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Conceptualising forensic science and forensic reconstruction. Part I: A conceptual model

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ABSTRACT

There has been a call for forensic science to actively return to the approach of scientific endeavour. The importance of incorporating an awareness of the requirements of the law in its broadest sense, and embedding research into both practice and policy within forensic science, is arguably critical to achieving such an endeavour. This paper presents a conceptual model (FoRTE) that outlines the holistic nature of trace evidence in the 'endeavour' of forensic reconstruction. This model offers insights into the different components intrinsic to transparent, reproducible and robust reconstructions in forensic science. The importance of situating evidence within the whole forensic science process (from crime scene to court), of developing evidence bases to underpin each stage, of frameworks that offer insights to the interaction of different lines of evidence, and the role of expertise in decision making are presented and their interactions identified. It is argued that such a conceptual model has value in identifying the future steps for harnessing the value of trace evidence in forensic reconstruction. It also highlights that there is a need to develop a nuanced approach to reconstructions that incorporates both empirical evidence bases and expertise. A conceptual understanding has the potential to ensure that the endeavour of forensic reconstruction has its roots in 'problem-solving' science, and can offer transparency and clarity in the conclusions and inferences drawn from trace evidence, thereby enabling the value of trace evidence to be realised in investigations and the courts.

1. Introduction

Forensic science offers an interdisciplinary approach that provides insights that can be applied to questions of law. This has traditionally been manifested in a range of fields that address directly individualising (such as fingermarks, DNA) or non-directly individualising (such as glass, paint, fibres, soils) forms of evidence. Forensic science has come under severe scrutiny for a number of reasons, with the underlying philosophical approach [1,2] and the validity of techniques [3] being significant areas of contention. In the light of these issues, the current situation of forensic science has been the subject of discussion, and at the heart of these debates is the fundamental issue of the identity of the discipline, and the aim, scope and capabilities of forensic science.

There have been significant discussions addressing the issue of identifying the current paradigm of forensic science and coming to a consensus of the nature of the discipline. The articulation and exploration of what has arguably become the dominant model of 'forensics' in contrast to that of 'forensic science' [4,5] is one of the key issues for reaching that consensus. Within 'forensics' the focus is predominantly on how the parent disciplines (such as chemistry, biology, computer science, geology) can assist in the exploitation of evidence within the criminal justice system. The crime scene is considered to be a distinct activity generally addressed by the police in an operational and processing capacity [4]. This paper has its foundations in the argument that there needs to be a wholesale return to the roots of 'forensic science', in a manner that enables the discipline to be a true scientific endeavour rather than solely a series of mechanical and standard technical operations. By offering robust, transparent and appropriate problem solving approaches to the whole forensic science process (crime scene to court), rather than focussing almost exclusively on the technical analysis and classification of exhibits, it is possible to regain the potential that lies in 'forensic science'. Such an argument is not new [4,6,7,8] but engagement with how we can regain 'forensic science' from the, more recently, dominant 'forensics' approach is imperative for setting the future course of the forensic science discipline.

It is important to acknowledge that forensic science is an intersecting discipline that lies at the nexus of practice, science, law and policy. There are multiple actors and voices that contribute to where the agenda for forensic science comes from, and that sets out what that agenda is. This affects what is being sought in practice and influences where efforts are channelled in research endeavours. This leads

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to large scale and overarching complexity as forensic science seeks to operate within the intersecting domains of practice, policy/law and research. Yet more complexity is present when the backdrop of cultural, economic and political factors are taken into account, which impinge on each domain to greater or lesser degrees at different times and places [9]. The practice, policy and research domains each have different aims, structures, and individual and corporate expertise, and there are therefore multiple calls made on forensic science. If we are to 'define what it can deliver and with what limitations' [8:102] and focus resources productively and effectively to enable that delivery, we must articulate conceptually what forensic science needs to achieve. Such a conceptual understanding will enable the identification and development of the approaches that bring together these different domains effectively in order to deliver robust, transparent, accurate, problem solving forensic science.

