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Forgery I—Simulation

REFERENCE: Leung, S. C., Cheng, Y. S., Fung, H. T., and Poon, N. L., "**Forgery I—Simulation,**" *Journal of Forensic Sciences*, JFSCA, Vol. 38, No. 2, March 1993, pp. 402–412.

ABSTRACT: A total of 189 volunteers were asked to simulate 21 isolated handwriting symbols consisting of single strokes, geometric figures, printed English alphabet letters, simple Chinese characters, and a plain signature, each of which contained one or two designated target features. The study shows that the simulators concentrate on the more eye-catching characteristics, neglecting the inconspicuous—and very often fundamental and therefore more useful—diagnostic features of handwriting. The experiment confirms the empirical information contained in authoritative texts of handwriting examination.

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

A document examiner is often required to provide an opinion on the authorship of handwriting or signatures, which is essentially an exercise of distinguishing forgery from genuineness. To be successful, forgers must discard all their own writing habits and at the same time, assume those unfamiliar characteristics of another writer. The conscious mental task is enormous and it involves the physical struggle of using an alien writing process in place of the well-founded, usual writing movements as well. Therefore, truly successful forgeries are rare. It is generally recognized that there are two methods of forgery, namely simulation and tracing, which have been extensively reviewed [*1–3*].

Most of the forged signatures that we have come across have been produced by freehand simulation. A study into the features normally associated with this popular method of forgery is therefore needed. Muehlberger [*4*] has discussed the characteristics of simulated forgeries and the conditions that allow for the comparison of simulations with handwriting of suspected forgers. Herkt [*5*] has studied faults observed in the examination of forged signatures written by 72 subjects and concluded that the 'best' forgeries were those produced freehand. Puri [*6*] has addressed the problems of detecting genuine and fraudulent tremors.

The majority of the facts and figures presented in authoritative texts and the few published articles available, are excerpts from case examples. Original experimental investigations of forgery are scanty. Written scripts embody a variety of characteristic features, which in combination form extremely complex patterns, so that it would be a very difficult task to identify, classify, and rationalize these intricate writing attributes and finally transform the results into general principles. To overcome this difficulty, we have devised an experiment to study simulated and traced forgeries. Based on the ex-

Received for publication 11 May 1992; accepted for publication 30 June 1992.
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periment, 189 participants were asked to simulate and trace 21 handwriting 'symbols' containing target characteristics and the abilities of the subjects to simulate or trace were studied. In this paper, the results on simulation were presented.

Method

Instead of asking volunteers to write selected passages, 21 handwriting symbols were chosen, each of which contained one or two target features. These symbols included single strokes, isolated capital letters, simple Chinese characters, geometric figures, and a signature of simple design. The handwritten symbols were randomly placed on a piece of single lined paper in such a manner that targeted characteristic features that they contained would not provide a clue to the simulators (Fig. 1).

The target features incorporated into the symbols represented certain individual characteristics that appear in normal handwriting. In this study, to avoid complications and possible involvement of subjective judgment, features in the handwriting symbols other than those designated target features were not included in the final results. Table 1 shows the various target features: features 1 to 4 are related to the thickness of strokes, whereas features 5 to 8 aim at imitating different writing movements. Feature 9 consists of a simple Chinese character bearing pen emphasis at the start of the horizontal strokes; pen emphasis denotes an abrupt application of pen pressure giving the part of the stroke a characteristic wedge- or nodelike shape [7]. Features 10 to 12 detect whether the writers can simulate the structural detail of the corresponding geometric figures. In addition, certain measurable parameters have been incorporated into features 11 to 18 to see how accurately the 'forgers' can reproduce them. Feature 19 consists of three connected semicircles, while feature 20 is an irregular zig-zag line, the total lengths of both of which are known. These last two symbols are used to detect how well the simulated (and traced) copies match with the original figures. Finally, feature 21 is a plain signature consisting of a series of eleven sharply pointed arches in which sudden change of direction occurred at two places.

