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Forgery II—Tracing

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ABSTRACT: A total of 189 volunteers were asked to trace 21 handwriting symbols consisting of single strokes, geometric figures, printed English alphabets, and simple Chinese characters. Each of these handwriting symbols contained target features and the ability of the participants to incorporate them in the tracing was assessed. It was found that the 'threshold superimposability' for tracing was about 50%, above which the probability of a questioned sample being produced by tracing was high. The subjects also signed and conducted tracing of signatures on a writing pressure meter that detected and recorded pen pressure. The writing pressure variation patterns of natural and traced signatures demonstrated that those signatures produced by tracing were highlighted by the presence of slow, measured strokes accompanied with hesitation, pen pause and the absence of vigor and spontaneity. To conclude, in traced forgeries, the general shape and pictorial effect of the model were closely followed but details were neglected.

KEYWORDS: questioned documents, document examination, handwriting examination, forgery, tracing

Traced forgery is defined as any fraudulent signature executed by following the outline of a genuine signature with a writing instrument [*1*], and can be produced by two categories of methods, namely direct tracing and the use of a guideline. Various techniques have been adapted to these methods. Characteristic features associated with traced forgeries and the various techniques used by forgers have been described in detail in standard texts on document and handwriting examinations [*1–3*]. The majority of the information contained in these authoritative books have been derived from the examination of hundreds of specimens of forged signatures produced by tracing. Research articles on traced forgeries are scanty. Herkt [*4*] has studied 144 forged signatures produced by 72 subjects, about 19% of whom preferred to trace. Hilton [*5*] has described the application of infrared photography to the examination of traced forgeries derived from guidelines produced by carbon paper. Vastrick [*6*] has reported the illusion of traced forgery generated by the ball point pen housing on coated photocopy paper. To further investigate forgery by tracing, the authors have devised an experiment in which 189 participants were asked to trace (and simulate) 21 handwriting symbols containing target characteristic features. Using the Writing Pressure Meter, pressure variations and other related properties of genuine signatures and those produced by tracing were also examined.

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Method

The 189 volunteers were each asked to simulate and then to trace 21 handwriting symbols as detailed in the article "Forgery I—Simulation" (this issue). The symbols consisted of single strokes, printed English capital letters, simple Chinese characters, and geometric figures. After this initial session, the participants were asked to sign their signatures on a piece of white paper placed on the pressure plate of an instrument called PS 325 Writing Pressure Meter supplied by Police Science Industry Ltd., 35-4, 5-Chome, Akatutumi, Setagayaku, Tokyo, Japan. The apparatus detected and recorded writing pressure variations. The gain was set at 3, while the chart speed was 30 mm per s. The subjects were then asked to trace their own signatures. Before the subjects started to trace, they were asked which method they believed would produce the best result. Material and equipment necessary for the suggested method of tracing, if available, were given to the volunteers so that they could use their preferred methods. After tracing their own signatures, the subjects were then asked to trace the signature of another participant. The recorded pressure variation patterns of the normal and traced signature specimens from each of the participants were studied. Basic statistical data were obtained with the aid of Lotus 123 software under an AST 386SX personal computer.

Result

Tracing methods—recommended by the subjects included direct tracing with or without the use of transmitted light from a light box, guidelines produced by carbon paper, guidelines produced by indentations and the use of tracing paper. Some volunteers also suggested the application of a scaled ruler, projector and transparent graph paper. Table 1 shows the tracing methods used by the participants in the experiment. Probably because of its convenience, the majority of the subjects (82%) used the direct tracing method. About 6% of the participants used carbon paper to produce a guideline and then covered up the guideline with ink. Tracing paper was used by 9% of the participants. However, because ordinary documents are rarely printed on tracing paper, unless the forged signature on the tracing paper is transferred by other means onto another piece of paper, the use of tracing paper itself will not have any practical significance. Less than 2% of the volunteers produced indentations of the model signature on the paper and then filled up the indentations with ink. The described methods can be found in forgery cases but none of them produced satisfactory results.

