If the Shoe Fits: Proposing a Randomised Control Trial on the effect of a digitised in-custody footwear technology compared to a paper-based footwear method.

Julie Henderson, Secure Socieites Institute, University of Huddersfield, and Bedfordshire Police

Julie.Henderson@bedfordshire.pnn.police.uk

Rachel Armitage

Director, Secure Socieites Institute, University of Huddersfield.

Abstract

In order to address the issue of footwear capture from individuals arrested for recordable crime, technology has been developed, which is known as Tread Finder. This technology and development was made possible through Home Office Police Innovation Funding. Tread Finder is now a finished product and the technology has been deployed into a North London custody suite. Tread Finder incorporates the use of a 300 dpi scanner and newly developed software enabling capture, assisted coding and automated geographical crime scene searching. This paper sets out the proposal of a Randomised Control Trial to replicate and upscale a previous lab based experiment into a field environment to assess the cost, efficiency and crime solving benefits realised as a result of deploying Tread Finder technology compared with the previous paper based alternative.

Key words: Footwear, Investigation, Technology, Intelligence, Forensic Podiatry

Introduction

The murder of Elizabeth Pullen, in Suffolk Street London, on 29th June 1697 (Old Bailey Online, 2015) was the first recorded case of footwear evidence forming part of the prosecution in the UK. The victim was killed in the larder of her own home, having had her throat slit. An impression of a slipper was left in blood at the scene. The suspect, a French woman, Margaret Martell, was traced and found with property stolen from the victim as well as a bloody slipper. Martell claimed to be innocent but the overwhelming evidence led to her finding of guilt and she was sentenced to death. She finally admitted murdering Mrs Pullen, when standing at the gallows (Old Bailey Online, 2015a).

A less serious case, but nonetheless relevant for it's account of the method used to compare footwear evidence between suspect and crime scene, was a 1765 theft of mutton and veal. The accused, Henry Laurence, was prosecuted in London's Old Bailey on 10th July 1765 (Old Bailey, Online 2015b). The evidence against him was provided by the victim, the butcher, who testified "I put Laurence's foot into the print of the mould in my garden, and it fitted exactly". Laurence and his co-accused were both found guilty.

The very next year, another case of murder was recorded in Kurkcudbright, Scotland, September 1786. The details were recounted in Chambers Edinburgh Journal (Chambers, 1832). In this case, a young pregnant woman was murdered in her cottage. The victim's throat had been slit – and footwear marks observed in the mud indicated the assailants escape route. The Stewart Depute Alexander Gordon made tracings of the footwear at the scene logging observations and crime scene notes in a fashion not dissimilar to

methods employed some 230 years later. Gordon attended the victim's funeral and screened the footwear of every male present, identifying the suspect through unique characteristics from the sole of the shoe.

A record of the tracing has been preserved and Gordon's comments can be seen written on the paper tracing and are cited by Bodziak (2016 p.4) – '3 October 1786 applied to William Richardson's foot and fits it exactly. That is, it fits the soul of this shoe. The nicks agreeing exactly with the heel.' Richardson was duly arrested and following further investigation to refute alibi, trace clothing and establish a motive he was charged with the murder. Richardson was found guilty and sentenced to be hanged. Prior to his execution, he confessed to the murder and directed Gordon to the location of the murder weapon.

These cases demonstrate the power and history of footwear evidence as a means to identify and convict offenders. In the years since these cases, scientific development introducing biometric samples such as fingerprints and DNA, have overtaken footwear as a means to identify and convict offenders. Whilst it is acknowledged that these biometric samples can offer stronger scientific certainty of guilt (Needham and Sharp 2016), footwear evidence can be a key contributor to prosecution cases and its value should not be underestimated (Bodziak, 2016). Dr Edmund Locard, a French pioneer in forensic science defined the 'Exchange Principle', that every contact leaves a trace. This theory was perfectly described by Paul Kirk (1963), cited by Boidziak (2016 p.18):

> Wherever he steps, whatever he touches, whatever he leaves even unconsciously, will serve as silent witness against him. Not only his fingerprints or his footprints, but his hair…..all of these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It cannot perjure itself. It cannot be wholly absent. Only its interpretation can err. Only human failure to find it, study and understand it can diminish its value.

