

Impact case study (REF3)

Institution: Maxwell Institute of Mathematical Sciences		
Unit of Assessment: UoA 10 – Mathematical Sciences		
Title of case study: Improving the evaluation and interpretation of evidence in forensic science casework		
Period when the underpinning research was undertaken: 2004 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Colin Aitken	Personal Chair in Forensic Statistics	Oct 1979 – Sep 2016
Amy Wilson	PhD Student	Sep 2010 – Jul 2014
	Research Associate	Oct 2016 – Sep 2019
	Lecturer	Oct 2019 - date
David Lucy	Research Associate	Mar 2001 – Aug 2006
Period when the claimed impact occurred: 2014 – 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact		
<p>Our judicial system increasingly relies on quantifying the value of evidence presented in court. As a result, advanced statistical methods have a strong impact on the administration of justice. Research by Aitken, Wilson (both Maxwell Institute, MI) and collaborators has applied Bayesian statistics to develop methodology for quantifying judicial evidence. They proposed and implemented procedures for evaluating forensic evidence from (i) multivariate hierarchical data and (ii) autocorrelated data. The procedures developed are now routinely used in forensic laboratories worldwide; the methods have been recommended in international guidelines for forensic scientists and have been used to support the accreditation of a UK laboratory. The underpinning research has been cited in expert witness reports in court cases worldwide. Therefore, the beneficiaries of the research include both forensic scientists and the justice system.</p>		
2. Underpinning research		
<p>The key research insight is the recognition that the Bayesian framework provides the tools needed for the interpretation of forensic evidence. This has led to the development of increasingly sophisticated statistical analyses driven by new measuring equipment for the examination of trace evidence and by the increase in computing power that enables the lengthy calculations required to be performed efficiently. Papers published from 2004 have contributed to this development and tackled two important problems: the treatment of multivariate, hierarchical evidence data and the evaluation of evidence in the form of autocorrelated data.</p> <p>(i) Likelihood ratios for multivariate hierarchical data. When samples of material obtained from a crime scene are compared with those obtained from a suspect, it is necessary to quantify the support for the proposition that they come from the same source. In many cases the data characterising the material are multivariate, continuous and hierarchical. Examples include the composition of glass taken from fragments of windows. The hierarchical nature then arises because variations within-source and between-source differ (variation of glass composition in a single windowpane versus variation between different panes). Research in the MI developed a Bayesian methodology to quantify the value of the evidence derived from</p>		

such multivariate and hierarchical data. This overcame the drawbacks of earlier methodologies (which often incorrectly assumed the independence of the different variables) by providing a likelihood ratio (LR) that can be combined with other forms of evidence in an integrated analysis and leads to readily interpretable conclusions. The initial work [3.1] considering a two-level hierarchy of data was extended to a three-level hierarchy in [3.2]. The paper [3.3] also developed an implementation based on graphical modelling techniques which is adapted to multivariate data. The methodology is described in [3.4]; a 3rd edition has just been published.

(ii) Likelihood ratios for autocorrelated data. This research was motivated by the need for methods to quantify the value of evidence relating to drugs on banknotes. Banknotes can be seized from crime scenes as evidence for suspected association with illicit drug dealing. Tandem mass spectrometry data are available from banknotes seized in criminal investigations, as well as from banknotes from general circulation. The aim of this research was to evaluate the support provided by the data gathered in a criminal investigation for the proposition that the banknotes were associated with a criminal activity related to cocaine in contrast to the proposition that the banknotes were from general circulation. Previous methods for assessment of the relative support for these propositions were concerned with the percentage of banknotes contaminated or assumed independence of measurements of quantities between adjacent banknotes. The research developed new methodologies for evaluating this support using the LR. These methods accounted for autocorrelation in the data caused by transfer of cocaine between banknotes and also modelled differences in contamination between different bundles of notes [3.5]. It has been argued in court that the datasets used for evaluating the evidence are inappropriate because there may be variability across the country in levels of cocaine on banknotes. In order to implement the methods developed in practice, further research [3.6] showed that there is no meaningful difference in quantities of cocaine on banknotes in different regions of Great Britain and hence there is no need to tailor the datasets to the region of the crime.

Additional research on the communication and interpretation of statistical evidence in the administration of criminal justice resulted in an interdisciplinary collaboration [3.7] designed to bring Bayesian ideas of the likelihood ratio and Bayesian networks to the attention of judges, lawyers, forensic scientists and expert witnesses.

