freehand simulation methods and disguise strategies. Typically simulation behaviour is encountered more frequently with signing behaviours, and disguise is more frequently associated with handwritten text. This module will approach simulation and disguise behaviour in light of this.*

Discussion

Simulation behaviour

For the purposes of forensic handwriting examination, a simulation is usually used to describe an attempt to copy, draw or imitate handwriting features. Much has been written regarding the act of simulation and its assessment (Al-Musa Alkahtani, 2013a, 2013b; Al-Musa Alkahtani & Platt, 2009, 2010, 2011; Bellemin-Noel, 1984; Berthold, 1997; Black, 1995; Boshir & Platt, 2012; Buglio & Gideon, 1997; Burrichter, 1959/60; Cabanne, 1980; Cadola, Margot & Marquis, 2013; Caligiuri, Mohammed, Found & Rogers, 2012; Cole, 1973; Conway, 1959; Dewhurst, Found & Rogers, 2008; Ellen, 1987, 1989; Foley, 1997; Fortenberry, 1996; Found, 1997; Found, Metz, Rogers, Schmittat, Black, Ganas & Dick, 1994; Harralson, Teulings & Farley, 2008; Harrison, 1958; Herkt, 1986; Hilton, 1952, 1969, 1982; Horan, 1995; Huber & Headrick, 1999; Lee, 1998; Legrun, 1962; Leung, Cheng, Fung & Poon, 1993a; Masson, 1992, 1996; Michel & Conrad, 1972; Mohammed, Found, Caligiuri & Rogers, 2015; Muehlberger, 1990, 1994; Pepe, Rogers, Sita, 2012; Pfanne, 1975; Pfefferli, 1995; Shimoda, 1974; Singh, Gupta & Saxena, 1994; Smith, 1993; Tappolet & Ottinger, 1982; Vastrick, 1994).

This section provides a brief overview of the hallmarks of freehand simulations where an attempt is made to replicate writing features based upon the existence of a model (or example) of writing, or completed from a memory of the writing features to be copied (see also Black, Found & Rogers, 2003).

Largely due to business practices, the signature, as opposed to text, is the most common type of writing simulated. The overall degree of similarity between a model (sample of writing being copied) and a simulation is dependent upon many factors which may include the intention, skill and ability of the simulator, the amount of practice that the simulator has had at reproducing the model formation, the similarity in style between the simulators normal signature and the signature being simulated, and the quality and range of samples the simulator had access to. There are several challenges and difficulties faced by a simulator, who must attempt to replicate spatial, baseline, height and size relationships as well as reproduce relative speed

reflected by elements of the line quality. The difficulty associated with the overall task is largely dependent upon the complexity of the writing being copied and the simulator's copying skill.

Simulators are required to imitate another person's complex mechanisms for controlling muscle contractions whilst suppressing the characteristics of their own system. The same areas of the brain will be used as for natural handwriting, however, there will be more input from sensory areas as the movement control is more feedback-dependent than for natural writing behaviour. This results in a much higher cognitive load for the simulator. The closed-loop (feedback dependent) mode of movement control includes the simulator referring to the model, pausing to check letter construction and progress against the model and monitoring the success of the simulated writing. These actions result in disturbance to the movements, which will generally be slower and less fluent than natural handwriting movements, and therefore writing. The features we may readily observe in the static handwriting trace include tremor, awkward or interrupted movements (elements associated with a lack of fluency), unusual pen lifts, pauses, retouches and internal inconsistencies in pen direction, letter construction or connectivity. Indeed it is these features that are generally accepted to be indicative of simulation behaviour. Generally, simulations may capture one or the other of the pictorial or line quality features of the genuine writing, but very rarely both.

Methods of simulating writing

There are two main methods of simulating the writing of another person using a freehand process. One is to simulate the writing using a physical model placed in close proximity for comparison purposes. The other is to simulate the writing from a mental model. Generally, simulations produced with the aid of a physical model for reference are likely to be more pictorially similar to the model than simulations produced from memory; however this is highly dependent upon simulator practice and the complexity of the formation being copied.

The following points on simulation are confined to the simulation of moderate to complex formations.

Features associated with the freehand simulation process

In the assessment of whether writing is genuine or the result of a freehand simulation, the examiner will focus on aspects such as line quality, pauses, pen lifts and added strokes, tapered lines and spatial inconsistencies. Each of these elements is discussed below.

1. Line quality (see also Module 9)

One of the most difficult features of a complex formation to simulate is line quality. These features result from the dynamics of writing behaviour. For a skilled signature, even transitions in the writing speed as the writing implement moves through its spatial trajectory are observed in the form of smooth direction changes and smooth changes in line feathering characteristics. Complex formations written with speed will generally display evidence of pressure variations in upward and downward strokes and feathering or pen drags between strokes. Such elements result from the interplay between the writing implement, the writing medium and the dynamics of the skeleto-muscular and motor memory systems producing the writing. Examples of signatures showing medium to fast pen movements can be seen in Figure 8.1a and b. It can be observed in Figure 8.1a that the speed variations of the pen result in variations of the amount of ink being deposited onto the paper surface. These speed variations and resultant pressure changes may also lead to observable physical indentations in the paper. Figure 8.1b shows a portion of a signature displaying significant pen pressure variations and pen drag associated with a fluently written form.

The ability to simulate pen speed dynamics is difficult, especially while trying to maintain other features of the writing such as correct letter constructions, spatial relationships, and accurate stroke sequences. Accordingly, it is common for simulation behaviour to result in a slower, more deliberate construction of the writing. This slower speed and deconstruction of the normal dynamic order associated with skilled writing usually results in either tremor within the line or the presence of a consistent even pressure and even application of ink onto the paper surface, as seen in Figure 8.2. Variations in pressure of upward and downward movements and

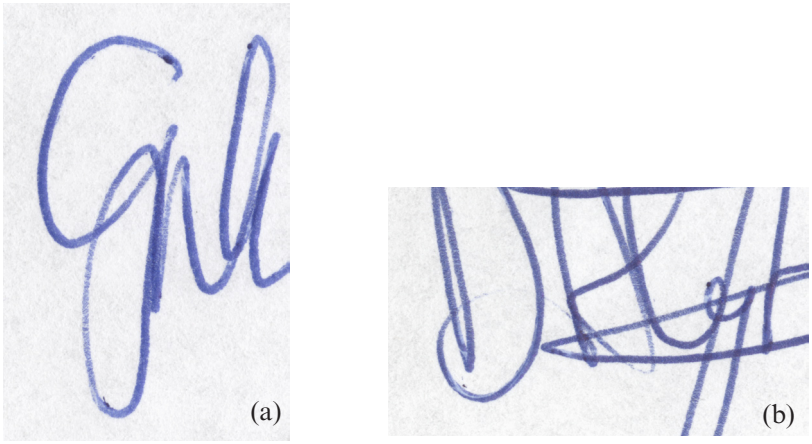


Figure 8.1 (a) Portion of a signature displaying smooth line direction changes and pen pressure variations, and (b) examples of pressure variations and pen drag in a portion of a signature which indicate medium to fast pen movements.

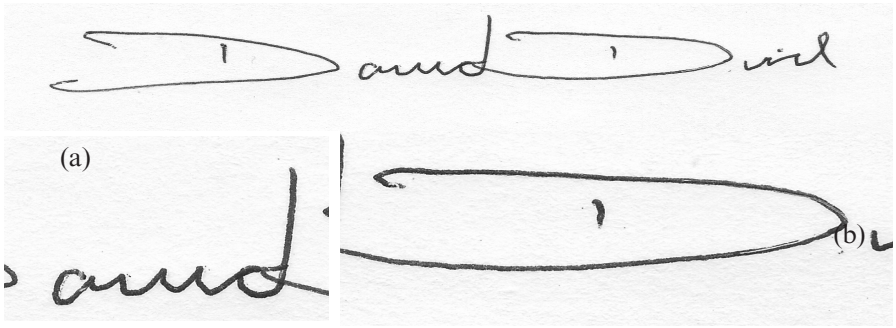


Figure 8.2. A simulated signature (above), showing (a) even pressure and (b) tremor (below).

any subsequent feathering are also less likely to be present, again resulting in even ink application.

2. Pauses, pen lifts and added strokes

Genuine writings (especially signatures which are complex) may contain pauses and pen lifts and pen stroke directions that are difficult for the forger to identify with the unaided eye. Simulated signatures may therefore not reproduce these features accurately. Simulated signatures may also exhibit pauses and pen lifts not displayed in genuine signatures. These additional features are usually associated with the copying act where the simulator needs to stop or pause in the middle of the copying process to refer to the model or assess progress. Additionally, writers may not be happy that they have produced a sufficient likeness to the model signatures they are copying and may attempt to refine or improve the simulation by retouching or

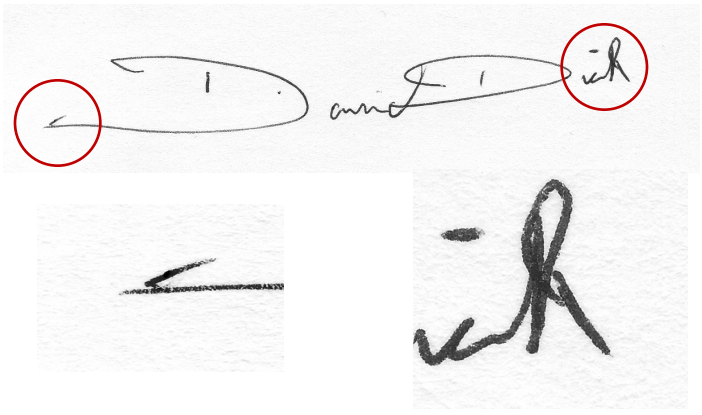


Figure 8.3. A simulated signature (above), showing two areas with added strokes and patching (below).