Footwear impressions are left at virtually every crime scene (Smith, 2009; Mikkonen, Suominen and Heinonen, 1996) and can possess unique characteristics sufficient to provide intelligence indicating height, weight, age, sex, gait, socio-economic status all contributing to suspect profiling (Ashley, 1996). As yet unpublished research, currently underway in the US, has provisionally demonstrated links between footwear and gang affiliation. The crime scene impression, combined with prompt seizure of suspect footwear (so as to prevent sole pattern degradation) can provide forensic scientists with greater opportunity to offer expert evidence that the mark left at the scene belonged to the footwear owned by the suspect (Bodziak, 2016 p.4). Despite the prevalence of crime scene footwear impressions, the development of methods to improve outcomes have been overtaken by developments in fingerprint and DNA. Various explanations for this lack of development are offered (Bodziak, 2016): these include logistical and IT barriers, lack of focus on repeat crime, limited resources and training, general lack of

understanding and competing demands. Footwear capture methodology, both at crime scene and in-custody, remain largely a paper based process, similar to that documented by Gordon in 1786. Not only is the paper based method outdated, it is also slow, laborious and expensive. As Professor Kirk alluded to in 1953, it is not the lack of footwear evidence that is the problem, it is the lack of development to improve retrieval (both at crime scene and custody events), coupled with the ability to study and understand this evidence, which has weakened its value.

Work has been undertaken to address the perceived lack of development with a view to developing technology enabling the real-time use of footwear intelligence in criminal investigations. This technology, known as Tread Finder (Henderson, 2015 cited by Bodziak, 2016), has been developed to enable in-custody capture of detained persons footwear samples, assisted pattern matching and evidence based crime scene searching. It is the effectiveness of this technological development of footwear capture, in the custody environment, compared with the paper based business as usual alternative, this research seeks to measure. The question this research seeks to answer is thus; does Tread Finder technology improve efficiency and reduce costs when compared to the paper based alternative?

Figure 1 Demonstration of “walk-on” digital scanner

A review of the literature

Footwear reference collections have been available in a number of countries for many years. Predominantly, these collections were formed to assist crime scene identification of footwear patterns. Some of these collections were formed using paper records and metal filing cabinets as early as 1937 (Bodziak, 2016) and required manual searching. These collections began to transfer to computerised database with the FBI recording this progress in 1981. Other countries have made use of various different types of collections, some computerised, some paper based. Ashley (1996) reported that a computerised footwear classification system was available in the Victoria Forensic Science Centre from 1981, Switzerland began a computerised database in 1990 (Alexandre, 1996), the Netherlands and Finland followed in 1992 (Geradts and Keijzer, 1996; Mikkonen, Suominen and Heinonen, 1996). In 2012, ChoChół and Świętek conducted a basic review

of footwear databases across Europe, concluding that a variety of databases existed in additional countries including Poland and The Czech Republic.

The National Footwear Reference Collection (NFRC) was developed in the UK in April 2009 (Bodziak, 2016). This collection was implemented by a now defunct government organisation known as the National Police Improvement Agency (NPIA, 2007). The purpose was to implement a national coding standard for forensic examiners across the UK. The NFRC was made available to all forces and now contains over 40,000 individual shoe sole pattern types, each with their own designated code. The benefits of this national system include cross-border information sharing and agreed standard of footwear coding (Bluestar Software, 2017). The NFRC is populated with new images appearing either at crime scenes, custody events or shared by footwear manufacturers, and is now one of the largest police owned databases in the world. Building on the success of the NFRC, Bluestar Software were commissioned by the Home Office to develop a National Footwear Database (NFD). This database, again available to all forces across the UK, provides law enforcement the ability to (automatically in some cases) record crime scene and custody event data in one single, national repository enabling intelligence and information sharing amongst all UK police forces.

The development of the NFD in the UK has been the catalyst supporting transformational technology to address the need to improve the way law enforcement captures samples from suspects. This experiment seeks to evaluate the efficiency of this newly developed digital footwear sampling process in a police custody environment.

Needham and Sharp (2016), and Richetelli, Lee, Lasky, Gump and Speir (2017) support the argument for the implementation of a digital acquisition system for footwear capture. These articles, however, focus mainly on the technical requirements of a scanning device and in the case of Richetelli et. al. (2017), provide interesting results from a series of randomly tested (lab based) assisted coding algorithms currently in use across the internationally forensic footwear community. The effectiveness of the Tread Finder pattern matching algorithm has been measured through a field trial over a 3-month period (October 2016 – January 2017) and will be subject of an as yet unpublished descriptive research paper. The data collected over this period formed part of the UK Forensic Regulator's acceptance criteria and was recorded in the implementation phase of Tread Finder. Needham and Sharp (2016) and Richetelli et. al. (2017) add little weight to the research question other than supporting the need for footwear image acquisition using digital methods. That said, Needham and Sharp do draw comparison between the National Footwear Database and the National Automated Fingerprint Identification System (NAFIS).

