# An Investigation into Biometric Signature Capture Device Performance and User Acceptance

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# An Investigation into Biometric Signature Capture Device Performance and User Acceptance


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***Abstract*— The human signature provides a natural and publically-accepted legally-admissible method for providing authentication to a process. Automatic biometric signature systems assess both the drawn image and the temporal aspects of signature construction, providing enhanced verification rates over and above conventional outcome assessment. To enable the capture of these constructional data requires the use of specialist 'tablet' devices. In this paper we explore the enrolment performance using a range of common signature capture devices and investigate the reasons behind user preference. The results show that writing feedback and familiarity with conventional 'paper and pen' donation configurations are the primary motivation for user preference. These results inform the choice of signature device from both technical performance and user acceptance viewpoints.**



***Keywords—Biometrics, Dynamic Signature Verification, Failure to Enrol, Usability***


## I. Introduction

Biometric systems are being used with increasing prominence across a range of security and authentication scenarios. Within biometrics there are two main types of modality, based on physiological characteristics (*who you are*) and behavioural characteristics (*what you do*). Biometric authentication based on the human signature has a long history of usage, conventionally through human inspection of signature images. Automated (computer-based) assessment of signatures can also be divided into two methodological divisions: static (digitized) and dynamic [1]. Dynamic or online signature verification captures dynamic traits during the act of signing, and includes information such as velocity, coordinates of the signature, pressure and others [2], [3], [4], [5]. The static signature, or offline, does not include this type of dynamic information. In offline signatures, the features are extracted from the image after the signature has already been signed [6].

One of the challenges that dynamic signature verification (DSV) has with respect to usability is that there are a series of assumptions made by users. For example, one assumption is that the signatures collected at a usage scenario such as a point of sale terminal on an electronic digitizer pad is equivalent to a DSV application [7]. Due to this assumption, DSV has the contradiction of being acceptable in these applications, and yet has the perception of a low security ranking when compared to other biometrics [9]. The act of signing has wide acceptance in society [7], in applications from finance [7], and retail transactions [8].

Regardless of perceived security aspects of signature by the public, new and improved multi-use terminals are being introduced by retailers. These multi-use electronic touch screen devices allow for multiple collections of information, from magnetic stripe or smart card information, electronic surveys, collection of loyalty points, and a graphical signature. Over 49% of big retail companies in Europe have looked at signature verification in combination with the purchase of these advanced terminals [10].

An integral part of the signature collection system is the digitizer. The main challenge with all biometrics is the requirement of repeatability of the sample. Specifically, signatures have a number of challenges, not only because of their inherent variability as a behavioural biometric, but because the collection of the signature occurs in many applications and settings [11]. There are a number of variables that impact the performance of the digitizer, as well as the interaction with the sensor and the signer. These variables include the active area of the signature, which can impact how the signer signs, the electronic specifications of the device, the feel and ergonomics, and the physical design of the device. Digitizers come in various designs and specifications, and taking the point of sale scenario as an example, are located at various heights and on various fixtures at the point of sale. Position of the digitizer at the point of sale could require the subject to stabilize it [12].

The active area of the device is important, as it is the area in which the handwritten signature is collected. A longer signature may not fit in the bounds of the active area, which results in a decrease in repeatability. The visibility or lack of visibility of the ink also impacts the signature. The parallax and glare can affect the signature. With parallax, the visibility of the electronic ink may be delayed, potentially causing the signer to delay the presentation of the signature. Alternatively, the signer may not be able to see the signature clearly. Many of the devices that present the ink have different contrasts, some are black ink on a grey background, or are colour. Because of the location of these devices in a number of environments, and the natures of these multi-function sensors require a conflicting set of parameters. Some of these devices may be touch input as well as stylus input (such as entering a PIN versus signing a signature). In some settings they are ruggedized, so that they tolerate the environments in which they are placed, and there could also be glare from the digitizer surface.

The physical design of the digitizer can also impact the performance of the biometric system. For example, many digitizers are used to the pen on paper feel, whereas the surface may appear slippery [13]. The pen is also sometimes tethered to the device by a short piece of plastic, which may impede the process of signing.

Combined with these physical attributes is the ceremony of the signature. Depending on the transaction, the signer may place different emphasis on the signature, and may take more care for one transaction versus another [6]. If the signer is in a hurry, their signatures may have varying levels of sloppiness [13], or if the pen tip is thick and the resolution is poor, the subject may try to clarify their writing by over compensating the clarity of the signature [13].