This paper therefore seeks to present a conceptual model that articulates a holistic, problem solving forensic science approach for the use of trace evidence in forensic reconstructions. From the model it is possible to offer insights into the pathways forward that will enable forensic science to deliver evidence based forensic reconstructions in a manner that incorporates the strengths of the intersecting domains and meets the diverse needs of each of those domains. Ultimately the conceptualisation of what forensic science is seeking to achieve with regard to trace evidence, will offer insights for setting forensic science on a course to future growth and development that is grounded in its traditional routes of scientific endeavour to assist the justice system.

2. The goal of forensic reconstruction: a new conceptual model for trace evidence

2.1. Problem solving and the interpretation of trace evidence

The scrutiny focussed upon forensic science in recent years has arguably been based upon the validation of techniques, standards and quality assurance (for example the National Academy of Sciences report [3]). The UK Law Commission [10] presented similar conclusions raising concerns that there were insufficient scientific bases for evidence that were being presented in court. This focus on the validity of fields of forensic science has led to both a focus upon the standards and validation of techniques within forensic science practice, and a call for a research culture in forensic science [8,11]. More recently in 2015, two UK reports, and in 2016 a US report, have been published addressing forensic science [12,13,14], and each has highlighted the importance of developing the means for effective interpretation of forensic evidence. This is a welcome voice that affirms arguments presented in the published literature, that to achieve robust and reproducible forensic reconstructions, it is important to not only identify the source of a questioned specimen, but also to have an empirical base for understanding its significance (i.e. what it means when it is identified as being present in a particular place at a particular time) [15,16,17]. Three factors are important for any effective trace evidence interpretation approach. Firstly, it is necessary to be able to incorporate a sensitivity to the context of the trace as the context will be different in every case. Secondly (and equally), the approach must offer sufficient generalisability so as to be able to be applicable to a wide range of cases. Thirdly, the interpretation of forensic trace materials should be underpinned by an evidence base that incorporates an understanding of the behaviour of such traces. It should also understand the role of human decision making and expertise in the production of inferences, and identify any assumptions being made that impinge upon those inferences and the significance assigned to the conclusions drawn.

2.2. Understanding the nature of trace evidence and human decision making in forensic reconstruction

Whilst trace evidence has been disregarded in some quarters in recent years, the value and importance of trace materials should not be underestimated [18]. Trace evidence is highly complex, and this complexity needs to be incorporated into any reconstruction approach. Forensic evidence is complex due to the nature of traces (its different forms, capabilities, ability to infer source/activity levels, and the interaction of different forms of trace with one another), and the integral part human decision-making plays in evaluating trace materials.

Trace evidence is a broad term that encompasses a range of different types of trace. Whilst some traces can offer directly individualising intelligence/evidence, others are non-directly individualising. The different capacities or natures of different forms of trace, means that different questions can be posed and addressed depending on the different forms present. All trace material should be approached as a means of reaching exclusionary inferences [19]. However, it is important to note that there are differences in the nature of different forms of trace [20]. For example, trace DNA may be able to infer a specific and individual source due to the existence of population databases that have established allele frequencies. In contrast, the analysis of trace amounts of soil may be able to offer comparative assessment between an exhibit and comparator sample, but is not able to infer a positive provenance to the exclusion of all other possible provenance sources.

Trace evidence can have different capabilities in different contexts. Every case is different, and the information that a particular trace can offer may vary between cases. For example, depending on the location of a crime scene, it may be that quartz grain analysis is able to provide highly discriminatory information between sediments from a crime scene with those from the footwear of a suspect or an alibi location [19]. However, there are some geographical locations where this form of analysis may not be able to provide sufficiently discriminatory information due to the underlying geology or nature of the surficial sediments at the scene in question [20]. In such cases the analysis of the trace quartz particles can provide descriptive information but not an exclusionary conclusion regarding the provenance of the quartz grains.

The role of a number of different forms of trace material in forensic reconstruction is often 'greater than the sum of its parts'. One form of trace may offer insight into one aspect of the forensic reconstruction. However, as outlined in the published literature (such as [2,21,22]), multiple forms of evidence will often offer independent lines of enquiry that can achieve a corroborative and stronger indication of activity and/or sources that are relevant in reconstructing events. The importance of having the capacity to map the interaction of the different and pertinent forms of trace material within a forensic reconstruction is therefore significant.