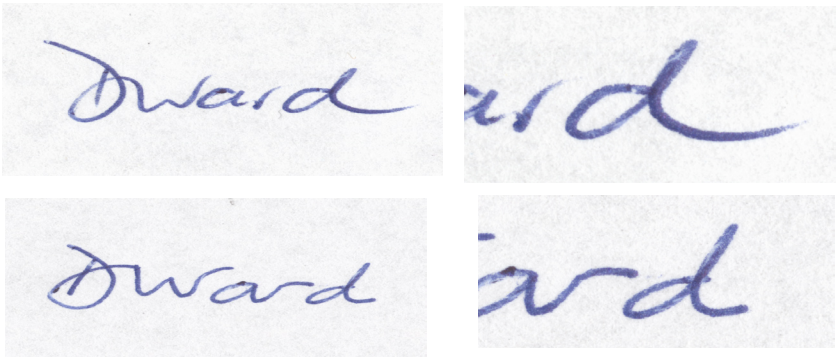


Figure 8.4. A genuine signature showing tapered lines (top), and a simulated signature showing blunt endings to lines (bottom).

adding additional strokes (to connect lines or create letters etc through a patching process [see Figure 8.3]).

3. Feathering, blunt initial and terminal strokes

In genuine skilled writing it is commonly observed that fluency is also evidenced in tapered beginnings and endings to lines. This phenomenon is generally known as *flying starts* or *flying finishes* respectively. Flying starts occur where the writing instrument is already in motion before it comes into contact with the page. Flying finishes occur when the moving pen is removed from the surface gradually. 'Feathering' of the line is a phenomenon observed within strokes where changes to pen pressure result in smooth transitions of thinning and thickening of the line trace. Simulated writing commonly lacks these tapered strokes and displays more blunt initial and terminal endings to lines. This is thought to occur under simulation conditions where a person is copying from a physical model. In this method of simulation the writer places the writing instrument onto the paper and commences the simulation from a stationary position. At the end of the simulation, or part way through the process, the writer may pause, or lift the writing implement, then continue with the signature. At the end of the simulation attempt the writing instrument may be brought to a complete stop and then removed from the page. This type of simulation process results in the finished writing displaying blunt beginning and/or endings to lines (see Figure 8.4).

4. Spatial considerations

The spatial complexity of the writing to be simulated is an important factor which may contribute to the number of feature differences present in the questioned formation. Genuine signatures which display combinations of overwritten elements, large fluently written curves and many pen direction changes are likely to be challenging for the simulator to reproduce without leaving evidence of the process behind either spatially or in the line trace. Spatial dissimilarities may be evidenced in the overall size of the simulation relative to the comparison sample, dissimilar height to length relationships, and dissimilar feature proportions.

The examples provided above relate to signature examinations. With respect to extended text simulations, the overall task difficulty in suppressing the simulator's own writing habits while attempting to adopt elements of the copied text may result in some of the simulator's own writing characteristics being included in the writing. Although observations of this type may provide evidence to assess authorship propositions in text, the inclusion of the writer's own habits in simulated signatures is rarely evident.

Considerations and limitations relating to simulation predictor features

The writing materials used may affect the visibility or presence of the above indicators of simulation. Certain pen types may help hide these signs of simulation. For example, pencils may help

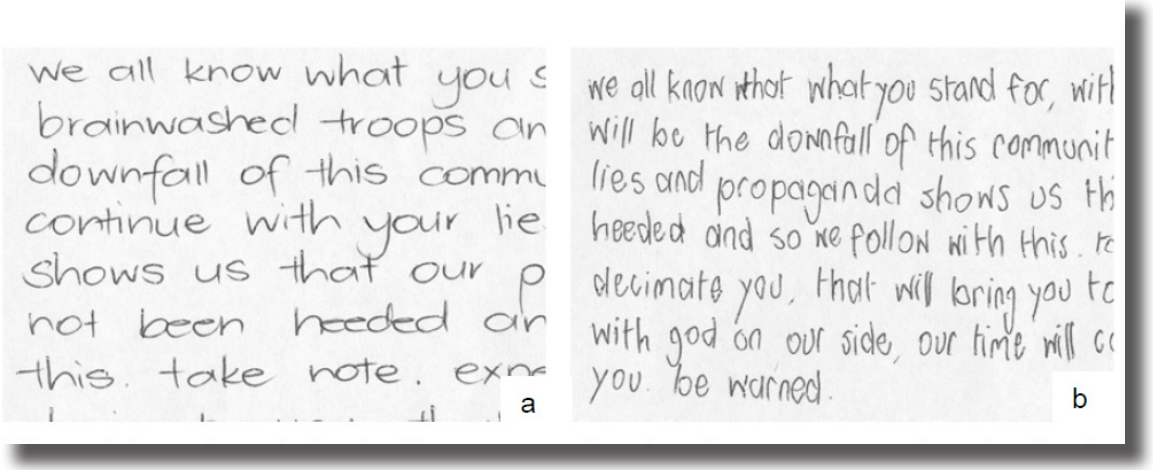


Figure 8.5 A naturally written sample (a) and corresponding disguised sample (b) showing less fluency and poor rhythm.

disguise a lack of speed while fibre tipped pens may conceal certain minute details. On the other hand, writing using a ball point pen onto paper that has a hard surface directly beneath it may result in the appearance of tremor which, although may be an indicator of simulation, in this case is an artifact of writing environment.

Although the features detailed above are predictors of a simulation process having occurred, it should be noted that there may be other plausible explanations for their presence other than copying by another writer. For example, internal influences on the genuine writer (e.g. ill health) may result in changes to handwriting features which may not have been evidenced in the specimen writing population (due to skewed samples, samples that were edited prior to their submission, or samples that do not cover the relevant period of time). External influences such as unusual writing surfaces may also result in similar features to those discussed above. The possibility that such features have been intentionally included by the genuine writer to provide an avenue for later disowning of a genuine signature should also be taken into account (auto-simulations). This leads the discussion in this module on to disguise behaviours.

Disguise behaviour

Disguise behaviour is an attempt by a writer to purposefully alter their writing to avoid detection or for them to deny having created the writing. When attempting disguise, writers have to suppress their normal writing behaviour and introduce new features that they consider significantly different. However, some writers may not realize what characteristics are significant (Webb, 1977), or find the task of disguise so difficult, that their attempts are unsuccessful. Disguise in writing has been reported in numerous studies (Alford, 1970; Harrison, 1958, pp. 349-372; Herkt, 1986; Hull, 1993; Keckler, 1997; Osborn, 1929, pp.407-408; Mohammed, Found, Caligiuri & Rogers, 2011; including one on Swedish handwriting: Konstantinidis, 1987; and two on Chinese writing: Leung, Chung, Tsui & Cheung, 1988; Tsui, 1997). However, of the studies only Alford (1970), Konstantinidis (1987), Hull (1993) and Keckler (1997) deal with somewhat extended handwritten entries.

There is general consensus that disguise incorporates changes to obvious and superficial features, while the less conspicuous features remain unchanged (Huber & Headrick, 1999, p.279). Commonly reported beliefs regarding disguise include (Harrison, 1958, pp.349-372; Cain, 1998; Morris, 2000, pp.171-173):

- Disguised handwriting exhibits less fluency and poorer rhythm and line quality than natural writing (see Figure 8.5);
- Most disguises are relatively simple (e.g. change in size or slant, see Figure 8.6);

- Any disguise is rarely consistent over more than a few lines due to the writer becoming tired or losing concentration, therefore disguised writings often exhibit internal inconsistency;
- Certain features are rarely disguised. For example, word and line spacing, as well as arrangement on the page usually remain unchanged.