In this study we aim to assess the donation performance, in terms of being able to actively enrol on a standard signature system, using a range of common capture devices based on various ink feedback technologies. Alongside assessing this performance we also explore reasons for why users prefer particular technologies. These results can inform the capture technology choice with respect to both performance and user acceptance.

## II. METHODOLOGY

The data collection involved three different sensors used to capture user signatures. The first sensor (S1) was a non-backlit digitizer that, when signed with the attached stylus, did not show any feedback to the user. The second sensor (S2) was a backlit digitizer that, when signed with the attached stylus, provided a virtual ink feedback so that the user could see their signature. Unlike the other two sensors, the backlit display sensor allowed the user to clear their signature using a series of menu buttons on the screen and subsequently re-sign if needed. The third sensor (S3) contained a clip so that paper could be inserted and secured over the platen in order to be signed with a ballpoint ink pen. This sensor captured the dynamic aspects of the signature while the paper provided ink-based feedback to the user. Table 1 shows the full specifications for the sensors used in this study whilst Figures 1, 2, and 3 show the three sensors in operation.

TABLE I. SENSOR INFORMATION

| Sensor ID | Type | Platen Size (mm) |
|---|---|---|
| S1 | Non-backlit without feedback | 88.9 x 53.1 |
| S2 | Backlit with feedback | 76.0 x 56.0 |
| S3 | Ink with pen and paper | 88.9 x 38.2 |

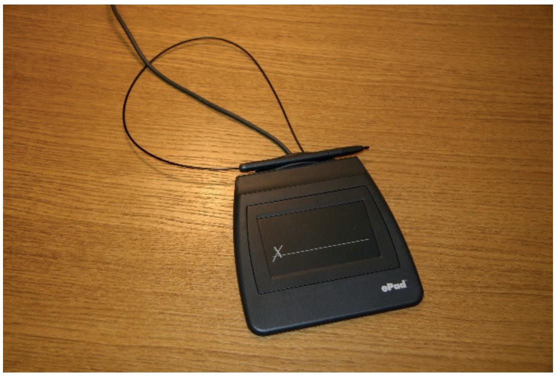


Fig. 1. Sensor 1 (S1) - Non-backlit without feedback

Fig. 2. Sensor 2 (S2) - Backlit with feedback

The study collected signatures from 42 subjects. The objective of the study was for each subject to enrol on each of the three sensors. Signatures were collected using a commercially available biometric signature capture program. For the purpose of the study, we treat the application as a black-box system as we are only interested in the intra-device rather the system performance. The system required the donation of three signatures on a particular sensor all within a particular similarity threshold to enable an enrolment template to be successfully created. Subjects were only allowed one attempt to donate three signatures and enrol on each of the sensors. Sensor signing order was randomized to prevent habituation from occurring. Habituation refers to the familiarity a subject has with the biometric device [14].

Sensors were also randomized in order to prevent signing fatigue from occurring during the course of the collection.

Fig. 3. Sensor 3 (S3) - Ink with pen and paper

After completing the third sensor, subjects were then presented with an electronic survey which asked about their experiences immediately after finishing the data collection. Subjects were surveyed on their handedness, their ability to enrol on each of the sensors, their sensor preference, and the reasons why they preferred a certain sensor. The preference reasons, submitted in the form of free text comments, were subsequently able to be categorised into four primary discussion themes pertaining to visual feedback, familiarity, comfort and ease of use.

## III. RESULTS

Our initial analysis investigated the number of devices that each subject could successfully enrol on. Table 2 shows these results with all 42 subjects, and furthermore, left- and right-handed subjects being considered separately. From these data it can be noted that 52% of the subjects could enrol on all three sensors, with right-handed subjects exhibiting better performance in this regard. No subject failed to enrol on all sensors. With the results generated by a common enrolment engine, these findings confirm that the type of capture device used is critical to the performance and usability of a system.