Trace evidence is also a complex entity given that it is not only able to offer insights to the composition of a particulate/trace but also possible provenance of a questioned sample (as is often the goal within the 'forensics' paradigm). In certain circumstances the activities that have led to the deposition of a trace may also potentially be inferred. In order to make these forms of inferences, an understanding of the dynamics of these different forms of trace is a prerequisite for being able to infer the significance of a trace when it is found in a particular location at a particular time. Trace evidence dynamics refers to how a specific form of trace behaves, for example, how and when it transfers, persists and is preserved in different environments and in different conditions. The importance of basing such inferences on evidence bases cannot be overstated. In addition, identifying where assumptions may be being made with regard to the nature of a transfer (direct or indirect contact for example, [23]) is important in determining the weight that can be assigned to those conclusions drawn from trace evidence in reconstructions.

To utilise the significant potential of trace material for robust forensic reconstructions, it is important to also incorporate an understanding of the role of human decision-making in any inferences and conclusions drawn from the detection, identification and analysis of trace materials. Human decision-making can be identified at each stage of the forensic process, for example identifying where to search at a crime scene, deciding the best strategy for evidence analysis in the laboratory, ascertaining the important factors integral to interpreting what the evidence means in a particular case, and assessing the means of presenting those findings to investigators as intelligence or to the court as evidence. As such, human decision-making is a fundamental part of any forensic reconstruction and this must be understood in a way that incorporates the different components that make up 'expertise' (skills, experience, routines, and technical knowledge [24]). Whilst automated systems can be built and trained to identify specific components or accurately measure the composition of a material, the role of the expert is integral to the reconstruction approach. This is in part due to the need for any reconstruction to be sensitive to the specific context of the case in hand, whilst at the same time drawing on established and general principles that underpin the primary sciences being utilised.

Therefore, the complexity of trace evidence both in terms of its nature and in its application to reconstruction activities can be acknowledged. The importance of incorporating an understanding of this complexity into any approach for forensic reconstruction is clear. Thus, the model presented here, hereafter referred to as the FoRTE model, aims to offer a conceptual understanding of trace evidence within forensic reconstruction. The model offers a holistic view with the purpose of enabling the wealth of information from different forms of trace material to be fully realised and effectively incorporated into forensic reconstruction approaches.

3. A conceptual model for holistic trace evidence interpretation and forensic reconstruction: FoRTE

The FoRTE model seeks to present the holistic system within which trace evidence is situated, that is needed for robust forensic reconstruction (Fig. 1).

This model seeks to identify the interacting components that contribute to the interpretation of trace materials (a key focus of forensic reconstruction approaches) and incorporate a focus on addressing distinctive forensic science questions such as how do we understand the 'problem'. Thus, the model presents a way of considering trace materials and forensic reconstruction in a manner that leverages the value of trace evidence and enables an integrated and effective approach to research within forensic science, the formulation of policy, and the development of best practice.

The model is composed of 4 components:

1. the forensic science process
2. the evidence base
3. the interaction of different forms of trace evidence
4. the role of expertise and human decision making

3.1. The forensic science process

The forensic science process has been articulated in a number of ways in the published literature with examples such as the models presented by Inman and Rudin [25], Morgan and Bull [2] Ribaux and Talbot Wright [26], and Ribaux et al. [27]. It is a connected and iterative process with each stage of the process intrinsically linked to the other stages and each stage dependent upon prior stages. It is acknowledged that the model presented in Fig. 1 provides a necessarily simplistic representation of this iterative and interconnected forensic science process as one component of the model.

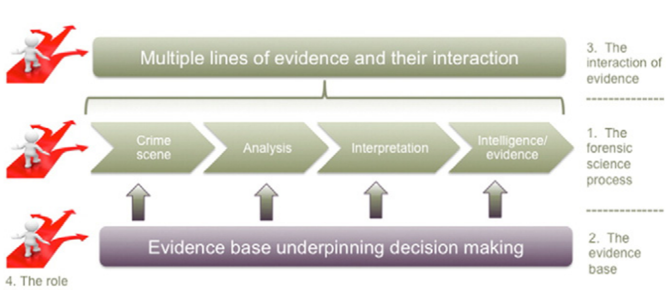

Fig. 1. A conceptual model of forensic reconstruction and the role of trace evidence (FoRTE).