More specifically, numerous studies have been carried out since the late 1950's investigating the nature of disguise behaviour in handwritten text, and reporting the most commonly encountered disguise strategies (Alford, 1970; Harrison, 1958, pp. 349-372; Keckler, 1997; Konstantinidis, 1987; Regent, 1977; Totty, 1991). Huber and Headrick (1999, pp. 280-281) have distilled from these studies a list of changes that may occur in disguised writings. The commonly occurring features are grotesque letter forms (see figure 5.8), addition of flourishes or embellishments and alteration of:

- Slant (see Figure 8.6)
- Letter design
- Commencement or terminating strokes
- Size
- Style
- Hand used
- Spacing
- Ascenders and descenders (see Figure 8.7)
- Speed or fluency
- Greater angularity
- Pen stops and pen lifts
- Connections

These changes may, in themselves, be intentional or simply a by-product of the intentional alterations and thus may occur alone or in combinations. In fact, Morris (2000, p. 169) notes that no single characteristic of writing can be changed without also affecting other characteristics. So, when slant changes, the pictorial appearance of writing also changes, perhaps along with the writer's relative speed and pressure habits, letter styles, construction and connecting strokes. When style is changed, the speed and fluency of writing may also be affected resulting from the increased cognitive load associated with writers changing their natural writing style. This implies that the disguise strategy intentionally employed by a writer may not be directly associated with the features that an FHE observes as predicting the behaviour.

Simulation and disguise behaviours

Both types of unnatural writing, disguised and simulated, are expected to display similarities and differences when compared to the corresponding genuine natural writing. In the case of disguised writings (by the genuine writer), the mixed signals arise from forms ingrained in motor memory, combined with purposefully altered features associated with the disguise behaviour. With simulated writings, the similarities occur from the copying process, while the differences reflect the difficulty in accurately capturing all of the characteristics of the subject writing. The hallmark features noted for simulation relate primarily to the parallel difficulty in suppressing the learnt motor behaviour for natural handwriting production while attempting to maintain an unfamiliar writing form, including good representation of structural elements as well as fluency. Many of the resulting features, including decreased fluency, line quality disturbance and increased internal inconsistency are said to be present in both simulated (Leung et al., 1993a; Muehlberger, 1990; Osborn, 1929, pp. 273-274) and disguised writings (Cain, 1998; Harrison, 1958, pp. 352-353, 357-359; Konstantinidis, 1987). This may be reasonably assumed to impact on the ability of FHEs to meaningfully evaluate disguised as compared to simulated writings in terms of authorship propositions. Based on blind testing of examiners' skills (Found & Rogers, 2005b, 2005c) it is these types of examinations that are the most problematic for FHEs (as characterised by their high inconclusive scores and high error scores on similar problems). Research by Bird (2012) suggests that FHEs as a group are limited with respect to accurately determining whether questioned samples of handwritten text are disguised or simulated. This provides support for the position that caution should be taken when expressing opinions as to the extent to which evidence supports authorship of writings that display a combination of similar and dissimilar features (whether they be handwritten text samples or signatures). In cases where FHEs reach the conclusion that there is

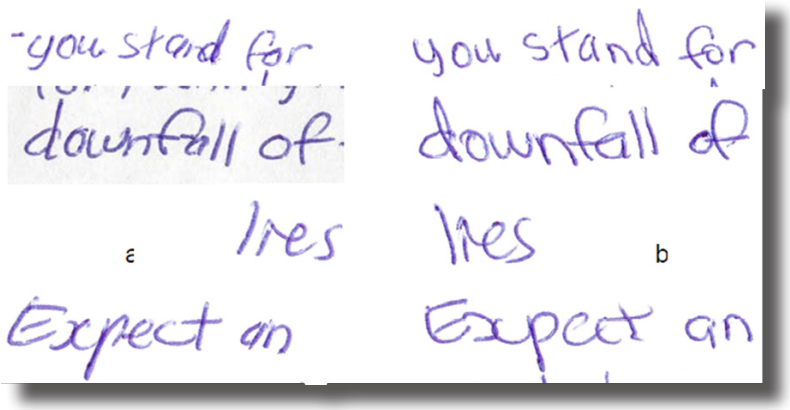


Figure 8.6 Portions of a naturally written sample (left) and a corresponding disguised sample (right) showing a change in slant.

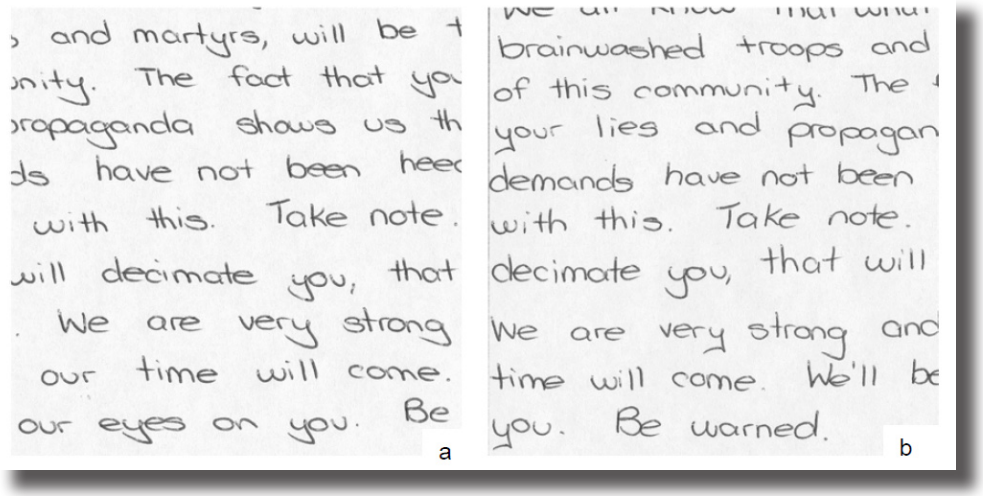


Figure 8.7 A naturally written handwriting sample (a), and a disguised sample (b) displaying a subtle change in 'y' descenders.

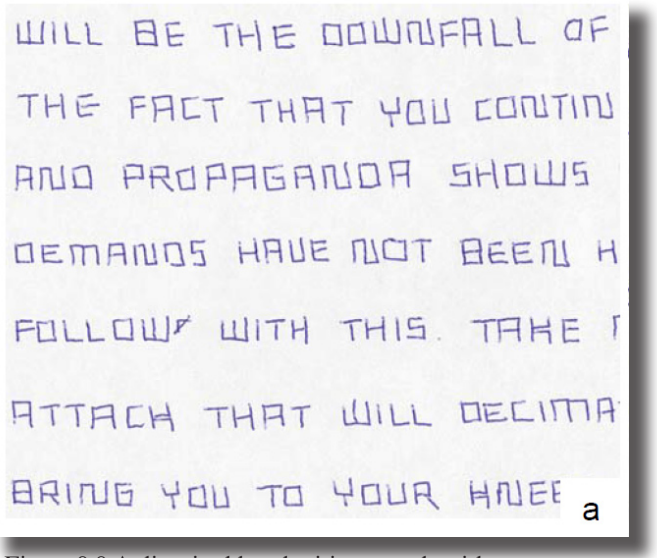


Figure 8.8 A disguised handwriting sample with grotesque letter forms.

a combination of features both similar and dissimilar to the comparison material, one of two opinions is generally expressed:

1. An opinion stating that the findings provide no assistance in addressing the issue of authorship i.e. the findings do not support the proposition that the writer of the comparison material wrote the questioned material over the proposition that a writer other than the comparison writer wrote the questioned material.

2. That the findings are more probable given the questioned writing is the product of an unnatural writing process than if it is the product of a natural handwriting behaviour. Aside from a chance match or internal or external factors, these unnatural behaviours are the only explanations as to why the observed combination of similarities and dissimilarities might occur, given that the comparison material has been written in the appropriate time frame. The handwriting production process opinion would usually be followed by an opinion similar to 1 above, where the opinion is that the findings do not provide support for the proposition that the questioned material is unnaturally written by the writer of the comparison material (disguised) over the proposition that the questioned writing is unnaturally written by someone other than the comparison writer (simulated).

Although there is an overlap in the predictor variables for disguised and simulation behaviours, there are some circumstances where disguise behaviour may be reasonably supported:

- In signature cases where a small number of gross features have been significantly changed while the remaining components of the signature remain within the variation displayed in the specimen material;
- In handwriting text cases where there is great similarity in the subtle features of the formation and difference only in gross features (which would normally be accompanied by an unnatural appearance in those gross features).

In most practical case examinations, the FHE faced with mixed signal writings is able to support the proposition that the questioned handwriting is not naturally written. Depending on the robustness of the comparison material, the FHE may opine that the evidence supports the proposition that the questioned sample is either the product of disguise or simulation.

Module 9

Line quality and skill

Overview: *At this stage of the method it has been determined that a fundamental dissimilarity between the questioned and comparison sample is the line quality. A determination may be made as to whether the line quality associated with the questioned writing provides evidence of a more or less skillful writing than appears in the comparison material. In this module, an overview of the basis for this determination is provided. This determination, if it can be made at all, will focus the examination either on the processes associated with the writing behaviour, or may provide support for the proposition that the writer of the comparison sample did not write the questioned material.*

Discussion

A fundamental aspect of handwriting comparison methodology is the examination of the line trace in terms of its quality. *Line quality* in the forensic environment refers to the relative fluency or dysfluency observed in the line. Examiners infer characteristics associated with the dynamics of pen movement, and therefore also the motor control system itself, from the qualitative assessment of line quality. Thomassen and van Galen (1997) provide an overview of the dynamic order associated with skilled handwriting and discuss possible approaches to reintroduce dynamic components into static line traces. Found, Rogers and Schmittat (1997) provided a diagrammatical overview of the stages in handwriting production and the corresponding dynamics that examiners may infer (see Figure 9.1).

