Signature Forgery and the Forger – An Assessment of Influence on Handwritten Signature Production

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***Abstract*—Signatures are widely used as a form of personal authentication. Despite ubiquity in deployment, individual signatures are relatively easy to forge, especially when only the static 'pictorial' outcome of the signature is considered at verification time. In this study, we explore opinions on signature usage for verification purposes, and how individuals rate a particular third-party signature in terms of ease of forgeability and their own ability to forge. We examine responses with respect to an individual's experience of the forgeability/complexity of their own signature. Our study shows that past experience does not generally have an effect on perceived signature complexity nor the perceived effectiveness of an individual to themselves forge a signature. In assessing forgeability, most subjects cite the overall signature complexity and distinguishing features in reaching this decision. Furthermore, our research indicates that individuals typically vary their signature according to the scenario but generally little effort into the production of the signature.**

Keywords—signature; biometrics; forgeability; user acceptance signature; biometrics; user acceptance

I. INTRODUCTION

Despite widespread deployment of alternatives forms (such as PINs and, latterly, biometric assessment including face, fingerprint and iris) the human signature is still a widely-used, legally admissible and globally-implemented and accepted method of personal authentication [1]. In conventional usage, wherein identity is verified through the static assessment of the similarity between two sample signatures, the main disadvantage of the modality is the possibility for fraudulent production (simulation/forgery) of a genuine sample [2]. The production of forgeries can be undertaken by skilled professionals or, at a 'semi-skilled' level, by members of the general public by copying a sample of an original signature, often seeking gain (financial or otherwise) from the production of the signature.

Understanding public perception of the use of signatures is critical to sustained widespread deployment – if there is concern about overall security and risk of fraudulent use then confidence is undermined [3]. Central to this is the trust in one's own signature, therefore a deeper understanding of the 'forgeability' of signatures will provide indicators as to the factors related to generic signature safety, and the criteria and characteristics associated with a particular signature deemed to be easier to copy. It is important to know if a subject adopts different analysis criteria in relation to different experiences they have had with signatures to assess the impact of modality compromise on continued use. In the same way, it is also important to establish how a signer uses the signature in daily interactions with respect to past experiences. In relation to the use of contemporary signature capture equipment such that shown in Fig. 1 where a non-conventional writing scenario is implemented (virtual ink on a back projected device as opposed to the standard pen-on-paper implementation), subjects' experiences with this equipment will inform the suitability for deployment, again adding to the overall trust of the modality.

Signature complexity is subjective in concept, but in general it is possible to hypothesise that it is linked to criteria of legibility (can characters/other distinguishing features be clearly observed?), ink path interaction (are there many intersecting lines?) and size/pen travel distance (generally a 'shorter' signature is deemed less complex). A number of previous studies have assessed perceived complexity of signatures [4, 5] and have suggested that simplicity may relate to forgeability in terms of biometric false accept rate (FAR). However, from this two general hypotheses emerge: i) that low complexity signatures are easier to forge (and hence lead to a high FAR) and ii) high complexity signatures require greater tolerance in assessment that equally may result in a higher FAR.

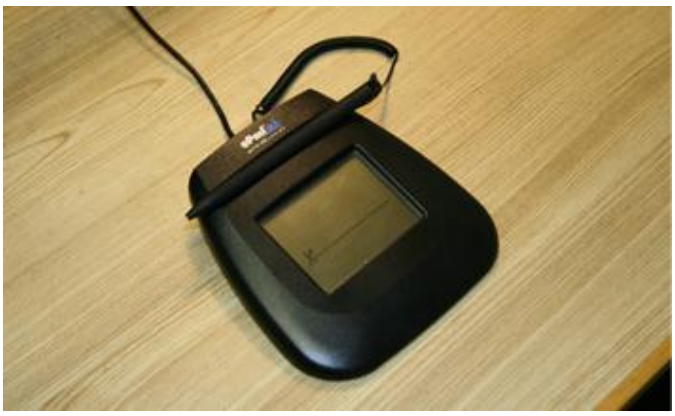

Fig. 1. Contemporary back-projection signature capture device.

