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A Comparison of the Identifying Features in Original Signatures and Electronically Scanned Signatures

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Electronically scanned signatures are increasingly being used as a form of personal identification on documents such as driving licences and passports. A comparison of identifying features in 150 handwritten signatures and electronically scanned versions showed that there was a statistically significant number of differences between the 2 groups (P>0.01). The pen type used to create the original signature—a ballpoint, a roller ball, or a fountain pen—was also shown to affect the number of differences observed. Electronically scanned ballpoint signatures showed the least number of differences, and the electronically scanned roller ball showed the most. Paired analysis using the Pearson χ^2 test between the groups of pens shows that they are statistically different from each other (P>0.01). The types of differences observed between the signatures are categorised and vary among the pen types. The variation appears to be related to the composition of the ink within the pens.

With electronic signatures being used commonly as record of identity in databases and on security documents, the forensic document examiner may frequently be required to make examinations of their authenticity or use them as specimen samples. However, the number of observed differences and the effects of a trivial matter, such as the pen used to create the signature, will make that difficult.

Introduction

Annual estimates of the cost of identity fraud (for 2006) in the UK is over 1.72 billion pounds (Home Office Identity Fraud Steering Committee 2006). The cost of this is in part due to the increasing number of fraudulent documents such as passports and driving licences in existence, some of which use electronic signatures as a security feature. Electronic signatures can exist in a variety of forms, including electronically scanned versions of handwritten signatures and are frequently being used as a personal identity feature (Mason 2005). Electronic signatures are, however, very different from digital signatures which are public key cryptographic signatures used to authenticate the sender of a message (Spyrelli 2002).

Electronically scanned signatures are incorporated into many forms of personal identification such as driving licences in the UK, Australia, and the USA and the proposed National Identity card in the UK (Identity Cards Act 2006). Electronically scanned signatures are also frequently incorporated into letters and emails. In the USA, the Electronic Signatures in the Global and National Commerce Act (ESIGN) (2000) gives electronically scanned signatures the same legality as handwritten signatures, meaning they are subject to the same legal scrutiny of authenticity that applies to paper documents.

With any advance in document-based technology, a forensic document examiner (FDE) will face new challenges around the identification of questioned signatures produced by such hardware. Hardware advances such as facsimiles, photocopiers, and microfilming have all shown that many of the features of a signature used by a FDE to aid in the identification of a questioned document are lost in signatures which have been processed by technology (Todd 1972).

Facsimile copies of handwritten signatures were shown to be useful for making preliminary determinations about the author of a questioned document (Carney 1984), although several key elements of the signature are lost, including minute adjustments of the writing implement within letters, joining letters, and variations in the pressure of the stroke line. In a study of facsimile transmitted signatures produced by 5 different processes (including thermal, inkjet, and laser printing), it was found that many of these subtle characteristics such as pen pressure, pen lifts, and presence of tapered lines were difficult to detect in a facsimile document (Kelley 1992). It was further noted that laser-type facsimile printers "clean up" distortions or marks in original signatures, making it difficult for the FDE to examine a document with all its identifiable features present.

Studies of signatures copied by photocopiers (Dawson and others 1998) used worldwide FDEs to compare original to photocopied signatures for the presence of features which, in combination, would help identify a signature as genuine. The study found that some of these genuine features such as pen lifts, hesitations, patching, and tremors were lost (not detected) or misjudged by the FDE. However, these genuine features did not stop the FDE from making accurate judgments 95.8% of the time (from 72 tests) on the identification of other features. A study of 15 FDEs' opinions of whether a photocopied signature was genuine or simulated found that FDEs could make accurate judgments when comparing an original to a photocopied signature with an overall misleading (error) rate of 0.9% (Found and others 2005).

Shading within a writer's handwriting has been shown to be an important element in handwriting identification (Moore 1983). In this case the subtle variations in pen pressure are a valuable attribute in preventing the forgery of 1 signature. If these unique features are lost in electronically scanned signatures, as shown in both facsimile and photocopied signatures, they will be much easier for the potential forger to copy (Kelly 1992; Carney 1984; Dawson and others 1998).