The actions and decisions taken at the crime scene will have an impact on the questions asked of the evidence and therefore the type of analysis undertaken on exhibits in the laboratory, the approach taken to make inferences about the results of the analysis, and how those conclusions are presented as intelligence and/or evidence. There are also different types of knowledge embedded into that process; the knowledge of the different actors involved at different stages (expertise), the forms of trace materials that are present and their interaction with other trace materials, and the degree to which those trace materials can lead to inferences of either source and/or activities pertinent to the forensic reconstruction.

Only with an appreciation of the whole process and the interactions within it can the most effective and valuable questions for forensic reconstruction be posed and addressed. For example, being aware of the specific variables in play at the crime scene will enable the most pertinent questions to be asked at that stage (for example, it may be that a question of 'who' is more important than a question of 'if' or 'how' in a specific case). When the most germane questions are established, the most pertinent and potentially most valuable evidence can then be sought and collected. Furthermore, the analysis of any of those materials can be tailored to those questions, in addition to incorporating an awareness of the ultimate use of that analysis (intelligence and/or evidence). An appreciation of each case specifically, and an awareness of every part of the process holistically, will enable the most effective questions to be asked. The formulation of the most effective questions also offers the means to guide where resources will be most efficiently directed to achieve the forensic reconstruction in that specific case.

3.2. Evidence bases

Therefore, there are multiple factors within the forensic process that need to be incorporated into an understanding of trace materials that will enable robust interpretation and ultimately forensic reconstruction. The importance of an evidence base that can underpin all the activities at each stage of the forensic process cannot be overstated. Indeed, the importance of a research culture within forensic science has been presented [11,15] and the value of empirical foundations for the interpretation of forensic evidence articulated [28]. These are important calls to incorporate into any conceptual understanding of forensic reconstruction. The strong knowledge bases that exist in many of the parent disciplines that have been validated and tested (such as analytical chemistry methods) need to be utilised in concert with a bespoke evidence base pertinent to the forensic science endeavour.

Forensic science therefore requires a specifically 'forensic science' evidence base that underpins each part of the forensic process. That evidence base needs to incorporate data that address the two major aspects of trace interpretation:

- trace evidence dynamics: the transfer, persistence, preservation of trace materials to allow inferences to be evidence based and the significance and weight of evidence to be transparently established.
- human decision-making in the interpretation of trace materials: the interaction of expertise, experience, and cognitive biases and their impact on decision-making, particularly probabilistic decision-making, under conditions of uncertainty.

In order to establish such evidence bases it is important that the data produced to create and develop them is empirically based (incorporating testable hypotheses), casework informed (addressing pertinent issues in the practice of the applied science), and designed to produce implementable results (outcomes that are applicable in the field).

Therefore, the role of context sensitive, specific evidence bases such as the studies undertaken within the forensic science domain during casework to provide context to questioned specimens collected from specific locations [29] are highly important in addition to the more generalized evidence bases that seek to offer insights into wider populations (such as national DNA and fingerprint databases). The existence of such evidence bases enables evidence-based practices (such as where to find pertinent evidence as outlined in Morgan et al. [30]), and the assessment of the significance and weight of trace evidence found in a particular form or in a certain amount and in a specific location (such as the experimental studies of French and Morgan [23] identifying the potential for multiple transfers of gunshot residue or of McElhone et al. [31] addressing the generation of footwear marks in blood).

3.3. The interaction of different forms of trace evidence

The third component of the model is the development of frameworks that harness the different forms of evidence from the whole forensic process in an integrated manner that is reproducible, transparent, evidence based, context sensitive and yet sufficiently generalisable. Such frameworks allow the body of evidence to be considered as a whole, but also offer a clear approach for incorporating different forms of evidence into the forensic reconstruction process.

This is arguably the least developed component within forensic reconstructions. Whilst a number of approaches have been outlined in the literature [32,33], there is still a need for a framework that can incorporate all the different types of evidence pertinent to a particular case and can assess the inferences that are feasible to be made from each form of evidence. It also needs to identify the interaction between the different forms of evidence and provide a means of clearly illustrating the significance of each line of evidence individually, and within the body of evidence as a whole.

