FINGERPRINT IDENTIFICATION: POTENTIAL SOURCES OF ERROR AND THE CAUSES OF WRONGFUL CONVICTIONS

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ABSTRACT
Fingerprint identification has long been used by law enforcement to either identify or eliminate potential suspects in a case. It relies on friction ridges – the upraised skin that forms grooves on fingers – and friction ridge impressions, which form from natural secretions of sweat and other trace components. Latent prints, a common term for friction ridge impressions, have many benefits and advantages as a type of forensic evidence. However, they are not a perfect tool: wrongful convictions identified by post-conviction DNA testing and the re-evaluation of forensic evidence have spawned criticism and investigation into the scientific basis of this branch of forensics. This literature review examines literature in both the scientific and legal fields, and investigates three main themes: the principle of uniqueness assumed in individualization, the presence of cognitive bias and human error in analysis, and the changing role of expert testimony in court. There are arguments both for and against uniqueness, but it is still difficult to prove using statistical models and data analysis. Bias in examiners, on the other hand, undeniably exists in different ways, and should be actively guarded against in fingerprint analysis and expert testimony. Expert witness testimony that misleads, exaggerates, or is scientifically unsupportable has been linked to wrongful convictions in the past, highlighting the importance of careful regulation of how an expert witness is advised to testify. In addition to these topics, the techniques of collecting latent print evidence and the standard procedures of analysis have also been examined and evaluated for potential sources of error.

INTRODUCTION
Latent print evidence has been used as a means of identification for almost a century and has played a major role in convictions across North America (van Dam et al., 2016; Cole, 2007). With efforts from policeman Edward Foster (1863-1956), remembered as the “Father of Canadian Fingerprinting”, an Order
of Council was passed on July 21, 1910, authorizing the use of the first fingerprint system in Canada (Lee and Ramotowski, 2001). After nearing a decade of operation, the Canadian bureau, headed by Foster, had received over 11,000 sets of fingerprints that led to 1,000 identifications (Lee and Ramotowski, 2001). This number grew drastically as time went on: by 1959, approximately 220,000 sets of fingerprints had been received in total (Lee and Ramotowski, 2001). A few of the earliest uses of latent print evidence in the United States of America occurred during the same time period, in 1910 and 1911 (Cole, 2001). In one Chicago murder trial, fingerprint identification successfully led to the conviction of the murderer. In another New York City burglary case, the thief confessed to the crime after his fingerprints were found on glass at the scene of the crime (Cole, 2001).

However, amongst the successes of fingerprint identification in court, several wrongful convictions – one of the most famous being the conviction of Brandon Mayfield in the Madrid bombing case (Stacey, 2004) – have spawned investigation from multiple sources into the reliability of latent print evidence and the accuracy of fingerprint examiners (Dror, 2013; Kassin, 2013; Saks, 2010; Ulery et al., 2011). Some of these investigations have commented on a lack of up-to-date research, calling for more studies on latent print evidence to establish a firmer scientific and statistical basis behind fingerprint identification and to collect data on the factors that could influence latent print examiner error rates (National Research Council, 2009; van Dam et al., 2016; Saks, 2010). Other investigators have focused on the issues associated with collection of latent prints and fingerprinting techniques (Ulery et al. 2011, van Dam et al., 2016).

The inherent disadvantages of latent print evidence, in addition to the flaws caused by human error, can be found at various steps in the process of analyzing latent prints from the scene of a crime (National Research Council, 2009; Expert Working Group, 2012). Development of latent prints could, for example, negatively impact the quantity and quality of DNA information available from the print (Kumar et al., 2015). Furthermore, the disadvantage of latent prints often being smudged or only partially formed presents challenges to latent print examiners in making comparisons (Kumar et al., 2015). During transport, it is possible for fingerprint evidence to be contaminated, lost, or damaged (van Dam et al., 2016). Additionally, cognitive bias from examiners could interfere with their judgement when making an analysis (Expert Working Group, 2012). During the presentation of evidence to the court, misleading or exaggerating terminology could interfere with the understanding of the jury (Saks, 2007). In this review, these potential downfalls of fingerprint identification are explored and compared to certain notable wrongful convictions in order to observe common patterns, with the goal of evaluating the value of latent print evidence in criminal investigations.