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In this study, we wish to obtain a deeper understanding on a range of issues relating to individual's experiences with signatures and signature usage. Furthermore, we wish to explore how these experiences relate to a person's interpretation of the relative ease of forging a third-party signature and how effective they feel they would be in producing an accurate forgery. By asking why a signature is rated in a particular way will enable us to understand the static components that are perceived as being hard or easy to forge. The specific objectives of this study are threefold: i) to understand opinions on everyday signature usage and interaction with fraudulent use, ii) to understand if these opinions lead to a significant difference in a person's perceived ability to forge if required and iii) to understand the reasons why a signature is deemed to be easy or difficult to forge

II. METHODOLOGY

A total of 55 subjects (10F, 45M) took part in the study. Subject ages ranged from 20 to 61 with a mean age of 23.51. A total of 48 subjects were right-handed (87.3%). The majority (52) of the subjects' native writing language was English. The study took the form of two phases:

In ***Phase 1*** subjects were asked a series of eight questions (Q1-8) relating to their own experience of signature production, forgery and use of automated signature devices. The text of these questions can be seen in Tables 1 to 5 in Section 3. Relationships between these factors were investigated using a Spearman Correlation for the between-ordinal data responses (Q5-8) and the Mann-Whitney U test investigating the effect of the "Yes"/"No" responses to Q1-4 on Q5-8.

In ***Phase 2*** subjects were asked to rate a series of 19 static signature images in terms of a) their perceived ease in forging the signature and b) a prediction of their ability to be able to produce an accurate forgery. Furthermore, subjects were asked to describe qualitatively why they reached such a decision in ranking the perceived ease in forging. Fig. 2 shows the 19 sample signatures that were individually presented in a random order to each test subject as a scanned image from the original paper-based signature.

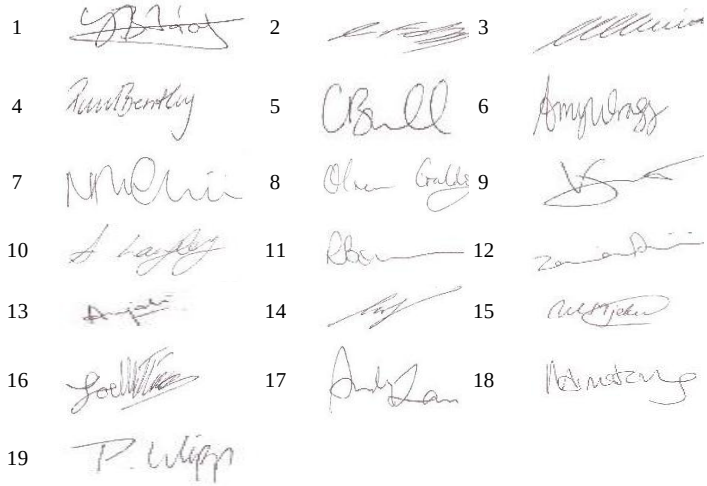

Fig. 2. Sample Signatures in Phase 2.

TABLE I. RESPONSES TO PHASE 1 Q1-4

Question ID	Question	Yes	No	No Response
1	Do you have trouble using signature devices?	10	45	
2	Do you vary your signature according to the importance of the situation?	38	17	
3	Have you forged a signature before?	37	18	
4	Have you ever had your signature forged to your knowledge?	15	39	1

TABLE II. PHASE 1 Q5 - HOW MUCH EFFORT DO YOU USE FOR DAY-TO-DAY SIGNATURES?

Group ID	Level of Effort	Frequency
1	Careful	4
2	Minimal	19
3	Neutral	10
4	Somewhat	22

TABLE III. PHASE 1 Q6 - DO YOU THINK YOU COULD BE EFFICIENT AT FORGING SIGNATURES?

Group ID	Answer	Frequency
1	Definitely Not	6
2	Probably Not	23
3	Maybe	19
4	Probably Yes	6
	Did Not Answer	*1*

TABLE IV. PHASE 1 Q7 - HOW HARD DO YOU THINK IT IS TO FORGE YOUR OWN SIGNATURE?