NAFIS was introduced across the UK in 2001. The technology within custody suites was, and is still known as, Livescan, and improved upon an earlier digital system, the Automatic Fingerprint Retrieval System, first implemented in 1992 (Morgan, Ponikiewski and Dunstan 2004 p.6). There are clear similarities between the introduction of both digitised systems.

Transformational technology within policing, specifically relating to scientific development is discussed by Manning (2003, p.130) as part of a wider debate in his chapter ‘Horizons of Technology’. Manning examines technology implementation and how police culture can create barriers to success as well as proceeding to discuss “Information Technology as a Source of Drama”. Manning (2003 p.173) advocates a close analysis and evaluation of technology innovation in policing in order to avoid abstract political funding decision making based on “dominant institutional clique’s” perceived to be less concerned with measuring effectiveness.

Research design

The research is a Randomised Control Trial to measure the effect of Tread Finder digital footwear technology compared to traditional paper based alternative. Sherman (2010) provided a key source of knowledge in respect of planning and implementation. The experiment commenced in May 2017. A Consort Statement (http://www.consort-statement.org) will be completed at the conclusion of the experiment. A Consort checklist and a Crim-PORT has been completed. A previous lab based ‘pilot’ was conducted in June 2016. This experiment had a small sample size of 50 different footwear patterns and was conducted in a controlled environment. This small RCT allocated treatment and control with the randomisation completed by Dr Barak Ariel. The RCT produced significant results which demonstrated the Tread Finder process was more efficient and cost effective than the paper based alternative. Tread Finder is now deployed in a live custody environment, has been operational since October 2016 and is now embedded as

business as usual in this location. This is an ideal opportunity to repeat the RCT in a field environment, tracking outcomes through the criminal justice process.

Eligibility criteria includes all offenders arrested and taken to the custody suite for a recordable offence. Case flow is easily managed as the computerised custody system automatically submits offender details to Tread Finder. Once the data is received in the Tread Finder Application, randomisation is applied through the Cambridge Randomiser. Treatment is footwear scanned using Tread Finder, control is footwear sample taken using traditional paper based method, manual data input, delivery to forensic practitioner and manual coding.

The experiment will be conducted using one Field Coordinator (Sherman, 2010) who is an embedded, respected member of staff within the custody suite so has a strong social foundation. Forensic practitioners currently supporting footwear development across the region are aware of the experiment. The custody suite concerned is served predominantly by one footwear expert who has a strong working relationship with the Field Coordinator. This expert is aware of the experiment and will support the manual process of paper based samples from the field site. This Field Coordinator also conducted the previous pilot and is considered a subject matter expert in respect of the Tread Finder technology. Experimental hours will be restricted to duty hours of this employee. Beyond these hours, Tread Finder will be used as is normal at this custody suite. Throughout the experiment, carefully consideration must be made in respect of the overall implementation of this

technology. Application of the RCT must not compromise wider implementation activity by involving staff who have already been subject to significant change in process. It is accepted that reducing experimental hours will result in the experiment running for longer in order to obtain the required sample size, however, this decision has been made balancing the overall impact on implementation and long-term sustainability of Tread Finder. The results of the experiment are expected to support the wider need for the technology and therefore compliment implementation.

Treatment and control will be measured on a case by case basis on a pre-agreed excel tracking document. A previous draft of this document was used during the earlier lab based experiment and adapted in view of learning. The document will be formatted to ensure data is standardised simplifying analysis. Weekly reviews of data will seek out anomalies ensuring, through checking IT systems, that the data recorded is a true reflection of the treatment administered. Each case will be recorded either on the treatment or control excel based tracking document and will enable tracking of processing time, crime types, intelligence links, time take for laboratory submissions, custody and long term criminal justice outcomes.

Conducting this research provides an opportunity to capture extra data which can be followed up at a later time (i.e. prosecution case outcomes) and will form the basis for further research. There are slight variatios between the control and treatment group tracking documents. This is necessary as the control group require additional manual

processing such as manual data entry, manual deliver to forensic practitioner and manual coding. Additionally, the generation of an intelligence pack is user driven therefore it is important that this is separately recorded for comparison purposes.

The effect will be measured through time and cost efficiency. Welsh, Farrington and Sherman (2001) emphasise the importance of monetising benefits and this advice is noted. Staff time will be converted to cost in order to fully capitalise on understanding the benefits.