Simulated (and traced) samples of these handwriting symbols obtained from 189 volunteers were studied. Relevant personal details namely, age, sex, education, country where educated, handedness, opportunity to write, and profession were obtained by questionnaires from the subjects. Table 2 shows a breakdown of the demographic data. Simplicity of the symbols eliminates interfering factors by offering isolated characteristic features to the simulators who are expected to be more able to reproduce the target features than in the case of forging ordinary signatures or handwriting. As a result the

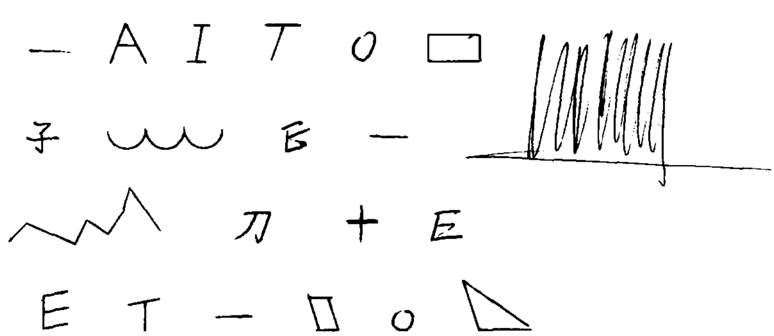
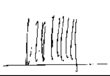


FIG. 1—*The 21 handwriting symbols used.*

TABLE 1—*Target features of 21 handwriting symbols.*

Symbol		Target Feature
1		Flying start
2		Tapering end
3		Uniform width
4		Thicker horizontal stroke
5		Tapering end pointing towards the left (anticlockwise movement)
6		Tapering end pointing towards the right (clockwise movement)
7		Writing sequence
8		Writing sequence
9		Emphatic starts
10		Tiny protrusions
11		(a) Width to height ratio (b) Small dot
12		(a) Ratios of 3 sides (b) Gap at one corner
13		Angle of the apex
14		Angle of the angular turning
15		Slant of the vertical stroke
16		Slant of the vertical stroke
17		Tilt of the horizontal stroke
18		Tilt of the horizontal stroke
19		Superimposability
20		Superimposability
21		(a) Number of 'arches' (b) Sudden change of direction

features can be studied more easily without the involvement of some degree of subjective judgment. Interpretations of the results are rendered easier and with greater accuracy. In addition, because the symbols are simple strokes, geometric figures, printed alphabets, and Chinese characters, the results and the inferences derived from the experiment can be applied to any language or handwriting system. On the other hand, as many of the symbols do not normally occur in handwriting, the natural writing habits of the participants will not affect the simulation process so that false positive result will be reduced. In order to further ensure accuracy, simulated (and traced) results of target features of certain symbols were considered together. For example, writing directions for the 'O' are normally either clockwise or counterclockwise so that the natural habit for the above of a participant will coincide with either symbol 5 or symbol 6. Hence, only those simulators who correctly copied both symbols were counted as successful. Similarly, symbols 1 to 3 and symbols 7 and 8 were considered together in groups. Basic statistical data were obtained with the aid of Lotus 123 software under an AST 386SX personal computer.

TABLE 2—*Demographic data.*

		Frequency	Percent
Age	under 20	5	2.6%
	20–29	104	55.0%
	30–39	49	25.9%
	40–49	25	13.2%
	over 50	6	3.2%
Sex	male	137	72.5%
	female	52	27.5%
Profession	student	5	2.6%
	law enforcement officers	49	25.9%
	technical & professional	109	57.7%
	banking	9	4.8%
	clerical staff	13	6.9%
	others	4	2.1%
Education	primary	5	2.6%
	secondary	95	50.3%
	post secondary	89	47.1%
Where educated	Hong Kong	163	86.2%
	China	1	0.5%
	overseas	9	4.8%
	Hong Kong then overseas	14	7.4%
	China then Hong Kong	2	1.1%
Handedness	left	3	1.6%
	right	186	98.4%
Chance to write	often	129	68.3%
	sometimes	47	24.9%
	rare	13	6.9%

Result

Qualitative features—cannot be measured and they are usually difficult to be explicitly described and classified. Therefore, in this experiment, features such as line quality have not been used to determine the ability of the subjects to simulate. Using the assessment scheme, statistical data of those subjects who could reproduce designated qualitative features in 12 of the 21 handwriting symbols are presented in Table 3. Symbols 1 to 3 are used to detect whether the subjects notice and copy the flying start, the tapering end and the horizontal stroke with uniform thickness. Symbol 4 consists of a vertical stroke and a horizontal stroke, the latter of which is thicker in width. Only about 13% of the participants simulated symbols 1 to 3 as a group and symbol 4 correctly. Symbols 5 and 6 are circles written respectively, with counterclockwise and clockwise movements and with their tapering ends pointing toward the left and the right, respectively. Because a lay person cannot be expected to take into consideration the different possible writing movements for the circle, and the ways to deciphering them, in the assessment of the ability to copy these symbols, the actual writing movements were not used as criteria. Those circles bearing the tapering ends at the correct positions were considered as successful simulations. Despite this, only about 7% of the simulated samples included the correct features in both circles. The writers were also not alert enough toward inconspicuous characteristics so that fewer than 6.5% of them reproduced the tiny dot at the upper side of the rectangle in symbol 11. The more conspicuous attributes such as the protrusions at the parallelogram in symbol 10 and the opening at the right apex of the triangle in symbol 12 have been copied by respectively 27% and 56% of the subjects.