Qualitative features—useful for the identification of signatures such as structural detail, shading, pen emphasis, vigor, and spontaneity are typically absent in signatures produced by tracing, which is actually not a writing but a drawing process [*1–3*]. The 21 handwriting symbols traced by the subjects were assessed in accordance to the same scheme that has been applied to the simulation results given in the previous article. Statistical data of those subjects who could reproduce designated qualitative features in 12 of the handwriting symbols are presented in Table 2. About 6% of the volunteers managed to include

TABLE 1—*Statistics of the tracing methods used.*

Method	Frequency	% Occurrence
Direct tracing	154	81.9
Use carbon paper	11	5.9
Use tracing paper	17	9.0
Indentation	3	1.6
Others	3	1.6

TABLE 2—*Statistical result of tracing of designated qualitative features of 12 handwriting symbols.*

Target Feature	Symbol	Frequency	% Occurrence
Variation of thickness of horizontal strokes	1–3	10	5.3
Relative thickness of two strokes	4	13	6.9
Writing direction	5,6	11	6.9
Writing movement or sequence	7,8	48	25.4
Pen emphasis	9	50	26.5
Structural detail (small protrusions)	10	31	16.4
Structural detail (dot)	11	9	4.8
Structural detail (gap)	12	77	40.7

in the traced samples all the target features of flying start, tapering end and uniform thickness of the horizontal strokes in respectively symbols 1, 2, and 3. Nearly 7% of the participants noticed the difference in the thickness of the horizontal and vertical strokes in symbol 4 and reproduced them in the traced samples. Considerably higher percentages (13%) of the simulated figures contained these target features. Similarly, about 7% of the traced circles in symbols 5 and 6 contained the correct shapes of the closing ends, indicative of having been written with clockwise and counterclockwise writing movements. This last datum was the same as the frequency of occurrence for the simulation of the corresponding symbols. Only 4.8% of the participants reproduced in the traced samples the tiny dot within the rectangle in symbol 11. Apart from this, in general, symbols produced by tracing displayed less detail as compared with the corresponding simulations. The volunteers were more familiar with symbols 7 through 9, which consisted of English capital alphabets and a Chinese character. This explains the observation that more of the traced samples (over one-quarter) contained the designated target features in these symbols. As far as the inclusion of inconspicuous characteristics is concerned, traced forgery, irrespective of whatever technique applied, is inferior to freehand copying, probably because the limitation that the outline of the model that has to be followed is usually masked by the paper on which the tracing is to be done, so that in the process, some minutiae are lost.

Measurable characteristics—were more faithfully copied by tracing. The nature of this method of forgery is such that the shape and form of the writing are duplicated, although the final result still depends on the skill and determination of the forger. Symbols 11 to 18 embodied measurable target features and the results of tracing for these symbols were much more satisfactory than those of simulation as shown in Table 3. Over 60% of the participants produced in their tracings, rectangles with the correct width to height ratio

TABLE 3—*Statistical result of width/height ratio of traced rectangles.*

	% Deviation	Frequency	% Occurrence
Decrease in ratio	1–10	19	10.1
Consistent in ratio	0	120	63.5
Increase in ratio	1–10	0	0
	11–20	18	9.5
	21–30	28	14.8
	31–40	4	2.1

TABLE 4—*Statistical result of ratios of three sides of traced triangles* (a) *AB:BC,* (b) *AB:AC and* (c) *BC:AC.*