It is the dynamic elements of handwriting production that form the visual features of the line trace that examiners focus on when gauging relative line quality. In particular, examiners may make observations regarding changes in pen pressure (as evidenced by relative indentation depth, relative density of ink deposits or relative width of the line), flying starts or finishes (as evidenced by the tapering of the line trace caused by the movement of the writing instrument as it comes in contact with, or leaves the writing surface), pen drag (caused by the connection between strokes where the pressure exerted on the page by the writing instrument is reduced) and smoothness (which results from smooth acceleration and decelerations of the writing instrument over the writing surface). Research on FHEs' ability to assess subtle dynamic features (e.g. speed) from the static trace has been reported by Will (2012). It is these features, usually in combination, that are assessed to determine whether one sample of writing was performed with greater or lesser skill than another.

Questioned writings exhibiting greater skill relative to specimen writings

In some circumstances the examination findings are more likely given the questioned writings were not written by the writer of a comparison sample than if they were written by the comparison writer. This usually occurs under the following conditions:

- The comparison material has been sampled over an extended period of time.
- The comparison material brackets closely the time that the questioned images being compared to it were allegedly produced.
- There is a sufficient quantity of comparison material (in terms of replication of line quality features).

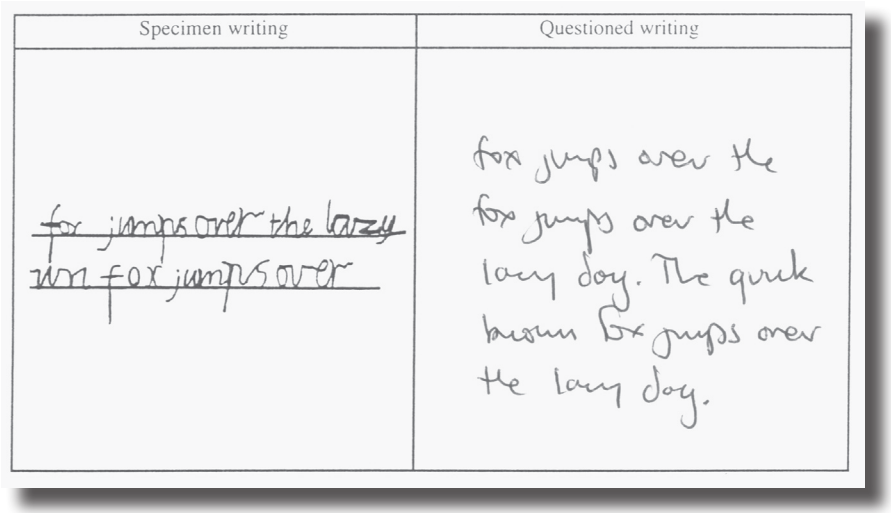


Figure 9.2. A sample of comparison (specimen) writings showing poorly skilled writings and a questioned sample showing a significantly higher writing skill.

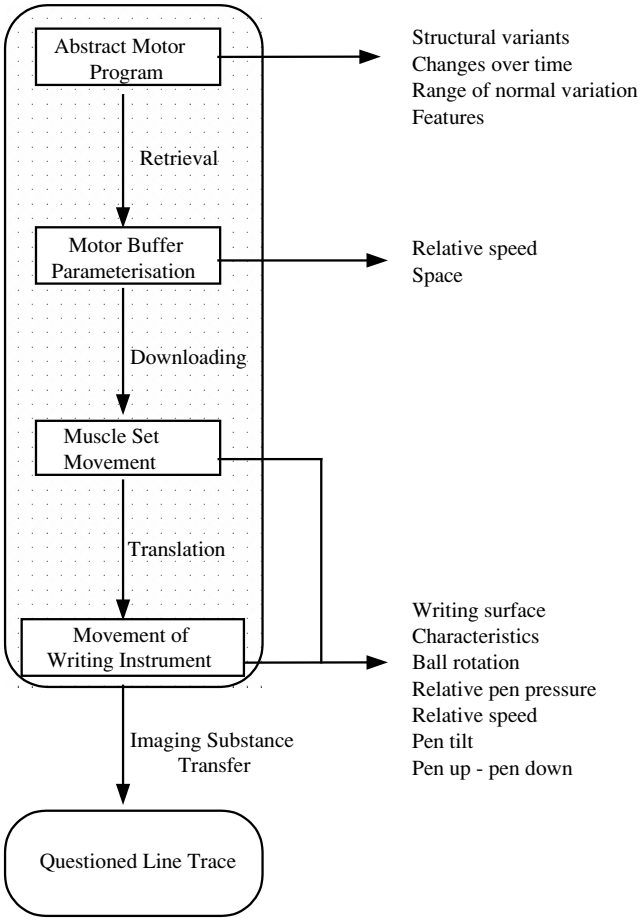


Figure 9.1. A diagrammatical overview of the stages in handwriting production and the corresponding dynamics, many of which may impact on the assessment of line quality, that FHEs may infer (Found, Rogers & Schmittat, 1997).

- The comparison material, without exception, displays poor line quality as may be evidenced by tremor in the line, dysfluencies, pressure differentials uncharacteristic of normal stroke formations and concatenations, and variations in the characteristics within allographic forms.

Under these circumstances it will be clear that the comparison sample writer lacks the skill to write fluently. Should the comparison base material display these characteristics and the material being compared displays line quality characteristic of a skilled writer, then an opinion may be expressed that the findings provide extremely strong support for the proposition that the questioned writings were not written by the comparison writer, rather than the questioned writings were written by the comparison writer (see Figure 9.2).

Questioned writings exhibiting lesser skill relative to comparison writings

Should the questioned writings exhibit a lesser skill than the comparison writings, but still share features in common with the specimen writings, then opinions regarding support for one authorship proposition over another are unlikely to be expressed (see Module 8).

Module 10

Evidence evaluation and reporting procedures

Overview: *Having explored the key elements of the examination process, in this module we consider how opinions are formed regarding handwriting and how the results are expressed in reports. Although reporting procedures remain diverse across forensic science disciplines, FHE's are working towards standardizing terminology for expressing opinions..*

Discussion

The wordings of opinions are diverse in the field of forensic handwriting examination. This is due to the large number of ways that an examiner's confidence in an opinion can be expressed in terms of words. Some scales express opinion confidence in terms of verbal probability (McAlexander, Beck & Dick, 1991). Wording typical of these scales state the probability of a proposition given the observations (e.g., it is highly probable that the writer of the comparison sample [specimen] wrote the questioned writing). There is a strong view from the leaders in the forensic science community (including forensic scientists, statisticians and lawyers) that this practice is not appropriate, and that results expressed in this way are potentially misleading (see Aitken, Berger et al., 2011; Berger, Buckleton, Champod, Evett and Jackson, 2011).

The approach used here is based on the logical framework approach summarized in the work of Evett (1998), who states that the expert should consider the probability of the evidence given each of the two stated propositions (the specimen writer [or comparison sample writer]) wrote or did not write the questioned handwriting) and thus assess the extent to which one of them is supported by the evidence. Relevant to this discussion are:

- reported investigations into the variation in perceptions as to the information experts intend to convey, as opposed to how lay people understand their communications (Martire, Kemp & Newell, 2013; Sjerps, Massier & Wagenaar, 1996),
- argument around differing views as to the best mechanism to convey evaluative opinions to courts of law (Ligertwood & Edmond, 2012), and
- research into quantitative likelihood ratios for handwriting evidence (Davis, Saunders, Hepler, Buscaglia, 2012; Hepler, Saunders, Davis & Buscaglia, 2012).

It is still the case that full engagement with empirically based approaches to the evaluation of handwriting evidence is in its infancy, and in the short term the basis of opinion in the discipline remains centered around FHE specialized knowledge. This does not mean however, that the elements of the logical approach to evidence interpretation cannot be adhered to. These elements have been described (Berger, 2010; Berger, Buckleton, Champod, Evett and Jackson, 2011; Biedermann, Voisard & Taroni, 2012; Evett, 2015).

The approach reported here is a further step toward Australian and New Zealand reporting uniformity in forensic document examination and there is significant common ground with it and the philosophy underlying the work of authors cited in this module. Here we use a verbal scale to convey the results of our examinations. Verbal scales based

on the underlying mathematics described within the logical approach are accepted as an appropriate basis for communication of an evaluative expert opinion to the court and are phrased in terms of support for one of a pair of clearly stated propositions over the other (Aitken et al., 2011). Further discussion around the relationship between the logical framework and verbal equivalents can be found in Nordgaard, Ansell, Drotz & Jaeger (2011). A good summary of the logic behind the approach discussed here can be found in The Association of Forensic Science Providers, "for the formulation of evaluative forensic science expert opinion" (2009). In addition, in 2015 the European Network of Forensic Science Institutes released a guideline for reporting evaluative opinions in forensic science. This report represents a standardised approach toward evaluative reporting across the broad spectrum of forensic science disciplines based on the logical framework discussed above.