Examinations of microfilms of handwritten documents have shown a loss of some detail as a result of the size-reduction process. For example, the lines of writing appeared thickened, and sharp turns appeared more blunt (as a result of this line thickening). Furthermore, whilst voids caused by pen lifts were evident on original documents, these were reduced or lost altogether in microfilm copies (Hanna 1998). In the study of microfilming of handwritten documents, it was also discovered that class characteristics produced by the writing implement used to create the original signature can be lost during the microfilming process. Striations (an example of decreased line density) and skipping of ink were lost when ballpoint pens had been used to write the original signature. This also sometimes resulted in breaks in the signature where it appeared that the ink was not dense enough to form a continuous stroke. Pens containing aqueous ink, such as fountain and roller ball, translated the opacity (blocking of the background) well. However, the edges and outline of the stroke appeared blurred and ill defined when compared with the original signature (Hanna 1998).

The loss of detail seen within signatures produced by modern technology is a problem for the FDE. Handwritten specimens are considered essential for the FDE to carry out the comparison of a questioned document; but with electronically scanned signatures being increasingly used as a form of personal identity and as a stored version of a person's signature to be used for comparison purposes (as seen in local government elections, UK), the FDE may be increasingly called upon to use these as a reference. This paper aims to investigate if electronically scanned signatures are a true representation of the original handwritten signatures and whether the choice of pen used to create an electronically scanned signature has a bearing on the comparability between it and the original signature.

Materials and Methods

Fifty random participants aged 18 to 50 were asked to provide 3 repetitions of 5 signatures on a template form; each repetition was produced using a different pen. The 3 pens provided were a Bic black ballpoint, Partners "fluency free" black roller ball, and a Partners fountain pen with black ink. Participants were asked to sign in the boxes on the template form, in the following order: ballpoint pen, fountain pen, and roller ball pen. They were seated with the paper resting on a hard surface. One signature from each person produced by each of the pen types was selected at random and electronically scanned using a Packard Bell Diamond 1200 Plus flatbed scanner at a resolution of 600 x 1200 dots per inch (dpi) and saved in JPEG format.

Signatures were examined using Adobe Photoshop CS® at x4 magnification and compared with the handwritten signature magnified using a x4 hand lens. The signatures were not manipulated in any way using the software, and the only feature used was the magnification to increase signature size. The examinations were not performed by qualified document examiners, but by author Turner or at his direction, after instruction by Document Evidence Ltd. (Birmingham, UK).

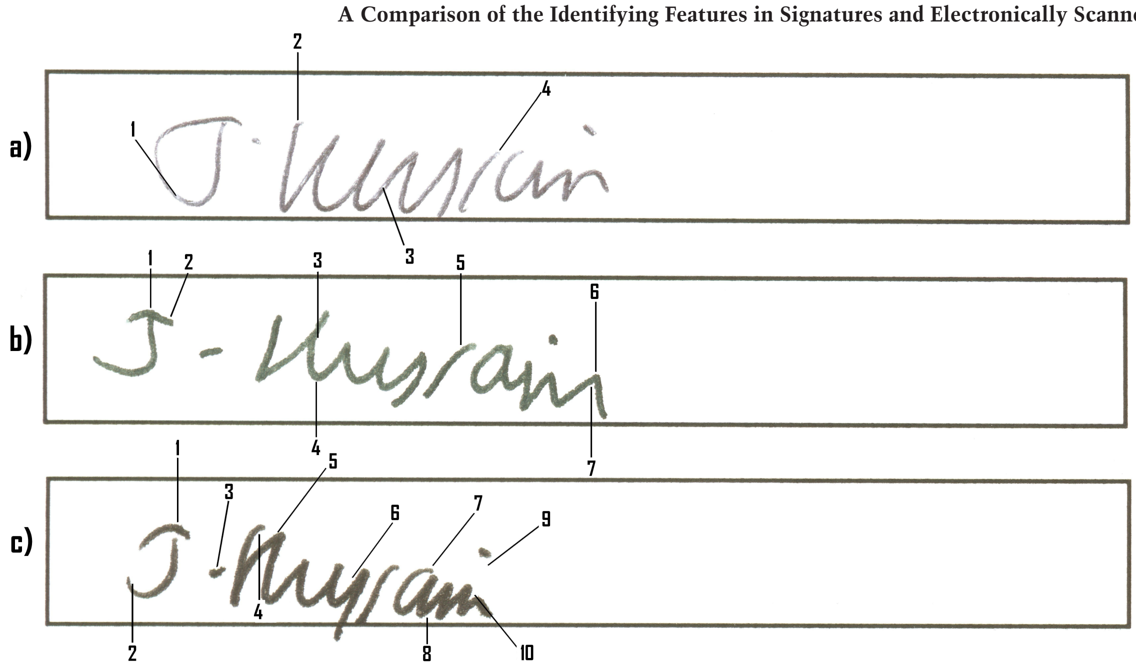

Figure 1. An example of an electronically scanned signature produced with a) ballpoint pen b) fountain pen, and c) roller ball pen. All observed differences between these and the original handwritten signatures are highlighted and sequentially numbered.