TABLE 3—*Statistical result of simulation of designated qualitative features of twelve handwriting symbols.*

Target Feature	Symbol	Frequency	% Occurrence
Variation of thickness of horizontal strokes	1–3	25	13.2
Relative thickness of 2 strokes	4	25	13.2
Writing direction	5 & 6	13	6.9
Writing movement or sequence	7 & 8	42	22.2
Pen emphasis	9	69	36.5
Structural detail (small protrusions)	10	51	27.0
Structural detail (dot)	11	12	6.3
Structural detail (gap)	12	106	56.1

Two of the symbols which are more familiar to the participants namely, the letter 'E' in symbols 7 and 8 and the Chinese character meaning 'son' in symbol 9 could be successfully simulated by 22% and 36% of the participants. The result indicates that the forgers often neglect inconspicuous structural detail, subtle shading and writing direction.

Measurable target features—have been assigned to symbols 11 to 18. In symbol 11, the width of the rectangle is 1 cm while the height is 0.5 cm, giving rise to a ratio of 2. Table 4 illustrates the result of simulation of the rectangle. About 24% of the subjects reproduced rectangles with identical width to height ratio to that in symbol 11. However, 60% of the writers produced rectangles with increased ratios; only 16% of them copied rectangles with decreased ratios. The result shows that while many participants failed to copy the tiny dot in the rectangle, which is less conspicuous, most of them have noticed the general flat and slender shape of the rectangle in symbol 11. Hence, the majority of the subjects tend to lengthen the longer horizontal sides of the rectangle rather than shortening them, the latter tendency of which would produce a shape closer to that of a square. A hypothesis can be derived from the above observation: a prominent feature of a signature, such as a dominating rubric or an extended cross stroke of 't', will be exaggerated and made even more prominent in the simulated signature. In symbol 12, the three sides of the triangle marked AB, AC and BC are respectively, 1 cm, 1.5 cm, and 1 cm in length. As illustrated in Table 5, 25% of the simulated samples are consistent in ratios of the sides AB and BC, whereas less than 8% of the samples are consistent in ratios of the sides of AB to AC and BC to AC. This is probably because detection of symmetric figures is easier. Since AB and BC are equal in length these two sides of the isosceles triangle are prominent enough to be noticed and copied. Hence, more partic-

TABLE 4—*Statistical result of width/height ratio of simulated rectangles.*

	% Deviation	Frequency	% Occurrence
Decrease in ratio	>30	3	1.6
	21–30	4	2.1
	11–20	11	5.8
	1–10	12	6.3
Consistent in ratio	0	45	23.8
Increase in ratio	1–10	1	0.5
	11–20	50	26.5
	21–30	23	12.2
	31–40	23	12.2
	>40	17	8.9

TABLE 5—*Statistical result of ratios of three sides of simulated triangles* (a) *AB:BC,* (b) *AB:AC* & (c) *BC:AC.*

	% Deviation	Frequency	% Occurrence	Frequency	% Occurrence	Frequency	% Occurrence
Decrease in ratio	>30	6	3.2	3	1.6	2	1.1
	21–30	21	11.1	10	5.3	8	4.2
	11–20	27	14.3	33	17.5	34	18.0
	1–10	27	14.3	59	31.2	43	22.8
Consistent in ratio	0	47	24.9	14	7.4	15	7.9
Increase in ratio	1–10	1	0.5	41	21.7	47	24.9
	11–20	35	18.5	20	10.6	23	12.2
	21–30	13	6.9	5	2.6	11	5.8
	31–40	6	3.2	3	1.6	5	2.6
	41–50	4	2.1	0	0.0	0	0.0
	>50	2	1.1	1	0.5	1	0.5
		(*a*)		(*b*)		(*c*)	