Approaches such as Bayesian Networks that can represent causal dependencies and probabilistic relationships between variables in addition to capturing the interrelatedness of a number of different types of evidence appear to have significant potential [34,35]. However, regardless of the specific tools used to achieve such frameworks, it is important to have the means of presenting the different forms of evidence pertinent to a case, and assessing the interaction between them. This should be in a manner that is reproducible, and that offers transparency to the process of inferring significance and weight of individual forms of evidence as well as the body of evidence within a case as a whole.

3.4. The interaction of expertise

The final component of the model is the role of expertise in the decision-making within each of the other three components (the forensic science process, the evidence base and the frameworks). It is important to recognise that decision-making is integral to each of these components. For example, within the forensic science process, decisions need to be made at the crime scene as to where to look for evidence, and what evidence to prioritise. It may be that prior knowledge of the crime situation exists and this will also inform the decisions made at the crime scene. At the analysis stage, decisions need to be made concerning the best analytical technique to apply, and the order to undertake different analyses of a sample. At the interpretation stage decisions need to be made to identify the competing hypotheses that need to be considered in order to discern the significance and weight of a trace material. Within the evidence bases required to underpin each of the stages within the forensic science process, decisions are made as to the pertinent questions to answer and the design of experimental work that is required to address those questions. All of these decisions require the application of varying levels of expertise.

Expertise can be considered to have two dimensions, knowledge ('knowing that') and skill ('knowing how') [36]. Experience is a quality that underpins all the facets of expertise that includes technical skills that are learnt and developed over time, skills that are acquired through practice, and routines or heuristics that are also developed over time and often to some degree at a subconscious level. An appreciation of the degree to which expertise is integral to each of the three components within the model highlights the importance of forensic reconstruction approaches that can incorporate both empirical evidence bases and expertise within each phase. It is highly important to recognise the value of different types of knowledge in forensic reconstructions. Given that every case is different and therefore effective forensic reconstruction requires sensitivity to the context of each case, there is a need to consider the best way of developing problem-solving reconstruction approaches that incorporate both empirical evidence bases and expertise. This is an issue related to, but outside of, the current debates addressing the role of experience and empirical evidence [37–40], yet it is a critical issue. It is highly important that trace evidence is interpreted and presented in an empirical, balanced, transparent, reproducible way that at the same time has the capacity to incorporate sensitivity to specific case contexts. This is not a simple task and will require a nuanced approach that ensures that the requirements of the science, law and policy domains are satisfied. Yet it is critical to engage with this issue in order to ensure the broad remit of 'forensic science' is supported and the value of trace evidence and robust reconstructions is fully realised. This is addressed and explored further in part II of this paper.

4. The recapturing of forensic science as a scientific endeavour rather than a mechanical practice

It can be argued that the remit of forensic science has been narrowed in the last 20 years. The focus has become primarily upon the ever more refined and accurate classification and identification of materials, with a particular emphasis on validity and quality assurances of the processes, procedures and protocols. This stands in contrast to the traditional approaches in forensic science of problem solving for forensic reconstruction [4]. It has been argued that a return to the approach of scientific endeavour rather than primarily focussing on the mechanistic validation of processes is critical [4,8]. Alongside this, incorporating an awareness of the requirements of the law in its broadest sense [16,41] and embedding research into both practice and policy within forensic science [11,15] is needed.

A return to 'scientific endeavour' will therefore need to incorporate both empirical and expert evidence bases. The FoRTE model presented here aims to articulate a conceptual understanding of the components of forensic reconstructions utilising trace materials. The model presents a means of developing a problem solving approach that incorporates both empirical evidence bases and the expertise of scientists and professionals within the forensic science domain. It is hoped that the incorporation of such a holistic and systematic view of forensic reconstruction has the potential to offer a transparent and evidence based foundation for adopting an 'ongoing critical perspective' [11:726]. Such a perspective will lead to the most effective questions being asked, the most appropriate analyses being undertaken and the enabling of robust inferences to be made thereby contributing to a distinctive 'forensic science culture' as outlined by Margot [42]. This perspective will ensure that research is focussed upon the critical questions we need to answer to underpin forensic science and ensure the potential of trace evidence is unlocked and can contribute to effective forensic reconstruction approaches.