COLLECTION AND ANALYSIS PROCEDURES

Latent print examiners (LPE) can classify their observations as first level, second level, or third level detail (Ashbaugh, 1999). First level detail encompasses the overall shape of the print, e.g. whorl, loop, or arch, and can be analyzed statistically for rarity in a given population (Ashbaugh, 2009; Saks, 2010; Ulery et al., 2011). Some of these investigations have commented on a lack of up-to-date research, calling for more studies on latent print evidence to establish a firmer scientific and statistical basis behind fingerprint identification and to collect data on the factors that could influence latent print examiner error rates (National Research Council, 2009; van Dam et al., 2016; Saks, 2010). Other investigators have focused on the issues associated with collection of latent prints and fingerprinting techniques (Ulery et al. 2011, van Dam et al., 2016).

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The Collection and Quality of Evidence

Latent print examiners make identifications by comparing latent prints, the friction ridge impressions left on objects by physical contact, to exemplar prints, which are collected in a controlled environment by
Latent print examiners face many challenges in analysis due to the varied quality of latent prints, with different prints posing unquantifiable levels of difficulty for an examiner (Ulery et al., 2011). Due to the extensive variation in the features from a print, an examiner's experience and judgment must direct them in making a conclusion (Ulery et al., 2011). Issues that a latent print examiner might face include only having a partial print to compare to the exemplars, or being given smudged and distorted prints to analyze (Saks and Faigman, 2008; Ulery et al., 2011). The latent prints could also overlap with other prints (Ulery et al., 2011), or be found on a surface where the difficulty of collection is greater (van Dam et al., 2016). It is also possible for a print to become distorted as it is made, influencing distances or angles between two traits on a latent print to misleadingly differ from an exemplar (National Research Council, 2009). The potential variability of surface – porous, non-porous, coloured, etc. – has also been identified as an obstacle for past studies on error rates of latent print examiners, which have typically used latent prints placed under controlled conditions on an appropriate or lower-difficulty surface (van Dam et al., 2016). In addition to this, two prints from the same source can appear different due to environmental influences or factors such as pressure distortion (Thompson and Cole, 2007). To make an individualization, examiners do not determine if an exemplar print is identical to a fingermark, i.e., exactly alike in details without any dissimilarities, but rather whether or not they come from the same finger source, where they may have explainable dissimilarities (Cole, 2007). Saks argues that it is impossible to identify an individual “to the exclusion of all others in the world” with a 100% certainty, instead suggesting that a more reliable usage of fingerprint evidence is in eliminating potential suspects from a pool of possible individuals (Saks and Faigman, 2008). A 2006 Federal Bureau of Investigation (FBI) Committee Review identifies quality issues of latent prints as a fundamental problem in the scientific basis of friction ridge analysis (Bruce Budowle et al., 2006).

Other Information from Latent Prints

Along with the physical patterns seen in latent prints, DNA in latent prints has become another means in which latent print evidence can be useful (van Dam et al., 2016). DNA in prints can be used to identify a variety of traits about the print's source, including race, hair colour, eye colour, or even height, with the key restriction that there must be sufficient traces of DNA available from the print for analysis (van Dam et al., 2016). Other components of fingerprints can provide information on the gender, blood type, or recent actions of the source as well, although the possibility of contamination could induce false positives (van Dam et al., 2016). There is still a lack of research into the different traits that can be identified from latent prints through their components instead of physical patterns (van Dam et al., 2016). However, van Dam suggests that advancements in technology would be necessary to give the DNA aspect of fingerprint identification more scientific support (van Dam et al., 2016).