ipants produced triangles with the correct ratio of these two sides. On the other hand, AB and BC are different in length from the third side AC. The mental task of estimating their lengths relative to AC and the process of reproducing them are expected to be more difficult and so considerably fewer simulators (about one-third of the former) produced triangles with AB/AC and BC/AC ratios consistent with those of the model. The angle of the apex of the capital letter 'A' (50°) and the angle of the angular turning of the Chinese character meaning 'knife' (70°) in symbols 13 and 14 have been used as target features. As demonstrated in Table 6, the volunteers simulated these with reasonable accuracy. These two symbols are familiar to the subjects and the angle of each of them is well defined by the strokes. On the contrary, the simulation of slant and tilt seems to be more difficult. While slant is the angle or inclination of the axis of letters relative to the baseline [*3*], tilt is defined as the angle of inclination of the horizontal stroke relative to the line of writing [*7*]. The slant of the vertical stroke of 'I' and that of 'T' of the standards are 10° and 20° respectively. The tilt of both the uppermost horizontal stroke of 'E' and the horizontal stroke of 'T' is 10°. All of them were measured with the aid of a slant plate or a protractor, or both. Tables 7 and 8 indicate that the simulation efforts of the participants for slant and tilt were less successful. The above two parameters are angles or inclination in relation to the imaginary line of handwriting and are therefore not as easy to imitate. Apart from this, because the slant and tilt of the respective letters are small in magnitude, the error produced in simulating them was larger. The normal writing habits of the subjects may have also affected the simulation process.

Superimposability—is a measure of the participant's ability to copy the general outline of the symbols. In terms of size and pictorial effect, 100% superimposability is the limit for any forgery. It would therefore be desirable to discover the degree of superimposability of a simulation with the original model despite that in an actual case situation the probability of the two completely overlapping one another would be very low. Symbols 19 and 20 consist of respectively, three connected semicircles with a total length of 3.3 cm, and an irregular zig-zag line 4.5 cm long, both of which were targeted to determine superimposability. The simulated samples were compared with the corresponding standard model figures by examining the two under transmitted light on a light box. Portions of the figures, wholly or partially overlapped were considered to be superimposable and were measured using a Peak Scale Lupe 10X magnifier with scale counter graduated in 0.1 mm intervals or a PAV 6511 Fino 150 mm electronic calliper gauge, or both. Of the 189 volunteers, very few could simulate either of the symbols with a reasonable degree of accuracy as seen in Table 9. Statistical data for the simulation of the two symbols closely correlated with one another: the majority of the participants produced simulated figures with superimposability percentages between 20% to 59%, giving an average superimposability of approximately 42%. The occurrence of the above sharply declined at both ends of the scale. This means that the symbols were easy enough for the subjects to imitate so that few produced simulated figures with less than 20% overlapping the model figures. However, the task of simulation was also not easy, so that few of the participants produced more than 60% superimposability. Figure 2 consists of histograms showing the result of simulation of the above mentioned handwriting symbols. The connected semicircles in symbol 19 are regular in shape and in this respect, it is not difficult to copy but in terms of writing movement, freehand production of a good curved line is not easy. The zig-zag line in symbol 20, consisting of a series of straight line sections can be written with simpler writing movements but the simulation is made difficult by the irregular length of the sections and the angles of various magnitudes that they form between one another. Considering the fact that both symbols are much simpler than normal handwriting, the task of simulation for the forger must be considerably more difficult in actual case situations.

TABLE 6—*Statistical result of simulation 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	74	39.2	116	61.4
11–20	50	26.5	52	27.5
21–30	34	18.0	17	9.0
31–40	21	11.1	3	1.6
41–50	7	3.7	1	0.5
>50	3	1.6	0	0.0
	(*a*)		(*b*)	

TABLE 7—*Statistical result of simulation of slant of* (a) *I and* (b) *T.*

% Deviation	Frequency	% Occurrence	Frequency	% Occurrence
0	13	6.9	10	5.3
1–20	37	19.6	81	42.9
21–40	37	19.6	61	32.3
41–60	34	18.0	28	14.8
61–80	22	11.6	6	3.2
81–100	22	11.6	3	1.6
>100	24	12.7	0	0
	(*a*)		(*b*)	

TABLE 8—*Statistical result of simulation of tilt of* (a) *the uppermost horizontal stroke of E &* (b) *the horizontal stroke of T.*