Starting at the beginning of the signature, the electronic and handwritten signatures for each participant were compared; any differences between the 2 (up to 10 differences) were marked using an arrow (Figure 1). After all comparisons were complete, the differences were categorised based on their type (see below). Analysis of the signatures was carried out "blind," with no knowledge of what pen type the electronic signature came from.

Types of Difference

1. Dimension change. Increased width of a feature present in original signature
2. Loss of detail. Feature or part of feature in original signature is missing
3. Addition of detail. New feature observed that is not present in original signature
4. Detail obscured. Features from original signature merge or feature still present but less defined
5. Increased line density. Light line density in original signature appears heavier
6. Decreased line density. Heavy line density in original signature appears lighter

The number of differences between the handwritten signatures and electronic signatures were tabulated and compared using the Pearson Chi-square test with a null hypothesis that:

$\mathbf{H_0^1}$ There is no difference between handwritten and electronically scanned signatures.

Subsequent paired analysis of the number of differences between the pen types was also carried out using the Pearson Chi-square test with the null hypotheses that:

$\mathbf{H_0^2}$ There is no difference in the number of differences produced by electronic scans of ballpoint and fountain pens.

$\mathbf{H_0^3}$ There is no difference in the number of differences produced by electronic scans of ballpoint and roller ball pens.

$\mathbf{H_0^4}$ There is no difference in the number of differences produced by electronic scans of roller ballpoint and fountain pens.

Results

From the examination of 150 handwritten signatures and their electronically scanned versions, a total of 1,050 differences were observed (Table 1). The greatest number of differences observed were from the "loss of detail," "addition of detail,"and "detail obscured" categories. Comparing the categories of observed differences as a percentage of the total number of differences (Figure 2) showed that these 3 categories contributed to 90% of the observed differences. The remaining 10% of the observed differences were caused by dimension changes and increased or decreased line density.

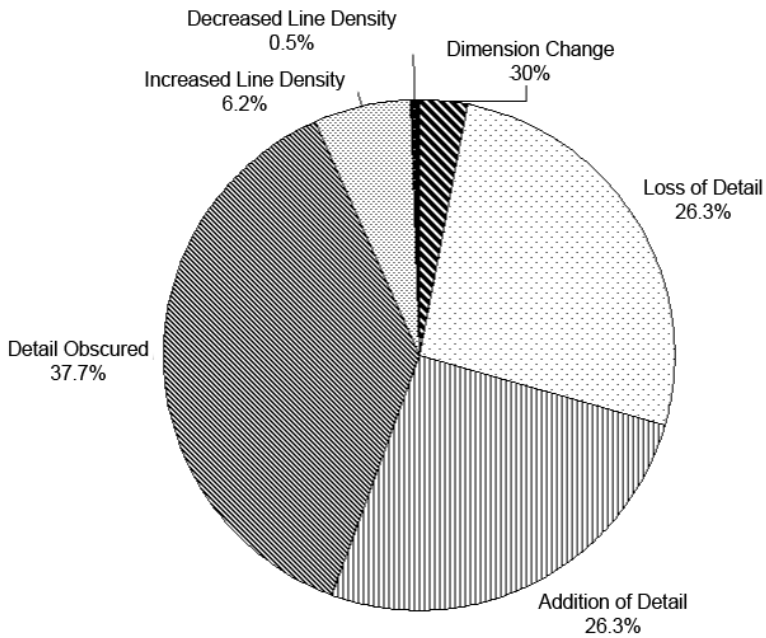

Figure 2. A percentage summary of the types of differences which occurred in the electronically scanned forms of handwritten signatures.