The field site is a large custody suite with an annual population of between six to seven thousand detained persons per year. Based on this population, and on results from the previous lab based experiment, the indications are that there will be a medium effect size. The ideal sample size has been calculated to 128 footwear scans in total, 64 per group. It is anticipated that the RCT in custody will continue for a period of 2-3 months in order to obtain sufficiently large sample size. This aspect of the RCT planning will require a degree of flexibility as case flow numbers cannot be guaranteed nor can competing operational demands be predicted. Weekly reviews by the Principal Investigator will assist demand and resource management and any changes to the experiment design will be recorded and reported upon.

The Police Service involved does not currently have an ethics committee, however, the Evidence Based Policing coordinator has been consulted and raised no experiment design concerns. Ethical and moral considerations have been carefully thought through.

The overriding concern is that of denying a new, effective technology to investigators seeking to bring offenders to justice expeditiously. Any perceived risk to justice is mitigated through oversight from a forensic scientist who is able to request expedition of specific samples that may otherwise have been subject to delay caused by the paper based method. The custody suite chosen was the test site for the development of the technology and so, since October 2014, have had the benefit of a digital footwear scanner. The staff have grown accustomed to the process and may struggle to accept returning to the paper based method. Reducing the impact on wider implementation is key and the mitigation in place is that all staff, with the exception of one Field Coordinator, will continue using Tread Finder technology. The balance to this view is that measuring effect in this way, for a short period of time, will ultimately provide scientifically powerful and unambiguous results (Sherman, 2010) which will support the wider use of the technology impacting on a much greater number of criminal investigations. The ethical conclusion is clear that any perceived risks have been mitigated and the benefit to the wider roll out of technology justifies the experiment to proceed.

A critique of the experiment could suggest a rival explanation for the outcome being the experimental location and staff with previous exposure to an earlier prototype version of Tread Finder therefore, the alternative paper based method may not be processed as efficiently as elsewhere due to a knowledge gap or system failings. This has been considered and mitigated against. All staff have the benefit of the same online training package, which clearly instructs staff to revert to paper based method in the event of

Tread Finder or wider system failings. The training is standardised and available through the College of Policing digital learning environment. During business as usual paper capture, forensic footwear experts actively contact investigators or custody suites and request copies of paper based samples of particular relevance. The footwear experts will follow this same process for the period of the RCT, actively seeking out any relevant paper based samples as they would in any of the other custody suites across London not yet benefiting from Tread Finder technology.

A RCT timetable has been designed, incorporating key dates for completion of fundamental activities for example, start, review, report dates. The timetable is subject to change dependent of case flow, in order to achieve the ideal sample size of 128 cases.

Conclusion

The planned RCT to test the effect of Tread Finder in a live custody environment is full of promise. The hardware and the supporting technology have been designed with practical application at its core and developed in partnership with front line police officers, investigators, custody staff and forensic practitioners from across the UK. The benefits to the criminal justice system have been defined through testing and tracking using descriptive research techniques. The original proof of concept trial was descriptively analysed in order to support the successful Home Office Police Innovation Fund bid. Conference presentations in the US, across Europe and the UK have gained further support and curiosity in the project. The development of footwear evidence is of truly

global interest. Tread Finder has been developed, tested, refined and deployed in a live custody environment and this moment in time, presents a wonderful opportunity to apply scientific rigour to measure the effect of the technology, through a carefully formulated research question and a meticulously planned and executed RCT (Sherman, 2010).

The results of the RCT are likely to present a compelling case for the use of Tread Finder technology across Law Enforcement Agencies. The results are anticipated to show that Tread Finder technology is far more cost effective than the paper alternative. The scientific rigour applied will enable all other competing explanations for the results to be eliminated. This technology has the capacity to make a great leap forward not only realising the benefit of footwear as a crucial addition to a criminal investigation but in revolutionising the way footwear evidence is captured in custody suites across the world. Tread Finder technology has the potential to impact law enforcement as significantly as digitising fingerprint evidence did in the early 2000s.

Footwear evidence is not a new science, in fact, was first used in a criminal prosecution 320 years ago, when the murderous Margaret Martell left the impression of her slipper in Elizabeth Pullen's blood. Footwear evidence is a long-standing, vital weapon in the forensic investigation armoury. Some would say, it has been severely undervalued and under-developed in the 320 years since Martell went to the gallows. Comparisons can be drawn between methods used by Stewart Depute Alexander Gordon, in the 1786 investigation of the cold-blooded murder of a defenceless pregnant girl, and now. Gordon

sketched footwear marks left at the scene, repeating the process with the suspects shoes to compare the two. A similar paper method is still employed in the vast number of custody suites across the world.