	% Deviation	Frequency	% Occurrence	Frequency	% Occurrence	Frequency	% Occurrence
Decrease in ratio	>30	2	1.1	0	0	0	0
	21–30	3	1.6	4	2.1	1	0.5
	11–20	15	7.9	35	18.5	29	15.3
	1–10	48	25.4	83	43.9	81	42.9
Consistent in ratio	0	75	39.7	41	21.7	37	19.6
Increase in ratio	1–10	0	0	17	9.0	26	13.8
	11–20	35	18.5	8	4.2	13	6.9
	21–30	10	5.3	1	0.5	2	1.1
	31–40	1	0.5	0	0	0	0
			(*a*)		(*b*)		(*c*)

and deviations from the standard value (= 2) were much smaller than in the case of simulation. However, similar to simulation, the same tendency of increasing the ratio rather than decreasing it could still be observed, the proposed reason for this is discussed in the previous article. The above observation of high accuracy also applies to the tracing results of the triangle in symbol 12 as shown in Table 4. Table 5 clearly indicates that results of tracing the angle of the apex of 'A' and the angle of the turning of the Chinese character meaning knife were overwhelmingly accurate. The tracing of slant and tilt of 'I,' 'E,' and 'T' as shown in Tables 6 and 7, appeared to be more difficult in comparison with the tracing of those measurable target features incorporated in the other handwriting symbols so far described because they were only marginally better than the corresponding results for the simulation of the same alphabets. This is because the slant and tilt of the respective symbols were small in magnitude (slant of I = 10°, slant of T = 20°; tilt of the upper horizontal stroke of both E and T = 10°); thus a relatively insignificant deviation from the standard value generated a greater error. In addition, slant and tilt, being angles of inclination in relation to the imaginary line of writing, were less conspicuous features and so in the tracing, poorer accuracy was achieved. In conclusion, tracing as a method of forgery is aimed at reproducing the general form and pictorial effect of the model so

TABLE 5—*Statistical result of tracing of* (a) *the angle of the apex of the capital letter 'A' and* (b) *the angle of the angular turning of the Chinese character 'knife.'*

% Deviation	Frequency	% Occurrence	Frequency	% Occurrence
≤10	137	72.5	153	81.0
11–20	47	24.9	30	15.9
21–30	5	2.6	6	3.2
	(*a*)		(*b*)	

TABLE 6—*Statistical result of tracing of slant of* (a) *I and* (b) *T.*

% Deviation	Frequency	% Occurrence	Frequency	% Occurrence
0	22	11.6	19	10.1
1–20	53	28.0	123	65.1
21–40	34	18.0	36	19.0
41–60	28	14.8	8	4.2
61–80	21	11.1	1	0.5
81–100	14	7.4	2	1.1
>100	17	9.0	0	0
	(*a*)		(*b*)	

TABLE 7—*Statistical result of tracing of tilt of* (a) *the uppermost horizontal stroke of E and* (b) *the horizontal stroke of T.*

% Deviation	Frequency	% Occurrence	Frequency	% Occurrence
0	19	10.1	16	8.5
1–20	40	21.2	56	29.6
21–40	36	19.0	46	24.3
41–60	36	19.0	31	16.4
61–80	23	12.2	20	10.6
81–100	16	8.5	10	5.3
>100	19	10.1	10	5.3
	(*a*)		(*b*)	

that attributes such as angles and ratios are more faithfully copied. Despite this advantage, the nature of tracing is such that the normal writing habits of the forger will have to be seriously inhibited. As a direct consequence of the limitation that a prescribed outline of the model has to be followed, the activity of tracing 'degenerates' to a drawing process.