Principles

In the first instance, FHEs must explicitly state the propositions that are under consideration. Historically FHEs have considered all explanations at once, that could account for similarities and/or dissimilarities with respect to authorship and handwriting process (which is reflected in the method documented here). But this position can be conditioned by specific requests in relation to a specific case, where only a limited number of propositions might be considered.

Although, the alternate propositions to be addressed may be obvious and even stated in the request, the complexity of handwriting behaviours will often result in a suite of propositions which will arise from following the approach outlined in this document.

The task of FHEs, based on their specialized knowledge, is to express an opinion as to the probability of their observations given each of the stated propositions. In this way, the FHE may form an opinion as to the extent of support for one proposition over each of the alternate propositions. Since the observations made by the examiner are on the product of human behaviour there are a large number of variables that could contribute to limiting the examiner's ability to express an opinion confidently. These factors include the amount of writing being compared, the degree of variability in the writing, the complexity of the writing and the relative timing of the questioned and comparison material. The extent of support for a proposition is based on a scale. The scale that is used in this method is provided in the guide below.

Standard Guideline for the Expression of Conclusions by Forensic Handwriting Examiners

1. Scope

1.1. This guide is intended to assist forensic document examiners when expressing conclusions or opinions based upon a formal evaluation of the evidence. It does not address the manner in which examiners arrive at their assessment of the strength or weight of the evidence with respect to the propositions that are of interest.

2. Standard framework for evaluation and reporting

2.1. Conclusions are expressed following an appropriate and complete evaluation of the evidence.

2.2. Forensic evaluations shall be performed

2.2.1. Within a framework of information pertaining to the matter at hand,

2.2.2. By considering at least two competing and mutually-exclusive propositions, and

2.2.3. With a focus on the evaluation of evidence given each proposition.

2.3. The examiner must evaluate the quality, quantity, and degree of correspondence (i.e., considering both similarities and divergences) observed when comparing the questioned and comparison samples, giving consideration to any potential limitations present in the evidence.

3. Reporting of results

3.1. All reporting, whether verbal or written, must be transparent, clear and complete.

3.2. As a minimum, reporting must include the following elements

3.2.1. A statement of propositions utilized in the evaluation of the evidence

3.2.2. A statement of relevant background information provided to the examiner

3.2.3. A statement of any assumptions made by the examiner, including those assumptions tested as part of the examination process

3.2.4. A statement of limitations affecting the assessment or evaluation of the evidence

3.2.5. An explanation of the potential effect if there is any change to propositions, assumptions or limitations in terms of the outcome of the examination (e.g., The opinion is based upon the information and exhibits provided to the examiner, as well as being based upon the specific propositions outlined here. Should this information, exhibit material or the propositions change, the opinion may also change.)

4. Conclusion format and wording

4.1. Conclusions are intended to convey the degree of support provided by the observed evidence for one proposition versus one or more specified alternative propositions.

4.2. Scale for conclusions

4.2.1. The conclusion must be expressed verbally in qualitative terms that relate to the magnitude of the degree of support that the evidence provides for each of the propositions, according to a pre-determined scale of conclusions.

4.2.2. Subject to research into the optimal

Results of evaluation of evidence (Conclusion wording)	Description of evaluation (Criteria for conclusion)
The evidence provides very strong support for proposition X over proposition Y	The evidence very strongly favours one proposition over the other.
The evidence provides qualified support for proposition X over proposition Y	The evidence favours one proposition over the other. Support for one proposition over the other may be qualified due to there being an identifiable limitation associated with the examination process.
The evidence provides approximately equal support for proposition X and proposition Y	The evidence does not differentiate between the propositions because the probability of the evidence given each proposition is roughly equal. This is an inconclusive opinion
No opinion can be reached regarding potential authorship	1. Limitations in the submitted material severely limited the comparison. 2. Limitations in the submitted material (e.g. a complete lack of comparability) precluded a meaningful comparison. This is an inconclusive opinion.
Note 1: Either proposition may be presented first in the conclusion wording to reflect whichever is supported more than the other by the evidence.	
Note 2: Although not within the logical framework approach upon which this evaluation and reporting is based, some examiners will form the opinion that the probability of the evidence given the proposition that a writer other than the comparison writer wrote the entries is so remote that they will discount this proposition, and conclude that the questioned writing was written by the writer of the comparison material. Some examiners will form the opinion that the probability of the evidence given the proposition that the comparison writer wrote the entries is so remote that they will discount this proposition, and conclude that the questioned writing was not written by the writer of the comparison material.	

Table 10.1

number of levels and the descriptive terms for each category, the scale recommended for conclusions is given in Table 10.1 below.

1.1.1.1. Acceptable alternative wordings

1.1.1.1.1. "<modifier> support for X, rather than Y"

1.1.1.1.2. "<modifier> support under X, rather than under Y"

1.1.1.1.3. "<modifier> support if X is true, than if Y is true"

1.1.1.1.4. "<modifier> support given X, than given Y"

1.1.1.1.5. "approximately equal support for both X and Y"

Written reports should contain a brief overview of the method that provides the reader with an understanding of the qualitative nature of the examination (Found & Edmond, 2012).

Conclusion

Forensic handwriting examination is a qualitative process that involves FHEs' perception and judgment. Both written and verbal reports are expected to reflect this reality. It is expected that there will be continual refinement of both the written method and the approach to reporting procedures in light of research and development within the field.

Acknowledgement

Note that significant elements of this reporting approach were developed with the assistance of Brent Ostrum of the Canada Border Services Agency.

Additional references

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QD guideline "Standard Guideline for the Evaluation of Evidence in Forensic Document Examination", unpublished draft

Annexure

Validation of method and blind testing

Overview: *Forensic Handwriting Examiners (FHEs) from Australian and New Zealand government laboratories who subscribe to this method committed to assessment of their claimed skills. This is ongoing and is achieved through subscriptions to various types of proficiency and collaborative testing programs (for example those supplied by the US based Collaborative Testing Services, Inc, ST²AR and previously by the Forensic Expertise Profiling Laboratory (FEPL) at La Trobe University in Australia). These trials are, to varying extents, blinded casework emulation experiments where the correct identity of questioned writings is known to the experimenters but not to the participants. In this way, although the method presented here can not be directly validated, inferences can be made regarding its validity from the behaviour of FHEs on known outcome comparisons.*

For the FEPL trials the estimation of misleading (error) rates for different categories of questioned writing has been investigated through the performance of Australian and New Zealand FHEs on two handwriting trials per year (one text-based and one signature trial) from 1998 - 2008. Between the years 2000 and 2002 FHEs subscribing to the method described here expressed 27730 opinions on three handwriting and three signature trials. It was found that although the misleading and inconclusive rates for different categories of writing varied between FHEs, the misleading rate was very small. This module presents a summary of those opinions expressed by the examiners over the six trials.

Discussion

Forensic handwriting evidence is routinely accepted as expert evidence in Australia and New Zealand. However, the field is one that grew out of practical application and not through normal scientific processes. Many of the characteristics normally associated with sound scientific endeavour failed to develop at what many commentators considered to be a satisfactory rate. This has lead to both literary and judicial based criticism since the landmark article by Risinger, Denbeaux and Saks (1989). Further critical US court decisions regarding the character of the evidence were to follow (for example see Risinger & Saks, 1996).

Forensic handwriting validation studies have been reported (Found, Sita & Rogers, 1999; Kam, Fielding & Conn, 1997; Kam, Gummadidala, Fielding & Conn, 2001; Kam, Wetstein & Conn, 1994; Sita, Found & Rogers, 2002). Many of these studies were designed principally to explore whether forensic handwriting examination could be characterised as true expertise by comparing the opinions expressed by FHEs with those opinions expressed by laypersons on materials where the ground truth of authorship was known. Each of the studies has provided statistical support for the proposition that the expertise itself is real and demonstrable. The characterisation of the nature of the 'skill' claimed by FHEs requires alternative approaches in order to capture the large number of variables which present to FHEs in routine casework scenarios. Again this is something that the critics have

requested (Risinger & Saks, 1996; United States v Hines, 1999).

The dynamics of FHEs work does not, however, lend itself to straightforward small-scale investigations of the properties of their method in order to yield estimates of the potential of the techniques to produce erroneous results. This arises from the myriad of ways that cases can present themselves in terms of the quantity and quality of both comparison (specimens) and questioned material. This is a feature of the discipline that, in terms of skill testing and error estimation, has not gone un-noticed. It has been stated that: "The level of correctness of the assertions made by examiners from day to day casework is not likely to prove to be a credible source for the (validation) data needed" (Huber & Headrick, 1999). "A process such as handwriting identification presents a number of potential subtasks dealing with variables such as writing instruments, forgery of various sorts, age, health and so forth. No single test can map the abilities of any one practitioner, or any group of practitioners" (United States v Hines, 1999). "A great many tests… would be necessary to know what, if anything, (examiners) can do accurately, and under what conditions"(United States v Hines, 1999). "A complete testing regime would have tests which covered the entire spectrum of conditions and difficulties" (United States v Hines, 1999).