The critical role of different forms of knowledge that are embedded in the components of the FoRTE model is addressed in part II of this paper. In order to identify potential paths forward within forensic science, an understanding of the diverse strengths and requirements of the different intersecting domains of research, practice and policy/law is needed. Articulating the dominant forms of knowledge and approaches to innovation within different institutions, is critical to successfully make use of the FoRTE model within the development of forensic science. Therefore, bringing together the FoRTE model with an understanding of the infrastructures of key institutions is the next step to identifying how to regain forensic reconstruction approaches that contribute to 'forensic science' as a scientific endeavour.

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References

[1] M.J. Saks, J.J. Khoeher, The individualisation fallacy in forensic science evidence, Vanderbilt Law Review 61 (1) (2008) 199–219.
[2] R.M. Morgan, P.A. Bull, The philosophy, nature and practice of forensic sediment analysis, Prog. Phys. Geogr. 31 (1) (2008) 43–58.
[3] National Academy of Science, Strengthening Forensic Science in the United States: A Path ForwardAvailable at: http://www.nap.edu/catalog 2009 (Washington D.C).
[4] C. Roux, F. Crispino, O. Ribaux, From forensics to forensic science, Current Issues in Criminal Justice 24 (1) (2012) 7–24.
[5] C. Roux, B. Talbot-Wright, J. Robertson, F. Crispino, O. Ribeaux, The end of the (forensic science) world as we know it? The example of trace evidence, Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 370 (2015) (Aug 51674: 20140260).
[6] P.L. Kirk, The ontogeny of criminalistics, J. Crim. L. Criminology & Police Sci. (1963) 235–238.
[7] P. De Forest, Recapturing the essence of criminalistics, Sci. Justice 39 (3) (1999) 196–208.
[8] P. Margot, Forensic science on trial - what is the law of the land? Aust. J. Forensic Sci. 43 (2–3) (2011) 89–103.
[9] J. Fraser, R. Williams, Handbook of Forensic Science, Willan Cullompton, 2009.
[10] The Law Comission, Expert evidence in criminal proceedings in England and Wales, The House of Commons (2011) 1–206.
[11] J.L. Mnookin, S.A. Cole, I.E. Dror, B. Fisher, M.M. Houck, K. Inman, D.H. Kaye, J.J. Koehler, G. Langenburg, D.M. Risenger, N. Rudin, J. Siegel, D.A. Stoney, The need for a research culture in the forensic science, UCLA Law Review 725 (2011) 725–779.
[12] The Forensic Science Regulator, Annual ReportAvailable at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/482248/2015_FSR_Annual_Report_v1_0_final.pdf 2015.
[13] Government Chief Scientific Advisor, Forensic science and beyond: authenticity, Provenance and Assurance, Evidence and Case Studies, The Government Office for Science, London, 2015 Available at: https://www.gov.uk/government/publications/forensic-science-and-beyond.
[14] President's Committee of Advisors on Science and Technology, Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods, 2016.
[15] J.J. Koehler, J.B. Meixner, An empirical research agenda for the forensic sciences, an empirical research agenda for the forensic sciences, J. Crim. Law Criminol. Forthcoming (2016) 09–16 Northwestern Public Law Research Paper No.
[16] G. Edmond, B. Found, K. Martire, K. Ballantyne, D. Hamer, R. Searston, M. Thompson, E. Cunliffe, R. Kemp, M. San Roque, J. Tangen, R. Dioso-Villa, A. Ligertwood, D. Hibbert, D. White, G. Ribeiro, G. Porter, A. Towler, A. Roberts, Model forensic science, Australian Journal of Forensic Sciences 48 (5) (2016) 496–537.
[17] R.M. Morgan, J. Flynn, V. Sena, P.A. Bull, Experimental forensic studies of the preservation of pollen in vehicle fires, Sci. Justice 54 (2) (2014) 141–145.
[18] D.A. Stoney, P.L. Stoney, Critical review of forensic trace evidence analysis and the need for a new approach, Forensic Sci. Int. 251 (2015) 159–170.