TABLE II. TOTAL NUMBER OF SUBJECTS WITH SUCCESSFUL DEVICE ENROLMENTS

| | Number of Subjects | | | | | |
|---|---|---|---|---|---|---|
| | **Total** | **3 Sensors** | **2 Sensors** | **1 Sensor** | **Mean** | **Std. Dev.** |
| **All** | 42 | 22 | 15 | 5 | 2.405 | 0.701 |
| **Right-Handed** | 35 | 21 | 11 | 3 | 2.514 | 0.658 |
| **Left-Handed** | 7 | 1 | 4 | 2 | 1.857 | 0.690 |

Recognising the potential effects of a small sample size, it is interesting to note however that only one out of the seven left-handed subjects was able to enrol on all of the sensors. Analysing the difference in performance between the group, there is a significant difference in the number of devices that left- and right-handed subjects could successfully enrol on: Handedness vs. Total Successful Enrols, $t(40) = 2.393$, $p = 0.022$.

Table 3 shows which sensors were used to make a successful enrolment attempt by each group. It can be noted that all subjects (regardless of grouping) could enrol with Sensor 2. 32 right-handed subjects could enrol on Sensors 1 and 2, with the three remaining subjects failing on Sensors 1 and 3. Left-handed subjects had a different profile, with five out of seven subjects failing to enrol on Sensor 1.

TABLE III. SUCCESSFUL ENROLS BY SENSOR

| | **S1** | **S2** | **S3** |
|---|---|---|---|
| **All** | 34 | 42 | 25 |
| **Right-Handed** | 32 | 35 | 21 |
| **Left-Handed** | 2 | 7 | 4 |

There may be a number of different reasons for these failure to enrol rates including the ergonomics of use. Two common errors were noticed on Sensors 1 and 3. On Sensor 1, some subjects accidentally had a 'stray' finger placed on the capture surface alongside the pen and did not notice the placement due to lack of feedback. This would lead to an erroneous recoding of data points. For Sensor 3, subjects believed that sufficient pressure was used if ink feedback was left on the paper. Due to this additional layer of paper over the sensor, additional pressure was actually needed and not all points of the signature was captured.

Exploring the sensor preference of each group, it can be seen in Table 4 that Sensor 2 is clearly favoured which means that most subjects favoured a device that they could successfully enrol on. Three subjects, however, preferred sensors that they did not successfully enrol on; in two of these cases the subject preferred the traditional pen and paper device (Sensor 3) and a single subject preferred Sensor 1 due to ease of use.

TABLE IV. SENSOR PREFERENCE BY TOTAL NUMBER OF SUBJECTS

| | **Sensor Preference** | | | **Able to enrol with preference?** | |
|---|---|---|---|---|---|
| | **S1** | **S2** | **S3** | **Yes** | **No** |
| **All** | 2 | 29 | 11 | 39 | 3 |
| **Right-Handed** | 2 | 24 | 9 | 33 | 2 |
| **Left-Handed** | 0 | 5 | 2 | 6 | 1 |

Analysing the free-text comments for why a signer preferred a particular device it was possible to make clear categorisations relating to the provision of visual feedback, donation familiarity, device comfort and device ease of use. Investigating these categorisations it was possible to explore the key attributes as to the underlying factors for device popularity and selection. Table 5 shows the number of comments made across the comment categories (it was possible for a single subject to make comments on more than one category). It can be observed that visual feedback of ink (either virtual or actual), alongside ease of use, were the primary attributes for choice.

Table 6 explores these data in more detail by examining the reasons for preference within the individually selected devices. Again, low sample sizes should lead to caution, but the underlying messages are that those who preferred Sensor 1 did so uniformly due to ease of use, Sensor 2 due to visual feedback and ease of use, and Sensor 3 for a range of reasons primarily including familiarity.

TABLE V. NUMBER OF COMMENTS RECEIVED FOR REASON OF DEVICE PREFERENCE BY HANDEDNESS

| | Visual Feedback | Familiarity | Comfort | Ease of Use |
|---|---|---|---|---|
| **All** | 29 | 6 | 5 | 17 |
| **Right-Handed** | 25 | 5 | 4 | 16 |
| **Left-Handed** | 4 | 1 | 1 | 1 |

TABLE VI. NUMBER OF COMMENTS RECEIVED FOR REASON OF DEVICE PREFERENCE BY SENSOR

| Sensor | Visual Feedback | Familiarity | Comfort | Ease of Use |
|---|---|---|---|---|
| **S1** | 0 | 0 | 0 | 2 |
| **S2** | 24 | 0 | 4 | 13 |
| **S3** | 5 | 6 | 1 | 2 |

## IV. CONCLUSIONS

There are many key factors which may explain why users prefer different sensors. The first possible reason may be due to personal experience when interacting with the device. The majority (93%) of users preferred a device that they successfully enroled on. In this regard, the backlit sensor with feedback had the highest number of successful enrolments as well as the most user preference choices. Only one left-handed user was able to enrol on Sensor 1 (no feedback) and no left-handed users preferred this sensor. This study also showed that right-handed users had a more successful time enroling on all three of the sensors. 60% of right handed users were able to enrol on all sensors as opposed to only 29% of left handed users. We are unable to draw any broad conclusions on handedness based on only seven left-handed users, however, despite the small sample size, it is important to note that there was a significant difference between handedness and the ability to enrol on all three sensors.