In the mid 1990's Australian and New Zealand Document FHEs, subscribing to this method, entered into a large scale sustained testing program with the support of the Senior Managers of Australian and New Zealand Forensic Laboratories and the National Institute of Forensic Science (Australia). In addition to the testing carried out with the assistance of these organisations, the New Zealand Police Document Examination Section engaged further detailed studies that have been reported (Found, Rogers & Herkt, 2001a; Found, Rogers & Herkt, 2001b).

Although it may be attractive at the outset to attempt to derive a global error rate for forensic handwriting examination by investigating a sample of the FHE population and making inferences about all types of writing and all examiners in general, a detailed consideration of the results of validation experimentation juxtaposed with documented method suggests that this is not an appropriate position to take. The rationale for this is derived from two principle sources. Firstly all validation studies to date have shown that examiners responses on blind trials vary, and can vary widely, particularly in terms of individuals' correct and inconclusive scores. Therefore the results from one group of examiners or an individual examiner may not be a good estimate of the potential results of an unrelated group or individual in spite of these examiners using the same resource materials, being the product of similar training regimes and even using similar methodology. As a human skill this is not entirely unexpected. Therefore the quotation of error estimates in the judicial environment by FHEs who have not themselves participated in testing (or where their work is not peer reviewed by those who have) would be a precarious position to take. Secondly, in the majority of instances questioned writing can be either normal writing by the specimen writer, disguised writing by the specimen writer, auto-simulated writing, normal writing not by the specimen writer, disguised writing not by the specimen writer or simulated writing not by the specimen writer (forgeries). The disguised and simulated categories are of course related (see Module 8). Since there are a number of different categories of questioned writing, there is the real possibility that the potential error for opinions expressed within each of these categories may be different. Research by Found and Rogers (2005b, 2008) suggests that this is the case, and as such a global estimate of error would not be a true estimate but rather one skewed according to the numbers of each category of writing within the testing program being undertaken. This is problematic and must be taken into consideration when arriving at a philosophy of potential error estimation.

The approach that we have taken, understanding the dangers described above, is to use a skill testing program to compile an 'estimate' of examiner error for each of the categories of questioned writing. This approach has been described (Found & Rogers, 2003). This annexure deals with the compiled results for the years 2000 to 2002, for Australian and New Zealand government FHEs. The group comprised nearly all government FHEs in the region and in fact the majority of all practicing examiners in these countries at the time. These blind trials all contained varying numbers of the 6 categories of questioned writing described above. The trials varied according to the amount of

comparison material and questioned writing and to a large extent we believed the tasks emulated the tasks involved in routine forensic handwriting practice. The aim of the study was to use this data to estimate the extent of error amongst the group to determine whether a numerical estimate strategy could be developed.

Twenty-eight Forensic Document Examiners (FHEs), the majority of government FHEs in the six major Australian and New Zealand government forensic laboratories, were used in this longitudinal study. Over a three-year period these examiners expressed opinions on three handwriting and three signature trials. Not all examiners participated in each trial however in the majority of instances the results were generated within the peer review system, as is the practice of the laboratories from which the FHEs used in this study were drawn. In each trial FHEs were required to compare a group of known signatures or handwriting samples with questioned signatures or handwriting samples where, for each of the questioned samples, the writer was known to the experimenters but not to the practitioners. For one trial all FHEs were provided with the originals of the exemplar and questioned signatures. In all other trials they were provided with either colour photocopied or high-resolution ink-jet printed handwriting samples along with the original scans of each of the questioned and exemplar material on CD. FHEs were also provided with proforma answer booklets with the levels of authorship opinion that they could choose from. FHEs were informed that the date range over which the exemplar material was taken was around the time that the questioned samples were written. They were asked, in each of the 6 trials, to compare each questioned sample with the exemplar group and express an authorship opinion where they were able using the answer codes provided.

Construction of the Exemplar (Specimen 'Sp') Sample Groups

Specimen writers were selected from the academic staff at La Trobe University and from the general population. These writers were provided with all materials required to form the exemplar material. The exemplar writers wrote samples that included their normal writings (Sp), disguised writing (DSp) and auto-simulated writing (SSp). For each of the six trials reported here each exemplar writer was only used once.

Construction of the Questioned Sample Groups

The questioned groups contained varying numbers of samples of normal handwriting written by the specimen writer (Sp), disguised handwriting written by the specimen writer (DSp), auto-simulated writing written by the specimen writer (SSp), normal writing not written by the specimen writer (NNSp), disguised writing not written by the specimen writer (DNSp) and simulated samples of the specimen writers writing (SNSp). One of the signature trials contained 260 questioned samples, one contained 250 questioned samples and one contained 200 questioned samples. Two of the handwriting trials contained 250 questioned samples and one contained 200.

Recording of FHEs' opinions

The opinions regarding the authorship of each questioned sample was reported by participants using the following scale (as was current and described in the original version of this method document):

Opinion level A. The writer of the specimens wrote/did not write the questioned writing. The level A opinion is used when the examiner believes that, given the limitations of the comparison, there is very strong support for one of the propositions.

Opinion level B. There are indications that the writer of the specimens wrote/did not write the questioned writing. The level B opinion is used when there is an identifiable limitation on the comparison process (e.g. a limited amount of questioned and/or specimen writing). This opinion level is only used when there is moderate support for one of the propositions.

Opinion level C. The examination was inconclusive.

Scoring of FHEs' opinions

Given that the description of strength of opinion varied from a Bayesian format (Evett, 1998) to one resembling the ASTM standard (McAlexander, 1977),

Questioned writing type	# Correct (U)	# Correct (Q)	# Inconclusive	# Misleading (Q)	# Misleading (U)	Totals
Sp	2753	80	17	0	0	2850
DSp	252	413	585	14	4	1268
SSp	284	146	308	10	0	748
NSp	593	1944	1425	0	0	3962
DNSp	315	958	1963	0	0	3236
SNSp	109	606	1206	8	7	1936
						14000

Table 1. Scores for FHEs' opinions regarding the authorship of each of the questioned handwriting types. Note Sp = Written normally by the specimen writer, DSp = Disguised by the specimen writer, SSp = Simulated by the specimen writer, NSp = Written normally not by the specimen writer, DNSp = Disguised not by the specimen writer, SNSp = Simulated not by the specimen writer. *Note that Q = qualified opinion and U = unqualified opinion.*

it was felt subsequent to personal communications with Ian Evett from the Forensic Science Service (UK) that the term 'error' might be inappropriate to use. Although the logic of this is not presented here it was decided to use the term 'misleading' in place of 'error' as it was thought to better describe the implications of opinions that were other than correct or inconclusive. For clarity it may be best for the reader to think of opinions in the investigatory or judicial setting as correct ('helpful' to the client), inconclusive (of little or no value to the client) or misleading to the client.

FHEs' authorship responses (opinion units) were therefore scored as correct, misleading or inconclusive. These marks were then analysed to produce scores for the simulated signatures. The scores are presented as numbers of opinions or as percentages that represent opinion rates. The following are definitions of the score categories used.

 # *Correct:* The number of authorship opinions that were correct.
 # *Misleading:* The number of authorship opinions that were misleading.
 # *Inconclusive:* The number of authorship opinions that were inconclusive.
% Correct: The number of correct authorship opinions divided by the total number of authorship opinions (expressed as a percentage).
% Misleading: The number of misleading authorship opinions divided by the total number of authorship opinions (expressed as a percentage).
% Inconclusive: The number of inconclusive authorship opinions divided by the total number of authorship opinions (expressed as a percentage).
% Correct called: The number of correct authorship opinions divided by the sum of the correct and misleading authorship opinions (expressed as a percentage).
% Misleading called: The number of misleading authorship opinions divided by the sum of the correct and misleading authorship opinions (expressed as a percentage).

The 'called' scores do not include inconclusive opinions and therefore equate to a number that reflects the opinion rate when an FHE is expressing an opinion that is other than inconclusive.

Other information provided to FHEs

FHEs were informed that only the principal and peer review FHE could discuss the trial or the results however that no discussion or consultation was allowed between any other participants or other individuals not involved in the study.

FHEs were informed of the writing implements used within each of the 6 trials and that the same make of writing material was utilized.

Questioned writing type	% Correct	% Misleading	% Inconclusive	% Misleading Called	% Misleading Called Q	% Misleading Called U
Sp	99.4	0.0	0.6	0.0	0.0	0.0
DSp	52.4	1.4	46.1	2.6	2.0	0.6
SSp	57.5	1.3	41.2	2.3	2.3	0.0
NSp	64.0	0.0	36.0	0.0	0.0	0.0
DNSp	39.3	0.0	60.7	0.0	0.0	0.0
SNSp	36.9	0.8	62.3	2.1	1.1	1.0
						14000

Table 2. Percentage scores for FHEs' opinions regarding the authorship of each of the questioned handwriting types. Note Sp = Written normally by the specimen writer, DSp = Disguised by the specimen writer, SSp = Simulated by the specimen writer, NSp = Written normally not by the specimen writer, DNSp = Disguised not by the specimen writer, SNSp = Simulated not by the specimen writer.