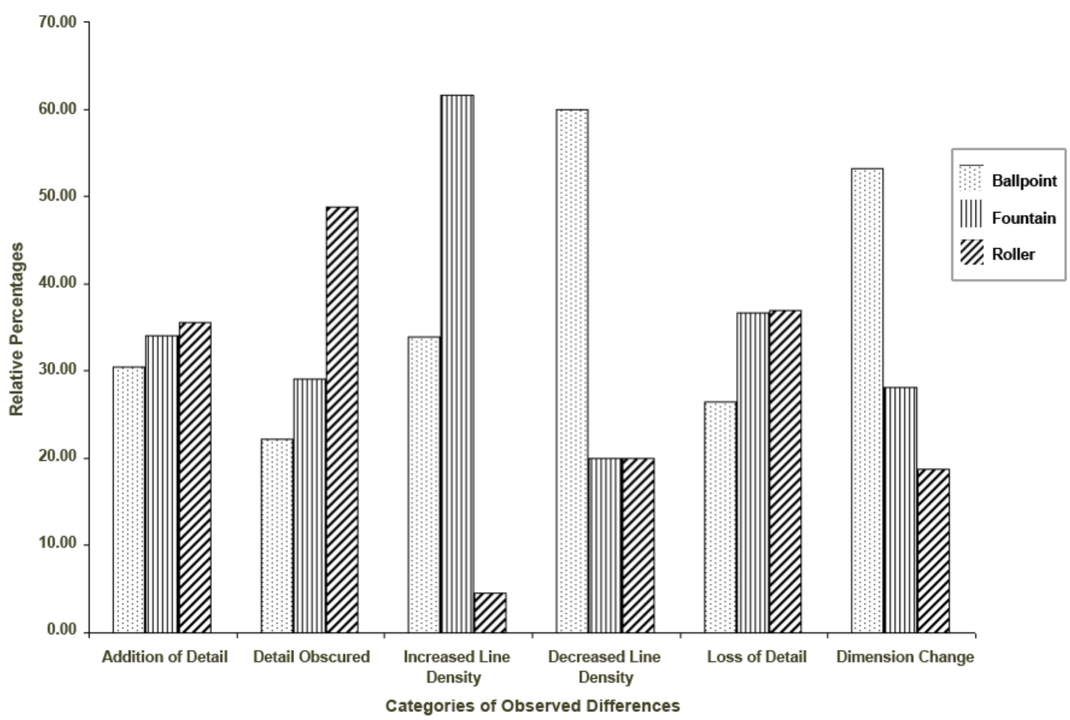

Figure 3. A relative percentage summary of the types of differences which occurred from the electronic scanning of handwritten signatures using 3 different pen types.

Observed Difference	*Number of differences*	*Pen Breakdown*	
Addition of Detail	276	Ballpoint	84
		Fountain	94
		Roller	98
Detail Obscured	396	Ballpoint	88
		Fountain	115
		Roller	193
Increased Line density	65	Ballpoint	22
		Fountain	40
		Roller	3
Decreased Line density	5	Ballpoint	3
		Fountain	1
		Roller	1
Loss of Detail	276	Ballpoint	73
		Fountain	101
		Roller	102
Dimension Change	32	Ballpoint	17
		Fountain	9
		Roller	6
Total	**1050**	**Ballpoint**	**287**
		Fountain	**360**
		Roller	**403**

Table 1. A summary of the types of differences which occurred in electronically scanned handwritten signatures produced by 3 different pen types.

There is a clear difference in the type of changes observed in signatures produced using the 3 pen types (Table 1), with the electronic ballpoint signatures having the least number of differences and the electronically scanned roller ball having the most. The changes observed from the different pen types did not all fall into the same category. Relative percentages were calculated of the number of differences found in the signatures produced by the 3 pen types (Figure 3). The 3 categories of "loss of detail," "addition of detail," and "detail obscured" were equally evident in signatures produced by all the pen types except for "detail obscured," which was predominantly seen in the roller ball pen signatures (50%). Increased line density was mostly observed in signatures created by the fountain pen (60%) and was only observed 3 times by the roller ball pen. Most of the observed cases of dimension change (51%), and decreased line density (60%) were observed in the ballpoint pen. However, there were only 5 observed incidences of decreased line density.

Overall analysis also showed that there was statistically significant difference ($P>0.01$) between the original signatures and the electronically scanned ones. Therefore, H_0^1 can be rejected and the alternate hypothesis accepted.

Statistical analysis of the number of differences observed using the Pearson χ^2 test showed that paired analysis of the pens were all significantly different ($P>0.01$) (Table 2). Furthermore, hypotheses $H0^{2,3,4}$ can all be rejected, and the alternate hypotheses that the pen used does lead to change in the number of differences observed when a handwritten signature is electronically scanned can be accepted.