Group ID	Answer	Frequency
1	Very Difficult	3
2	Difficult	5
3	Somewhat Difficult	16
4	Neutral	10
5	Somewhat Easy	15
6	Easy	6

TABLE V. PHASE 1 Q8 - DO YOU FEAR YOUR SIGNATURE COULD EVER BE FORGED?

Group ID	Answer	Frequency
1	Very Concerned	1
2	Concerned	20
3	Neutral	24
4	Secure	8
5	Very Secure	2

The two ratings asked of each signature in Phase 2 can be seen to be related, however the first question purely asks for an assessment of a signature's properties, whilst the second question asks the subject to map their own forgery ability onto the production of the signature. In this way, it is possible to

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decouple perceived difficulty with an individual ability to forge. Spearman's correlation was used as a mechanism to analyse the relationship between modal responses to these questions.

An assessment of the effects of Phase 1 responses on the answers given in Phase 2 was explored using a Kruskal–Wallis one-way analysis of variance.

III. RESULTS

The results from Phase 1 are shown in Tables 1 to 5 with Table 1 showing the Yes/No responses to Q1-4.

Q1 relates to the difficulty of use of an electronic 'back-projection' signature device (such as a point-of-sale signature tablet). As a definition of 'trouble' was not provided, it was left to the individual test subject to define whether they felt that any interactions with such a device were problematic. As can be seen, the majority of subject felt that there was not an issue with using such non-paper devices, thereby inferring that subjects are happy with the composition of the signature that they produce, even though it is abstracted away from the conventional pen-on-paper scenario.

Q2 to Q4 provide an insight into the use of signatures and forgery. It is interesting to note that the majority of subjects vary their signatures according to the importance of the situation (for example, when signing a letter or legal document, in comparison to signing for low-risk authorisation or attendance). It is possible to hypothesise that this may cause issues for automated signature verification systems as enrolment may be seen as 'high importance' whilst general donation for verification could have varying importance, resulting in variance in signature production. A surprising result is seen in answer to Q3, with the majority of subjects claiming to have forged a signature in the past. The context of this forgery was not probed, however this result is in contrast to the response to Q4 wherein the majority of subjects are not aware of an attempt to forge their own signature. The responses to Q3 and 4 seem to indicate a more prevalent but secretive nature of signature forgery production. Allied to the response of Q2, Table 2 shows the response of subjects concerning their day-to-day care in using their own signature. The low number of subjects using care with signature production further highlights potential problems with natural variance within everyday signatures and how that may vary against an enrolment signature. Subjects seem to take the view that as long as a signature is semi-recognisable in structure, this is sufficient to enable verification, if needed.

Q6-8 addressed issues concerning perceptions of ability to forge accurately. Opinions are mixed as to whether a signer perceives they are able to produce an efficient forgery with the majority of answers being 'Maybe' and 'Probably Not' (Table 3). Again the message is mixed when considering how hard individuals think that their signature is hard to forge (Table 4) with a spread of results across 'Somewhat Easy', 'Neutral' and 'Somewhat Difficult'. These two questions show that whilst subjects are not sure of their own ability, they perceive a greater ability in others to forge. Supporting this view is the clear concern about their own signature falling victim to forgery (Table 5).

Examining the interaction between these answers to Q5-8, there is little in the way of significant relationships between variables. Furthermore, no significant differences were detected in the answers to Q5-8 provided by the groups determined by the answers to Q1-4. Only between Question 7 and Question 8 was there a significant negative correlation of -0.322 ($p=0.017$) confirming that the easier a person believes their signature to be, the more fear they have about it being forged. Other tested relationships indicate (amongst other results) that if a subject has been a victim of forgery in the past does not affect the construction of their signature, that fear of forgery does not affect the amount of effort being used in signing, that effort used is not related to whether a person feels that their signature is hard to forge, and if someone has forged in the past does not mean that they think that they are efficient at forging.