Standard Analysis Procedures

Beyond the physical quality of the latent print being compared to the exemplar, some criticism has risen over the scientific basis of the procedure followed by latent print examiners (Saks and Faigman, 2008). A standard set of steps followed by forensic examiners in many branches, including fingerprint identification, is ACE-V: analysis of the quality/quantity of details under magnification, comparison to the potential sources and exemplar prints, evaluation and final conclusion, and verification by other examiners (Saks and Faigman, 2008). In their 2009 Report, the National Research Council notes that unlike DNA, this procedure has not been standardized due to the high variation in latent prints – each set of print will have different features that are more noticeable and therefore more suitable for comparison, and an examiner must decide this using their training and experience (National Research Council, 2009). United States Judge Susan Souder calls the standard technique of fingerprint identification “subjective, untested, [and] unverifiable” (Koppl, 2010), and
Commentators on fingerprint identification often criticize the “lack of scientific rigour in methodology” employed by latent print examiners (Broeders, 2006). Even the use of large databases, such as the Automated Fingerprint Identification Systems (AFIS), involve some subjective element of identification when inputting features to search (National Research Council, 2009). Law enforcement generally rely on the experience and training of a qualified fingerprint expert to make their final judgments and interpretations in criminal cases (National Research Council, 2009).

**THE SCIENTIFIC BASIS OF INDIVIDUALIZATION**

The concept of ‘uniqueness in nature’ is core to the principles of fingerprint examiners (Page et al., 2011). Applied to fingerprint identification, it is the argument that no two fingerprints in the entire world are exact duplicates (Page et al., 2011). However, some criticize the unsupported nature of the principle: FBI forensic scientist Bunch observes, “There is no rational or scientific ground for making claims of absolute certainty in any of the traditional identification sciences” (Saks, 2010).

*Arguments For and Against Uniqueness*

Opinions conflict on the topic of uniqueness in fingerprints, with opposing arguments on whether or not it is a scientifically reliable principle (Peterson et al., 2009; Saks and Faigman, 2008). Some articles conclude that individualization is supported by biological theories of uniqueness and permanence, probability modeling, and the large precedent of experience from a century of usage (Peterson et al., 2009; SWGFAST, 2003). Another view focuses on the logical conundrum of confirming that every print in the world is unique, further criticizing the reliance on experiential evidence (Saks and Faigman, 2008). Thompson discusses the formation of fingerprints in support of individuality: an individual’s fingerprints are developed during the embryonic stage, where they are exposed to theoretically infinitely variable conditions of temperature and pressure (Thompson and Cole, 2007). Theoretically, therefore, they are of infinite variability themselves (Thompson and Cole, 2007). This applies in the case of identical twins as well: friction ridges may be very similar between twins, but ultimately they have still consistently been found to be unique (Ashbaugh, 1999). In later life, friction ridges can be physically changed by cuts, diseases, surgical procedures, or acid-burning (Koppl, 2010), but otherwise are assumed to be permanent until death (National Research Council, 2009). Support for the premise of uniqueness can be summarized by the three foundations of friction ridge identification given by Ashbaugh: friction ridges are definitively developed at birth, friction ridges remain constant throughout life excepting permanent scar damage, and friction ridge patterns exhibit minute details that are unique and not duplicated between any two prints (1999).