Superimposability—of the traced samples for symbols 19 and 20 was generally high as illustrated in Table 8. For the semicircles in symbol 19, about 67% of the traced samples had 70% to over 90% of their lengths overlapping the model. Superimposability percentages of 50% to 69% were found in about 28% of the traced semicircles. Only a negligible proportion of the volunteers (4.3%) traced the semicircles with less than 50% matching the model. While the results of tracing for the irregular zig-zag line in symbol 20 were slightly poorer in superimposability than those of the semicircles, the same trend that the majority of the traced samples exhibited high percentages of superimposability and that the frequency of occurrence sharply declined at less than 50% have been observed. These results of tracing are completely opposite to those of simulation as shown in Fig. 1. Osborn [2] has maintained that traced forgery is intended to reproduce not only the form but also the size, proportion, and exact relations of all the parts of the original model signature. In these respects, tracing produced better results than free hand simulation. Despite the difference in superimposability percentages however, for both tracing and simulation, the semicircles exhibited higher superimposability and therefore appeared to be easier to forge than the zig-zag line. The finding is attributed to the irregularity of the sections of the zig-zag line, which rendered tracing (and simulation) more difficult compared with the identical curves of the semicircles. The effect of irregularity was such that the forgers were not certain what would be the exact course for the pen to travel, thus causing inaccuracy. Figure 1 shows the graphical presentation of the statistical results of superimposability for the tracing and simulation of the semicircles and the zig-zag line. It is particularly significant to discover that irrespective of the symbols concerned, the crossover points of the graphs for tracing and simulation are virtually identical at about 55%, which therefore represents the 'threshold value' of superimposability for traced forgery: the probability of a signature being produced by tracing is proportional to its superimposability with the suspected model. On the other hand, a signature with less than 50% overlapping with the suspected model will imply that it was produced by simulation.

Practical consideration—of a signature produced by tracing can be realized by examining the result of tracing of the plain signature consisting of eleven arches and a horizontal line rubric in symbol 21. Table 9 shows that about 14% of the volunteers correctly produced signatures with eleven arches, which is slightly lower than the corresponding

TABLE 8—*Superimposability of the tracing of* (a) *three connected semicircles* (b) *an irregular zig-zag line.*

Superimposable percentage	Frequency (a)	% Occurrence (a)	Frequency (b)	% Occurrence (b)
≥90	46	24.3	24	12.7
80–89	42	22.2	34	18.0
70–79	39	20.6	44	23.3
60–69	31	16.4	42	22.2
50–59	23	12.2	25	13.2
40–49	6	3.2	16	8.5
30–39	2	1.1	3	1.6
20–29	0	0	1	0.5

