A Survey of Forensic Handwriting Examination Research in Response to the NAS Report

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Abstract. Advances in technology and scientific development in forensic handwriting examination (FHE) require a review in response to the challenges published in the NAS Report. This survey summarizes the advances made in theoretical and methodological approaches to handwriting examination including a review of research on the proficiency of FHEs. Technology has impacted FHE including analysis of e-signatures and use of technology for signature and handwriting authentication. A review of legal cases in the U.S. confirms how research and technological advances have met legal challenges and impacted decisions in the courtroom.

1. Introduction

In 2009, the NAS Report challenged the forensic sciences in several areas including forensic handwriting examination (FHE). Specifically, the NAS Report stated that the "scientific basis for handwriting comparisons needs to be strengthened…there has been only limited research to quantify the reliability and replicability of the practices used by trained document examiners" (p. 5-30). In the report there was discussion about the variability of handwriting. To determine if those challenges have been addressed by recent research, a literature review of FHE research for the time period 2009-2014 was conducted using Google Scholar, journal databases, and specific journals pertaining to forensic science. Publication information was extracted and organized according to subject themes that are relevant to FHE. A comprehensive review of the state of the art in FHE over the past 10 years will be published separately. This paper is a condensed survey of FHE research in response to the NAS Report and a review of U.S. legal decisions related to FHE challenges.

2. Handwriting Examination: Theory, Proficiency, and Methods

1. Theory. Definition of a complexity theory for handwriting began in 1996 with publications of the work of Drs. Bryan Found and Doug Rogers, then at LaTrobe University in Australia. There has been work on this topic since 2009 by Alewijnse et al. (2011) and Pepe et al. (2012). Continued refinement of the complexity theory supports scientific methodology in the evaluation and comparison of handwriting.

2. Proficiency. Several studies discuss the expertise of FHEs and proficiency testing, all related to the identification of handwriting authorship. Proficiency in evaluating disguised and simulated signatures and/or handwriting was researched by Bird et al. (2010, 2011, 2012) and Al-Musa et al. (2010). Guest et al. (2011) studied the inferences made by FHEs regarding handwriting dynamics as indicators of accuracy. The nature of FHEs authorship opinions was evaluated over a five year period of blind validation trials (Found & Rogers, 2008). Dewhurst et al. (2014) looked at the effects of motivation on the behavior of lay subjects when participating in handwriting trials. Holmes et al. (2011) discussed the use of online proficiency testing, as compared to more traditional methods of testing. The research in this area continues to inform us as to the proficiency of FHEs and helps to target problematic areas that can be corrected by training and testing.

3. Handwriting Features and Variability. There is a considerable body of recent research on handwriting features and variability which increases the information we have concerning inter-writer and intra-writer variability and handwriting individuality lending support for the scientific basis of handwriting comparison.

Research was found on handwriting features of special populations representing languages, special groups, etc. (Durina, 2009; Haddad et al., 2009; Turnbull et al., 2010; Al-Musa & Platt, 2011; Savoie, 2011; Al-Hadhrami et.al., 2014). Factors influencing handwriting included studies on writing position and conditions (Equey et al., 2007; Sciacca et al., 2011). A study on handedness, age, and gender was carried out by Hayes et al. (2009). Simsons et al. (2011) studied the effects of spatially constraining signatures. Studies associated with simulation and disguise were carried out in order to understand processes and obtain handwriting feature predictors (Al-Musa et al., 2013; Al-Musa & Platt, 2011; Cadola et al., 2013; Bird et al., 2013; Mohammed et al., 2014; Caligiuri et al., 2012). Specific features were researched including evaluation of letter shapes (Marquis et al., 2011) and inferring speed from writing (Will, 2012). The handwriting variability associated with electronic signatures and the dynamic features that can be examined from them was reviewed by Flynn (2012) and Nicolaides (2012). A methodology for electronic signature examination was developed by Harralson (2013).

The influence of health on handwriting production is another handwriting variable that has received considerable research attention. Cognitive impairment, dementia, mental and developmental disorders and their

effects on handwriting were researched by Balistrino et al. (2012), Caligiuri et al. (2014), Prunty et al. (2014), and Schwid & Teulings (2013). Kinematic studies examined handwriting features associated with healthy adults, movement disorders, and forgery (Harralson et al., 2008; Caligiuri & Mohammed, 2012; Caligiuri et al., 2014). Sadreddin (2013) reviewed the impact of DBS on daily motor activities, including handwriting.

4. Replicability and Reliability. In quantifying the replicability and reliability of handwriting, there has been research into the application of likelihood ratios in handwriting examination. Specifically, Marquis et al. (2011) applied multivariate likelihood ratios to evaluation of the shape of handwritten characters and studied the Bayes factor of assessment of handwriting features. Davis et al. (2011) studied subsampling to estimate the strength of handwriting evidence. Application of likelihood ratios for handwriting evidence was studied by Marquis et al. (2011), Hepler et al. (2012), and Taroni et al. (2012; 2014). In critiquing the reliability of FHEs in the application of methods, Reinoud et al. (2013) discussed procedural changes needed to counter bias among FHEs and Found & Ganas (2013) studied the management of domain irrelevant context information in FHE casework.