Sensor 3 exhibited the lowest performance among the three sensors. Only approximately 60% of users were able to enrol on this pen and paper device. Despite having the lowest enrolment rate, it was preferred above Sensor 1 due to its familiarity to users. This shows that that a capture environment using this device needs to assist uses in overcoming issues of non-familiarity in terms of the non-inking feedback and non-paper 'feel' of the writing surface. The use of pen and paper overlaid on a digitizer is something that can be improved on in future development. An ideal sensor should have the success rates of Sensor 2 with the feel and familiarity of Sensor 3, maybe through the use of different surface textures emulating those found on a pen and paper environment.

Building on other recent studies interoperability can also be examined on these different types of sensors investigating if users are able to enrol on one sensor and then subsequently verify on that template on a different sensor. By determining which devices are most interoperable may allow systems integrators to select digitizer pairs to ensure a balance between biometric performance and signer acceptance. Currently, certain aspects of digitizers may adversely affect the performance of biometric systems. For example, the usability flaws such as a lack of visual feedback, or lack of familiarity will prove challenging for some users. In order to establish interoperable results, aspects such as these will need to be considered and improved on.

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## REFERENCES

[1] V. Nalwa, "Automatic on-line signature verification," Proceedings of the IEEE, vol. 85, no. 2, pp. 215–237, 1997.

[2] 2. J. G. A. Dolfing, E. H. L. Aarts, and J. J. G. M. van Oosterhout, On-line signature verification with hidden Markov models, vol. 2. Brisbane, Australia: IEEE Comput. Soc, 1998, pp. 1309–1312.

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

[4] 4. C. O'Reilly and R. Plamondon, "Development of a Sigma–Lognormal representation for on-line signatures," Pattern Recognition, vol. 42, no. 12, pp. 3324–3337, 2009.

[5] 5. G. Rigoll and A. Kosmala, "A systematic comparison between on-line and off-line methods for signature verification with hidden Markov models," in Proceedings. Fourteenth International Conference on Pattern Recognition (Cat. No.98EX170), 1998, vol. 2, pp. 1755–1757.

[6] 6. S. J. Elliott, "Differentiation of Signature Traits vis-a-vis Mobile-and Table-Based Digitizers," ETRI Journal, vol. 26, no. 6, pp. 641–646, 2004.

[7] 7. L. a. Jones, A. I. Antón, and J. B. Earp, "Towards understanding user perceptions of authentication technologies," in Proceedings of the 2007 ACM workshop on Privacy in electronic society - WPES '07, 2007, p. 91.

[8] 8. C. Hozanne, "The future of biometrics in retail," Biometric Technology Today, vol. 2012, no. 6, pp. 5–7, Jun. 2012.

[9] 9. A. Oermann, C. Vielhauer, and J. Dittmann, “Sensometrics: Identifying Pen Digitizers by Statistical Multimedia Signal Processing,” 2007, vol. 6507, p. 65070I–65070I–12.

[10] 10. T. McCool, “Biometric technology and electronic signature devices,” Biometric Technology Today, vol. 2012, no. 9, pp. 7–8, Oct. 2012.

[11] 11. C. Rabasse, R. Guest, and M. Fairhurst, “A method for the synthesis of dynamic biometric signature data,” Proc Ninth International Conference on Document Analysis and Recognition, vol. 1, pp. 168–172, 2007.

[12] 12. K. S. Wilson and T. R. Callaghan, “Handheld Computer Terminals: Starting off Right the First Time,” Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 38, no. 5, pp. 355–359, Oct. 1994.

[13] 13. J. L. Snowdon, “Pen Computing : Challenges and Applications.” New York, 2003.

[14] 14. International Organization for Standardization (ISO)., “Information technology – Biometric performance testing and reporting – Part 6: Testing methodologies for operational evaluation. ISO/IEC FCD 19795-6.2,” 2011.