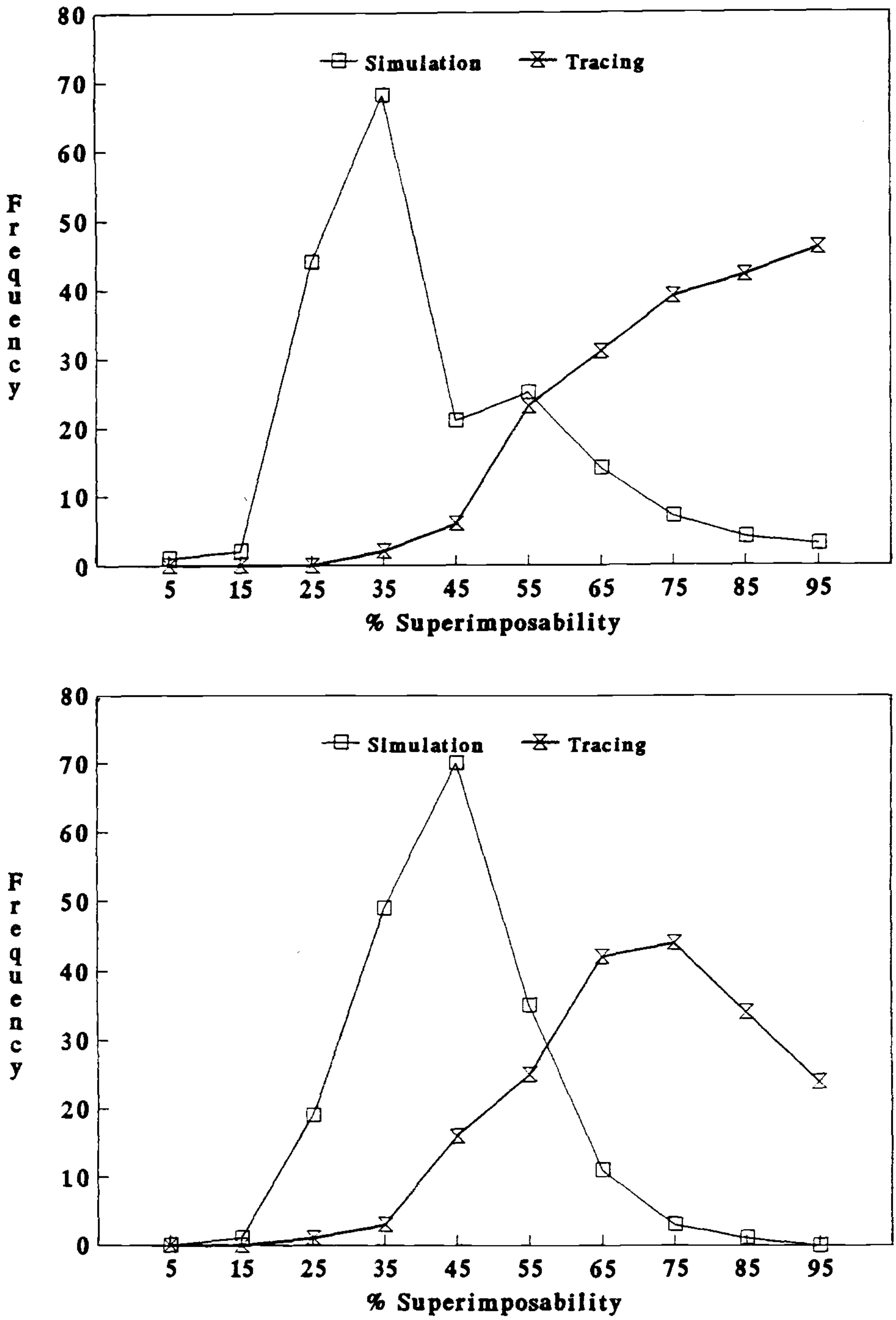

FIG. 1—*Graphical representation of the simulation and tracing of three semicircles* (top) *and an irregular zig-zag line* (bottom).

TABLE 9—*Statistical result of the number of arches in the traced signatures.*

No. of Arches	Frequency	% Occurrence
6	1	0.5
7	8	4.2
8	24	12.7
9	70	37.0
10	58	30.7
11	26	13.8
12	1	0.5
13	1	0.5

figure of about 16% for simulating the same signature; traced signatures with nine and ten arches (67.7%) were nearly double the corresponding number of signatures produced by simulation (38.6%). In other words, compared with tracing, the simulated signatures deviated more from the model. Therefore traced forgeries are better in duplicating the general form and in actual case situation, as far as the number of arches is concerned, more of the traced signatures are expected to fall within the range of natural variations of the control specimens. On the other hand, the signatures produced by tracing displayed much poorer line quality than those by simulation: over 97% of the signatures traced from symbol 21 contained strokes with obvious tremor.