3. Handwriting Examination Technology

Extensive published research exists on developments in signature verification which supports research into the replicability and reliability of handwriting. A survey of computer methods in FDE was previously explored by Srihari & Leedham (2003). Automated handwriting examination systems such as FISH and WANDA (Franke et al., 2004) and CEDAR-FOX (Srihari et al., 2005, 2007; Owen, 2013) rely on handwriting databases, enable automated examination features, and produce statistical analyses. FISH and WANDA were designed to help automate the handwriting examination process and increase efficiency through the computerized ability to scan, digitize, measure, store, and compare handwriting samples. Automatic feature extraction is based on the premise that it is the combination of unique characteristics that establishes handwriting identification; one feature alone is not sufficient to establish identification. The FBI, through the coordinated efforts of scientists and computer engineers, developed the Forensic Language-Independent Automated System for Handwriting Identification (FLASH-ID) (Sciometrics, LLC, 2014). Although not meant to replace FHEs, computerized methods of analysis aid in establishing statistical support for forensic opinions.

Research using computational methods to quantify the individuality of handwriting has been explored more recently by Saunders et al. (2011). The role of automation in handwriting examination was discussed and illustrated through a case study by Srihari & Singer (2014) in a way that synthesizes the role of the human expert with the computational ability that automation provides in offering statistical analysis. Essentially, automating some of the work carried out by human examiners offers efficiency in case load especially when there is a large volume of documents requiring analysis. Automation also operationalizes the process providing efficiency, reliability, and standardization in forensics. Other studies involving automation included Liwicki (2012), Parodi et al. (2014), Parziale et al. (2014), and Putz-Leszczynska (2012, 2014) who studied various aspects of online verification. Malik et al. (2014) compared the signature verification performance of humans versus machines.

Experimental eye-tracking is a technologically novel way to learn about FHE cognition. An eye-tracking study found that FHEs spend more time examining model signatures than forged signatures, and that genuine signatures with a higher degree of complexity also had longer observation times than signatures with low complexity (Pepe et al., 2012). These studies may have future relevance in developing technology that can be linked to the computer in evaluating handwriting, especially in programming software that evaluates handwriting similar to the way a human examiner evaluates handwriting.

4. Legal Review

Recent court decisions continue to interpret the *Daubert* requirement of reliability in assessing new scientific and technological developments. Standardized methods developed by independent laboratories continue to confer legitimacy when used to develop new technologies (*City of Pomona*, 2014). Thus, the traditional "battle of the experts" is an element given to the weight of evidence by a jury, and should not be excluded pre-trial by the judicial officer. The existence of scholastic disagreement is an appropriate courtroom debate, and was the reason why opponent's argument of a relatively small a reference database in *Pomona* was insufficient objection for the Court to question technological reliability solely based unknowns in the potential rate of error. Pre-trial challenges to expert testimony are overcome when the testimony is shown to be reliable and helpful to the jury, not "whether the expert is right or wrong" (*City of Pomona*, p. 13).

Where technology is "novel and untested," case law has affirmed the exclusion of evidence (*Tyson*, 2009). The exception appears to be government investigative software, as courts are hesitant to permit public disclosure (*Chiardio*, 1st Cir. 2012). FBI investigative innovations were excused from peer review (*Chiardio*, p. 278). Similarly, selective application of some, but not all, potential factors into a structured analysis amounts to a "disagreement over, not an absence of, controlling standards [and] is not a basis to exclude expert testimony" (*Pomona*; see also *Tampa Bay*, 11th Cir., 2013). The District of Columbia Court of Appeals has similarly

reasoned that "scientists significant either in number or experience must publicly oppose a new technique or method as unreliable before the technique or method does not pass muster under *Frye*" (*Pettus*, 2012).

The *Herrera* opinion, penned by the learned Judge Posner, provides that handwriting expert evidence "doesn't have to be infallible to be probative" (*Herrera*, 7th Cir., 2013). Also from the Seventh Circuit: "Law must apply itself to the life of a society driven more and more by technology and technology improvements" (*Lapsley*, 2012). The courts have previously recognized that "experience is the predominant, if not sole, basis for a great deal of reliable expert testimony" (*Jones*, 6th Cir., 1997; see also 2000 Advisory Comment to Fed. R. Evid. 702). The use of cutting edge tools in conjunction with an expert's independent confirmation of system accuracy is therefore generally admissible evidence to support the expert's testimony and ultimate professional opinion.

5. Conclusion

A review of the research published over the past few years clearly shows that there has been a response to the challenges presented in the NAS Report. Prior research established that FHEs are more skilled than laypersons. However, recent research is instructing us as to the limitations that FHEs demonstrate concerning problematic areas and where further training and testing is required. Published research shows that FHEs are addressing concerns regarding handwriting variability, reliability, and replicability. Methods have been refined that incorporate advancing technology and research. A legal challenge to use of handwriting evidence in the courtroom, based on criticism from the NAS Report, was successfully defended (*Pettus*, 2012). While continued research work is necessary in all forensic disciplines, especially in the face of technological advances, published research since 2009 clearly shows that the scientific basis for handwriting comparison is being addressed through research, application of advanced technology, improved methods, and in the successful rebuttal of legal challenges.

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