Results

In all 27730 opinions were expressed by the 28 participants in the trials. Table 1 represents the scores for group authorship opinions for the three handwriting text trials only. Of the 14000 opinions expressed on handwritten text 32 qualified misleading results were expressed and 13 unqualified misleading opinions. No misleading opinions were expressed associated with normal writing by the specimen writer (Sp), normal writing not by the specimen writer (NSp) and disguised writings not by the specimen writing (DNSp). The misleading opinions being expressed were associated with the disguised by the specimen writer (DSp) and the disguised and simulated samples (SSp and SNSp respectively).

As can be observed the Sp writings were confidently (inconclusive score of 0.6%) and correctly called by the FHEs as no misleading opinions were expressed across the group. This relative combination of scores was not observed amongst any of the remaining categories of questioned writings. The DNSp and NSp scores showed a significantly higher % inconclusive score however did not exhibit any misleading opinions. The DSp and SSp categories of writing are related in that auto-simulation (SSp) is a form of disguise (DSp). Disguise (by the specimen writer) is an interesting category of questioned writing in that FHEs scores are likely to be principally influenced by the effectiveness of the disguise strategy utilised by the specimen writer. Both qualified and unqualified misleading opinions were expressed by individuals in the group on these categories of questioned writings, however the magnitude of these misleading opinions is very small (no unqualified misleading opinions were expressed for the SSp category) and examiners as a group maintain an overall high % correct called score (97.4% for DSp and 97.7% for SSp). It could be argued that misleading opinions in this category are a lesser concern than ones in the NSp group (NSp, DNSp and SNSp) as opinions in this group would amount to evidence in support of an exemplar writer not writing a questioned sample.

Both the DNSp and SNSp categories of questioned writings exhibit very large % inconclusive scores in comparison to the Sp writings, and the SNSp category exhibits a small misleading rate. It is the NSp, DNSp and SNSp categories that may be of concern. Misleading opinions on these categories of questioned writing can result in evidence in support of the proposition that the writing was written by a person who did not in truth write it. The NSp and DNSp writings are not found to result in misleading opinions. The SNSp category has an associated misleading score, however, it is small.

Signatures are considered separately in terms of estimation of misleading rates, as they tend to methodologically have dissimilar properties to handwritten text. This is due to the reality that in casework signature comparisons require the FHE to compare similar formations and therefore normal

Questioned signature type	# Correct (U)	# Correct (Q)	# Inconclusive	# Misleading (Q)	# Misleading (U)	Totals
Sp	2410	741	236	0	0	3387
DSp	255	135	1697	0	0	135
SNSp	0	444	7809	3	0	8256
						13730

Table 3. Scores for FHEs' opinions regarding the authorship of each of the questioned signature types. Note Sp = Written normally by the specimen writer, DSp = Disguised by the specimen writer, SNSp = Simulated not by the specimen writer.

signatures by someone other than the exemplar writer, if required to be compared, are done so with handwriting specimens, if indeed there are any text-based handwriting features at all to compare. Therefore, we practically consider three categories of questioned signature: Normal signatures by the exemplar writer (Sp), disguised signatures by the specimen writer (DSp) (which incorporate auto-simulations) and simulated signatures not by the specimen writer (SNSp). As can be observed in Table 3, of the 13730 opinions expressed, only 3 of these were misleading and all were in the qualified misleading score category.

In Table 4 the percentage scores for signatures are presented showing the pattern of conservatism observed with the handwritten text (Table 3). The group displays a low % inconclusive with Sp signatures and very high % inconclusive scores with the DSp and SNSp categories of questioned signatures. Again there were no recorded misleading opinions associated with the Sp category of writing and the misleading called rate for SNSp was very low at 0.7% (which corresponds to a correct called % rate of 99.3%). This indeed is a positive outcome for FHEs involved in this longitudinal study of their skill.

Given that only a small number of misleading opinions were expressed across the group it is important to realise that the group misleading data, presented in this way, can itself be misleading. As a human skill it is reasonable to expect that FHEs might vary from person to person and even perhaps over time. There are an enormous number of variables that might participate in the ultimate ability of any FHE to express opinions. Examples might be the depth and understanding of theoretical factors underlying the discipline, the presence or absence of documented method, the extent to which any peer review process plays a role in their casework or even their natural ability to focus their personal perceptual and cognitive abilities to the task at hand. Table 5 shows the spread of misleading opinions amongst the examiners and a corresponding breakdown of the category of questioned writing where each of the misleading opinions were expressed.

As can be observed 9 of the 28 examiners involved in this study did not express any misleading opinions in the trials that they undertook. To apply any group misleading opinion rate to these individuals would therefore be unfortunate as it may well underestimate their skill to the detriment of any evidential opinion that they may be expressing. Alternatively there are other examiners that expressed a larger number of misleading opinions for whom a group misleading rate may well under-estimate the magnitude of the potential of these individuals to express misleading opinions. This position must be balanced with the reality that those individuals expressing misleading opinions on these trials may well learn from their experience and may not approach similar problems in a similar way. These considerations must also be made in view of the category of writing and the correspondingly large difference between them in relation to the misleading scores. Added to this is that the effect of examiners expressing opinions on trials that are mentally demanding, due to their size, is not known. FHE fatigue may have resulted in at least some of the recorded misleading opinions.

Discussion

It is clear that any estimation of any potential misleading rate in the forensic handwriting discipline

Questioned writing type	% Correct	% Misleading	% Inconclusive	% Misleading Called	% Misleading Called Q	% Misleading Called U
Sp	93.0	0.0	7.0	0.0	0.0	0.0
DSp	18.7	0.0	81.3	0.0	0.0	0.0
SNSp	5.4	0.04	94.6	0.7	0.7	0.0

Table 4. Percentage scores for FHEs' opinions regarding the authorship of each of the questioned signature types. Note Sp = Written normally by the specimen writer, DSp = Disguised by the specimen writer, SNSp = Simulated not by the specimen writer.

# of Misleading opinions	# of xaminers expressing misleading opinions	Sp HW	DSp HW	SSp HW	NSp HW	NSp HW	NSp HW	Sp Sig	DSp Sig	NSp Sig
0	9	na	na	na	na	na	na	na	na	na
1	9		4				4			1
2	5		3				5			2
3	0	na	na	na	na	na	na	na	na	na
4	0	na	na	na	na	na	na	na	na	na
5	3		10	5						
6	2		1	5			6			
Total	28	0	18	10	0	0	15	0	0	3

Table 5. Number and breakdown of types of misleading opinions expressed by individual examiners. HW=handwriting, Sig=signature.

must be accompanied by an understanding of the underlying theoretical construct within which FHEs operate. The study described here attempts to begin to address the issue of potential misleading rates and in doing so indirectly provides validation information regarding theoretical and methodological approaches by these examiners to the tasks undertaken.

What is becoming clear is that the best estimation of the potential for opinions to be misleading will emerge through individual or closely related individual skill testing of the type described (Found, Rogers & Herkt, 2001b; Found & Rogers, 2003, 2008). The appropriate treatment of any misleading scores present will then be required to be related back to both method and the relationship between questioned writing categories. Further work on FHE skill testing and characterisation can be found in Al-Musa Alkahtani (2010), Bird, Found, Ballantyne & Rogers (2010), Bird, Found & Rogers (2010), Bird, Stoel, Found & Rogers (2011), Dewhurst, Found & Rogers (2007), Dyer, Found & Rogers (2006 & 2008). Research regarding the potential for testing of FHEs on-line has also been reported (Holmes, Ostrum & Barton, 2011).

Conclusion

For the group of FHEs tested, using this methodology, the potential misleading opinion rate, although different between the different categories of questioned writing, is very small and is not uniformly spread amongst the examiners. This group of FHEs has however been exposed to large and sustained

independent testing prior to the trials reported here. These examiners, to their credit, have endured more detailed testing of their skill than any others reported internationally and consequently, for many, have had the opportunity to learn from any misleading opinions they may have expressed. It is the case that using the individual skill data from the trials reported here we can now move forward to providing the judiciary with estimates of the potential misleading rates for the different opinion levels and for the different categories of questioned writings. As more trials are undertaken, taking in the different variables, it is hoped that the probative value of the opinions FHEs express will be characterised.

Author's Note:

As stated in the introduction, this Modular Method is an ever-evolving document that reflects the agreed forensic handwriting methodology in use by laboratories that are part of the Australian and New Zealand DocSAG.

The DocSAG are committed to moving toward the logical approach to evidence interpretation and reporting, However, the Group recognizes that adhering to this approach will take more education and discussion before examiners are comfortable with this significant change.

The inclusion of the disclaimer at Note 2 is to acknowledge that some examiners will give conclusive opinions about propositions; that is, they will form the opinion that the probability of the evidence given the one proposition is so remote that they will discount this proposition, and give a conclusive (identification or elimination) opinion. However, this cannot be done if properly applying the logical approach, as outlined in the Modular Method. The issue with giving conclusive opinions is explained more fully below.