Pen pressure variations—of signatures have been detected and recorded by the PS 325 Writing Pressure Meter. The recorded pressure variation patterns of the normal signature, the same signature traced by the signatory and the 'traced forgery' of the signature by another subject were obtained from each of the volunteers and were examined and compared. Figures 2 and 3 illustrate the typical pen pressure charts obtained from the writing pressure meter. In Fig. 2*a*, is the writing pressure pattern from the signing of a Chinese signature consisting of three characters by one of the subjects. The signature as shown in the inset, was fluently executed and this was reflected in the chart by the constant and rhythmic changes of pen pressure. Vigor and spontaneity generating high transient pen pressure can be appreciated from the chart by the observation of sharply pointed 'peaks' without record of zero pen pressure indicating that the pen was exerting pressure throughout the signing of the original signature. Figure 2*b* shows the pressure variation during the tracing of the subject's own signature. Much more time (about five times longer) was needed for the signatory to accomplish the tracing of her own signature. There were seven instances of zero pen pressure, indicating that the person doing the tracing lifted the pen, hesitated, or paused with the pen still touching the paper but not exerting pressure on the instrument. The peaks are more rounded indicating a loss of vigor and spontaneity. The 'plateaus' on the pressure charts indicate the application of a uniform pen pressure. However, the individual peaks or groups of peaks in the chart of tracing still correspond, albeit vaguely, with those in the chart of the original signature. Figure 2*c* is the pressure chart of the same signature traced by another subject. In the latter case, the degeneration of fluency and spontaneity was even more serious and there was evidence of longer hesitation and pen pause. This is attributed to the fact that the other subject was less familiar with the model signature. Similar pen pressure charts corresponding to the signing and tracing of English signatures are presented in Fig. 3. Table 10*a* shows the highest- and the lowest-peak pressures of signatures traced by the signatory in comparison with the corresponding pressures recorded during the signing of the original signatures. The observation from the writing pressure charts that the highest and the lowest peaks of the majority of the self-traced signatures are less pronounced than the corresponding peaks of the original model signatures, supports the hypothesis

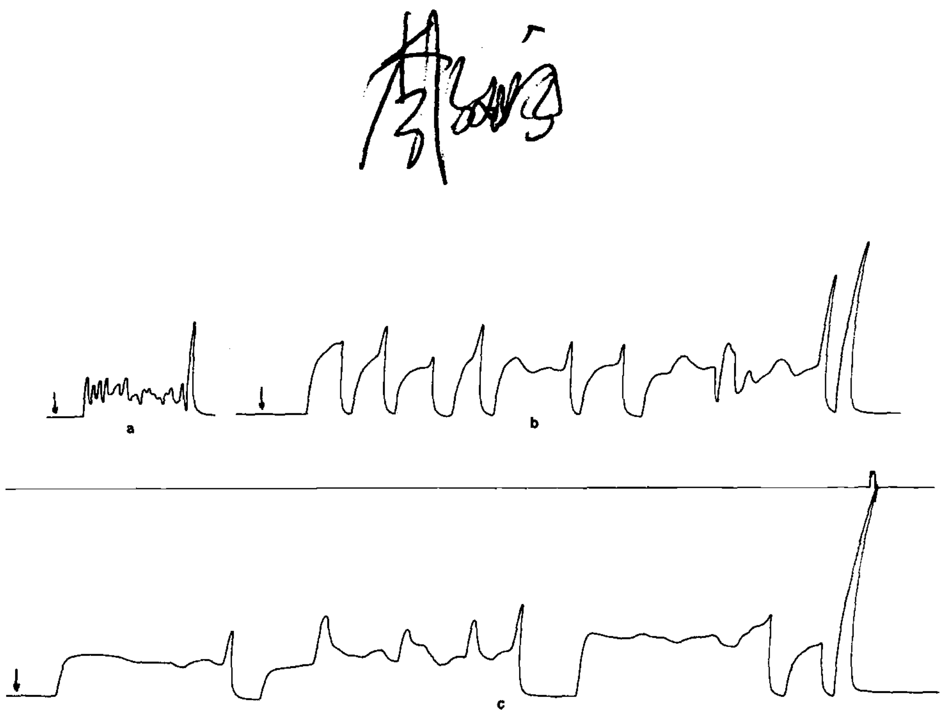

FIG. 2—*Pen pressure patterns of* (a) *the original signature shown at the top,* (b) *the same signature traced by the signatory, and* (c) *the same signature traced by another subject.*