Galton was one of the first to conduct original research into the uniqueness and permanence of fingerprints, reaching a conclusion that supported uniqueness in fingerprints (Galton, 1892). However, his conclusions were met with initial criticism as early as 1930 (Roxburgh, 1933). This criticism questions Galton’s final conclusion, in which he first estimates the frequencies of ridge details without experimentally verifying the values, and then calculates the probability of two individuals sharing the same print attributes from these estimations (Page et al., 2011). The National Institute of Justice in the United States made a solicitation for more research to support fingerprint evidence, but generated controversy after allegedly postponing the request until a large case, United States v. Mitchell, had concluded (Giannelli, 2008). Critics of the assumption of uniqueness characterize the arguments supporting the principle as resting on inductive reasoning and anecdotal evidence, lacking logical or scientifically-based support (Page et al., 2011; Saks, 2010). Efforts to calculate the likelihood of uniqueness based on statistical models must be very careful to avoid unrealistic assumptions made in order to fit a formula, and non-representative or non-random sample populations (Page et al., 2011). The distribution model used in studies analysing population data has also been marked as a problem in past studies as well: the commonly held assumption that there is an equal probability for any individual to have a particular trait was disproved for fingerprints in the late 1980s (Stoney, 1988). The ‘50-K fingerprint
study', as it is commonly referred to, also investigated uniqueness in prints for the same case mentioned above, United States v. Mitchell: the study compared 10,000 fingerprints of the same type of finger and the same basic ridge pattern in order to assess uniqueness of prints, but was criticized for making faulty assumptions about the distribution of their data when creating statistical models (Page et al., 2011).

Statistical Analysis of Fingerprint Data

Statistical analysis of fingerprints is also extremely problematic due to a lack of data. Thompson estimates there are 50 to 60 billion fingers, and therefore potential prints, in the world, making an accurate assessment of the likelihood of duplication extremely difficult (Thompson and Cole, 2007). It is important to note that some statistical models suggest a high level of variability in prints, suggesting a low probability of exact duplication (Thompson and Cole, 2007). When a latent print examiner testifies 100% certainty in an individualization in court, critics of the method note that there is no support towards their assurance from the statistical significance of the number of correlating traits found, as there is insufficient data to analyse (Saks and Faigman, 2008) (Thompson and Cole, 2007). Forensic scientist David Stoney remarked on the topic, “From a statistical viewpoint, the scientific foundation for fingerprint individuality is incredibly weak” (Thompson and Cole, 2007).

HUMAN ERROR IN ANALYSIS: COGNITIVE BIAS, ERROR RATES, AND EXAMINER QUANTIFICATION

Examiner Bias and Subjective Judgment

Beyond the arguments surrounding uniqueness in fingerprints, forensic identification is also under criticism for the examiners’ susceptibility to bias, an especially large issue when their experience and judgment are imperative in analysis (Thompson and Cole, 2007). The Interpol European Expert Group on Fingerprint Identification (IEEFGI) claims that latent print examiners do not rely on subjective opinion (Thompson and Cole, 2007), but the National Research Council conclude that bias is difficult to avoid in experience-based judgements (National Research Council, 2009).

Examiner bias can manifest itself in several ways. Prosecutorial bias occurs when a latent print examiner is biased towards the position of the prosecution in their testimony (Broeders, 2006). Contextual bias can present itself when emotionally stimulating photos or details are released to latent print examiners involved in a violent case (Thompson and Cole, 2007). Finally, cognitive/confirmation bias occurs when an examiner’s opinion on evidence is swayed by the knowledge of another expert’s conclusion or their preconceived expectations for the outcome (Peterson et al., 2009; Expert Working Group, 2012). A reliance on the subjective judgement of forensic experts must be acknowledged to help reduce miscarriages of justice (Broeders, 2006; Saks and Faigman, 2008). Nor does the use of pattern-searching software and large databases, such as the AFIS, entirely remove bias – latent print examiners must determine which features should be entered in the search, or excluded if a certain trait’s inclusion could skew results (National Research Council, 2009). There is also a lack of information on the frequency data of traits in a large population, meaning latent print examiners cannot provide accurate probabilities of the appearance of certain features in support of their conclusions (Saks and Faigman, 2008). Thompson also points to this as a cause of the lack of scientific basis in individualization, highlighting the need for knowledge about the rarity of ridge details or combinations of ridge details in order to make a latent print examiner's estimations (Thompson and Cole, 2007).