The results from Phase 2 are shown in Tables 6 to 9. Tables 6 and 7 show, respectively, the responses from the questions of how difficult subjects perceived each of the sample signatures and their perceived effectiveness in producing a forgery. In each case the modal response heighted. As predicted there is a strong negative correlation of -0.91 ($p<0.001$) between the modal grouping across the 19 signatures. This strongly indicates that the harder a subject believes a signature is to forge, the less able they feel to be able to produce an accurate reproduction. It can also be observed that within our samples existed a range of both 'difficult' and 'easy' signatures in terms of forgeabilty.

Subjects' free-text responses as to the reasons as to why they perceived a signature with a particular ease of forgeability were analysed by grouping responses according to thematic content. Analysing the responses across all subjects four clear themes emerged:

- **Character Legibility:** comments relating to the ability to read characters within a signature image.
- **Distinguishing Features:** comments relating to identifiable aspects of signatures (other than characters) such as loops or overlaps.
- **Ink Path Interaction/Complexity:** comments concerning the overall complexity of the signature.
- **Ability of Forger:** comments regarding the perceived ability of the forger to produce the signature.

These groups largely support the hypothesised groups defined in Section 1. We have divided our original group of 'legibility' into comments pertaining to the readability of characters and distinguishing features (such as loops and crossings). As predicted, there also existed a group of comments related to ink path interaction and the complexity/simplicity of this path. Likewise, we have noted that a (small) number of comments relate to the ability of the subject to forge the signature.

Table 8 shows the percentage of comments attributed to each of these categories. As can be observed most of the comments relate to distinguishing features and ink path interaction. Only for one signature (Signature 3) was character legibility was the predominant comment class. Visualising this

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TABLE VI. SAMPLE SIGNATURE – PERCEIVED EASE OF FORGEABILITY (MODAL RESPONSE HIGHLIGHTED)

	Sample Signature ID																		
Response	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Very Difficult	11	5	4	2	0	4	3	9	3	12	1	4	7	6	9	27	4	7	4
Difficult	32	10	10	10	3	21	11	24	1	23	5	6	18	7	26	17	23	25	12
Somewhat Difficult	8	12	7	10	2	16	16	17	10	14	8	10	18	12	12	4	15	16	17
Somewhat Easy	3	20	16	23	17	10	17	4	17	5	20	17	6	19	7	5	13	6	15
Easy	1	7	12	9	22	3	7	1	18	1	18	13	4	9	1	1	0	1	6
Very Easy	0	0	6	1	11	0	1	0	6	0	3	5	2	2	0	0	0	0	1
No response	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0

TABLE VII. SAMPLE SIGNATURE – PERCEIVED EFFECTIVENESS OF FORGEABILITY (MODAL RESPONSE HIGHLIGHTED)

	Sample Signature ID																		
Response	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Very Effective	0	0	6	0	5	0	1	0	5	0	4	7	2	2	0	0	0	0	2
Effective	1	3	13	15	27	3	7	2	17	2	20	12	4	15	3	2	2	3	9
Somewhat Effective	9	21	14	19	16	13	19	7	17	7	13	16	9	12	10	3	13	4	11
Somewhat Ineffective	12	13	7	10	1	12	11	15	8	13	10	9	12	10	10	6	11	14	13
Ineffective	21	9	9	7	4	21	11	21	4	18	5	6	18	9	20	17	21	24	14
Very Ineffective	12	9	6	4	2	6	6	10	4	15	3	5	10	7	12	26	8	10	6
No response	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

TABLE VIII. PERCENTAGE DIVISION OF COMMENT CATEGORIES FOR EACH SAMPLE SIGNATURE JUSTIFYING CHOICE OF EASE OF FORGEABILITY

	Sample Signature ID																		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Character Legibility	21	22	7.5	50	13	20	27	31	14	18	14	19	14	4.4	12	11	18	16	14
Distinguishing Features	36	30	66	9.6	46	46	31	46	42	35	45	38	67	44	37	38	32	37	50
Ink Path Interaction/Complexity	36	48	26	29	39	34	40	21	44	43	39	43	16	44	49	51	48	40	33
Ability of Forger	7.5	0	0	12	1.9	0	1.9	2.1	0	4.1	2	0	2	6.7	2.3	0	2.3	7	2.4

signature, it is obvious that the subject's name is clearly readable therefore prompting the primary observation for those seeking to forge the signature.