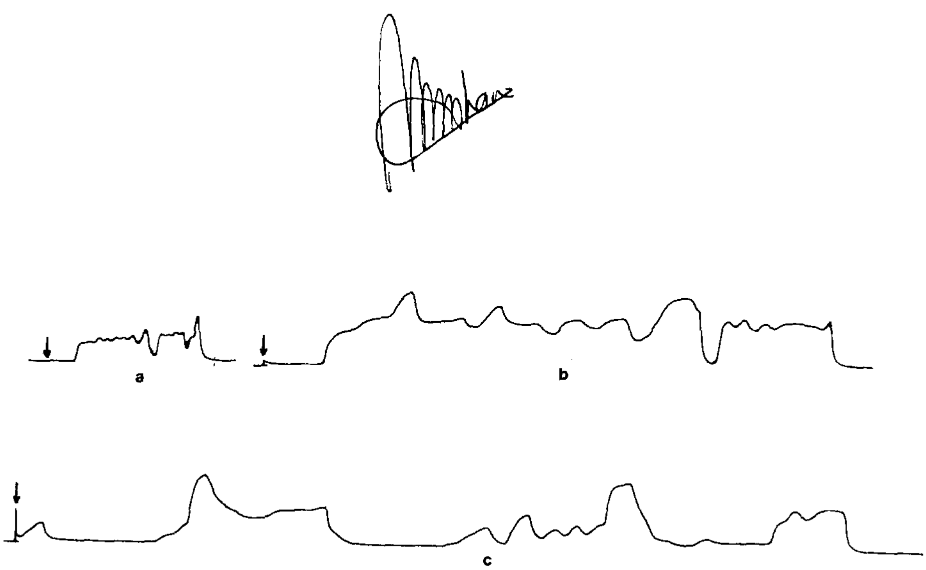

FIG. 3—*Pen pressure patterns of* (a) *the original signature as shown at the top,* (b) *the same signature traced by the signatory, and* (c) *the same signature traced by another subject.*

TABLE 10—*Comparison of writing pressure of* (a) *tracing one's own signature and* (b) *tracing the signature of another person with that of the normal signature of the subject.*

	(a) Highest peak pressure	(a) Lowest peak pressure	(b) Highest peak pressure	(b) Lowest peak pressure
Increased	64(34.0%)	66(35.1%)	84(44.7%)	66(35.1%)
Unchanged	12(6.4%)	13(6.9%)	9(4.8%)	13(6.9%)
Decreased	112(59.6%)	109(58.0%)	95(50.5%)	109(58%)

that there has been a loss of vigor and spontaneity. Table 10*b* illustrates the comparison of pressure patterns derived from the tracing of signatures by another person with those of the normal signatures of the signatory. The tracing of the unfamiliar signature of another person appeared to have imposed a greater stress on the 'forgers' so that a larger proportion of the corresponding traced samples exhibited increases in the highest-peak pressure. For most of the tracings, the average pen pressure might have been higher but this information cannot be obtained from the writing pressure meter.

Statistics of the time spent—on tracing their own signatures in comparison with the time for writing the original model signatures are given in Table 11. A great majority of the participants used considerably longer time—a multiple factor of over ten times the original time, even in tracing their own signature. This lengthening of time required for tracing is attributed to the constant need to refer to the model signature, thus causing hesitation, pen pause, or pen lift, or both. This uncertainty restricted the movement of the pen and it imposed a tiring strain to the forger who subsequently could not introduce additional variations of pen pressure and other detailed features of the genuine model. The result confirms the general observation that the typical traced forgery is drawn with a slow measured stroke, usually filled with points of hesitation.

Hesitation, pen lift, or pen pause—can be measured by counting the number of instances of zero pen pressure. In Table 12 statistical results of the number of instances of zero pen pressure of the original signatures, signatures traced by the signatory and signatures traced by another subject are presented. About 62% of the original signatures did not exhibit zero pen pressure; the maximum number of pen pause in an original signature was seven. Pen pressure patterns of traced signatures show considerably more instances of zero pen pressure indicating that the 'forgers' were more hesitant. Statistical results for signatures traced by the signatory and those traced by the other volunteers are similar, although signatures traced by another person tend to have more pen pauses or hesitations; among the former of which the maximum number of zero pen pressure was 17, while in the latter it was 25.