3. References to the research

- [3.1] Aitken, C.G.G. and Lucy, D., Evaluation of trace evidence in the form of multivariate data. *Applied Statistics*, 53, 109-122 (2004). <https://doi.org/10.1046/j.0035-9254.2003.05271.x>
- [3.2] Aitken, C.G.G., Lucy, D., Zadora, G. and Curran, J.M., Evaluation of transfer evidence for three-level multivariate data with the use of graphical models, *Computational Statistics and Data Analysis*, 50, 2571-2588 (2005). <http://dx.doi.org/10.1016/j.csda.2005.04.005>
- [3.3] Aitken, C.G.G., Zadora, G. and Lucy, D., A two-level model for evidence evaluation. *Journal of Forensic Sciences*, 52, 412-419 (2007). <http://dx.doi.org/10.1111/j.1556-4029.2006.00358.x>
- [3.4] Aitken, C.G.G. and Taroni, F., *Statistics and the evaluation of evidence for forensic scientists*, John Wiley and Sons Ltd (2004), 2nd edition, <http://dx.doi.org/10.1002/0470011238> and (2021), 3rd edition <http://dx.doi.org/10.1002/9781119245438>
- [3.5] Wilson, A., Aitken, C.G.G., Sleeman, R. and Carter, J. The evaluation of evidence for auto-correlated data in relation to traces of cocaine on banknotes. *Applied Statistics*. 64, 275-298 (2014) <http://dx.doi.org/10.1111/rssc.12073>
- [3.6] Aitken, C.G.G., Wilson, A., Sleeman, R., Morgan, B., Huish, J. Distribution of cocaine on banknotes in general circulation in England and Wales. *Forensic Science International*, 270, 261-266 (2016). <http://dx.doi.org/10.1016/j.forsciint.2016.10.017>

[3.7] Four Practitioner Guides for interpreting statistical evidence published by the Royal Statistical Society on “Communicating and Interpreting Statistical Evidence in the Administration of Criminal Justice” (2010-2015)
<https://rss.org.uk/RSS/media/News-and-publications/Publications/Reports%20and%20guides/rss-fundamentals-probability-statistical-evidence.pdf>
<https://rss.org.uk/RSS/media/News-and-publications/Publications/Reports%20and%20guides/rss-assessing-probative-value.pdf>
<https://rss.org.uk/RSS/media/File-library/Publications/rss-inferential-reasoning-criminal-evidence-forensic-science.pdf>
<https://rss.org.uk/RSS/media/File-library/Publications/rss-case-assessment-interpretation-expert-evidence.pdf>

4. Details of the impact

The research has had an impact on the administration of justice, leading to a better use of evidence and accompanying judicial and economic benefits. This is split into three main areas:

(i) The procedures developed in [3.1-3.3] are now routinely used for forensic casework internationally.

This is confirmed by various forensic experts from across Europe: *“The work of Aitken and Lucy ... is the basis of our method for e.g. calculating LR_s in glass and is still used routinely”* [5.1]; *“His [Aitken’s] research papers and books are used as teaching material, [and] reference material to justify approaches in practical works such as forensic reports”* [5.2]; *“Results of Aitken’s research, ... are used in my daily forensic practice as a forensic expert in microtraces, i.e. in cases involving the analysis of glass fragments. I use it (... LR model) for the evaluation of the evidential value of results of glass analysis... The method is used in about seven cases per year..., about one hundred cases in total to date”* [5.3].

A software package in the statistical programming language R known as ‘comparison’ which follows [3.1] was developed by Lucy and has been downloaded around 25,000 times since 2014, indicating the acceptance of the methods by the applied community.

(ii) Research on cocaine traces on banknotes in [3.5-3.6] has been used to support the accreditation of a UK forensic science laboratory and to support expert evidence delivered in UK court cases.

The Scientific Director, Mass Spec Analytical Ltd (MSA) confirms this [5.4]: *“The work ... is routinely referred to in the supporting material [in] every court statement sent out by [MSA].... As such, it is frequently subject to cross examination in Court, and the expert witnesses make reference to the peer reviewed papers regularly. It is difficult to quantify, but the experience of the court attending witnesses is that ensuring that our offering is on a sound scientific footing has greatly reduced the ‘attacks’ on our methodology.”* and *“the work demonstrating that the general circulation background samples do not vary greatly across the country has proved to be enormously useful following adverse criticism of the sampling strategy in the trial of Rashid et al in Sheffield Crown Court in 2015. This work is referred to in talks given to police officers for marketing purposes, and is included in the “In-house method validation” documentation provided to UKAS [the United Kingdom Accreditation Service] at Accreditation Assessment visits (the most recent being February 2020).”*

More broadly, the research in [3.5] has changed the way in which forensic scientists at MSA think about the presentation of their forensic evidence, resulting in improvements in the administration of justice [5.4]. MSA provided evidence for around 200 cases per year in the UK (most of the UK cases featuring this evidence type). Key Forensics purchased the banknotes part of the business in January 2020 and have continued using the research as described above. Further to the above, Aitken has given evidence as an expert witness based on research in [3.6] under oath in two trials: R. v. Hussain and others (Snaresbrook Crown Court) and R. v Parry and others (Liverpool Crown Court).