No relationship between perceived ease and types of comments, or the responses to Q1-8 showing that there is no difference in how people perceive signatures forgery difficult with respect to how they approach signatures and their past experience. No other clear patterns emerge as to why particular comments were chosen, however it is possible to look at the signatures where 50% or more of all comments were in one of the groups:

- **Signature 3** (Dominant Group: Distinguishing Features): Subjects identified the 'loopiness' of the signature as the dominant feature.
- **Signature 4** (Dominant Group: Character Legibility): The readability of the characters in the signer's name was identified as the dominant feature.
- **Signature 13** (Dominant Group: Distinguishing Features): The small size of the signature was the dominant feature.
- **Signature 14** (Dominant Group: Ink Path Interaction): The complex nature of ink path crossings produced the most comments.
- **Signature 19** (Dominant Group: Distinguishing Features): The small size of the signature was the dominant feature.

It is therefore possible to observe that while no clear pattern emerges as to perceived forgeability of a signature where prominent characteristics exist (too small, too loopy, readability of characters), there will be commonly picked up on by forgers as being defining areas for close observation.

IV. CONCLUSIONS

The study has revealed a number of issues regarding the use of signature systems, perceived safety of signatures and ability to forge. The key findings are:

1. There is generally not an issue in using signature collection devices.
2. Most subjects in our study vary their signature according to the scenario but do not, in general, put significant effort into the production of their signature.
3. The majority of subjects admitted to have forged a signature in the past but are unaware of being victims of forgery themselves.

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4. The majority of subjects also are uncertain as to their ability to produce an accurate forgery.
5. There is a significant relationship between the perceived ease of forgeability of a signature and a subjects' perceived ability to produce an accurate forgery.
6. No interaction was identified between subjects' perceived ability to forge or how they use their signatures on a daily basis, and their experience with signatures and signature systems related to forgery. Subjects however fear being forged if they have a simple signature.
7. In general, there is no interaction between experiences of signature systems and how subjects' perceive their ability to forge.
8. There is no clear pattern as to the reasons why a signature a deemed forgeable except in cases where a signature is at an extreme of a particular characteristic (for example very simple or complex or loopy).

Our findings have two main commercial implications for the use of signatures as biometrics. The general acceptance of signatures (even having been a victim of sample compromise) as a means of verification points to the continued use within a biometric system. Secondly, the characteristics that a forger focuses on when assessing a signature have been explored illustrating the 'feature outlier' effect. If these characteristics can be trapped at enrol time, this would lead to the possibility of a less-forgeable signature. An assessment of the performance of these signatures within an automated static system as future work will provide metrics on the FAR of a particular signature in relationship to their perceived forgery characteristics.

REFERENCES

[1] D. Impedovo and G. Pirlo, "Automatic signature verification: the state of the art," *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Application and Reviews*, vol. 38, no. 5, pp. 609–635, 2008.

[2] R. Guest and O. Miguel-Hurtado, "Enhancing static biometric signature verification using speeded-up robust features," in *Proceedings of the 2012 IEEE International Carnahan Conference on Security Technology (ICCST)*, 2012, pp. 213–217.

[3] H. Harralson and L. Miller, *Developments in Handwriting and Signature Identification in the Digital Age*, Routledge, New York, 2014.

[4] M. Fairhurst, E. Kaplani, and R. Guest, "Complexity measures in handwritten signature verification," in *Universal Access in Human-Computer Interaction*, Stephanidis, Constantine, Eds. Lawrence Erlbaum Associates, ISBN 0-8058-3609-8, 2001, pp. 305–309.

[5] L. C. Alewijnse, C. E. van den Heuvel, R. Stoel, and K. Franke, "Analysis of signature complexity," in *Proceedings of the 14th Conference of the International Graphonomics Society (IGS 2009)*, Dijon, 2009.

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