Latent Print Examiner Accuracy and Error Rates

There has also been research into the accuracy of fingerprint examiners. In 1973, Bar-Hillel identified human tendency to underestimate the likelihood of two disparate events to occur, thereby leading to potentially hasty conclusions of uniqueness and individualization by forensic examiners (Thompson and Cole, 2007). In more recent times, Dror et al. conducted a study in 2006 where fingerprint examiners were unknowingly given evidence from their past
cases, to compare their consistency in judgment (Saks and Faigman, 2008). After being informed that other examiners had already made a certain conclusion, 80% of the examiners reached a different conclusion from their initial judgment (Saks and Faigman, 2008; Saks, 2010). A different study had 169 latent print examiners compare approximately 100 pairs of latent and exemplar prints from a pool 744 pairs (Ulery et al., 2011). The results of the study showed a false positive rate (FPR) of 0.1%, a false negative rate (FNR) of 7.5%, and a major or complete reduction of each respective error when blind verification was made (Ulery et al., 2011). Another trend observed was frequent disagreement on whether or not a print had sufficient information to make a match (Ulery et al., 2011). Saks’ criticism of the verification stage of ACE-V stems from his claim that blind verification is not always conducted (Saks and Faigman, 2008); however, SWGFAST’s most recent publication on blind verification states that blind verification can be used during any part of the ACE-V process for quality assurance, and should unquestionably be used in cases with highly emotionally-charged material (SWGFAST, 2012). Saks highlights the lack of research on factors that could increase or reduce the error rate of fingerprint identification as a general issue of its scientific credibility (Saks and Faigman, 2008). This sentiment appears again in an FBI committee conclusion that friction ridge analysis could be improved by determining the error rates of latent print examination and the sufficiency of latent prints (Peterson et al., 2009).

Examiner Qualification and Training

Latent print examiners have no universally accepted standard for measuring skill in experts, although such a test would ideally quantify an examiner’s standard false positive and false negatives rate (FPR and FNR) compared to their true positives and true negatives rate (TPR and TNR), in addition to the value of individualization/exclusion (VID/VEO; Ulery et al., 2011). The most essential claim of the latent print examiner – that they can accurately identify a person based on their fingerprint – has never been formally validated in a study, according to Thompson (Thompson and Cole, 2007). It is vital that courts have evidence of capability from latent print examiners who testify, particularly since both a judge’s ruling and another latent print examiner’s verification cannot guarantee a mistake was not made in an identification (Cole, 2007). Efforts to collect data on error rates of latent print examiners include the Collaborative Testing Services (CTS) proficiency tests and a study from Wertheim et al., on the accuracy of trainee fingerprint examiners (Cole, 2007). Both tests have been criticized for issues in set-up, although the CTS claim the test was never intended to measure accuracy across the field (Cole, 2007). Cole suggests that an acceptable test of a latent print examiner’s accuracy should control the creation of the latent print and take into account the factors that could influence results: information given to the latent print examiner, the quality of the prints, the number of prints found, or any other situational influences that would increase the difficulty of the prints being examined (Cole, 2007). There have also been attempts in the past to establish programs of certification, such as from the International Association for Identification (IAI) (National Research Council, 2009). A latent print examiner could expect up to 3 years of training to qualify to work on independent cases (National Research Council, 2009). An FBI committee offered three suggestions for increasing examiner proficiency: creating a national latent print examiner school, establishing federally based latent print training, or beginning a university-based latent print training program (Peterson et al., 2009).

WRONGFUL CONVICTIONS

In the past, there have been several attempts to estimate the error rate of the “soft” forensic sciences by collecting and analysing every instance of a wrongful conviction involving forensic testimony (Cooley, 2007; Garrett and Neufeld, 2009). Though sound in theory, this enormous task poses several challenges: despite the long history of forensic evidence in court, and the almost equally long history of wrongful convictions based on forensic testimony (Cole, 2005), there is no universally accepted way of collecting, recording, and archiving cases of wrongful convictions for analysis (Cole, 2005). It is highly difficult to assert that every known and publicized case of a wrongful conviction represents every wrongful conviction that has ever
occurred (Cole, 2005). As research advances DNA technology, even more wrongful convictions may be identified in the future (Cole, 2005). This makes it highly difficult to calculate an accurate error rate of fingerprint identification (Cole, 2005), and virtually impossible to state how often invalid forensic testimony is presented (Garrett and Neufeld, 2009).