Footwear evidence is as frequently found at crime scenes as DNA and fingerprints (Bodziak 2016 citing NPIA 2007), yet 230 years of technological advancements across the world have only resulted in the development of computerised databases, barely touching either crime scene or custody capture processes. The compliance rates across the trial site for footwear capture from offenders is currently less an 1.5%. When considering this against the regularity in which footwear is recovered from crime scenes, it is no wonder that many investigative opportunities are lost. Tread Finder will change this landscape forever. This technology bridges the gap, bringing footwear capture methods within custody suites into the modern age. The RCT will serve to support this development with true scientific precision and aim to replicate findings from an earlier lab based experiment which will further serve to convince sceptics that findings can be safely generalised.

Footwear impressions at crime scenes tell their own story. They can determine the number of suspects present, their path into, within and out of the crime scene as well as providing compelling evidence refuting any explanation offered by the accused. Footwear left adjacent to a murder victim, or in the form of a bruise on the victim of an assault, or inside a burgled house is evidence which, as Professor Kirk said, bares silent witness

against an accused (Bodziak, 2016 p. 18). Until technology removes the need for humans to walk, footwear evidence can never be wholly absent from a crime scene. What has been largely absent, up until now, is the “human failure to find it, study it and understand it, which has diminished its value” (Kirk, 1953, cited by Bodiak, 2016, p.18). Tread Finder directly addresses this human failure and, the findings from this research, will further underpin and endorse this truly ground-breaking technology.

References

Alexandre, G. (1996). Computerized classification of the shoeprints of burglars' soles. *Forensic Science International*, 82(1), 59-65.

Ashley, W. (1996) What shoe was that? The use of computerised image database to assist in identification. *Forensic Science International*, 82(1), 7-20.

Bodziak, W.J. (2016). Forensic Footwear Evidence. CRC Press

Bluestar Software, (2017). UK National Solutions. Retrieved 29th April 2017 from http://www.bluestar-software.co.uk/products/uk-national-solutions/

Chambers, W. (1832). 'Discover and Punishment of Murder by Circumstantial Evidence'. Chambers Edinburgh Journal No. 6: 1. Retrieved 7th April 2017 from http://www.maxwellancestry.com/ancestry/images/cej/0041.jpg

ChoChół, A. and Świętek, M. (2012). Characteristics of forensic shoe sole databases. *Problems of Forensic Sciences,* 1(90), 164-177.

Geradts, Z. and Keijzer, J. (1996). The image-database REBEZO for shoeprints with developments on automatic classification of shoe outsole designs. *Forensic Science International,* 82(1), 21-31.

Kirk, P.L., Crime Investigation, 2nd ed., John Wiley & Sons, New York, 1963.

Mikkonen, S., Suominen, V. and Heinonen, P. (1996) Use of footwear impressions in crime scene investigations assisted by computerised footwear collection system. *Forensic science international*, 82(1), 67-79.

Morgan, J., Ponikiewski, N. and Dunstan, E. (2004). *The Processing of Fingerprint Evidence after the Introduction of the National Automated Fingerprint Identification System (NAFIS).* Home Office Research, Development and Statistics Directorate.

Manning, P. (2003). Police Contingencies.

National Police Improvement Agency (NPIA), Footwear Marks recovery Manual, 2007, UK

Needham, J.A. and Sharp, J.S. (2016). Watch your step! A frustrated total internal reflection approach to forensic footwear imaging. *Scientific reports*, 6, 21290.

Old Bailey Online, March 2015. The Proceedings of the Old Bailey. Retrieved 29th April 2017 from https://www.oldbaileyonline.org/browse.jsp?id=t16970707-46-defend123&div=t16970707-46#highlight

Old Bailey Online, March 2015a. The Proceedings of the Old Bailey. Retrieved 29th April 2017 from https://www.oldbaileyonline.org/browse.jsp?id=OA16970716n54-1&div=OA16970716#highlight

Old Bailey Online, March 2015b. The Proceedings of the Old Bailey. Retrieved 7th April 2017 from https://www.oldbaileyonline.org/images.jsp?doc=176507100017.

Richetelli, N., Lee, M.C., Lasky, C.A., Gump, M.E. and Speir, J.A. (2017). Classification of footwear outsole patterns using Fourier transform and local interest points. *Forensic Science International, 275*, 102-109.

Sherman, L.W. (2010). An introduction to experimental criminology. *In Handbook of quantitative criminology* (pp. 399-436). Springer New York

Smith, M. B. 2009. ‘The Forensic Analysis of Footwear Impression Evidence’. Forensic Science Communications 11: 3. Retrieved 7th April 2017 from https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/july2009/review/2009_07_review02.htm.

Welsh, B.C., Farrington, D.P. & Sherman, L.W. (2001). Costs and Benefits of Preventing Crime. Boulder: Westview Press