[19] R.M. Morgan, P.A. Bull, Forensic geoscience and crime detection. Identification, interpretation and presentation in forensic geoscience, Minerva Med. 127 (2) (2007) 73–89.
[20] A.P.A. Broeders, Of earprints, fingerprints, scent dogs, cot deaths and cognitive contamination—a brief look at the present state of play in the forensic arena, Forensic Sci. Int. 159 (2006) 148–157.
[21] G. McCulloch, P.A. Bull, R.M. Morgan, High performance liquid chromatography as a valuable tool for geoforensic soil analysis, Aust. J. Forensic Sci. (2016) (in press).
[22] A. Ruffell, J. McKinley, Forensic geomorphology, Geomorphology 206 (2014) 14–22.
[23] J.C. French, R.M. Morgan, An experimental investigation of the indirect transfer and deposition of gunshot residue: further studies carried out with SEM-EDX analysis, Forensic Sci. Int. 247 (2015) 14–17.
[24] E. Salas, M.A. Rosen, D. Diaz Granados, Expertise-based intuition and decision making in organizations, J. Manag. 36 (4) (2010) 941–973.
[25] K. Inman, N. Rudin, The origin of evidence, Forensic Sci. Int. 126 (1) (2002) 11–16.
[26] O. Ribaux, B. Talbot Wright, Expanding forensic science through forensic intelligence, Sci. Justice 54 (6) (2014) 494–501.
[27] O. Ribaux, A. Baylon, C. Roux, O. Delemont, E. Lock, C. Zingg, P. Margot, Intelligence-led crime scene processing. Part I : forensic intelligence, Forensic Sci. Int. 195 (1–3) (2010) 10–16.
[28] R.M. Morgan, J. Cohen, I. McGookin, J. Murly-Gotto, R. O'Connor, S. Muress, P.A. Bull, The relevance of the evolution of experimental studies for the interpretation and evaluation of some trace physical evidence, Sci. Justice 49 (2009) 277–285.
[29] N. Farmer, A. Ruffell, W. Meier-Augenstein, J. Meneely, R.M. Kalin, Forensic analysis of wooden safety matches - a case study, Sci. Justice 47 (2006) 88–98.
[30] R.M. Morgan, E. Allen, T. King, P.A. Bull, The spatial and temporal distribution of pollen in a room: Forensic implications, Sci. Justice 54 (1) (2014) 49–56.
[31] R.L. McElhone, G.E. Meakin, J.C. French, T. Alexander, R.M. Morgan, Simulating forensic casework scenarios in experimental studies: the generation of footwear marks in blood, Forensic Sci. Int. 264 (2016) 34–40.
[32] C. Aitken, F. Taroni, Statistics and the Evaluation of Evidence for Forensic Scientists, Wiley, Chichester, 2004.
[33] A. Biedermann, F. Taroni, O. Delemont, C. Semadeni, A.C. Davison, The evaluation of evidence in the forensic investigation of fire incidents (part I): an approach using Bayesian networks, Forensic Sci. Int. 147 (1) (2005) 49–57.
[34] N.M. Smit, D.A. Lagnado, R.M. Morgan, M. R., N.E. Fenton, Using Bayesian networks to guide the assessment of new evidence in an appeal: a real case study, Crime Science 5 (2016) 9–21.
[35] N.E. Fenton, M. Neil, D. Lagnado, W. Marsh, B. Yet, A. Constantinou, How to model mutually exclusive events based on independent causal pathways in Bayesian network models, Knowl.-Based Syst. (2016) (in press).
[36] F. Gobet, Understanding expertise, A Multidisciplinary Approach, Palgrave Macmillan, 2015.
[37] R.V. Weller, EWCA Crim (2010) 1085.
[38] I.E. Dror, Cognitive neuroscience in forensic science: understanding and utilizing the human element, Philos. Trans. R. Soc. B 370 (2015) 20140255.
[39] D. Casey, N. Clayson, S. Jones, J. Lewis, M. Boyce, I. Fraser, F. Kennedy, K. Alexander, Response to Meakin and Jamieson DNA transfer: review and implications for casework, Forensic Sci. Int. 21 (2016) 117–118.
[40] G.E. Meakin, A. Jamieson, A response to a response to Meakin and Jamieson DNA transfer: review and implications for casework, Forensic Sci Int Genet. 22 (2016) e5–e6.
[41] T. Raymond, R. Julian, Forensic intelligence in policing: organisational and cultural change, Aust. J. Forensic Sci. 47 (4) (2015) 371–385.
[42] P. Margot, Commentary on the need for a research culture in the forensic sciences, UCLA L. Rev. 795 (2011).