TABLE 11—*Statistics of the ratios of the time needed for the subjects to trace their signature to that they spent to sign their own signature.*

Multiple factor	Frequency	% Occurrence
≤1	4	2.1
1.1–2.0	43	23.0
2.1–3.0	46	24.6
3.1–4.0	28	15.0
4.1–5.0	29	15.5
5.1–6.0	15	8.0
6.1–7.0	10	5.3
>7.0	12	6.4

TABLE 12—*Statistical result of instances of zero pen pressure.*

Instances of zero pen pressure	Original signature	Tracing own signature	Signature traced by another person
0	116	44	35
1–2	59	75	62
3–4	12	28	39
5–6	0	19	23
7–8	1	12	12
9–10	0	2	4
11–15	0	5	6
Over 15	0	1	3

Discussion

Successful forgers must be able to discard all their own writing habits and at the same time assume those unfamiliar characteristics of the original writer. In the case of tracing, forgers are very successful in abandoning their own writing habits because by following the outline of the model, they are actually not writing, but are drawing and so their usual writing habits will be seriously perturbed and prevented from appearing in the tracing. However, the restriction that the forger has to follow a prescribed form inevitably limits the freedom of the pen, thus giving rise to the various defects of tracing, some of which coincide with those of simulation. Under experimental conditions, apart from the absence of guilt, the physical and psychological conditions of the participants doing the tracing should be very similar to those of the criminal forger.

While the result of simulation is related to writing skill, that of tracing is by and large independent of the writing ability of the forger. The writing pressure meter has shown that all the signatures traced by the 189 subjects were highlighted by the pressure of a slow measured stroke accompanied with hesitation, pen pause and absence of vigor and spontaneity. Osborn [*2*] has proposed that it is impossible to trace even one's own signature and produce a good result because the method itself necessarily interferes with the natural writing movement. As each and every signature is unique, the signatory will therefore be the one person who is most adept to write his or her own signature. However, because tracing is not related to the writing ability of the forger; the result of the signatory tracing his or her own signature therefore exhibits similar defects to the same signature traced by another person, despite the latter being less familiar with the signature being traced. The experimental results correlate well with the above hypothesis.

It has been generally accepted that the model signature is important for the investigation of traced forgery, and that a tracing and the model do not overlap exactly throughout. Harrison [*3*] proposed that although well-written genuine signatures of a particular person may have a great deal in common, no two will be identical and so the very perfection of form of a traced forgery may prove to be its undoing. Osborn [*2*] suggested the use of transparencies to superimpose the suspect signature and the model thus making manifest the exact degree of correspondence. Hilton [*1*] maintained that although the questioned and model signatures do not coincide precisely, when the strokes of the disputed signature wander away from those of the genuine, they invariably return to the common track, particularly at prominent points. None of these authors have provided a reference datum of superimposability of signatures rendering a justification of the possibility of traced forgery.

The experimental observation that the statistical distribution curves of superimposability percentages for tracing and simulation crossed over one another at about 55% has provided important inferences: first, the probability that a questioned signature has been produced by tracing from another (genuine) signature is related to the superimposability of the two. Secondly, depending on the presence of other evidence, if two or more signatures have over 50% of the total lengths of their component strokes overlapping one another, then there is a high probability that one of the signatures is genuine and has been used as the model for tracing for the other signature(s); or, the signatures are all traced forgeries deriving from the same genuine model signature.

In a casework situation, the measurement of superimposability of one signature in comparison with the suspected model is tedious and is difficult to accurately obtain. In practical terms, it would be necessary to develop a computer image processing software to capture images of signatures and compare the number of pixels of the overlapping portions of the suspect signature with those representing the total length of the various components of the model signature.

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