% Deviation	Frequency	% Occurrence	Frequency	% Occurrence
0	10	5.3	16	8.5
1–20	52	27.5	52	27.5
21–40	38	20.1	35	18.5
41–60	25	13.2	31	16.4
61–80	24	12.7	24	12.7
81–100	17	9.0	13	6.9
>100	23	12.2	18	9.5
	(*a*)		(*b*)	

TABLE 9—*Superimposability of the simulation of* (a) *3 connected semicircles* (b) *an irregular zig-zag line.*

Superimposable percentage	Frequency	% Occurrence	Frequency	% Occurrence
≥90	3	1.6	0	0.0
80–89	4	2.1	1	0.5
70–79	7	3.7	3	1.6
60–69	14	7.4	11	5.8
50–59	25	13.2	35	18.5
40–49	21	11.1	70	37.0
30–39	68	36.0	49	25.9
20–29	44	23.3	19	10.1
10–19	2	1.1	1	0.5
<10	1	0.5	0	0.0
	(*a*)		(*b*)	

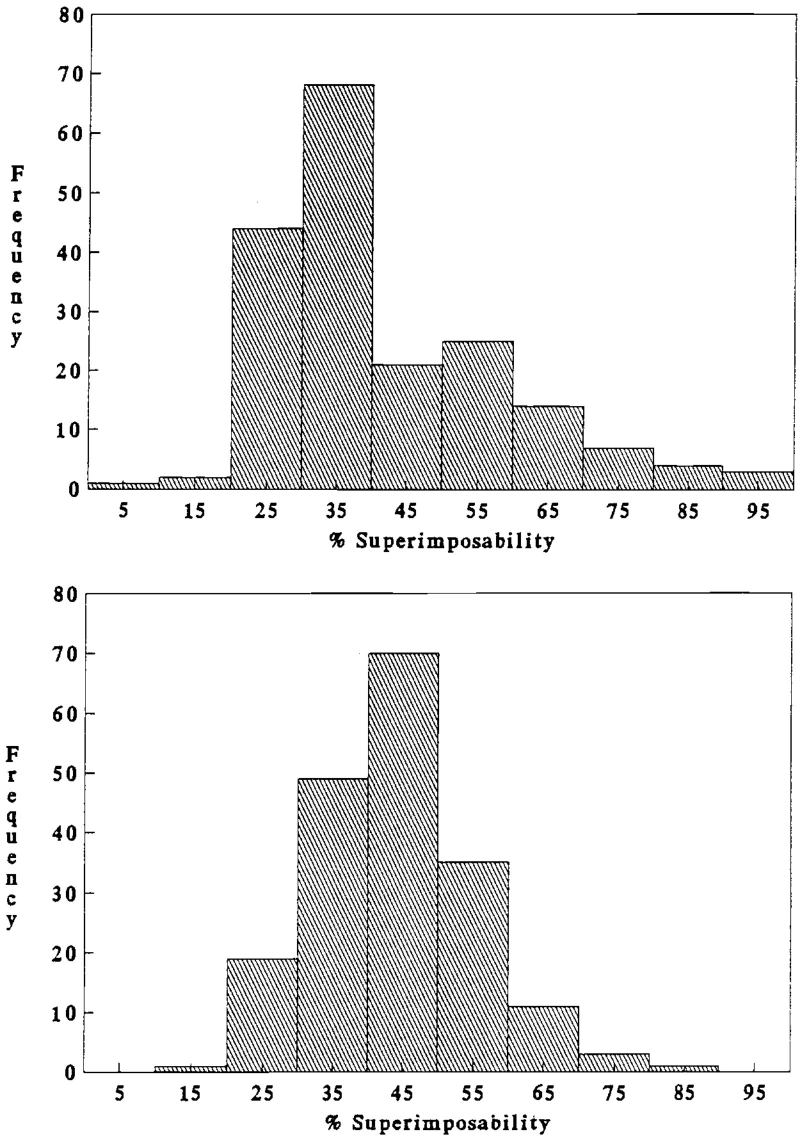


FIG. 2—*Graphical presentation of simulations of three connected semicircles* (top) *and an irregular zig-zag line* (bottom).