Identifying Wrongful Convictions

In general, there are two basic ways a wrongful conviction can be identified. The first, post-conviction DNA testing, began to make an impact on forensic science during the 1980s (Garrett and Neufeld, 2009). As of 2009, 232 people had been exonerated through post-conviction DNA testing, sometimes – as with the case of David Milgaard – for convictions that had occurred years in the past (Garrett and Neufeld, 2009). The second way a wrongful conviction can be identified is through the re-evaluation of forensic evidence, deemed by Cole as slightly more problematic since it relies on an assumption of infallibility in forensic experts (Cole, 2005). An example of this is the case of Detective Constable Shirley McKie, who was placed at a crime scene by a print and charged with perjury before being cleared by two leading fingerprint experts two years later (Cole, 2005). Critics of the accuracy of latent print examiners say that the discrepancy in judgements lessens confidence in the re-evaluation of the evidence, citing reasons such as the reliance on infallible judgement of each forensic expert involved, and an assumption that confirmation bias was not a factor (Cole, 2005; Thompson and Cole, 2007).

The Causes of Wrongful Convictions

Several people have made efforts at creating comprehensive lists of wrongful conviction cases for analysis (Thompson and Cole, 2007; Cole, 2005; Cooley, 2007). There have been a few different conclusions on the main causes of wrongful convictions as seen in each source’s analysis. Cooley identifies eyewitness misidentification, false confessions, jailhouse snitches, incompetent defense, and “fraudulent or unreliable forensic evidence” as leading causes (Cooley, 2007). He further includes the conclusions of other academics and professionals, listing “tainted” science, false or misleading expert witness testimony, testing errors and faulty crime lab work, and intentional fraud as frequent causes (Cooley, 2007). The FPT Heads of Prosecutions Committee Working Group created a report on leading causes for wrongful convictions, summarizing their findings with the following five flaws of expert evidence:

- prosecutorial bias or misleadingly presented evidence to support one theory alone,
- evidence presented with exaggerated probative value,
- poorly communicated evidence with excessive jargon and terminology,
- testimony on contaminated or tainted evidence, and
- testimony on evidence reliant on scientifically out-of-date methodologies or evidence reliant on subjective judgments (2004).

Garrett and Neufeld also looked specifically at invalid scientific testimony and found three issues: a misinterpretation or misuse of population data, expert testimony presenting the probative value of evidence without empirical support, and the intentional withholding of exculpatory evidence (Garrett and Neufeld, 2009).

Legal Standards for Forensic Evidence

Forensic evidence is not accepted in court if it does not meet certain standards of scientific basis and support, with specific standards and requirements laid out in Daubert (Daubert v. Merrell Dow Pharmaceuticals, Inc., 1993). There are two basic approaches when it comes to the individualization of fingerprints: European countries will typically set a minimum threshold of corroborating traits, whereas North American standards rely on the individual latent print examiner to judge if they have enough information to accurately testify (Thompson and Cole, 2007; Cole, 2007). Evett comments that given confidence in the competence of each expert, a national numerical points standard is unnecessary (Evett and Williams, 1996). Indeed, minimum standards adopted by different countries do not have any empirical basis, and often differ significantly, for example England and Wales hold a 16-point standard whereas Spain
only requires a 10-point minimum for courts to accept evidence (Cole, 2005).