(iii) **The research has influenced the framework in which scientific evidence is presented in court and is widely used to train forensic scientists and lawyers.**

The book [3.4] is a well-cited authority on the role of statistics in the evaluation of evidence in forensic science. One of the main methodologies set out in the book is that of [3.1]. The influence of the book on forensic casework is illustrated in [5.1]: “*The Bayesian framework explained in the book is the basis for evidence interpretation and evaluation in the casework of the NFI*” and [5.6]: “*The well-known text book... is the fundamental literature in this field*”. This is further supported by the inclusion of the methodology set out in the book (e.g. paragraph 2.4 on p6) in the European Network of Forensic Science Institutes (ENFSI) Guidelines [5.7] which sets out a framework for reporting statistical evidence in forensic science. The book and methodology contained in it is used consistently by laboratories in ENFSI to train forensic scientists and lawyers [5.1, 5.2, 5.3, 5.6].

The practitioner guides [3.7] are on the communication and interpretation of statistical evidence in the administration of criminal justice. These set out the likelihood ratio methodology in [3.1-3.4] for legal practitioners, e.g. Sections 2.17-2.19 in the first guide and Section 2.21 in the fourth guide. The influence of [3.1], [3.4] and [3.7] on forensic casework is corroborated in [5.3]: “*The general ideas on application of LR approach in forensic sciences as expressed in [3.1] and [3.4] (and disseminated in the practitioner guides of the Royal Statistical Society and the ENFSI guidelines) are used routinely by me in the evaluation of evidential value of results of blood pattern analysis.*” The practitioner guides have been used in court cases (e.g. in the Kentucky Supreme Court - *Ivey v. Commonwealth* in 2014), indicating that they add value to the presentation of expert evidence in court (also see [5.4]). The Royal Statistical Society and the Inns of Court College of Advocacy published an introductory guide to statistics for barristers and advocates [5.5] describing the general approach to evidence evaluation set out in [3.4] and [3.7] (e.g. Section 1.7 and p66-68). As the Chair, Aitken led the contribution from the Statistics and Law Section of the Society and Wilson contributed as a committee member. This guide was recognised as a useful resource for training lawyers and judges in a House of Lords Science and Technology Committee inquiry in 2019 on “Forensic science and the criminal justice system: a blueprint for change” [5.8, paragraph 132].

As evidence of the overall impact of the research in the forensic and legal communities, Aitken was awarded the Howard Medal of the Royal Statistical Society in 2018 [5.9] for work that is an “*outstanding example of how a statistician can integrate with those in a substantive area*”. Reasons for the award included the research on cocaine on banknotes, [3.5, 3.6]. Further to this, [5.2] states “*I can testify that Professor Aitken’s research in general has deeply influenced the way a scientist approaches the evaluation of evidence and the way he/she presents evidence in a written report or during a testimony in front of a Court of Justice.*”

5. Sources to corroborate the impact

[5.1] Letter of support from a Forensic Statistics expert at The Netherlands Forensic Institute in The Hague and Professor of Forensic Statistics (by special appointment) in the Institute of Mathematics at The University of Amsterdam.

[5.2] Letter of support from the Professor of Forensic Statistics at the Institute of Criminal Sciences at the University of Lausanne, Switzerland, the world's premier research institute in forensic science.

[5.3] Letter of support from Professor at the Institute of Forensic Research, Krakow and University of Silesia at Katowice, Poland

[5.4] Letter of support from the Scientific Director, Mass Spec Analytical Ltd., Bristol, UK

[5.5] “Statistics and probability for advocates: Understanding the use of statistical evidence in courts and tribunals” produced by the Royal Statistical Society and the Inns of Court College of Advocacy (2017)

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<https://rss.org.uk/RSS/media/File-library/Publications/ICCA-RSS-guide-version-6-branded-171019-REV03-designed-covers.pdf>

[5.6] Letter of support from a Forensic Specialist in Statistics at the National Forensic Centre and Reader in Statistics at the University of Linköping Sweden.

[5.7] European Network of Forensic Science Institutes Guideline for Evaluative Reporting in Forensic Science (2014), https://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf

[5.8] House of Lords Science and Technology Committee, 3rd report of session 2017-19, "Forensic science and the criminal justice system: a blueprint for change".
<https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/333/333.pdf>

[5.9] Royal Statistical Society Howard Medal awarded to Colin Aitken in 2018,
<https://rss.org.uk/news-publication/news-publications/2018/general-news/rss-announces-recipients-of-2018-honours/>