Practical Consideration—of the forgery of a signature was given in symbol 21, which consists of a signature with eleven sharply pointed arches and a horizontal line rubric. Sudden changes of writing direction were present in the vicinity of the third and the fifth arches. The subjects were tested to see whether they noticed the number of arches; the sudden changes of writing direction; and the locations of them. As shown in Table 10, the number of arches of the simulated signatures produced by 189 subjects varies from five to twelve; only about 16% of the participants correctly produced signatures with eleven arches and over one-quarter of the simulated signatures contain less than eight arches. The results indicate that over 80% of the simulators probably did not count the number of arches or that they did not consider the number of arches as an important

TABLE 10—*Statistical result of the number of arches in the simulated signatures.*

No. of Arches	Frequency	% Occurrence
5	6	3.2
6	16	8.5
7	26	13.8
8	36	19.0
9	42	22.2
10	31	16.4
11	30	15.9
12	2	1.1

TABLE 11—*Statistical result of the ratio of the length of the horizontal line rubric to the vertical distance between the tallest arch and the lowest trough of the simulated signatures.*

Ratio	Frequency	% Occurrence
≤1.5	1	0.5
1.6–2.0	19	10.1
2.1–2.5	56	29.6
2.6–3.0	64	33.9
3.1–3.5	30	15.9
3.6–4.0	13	6.9
4.1–4.5	3	1.6
4.6–5.0	3	1.6
>5.0	0	0

feature of the signature in symbol 21. In addition, only 34.4% of the subjects attempted to simulate the sudden changes of writing direction and an even smaller fraction of the volunteers (22.2%) placed them correctly within the signature. In practical consideration, it seems that for the signature in symbol 21, the above three characteristics are enough to determine the authorship of the signature. However, in an actual case situation, the 'forged' signature may fall within the range of natural variation of the control specimens which in normal circumstances would consist of over ten signatures. Because more than 76% of the simulated samples displayed degenerated line quality with obvious tremor, the additional consideration of line quality would certainly offer sufficient evidence for an opinion to be given. Because the signature in symbol 21 consists of a prominent horizontal line rubric with a number of sharply pointed arches that can be imagined as being accommodated in a rectangle, the hypothesis proposed in the previous paragraph that a prominent feature in a signature will be exaggerated by the simulator can be tested. Using a grid graduated in 1 mm intervals, the length of the rubric and the vertical distance between the highest arch and the lowest trough of the signature were measured and their ratios compared with that of the original signature (which is equal to 2.6). The statistical results are given in Table 11. It is obvious that most of the subjects (about 60%) wrote simulated signatures with ratios greater than the standard ratio of 2.6; in other words most of them have exaggerated the horizontal line rubric. This statistical result correlates strikingly well with the simulation result of the rectangle in symbol 11 given in Table 4. The hypothesis proposed in the previous paragraph that a prominent feature of a signature will be made even more prominent by the forgers doing the simulation is thus verified.

Discussion

The experimental results indicated that the participants concentrated on the eye-catching features. Hence, the general shape of the rectangle was reproduced more accurately by the subjects, whereas the tiny dot within the rectangle was overlooked by most of them; the angle of the apex of 'A' and that of the angular turning of the Chinese character 'knife,' being clearly demarcated by two strokes, were copied by more volunteers than the number of those who simulated the slant and tilt of 'I,' 'E,' and 'T,' which are features using imaginary lines as references. Among the qualitative parameters, inconspicuous structural detail and certain subtle features such as the writing directions of the circle have escaped being observed and imitated by most subjects. This is because the simulators neither comprehended nor appreciated the finer and more delicate features of the writing symbols they were attempting to copy. The experiment therefore confirms the empirical information contained in standard texts of handwriting examinations.

Hilton [3] maintained that to imitate the signature of another person with fraudulent intent is to undertake an abnormal act that brings about in the individual a mental and physical conflict of serious proportion. While a sense of guilt harasses the forger during the execution of the forgery, he is further subjected to other mental conflicts coupled with a difficult task. Although some of the volunteers did take prolonged time to study and to simulate the handwriting symbols, their drive to forge may be less than many of the real forgers; on the other hand, they would be deficient in the sense of guilt, which can never be produced under experimental conditions. Apart from this, other mental and physical stresses that the subjects were experiencing during simulation should be similar to those of the fraudulent criminals. In this respect, the results from this research can provide a useful reference.

Acknowledgments

The authors would like to express their gratitude to Mr. N. S. Lee, the Government Chemist of Hong Kong, for his interest and encouragement in this work, to Dr. B. N. Dailly, Assistant Government Chemist for proofreading the draft, and to Miss Y. L. Yip who helped to collect the samples and processed the data. Thanks are also due to those volunteers who participated in the research by providing samples.

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