**Expert Witness Testimony**

It is vital that expert witness testimony have clear outlines on what terminology can be used to avoid misrepresenting the evidence, either by giving it excessive probative value or by misleading the jury regarding the probability that an individualization is accurate (National Research Council, 2009). Solutions to this include guidelines for terminology and jargon that ought to be discarded by latent print examiners in official testimony, which several sources have outlined with a basic similarity (SWGFAST; National Research Council, 2009; Saks, 2007). Other measures that have been suggested in the past include having a judge instruct the jury on the value of the expert testimony (Saks, 2007), or having the expert witness acknowledge exposure to bias in testimony (Dror et al., 2013). Dror et al. observe that although introducing change from tradition can sometimes meet strong resistance, given time new implementations in procedure will become commonplace and accepted as the current standard (2013).

**Examples of Wrongful Convictions**

Brandon Mayfield was wrongfully convicted for the Madrid train bombing case in 2004, after being misidentified by the FBI from a latent print (Stacey, 2004). The Spanish National Police found 8 points of comparison between Mayfield and the latent print, which fell below their national minimum standard (Cole, 2005). FBI examiners found 15 points and concluded that Mayfield was the source of the print (Cole, 2005). Shortly after, the Spanish National Police concluded that the print belonged to a different individual than Mayfield and informed the FBI of their judgement (Stacey, 2004). After the FBI was informed of their error, they conducted a report that noted several significant details about the case:

- the latent print was not of a high difficulty,
- proficiency testing of the examiners was insufficient,
- confirmation bias influenced examiners to find features that were not there,
- no blind verification was conducted,
- the lab culture was not conducive to detecting mistakes (Giannelli, 2008).

The procedure of the examiners, which had them taking visible features in Mayfield’s print and trying to find them in the latent print, contributed to their error (Giannelli, 2008).

Several other cases are also note-worthy, if perhaps less publicized than the Mayfield affair. In 1948, John Stoppelli was convicted for the sale of narcotics based almost completely on a latent print found on an envelope (Cole, 2005). No other evidence linked Stoppelli to the crime, however, he was convicted and served two years before the FBI re-evaluated the print and excluded him as a source (Cole, 2005). In 1997, Richard Jackson was convicted of murder after being identified by a bloody fingerprint left at the scene of the crime (Cooley, 2007). Conflicting judgments were made on the evidence: an investigator with latent print examiner training declared the print an individualization and was verified by two members of the IAI, but two retired FBI examiners testified that there was no match (Giannelli, 2008). The print was the only linking evidence and played a central role in the prosecution (Cooley, 2007). In 2000 the FBI concluded there was not a match and released Jackson (Cooley, 2007).

**DISCUSSION**

The reputation of reliability that latent print evidence carries has been built off a history of almost a century of use by law enforcement as a means of identification (Cole, 2007). However, this reputation is not entirely supported by scientific research, nor by frequency data taken from large, random population samples (Saks and Faigman, 2008). Studies aiming to find empirical data in support or denial of uniqueness have been hindered by faulty assumptions or unrepresentative population sizes (Page et al., 2011). It is important to recognize that although the arguments against uniqueness (Saks, 2007) (Cole, 2005) make a valid point, in that it is virtually impossible to prove that
every fingerprint is unique across the globe, and fingerprint identification can still be greatly useful. In addition to excluding potential people from a smaller pool of suspects, they can also act as further support in a case by identifying a suspect in conjunction with other evidence. However, the debate still stands over whether LPE can testify that they have made an individualization with 100% certainty: without proper statistical data to calculate probabilities, fingerprint examiners can only give relative certainties that are based off their experience and knowledge from past cases (SWGFAST; Saks, 2010).

In terms of wrongful convictions, the examples given here highlight aspects of fingerprint identification that need to be addressed in order to improve the successful use of latent print evidence in court. The potential for error in fingerprint evidence indicates that it is not infallible: latent print evidence, circumstantial by nature, is most effective if used as a single piece of supporting evidence amongst others rather than the sole basis of a prosecution. The common causes of wrongful convictions are seen to include poor legal communication of this potential fallibility, human error, and flaws in evidence analysis. A few authors suggest that education on the role of the expert witness is necessary to remedy this, as well as taking steps to avoid specific terms and jargon while testifying in court (Expert Working Group, 2012; National Research Council, 2009; Saks, 2007). Bias is another area where some have suggested improvements. Simple, undemanding changes can be taken to reduce contextual bias, for example by actively preventing LPE from seeing unnecessarily emotional case details (Dror et al., 2013). Fingerprint identification is continuously undergoing improvements in technology for collection and analysis (van Dam et al., 2016), and in standardizing guidelines for LPE to follow (SWGFAST, 2003).