Signatures Compared	*X^2 Observed Value*	**Significant at 99% level**
Ballpoint pen and Fountain pen	8.914	YES
Fountain pen and Roller pen	2.094	YES
Roller pen and fountain pen	19.558	YES
All Pens	19.840	YES

Table 2. A statistical comparison of the observed number of differences between the various pen types used to create the electronically scanned signatures.

Discussion

Handwritten signatures reproduced by facsimiles (Carney 1984; Kelley 1992) and photocopiers (Dawson and others 1998) have been shown to lose some of their original features during the reproduction process. In this study, we investigated whether the same is true of electronically scanned signatures. Out of 150 signatures analyzed, 1,050 differences were observed; and the number of differences between original signatures and electronically scanned signatures was statistically significant ($P < 0.01$) (Table 2). Paired analysis among 3 different pen types used to create the original signatures also revealed statistically significant differences ($P < 0.01$). This suggests that what may be considered a trivial matter in the production of a signature—the choice of pen—actually has serious implications if that signature is to be electronically scanned and stored and used as a representation of an individual's true signature.

The 3 most common differences observed between the original signature and the electronic signature were "loss of detail," "addition of detail," and "detail obscured" (Table 1, Figure 2). The loss of such features is important because they are the basis of an examination of a questioned signature by a FDE; and even though the overall geometry of a signature can be copied, these features are much more difficult to reproduce. A study of photocopied signatures showed that if these features were observable, FDEs were accurate in identifying genuine and forged signatures (Found and others 2005).

Examination of the signatures produced by different pen types revealed that ballpoint pens display the least number of differences and roller ball the most (Table 1). The 3 most common types of differences were seen equally in signatures produced by all pen types apart from "detail obscured," which is predominantly seen in roller ball pens. This may be because the high water content of most roller ball pens leads to the ink being less well translated into an electronic image (Figure 3). A similar observation was noticed in the microfilming of ballpoint pen signatures where ridges of strokes appeared blurred and ill defined (Hanna 1998). Other types of differences are more commonly seen in signatures produced by 1 pen type; for example increased line density is mostly seen when a fountain pen is used, whilst decreased line density occurs mostly when a ballpoint pen is used. Microfilming of ballpoint pen ink has been previously shown to cause striations, as the ink was not dense enough to form continuous strokes (Hanna 1998).

When scanning signatures, a high resolution of 2,400 dpi was used; and images were stored in a high-quality JPEG format because low-quality image formats have previously been found to compress images and distort colour when viewed by Adobe Photoshop (Chaikovsky and others 2003). It is possible, however, that in commercial applications, lower scanning resolutions are used or images are stored in a variety of formats. Combined with the fact that signatures are often shrunk to a desired size (such as the UK driving licence), this could result in further details being lost. Many class characteristics of signatures have been shown to be lost during the reproduction process, for example in microfilming (shrinking) of signatures (Hanna 1998). Some of our authors' signatures may have been restricted/contained less features by producing them in the small box on the template form; however, this replicates the conditions experienced on many application forms which are electronically scanned.

Despite a consistent methodology, it is possible that some of the differences present in the electronic signatures, especially the addition of material, could be a result of the scanner used although the scanner was clean and scratch-free. An additional study using multiple scanners to generate electronic signatures would show if any differences observed were from the scanning process.

In many practical cases, electronically scanned signatures are printed onto security documents as a means of identification. The printing process has also been shown to affect the quality of the signature, with each type of printer leaving characteristic marks on the document (Ellen 2006). Therefore, there could be many more differences between an original signature and an electronically scanned signature once the signature has been printed.

Writers apply varying amounts of pressure when creating their signatures, and it is possible that some differences observed are generated by variations in pressure applied by the individual author. Multiple signatures produced by an individual are never the same, and therefore some small changes would be evident in the multiple signatures supplied by participants. Random selection was practiced in this study to avoid this variable. Additionally, if multiple signatures from 1 individual with the same pen type were examined, the number of differences observed might vary. If there is great variation among an individual's electronically scanned signatures and they are stored as exemplars of that person's signature in a database for comparison, the FDE's examination would become much more difficult due to missing or added details in the electronic specimen.

In conclusion, we have shown that statistically significant differences exist between original handwritten and electronically scanned signatures produced by a range of pen types. We also showed that the pen type used to create the original signature can have a bearing on the number of differences observed. These findings have implications in the many security documents that use electronic signatures as a means of identification and the FDE who may be asked to examine questionable signatures.

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