The logical approach is based on Bayes Theorem (also known as the Bayesian Approach or Likelihood Ratio approach) and can be expressed as: Prior odds x Likelihood ratio = Posterior odds.

Prior odds (or prior probability) express the beliefs about the scenario before the current evidence is taken into account. The posterior odds (or posterior probability) of a proposition is the conditional probability that is assigned after current evidence (i.e. after the prior odds have been updated using the LR) has been taken into account.

The prior and posterior odds are the provision of the court. The court will evaluate the hypotheses given the evidence, including the scientific evidence, and the relevant information. The examiner's domain is by necessity the evaluation of the likelihood ratio where the probability of the evidence is considered given the hypotheses (or propositions) and the relevant information.

There are three guiding principles when evaluating findings in a logical manner:

- Examiners must recognized that the event has occurred within a framework of circumstances;
- The findings must be considered in light of two competing propositions;
- The role of the examiner is to comment on the probability of the findings given the propositions and not on the probability of the propositions themselves. By discarding one hypothesis over another, as we do for individualisation or uniqueness, we are no longer considering two competing propositions and we are moving towards evaluation of the hypothesis given the evidence rather than the evidence given the hypothesis.

The determination of individualization or uniqueness can be perceived as a leap of faith on the part of the examiner. The examiner is not comparing the questioned sample to all the other signatures or handwritings in the world to confirm the uniqueness of the sample at hand. Examiners are concluding that based on the examination and their experience that the probability of there being another matching print sample is so low that it can be discarded. This leap to identification or elimination requires the examiner to discount the potential error in assessment.

There is a need in many fields of forensics, including forensic handwriting examination, to further research uniqueness. The current research as it now stands is not sufficiently robust to support uniqueness. Until this occurs the only logically reportable evidence is an expression of the magnitude of the LR, the likelihood ratio.

Glossary

Accidental: An unusual feature or characteristic, deemed to be unintentional, not seen in the bulk of the handwritten material.

Allograph: A particular design of a character, where there can be more than one design per character e.g. capital letter A is a different allograph than a cursive letter *a*.

Artifacts: Remnants. For example, trash marks are artifacts of a copying process; writing is an artifact of human movement.

Authentic: When a document/handwriting is genuine.

Authorship: Who wrote the document.

Baseline: The real or assumed line upon which handwriting is produced.

Chance match: The occurrence of naturally produced handwriting by two different writers that displays the same handwriting characteristics such that the writing cannot be distinguished.

Character: Letters, numbers and symbols; graphemes.

Collected Specimen: Samples of a known person's handwriting/signatures that have been produced throughout the course of day-to-day business and have been collected by the investigator for the purposes of comparison against questioned material. Examples include letters, diaries, business records, forms or cheques. These can also be known as normal course specimen or course of business specimens.

Common Authorship: A comparison of handwriting where the examiner is asked to give an opinion on whether a group of questioned documents have been produced by the same writer.

Comparable: Material that is suitable for comparison e.g. similar style, case.

Complexity: A combination of speed, style and construction; how difficult the writing is to simulate.

Concatenations: Connections.

Connections: The union of two characters e.g. in cursive writing.

Consistent: Similar, regular throughout a passage of writing or between multiple signatures.

Construction: How a character, word or signature has been produced, including features of number, direction and sequence of strokes.

Disguise: A deliberate attempt to hide normal writing habits.

Dissimilarities: Differences between writings.

Drag (pen drag): A very fine ink stroke where the writer has not completely lifted the pen from the surface of the page between strokes.

Embellishments: Flourishes added to the writing.

Excluded: Material that is not examined.

Feature: An aspect of a character or the handwriting in general.

Flourish: An ornamental or exaggerated pen stroke.

Fluency: The speed and skill level of the writing.

Formation Variation: Differences in the method of constructions of a character.

Fundamental Difference: A repeated difference in the questioned material that is significantly different to the specimen material.

Grapheme: Characters (a, b, c, A, B, C, 1, 2, 3 etc).

Guidelines: Lines that show a route to follow when simulating handwriting or signatures. These can exist in the form of pencil lines or indentations or be created by the use of transmitted light shone through a document containing the entries to be copied.

Height Relationship: The size differences within and between handwritten characters.

Indented Impressions: Markings or imprints on the

paper surface caused by the pressure of a writing instrument on the pages or paper above.

Inter-comparison: Comparison of handwriting on more than one document or by more than one writer.

Intra-comparison: Comparison of handwriting within one document or by one writer.

Legible: Decipherable or readable material.

Limitation: A constraint to the examination, comparison or opinion formation process e.g. non-original documents, limited quantity of material.

Line Quality: A measure of fluency in handwriting, resulting from a combination of features including speed, skill, fluency and pen pressure of the writing stroke.

Motor Memory: The memory for motor skills that controls movements such as that of the hand during the writing process.

Movement: The motion of the writing stroke.

Natural Variations: Normal or usual deviations that occur in repeated specimens of a person's handwriting.

Nexus: A connection or link.

Non-Original: Reproduction of a document e.g. photocopied, faxed, scanned, photographed.

Normal Behaviour: Any specimen or writing executed without an attempt to control or alter its usual quality of execution. Also referred to as natural behaviour.

Overwritten: Writing over other writing.

Pause: A temporary interruption to a stroke without removing the writing instrument from the writing surface.

Pen Direction: The direction the pen moves to produce a character, connection or signature.

Pen Lift: An interruption in a stroke caused by removing the writing instrument from the writing surface.

Pictorially consistent / similar: Having a similar shape, allowing a more detailed examination to take place (in relation to signatures).

Pictorially inconsistent / dissimilar: Having a dissimilar shape, meaning no further comparison can take place (in relation to signatures).

Preliminary Examination: An initial examination preceding the main examination; giving initial observations regarding the ability to examine the items in question.

Proportion: The height and spatial aspects within or between characters.

Proposition: A statement or outcome to be tested during examination. There are generally two opposing propositions to be tested: : 1. The same writer produced A and B: 2. Different writers produced A and B

Questioned: Handwriting or signatures about which the authenticity or authorship is in doubt

Repeated Difference: Differences between writings that are seen consistently throughout the passages of writing.

Requested Specimen: Specimen samples written specifically for the purpose of comparison to questioned material (as requested by an investigator).

Retouching: To add lines or strokes in order to correct, improve or alter.

Similarities: Having mutual resemblance and a number of features in common.

Simplistic: Characterised by non-complex characters or strokes.

Simulated / simulation: An attempt to copy or reproduce writing or a signature.

Size/size relationship: The dimensional associations within and between handwritten characters.

Skill: How well an individual is able to produce and repeat the formation of handwritten characters.

Slant/slope: The angle or offset that the handwriting is produced at, relative to the baseline.

Spacing: The distance between characters, words or lines.

Spatial Relationship: The height or width relationships between characters, words or lines of writing.

Specimen: Proven samples of handwritten material from a nominated person, used to compare against the questioned handwriting.

Speed: How fast the writing is produced.

Spurious: In relation to signatures: one created without the apparent use of a model or template such that it bears no resemblance to the genuine signature. May also referred to as fabricated.

Striation marks: Fine voids in the ink line of a ballpoint pen caused by obstructions between the ball and housing wiping the ink off the ball. These can be used to determine pen direction.

Structural Features: Features relating to the construction of handwriting e.g. number, position, order and direction of strokes.

Style: The overall pictorial design of the handwriting e.g. printed, cursive, uppercase, lowercase.

Substrate: The material that is written on, usually paper.

Tapering: Narrowing of the pen line due to the speed of the movement used or a lifting of the pen as a stroke is started or finished. Tapering is a characteristic that can assist in determining the speed at which a character has been produced.

Terminal Stroke: The final stroke of a character or word.

Tracing: Writing that is created by placing a model underneath the paper to be written on, such that the model can be observed through the paper to provide guidelines to assist in copying.

Trash Marks: Remnants from the printing, scanning or photocopying process used to produce a document. They can be placed on to a document through defects or dirt in the machinery or from markings on the scanning surface.

Tremor: A lack of smoothness in the writing trace, due to lack of skill, deliberate control of the writing implement, or involuntary movement e.g. illness.

Turning Points: Position at which a pen line changes direction.

Unnatural: A movement that is forced or difficult to execute. Unnatural writing is seen when a person is trying to disguise their own writing, or trying to simulate that of another writer. Some characteristics of unnatural writing movements include slow speed, low fluency, stops or pauses in the pen line or blunt endings and beginnings.

Variation: Having one or more forms of a character or word in a naturally produced sample of handwriting.

Writing Implement: Any tool used to create a handwritten marking on a substrate. Typically however, used to describe the use of a pen, pencil, marker or crayon to create words on paper.

Writing Surface: The underlying surface that a substrate (e.g. paper) is placed on whilst handwriting is produced. The writing surface will impact on the pictorial qualities of the writing and can impose a limitation on comparisons.

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