Taking steps towards meeting the recommendations on analysis procedures, expert witness testimony, and LPE training and proficiency tests as outlined by governmental summary reports will be greatly beneficial towards improving the reliability and accuracy of fingerprint identification (National Research Council, 2009; FPT Heads of Prosecutions Committee Working Group, 2004). Latent print examiners should strive for reproducible results and higher standards of quality assurance, with SWGFAST standards outlining best methods of practice. Fingerprint identification would benefit greatly from more research, into topics such as the collection of DNA from latent prints, the factors that influence error rates of examiners, the statistical basis of uniqueness, and frequency data of print features in large populations. In the collection of fingerprints alone, there is large potential to expand the breadth of information that can be gathered from even an imperfect print. Studying morphological and chemical aspects of prints could be key for determining gender, improved detection of certain organic molecules might increase accuracy in age estimation, and greater knowledge on certain compounds found in gunshot residue and explosive particles could be used in donor profiling (van Dam et al., 2016). Conducting more research into frequency data and statistical analysis of fingerprint identification would also improve upon the accuracy of expert witness testimony and provide scientific support to the conclusions made by LPE.

In spite of room for improvement, as it stands latent prints are nevertheless an extremely valuable form of evidence in a criminal investigation.

CONCLUSION

Latent print evidence is subject to various potential sources of error, at almost every step of the process. The prints could be of low quality during collection, an error could be made during analysis, bias could be influencing the examiner, evidence could become contaminated or lost in a crime lab, or expert testimony could unintentionally mislead a jury. In order to prevent future wrongful convictions, it is important that more research be conducted into latent print evidence with a few goals in mind. Firstly, the development of new techniques in collection and analysis of fingerprint evidence will lead to more information being collected from latent prints. Secondly, studies on large random populations should be conducted in order to establish more accurate ways of indicating probabilities and
likelihoods of conclusions. Finally, analysis of wrongful convictions can be used in many ways, such as in the development of trends that could point to flaws in latent print evidence, or in improvements that could be made by learning from the past. Multiple wide-scale Canadian and American governmental reports have been conducted regarding the questioned scientific basis of forensic sciences, and fingerprint identification features largely in them all. Most significantly, it is important to note that human factors – which have the potential to be reduced or removed altogether by introducing procedures and implementing guidelines – are just as much of a problem as the potential disadvantages to the evidence itself and its scientific support. Fingerprint evidence has a history of success in court alongside its notable failures, but this is not necessarily suggestive of some inherent problem in latent print evidence. Rather, its successes prove how useful it can be when effectively made use of. Research into the history of wrongful convictions has identified that the presentation of testimony is a problem of equal importance as issues with subjective judgements of latent print examiners. Although latent print evidence is not perfect, and by no means infallible, its usefulness in criminal prosecutions is apparent given its long history of success. As a branch of forensic science, it would improve greatly with technological advances and a gain in scientific support through further research into these topics.

ABBREVIATIONS

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<th>Abbreviation</th>
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<tr>
<td>ACE-V</td>
<td>Analysis, Comparison Evaluation, Verification</td>
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<td>AFIS</td>
<td>Automated Fingerprint Identification System</td>
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<td>CTS</td>
<td>Collaborative Testing Services</td>
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<td>FBI</td>
<td>Federal Bureau of Investigation</td>
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<td>FNR/TRP</td>
<td>False Negative Rates/ True Negative Rates</td>
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<td>IAI</td>
<td>International Association of Identification</td>
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<td>LPE</td>
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VEO  Value of Exclusion
VID  Value of Individualisation

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