From Forensics to Forensic Science

Claude Roux, Frank Crispino and Olivier Ribaux*

Abstract

The dominant conception of forensic science as a patchwork of disciplines primarily assisting the criminal justice system (defined as 'forensics' in this article) is in crisis, or at least shows a series of anomalies and serious limitations. While the symptoms have been largely discussed previously, we argue that many of the commonly suggested solutions may not solve the fundamental problem. As a solution, we propose the forensic science community revive the forensic science perspective from its historical roots; that is, the study of crime and its traces. This will lead to the development of holistic models to provide a strategy to integrate technologies, and to help scientists develop their potential to engage in a more significant way in policing, crime investigation and, more generally, in criminology, instead of further compartmentalising the various forensic fields.

Introduction

Forensic science is at the crossroads. Its future largely depends on if and how a consensus can emerge about its own nature. There are many alternative ways of conceiving the discipline (Inman and Rudin 2001; Margot 2011a). The current dominant model, let's call it 'forensics', is defined as a series of scientific disciplines that assist the criminal justice system. For instance, chemistry, biology, physics or computer sciences, are viewed as core enabling scientific disciplines and associated technologies. Forensic chemistry, forensic biology or computer forensics are technical applications of the enabling disciplines based on the exploitation of samples collected at the crime scene and transmitted, in a more or less formalised way, by the police or the justice system. All the forensics disciplines share their subordination to the requirements of the criminal justice system, underpinned by jurisdictional, political and organisational philosophies, as well as being subject to specific legislation. These disciplines mostly (if not exclusively) serve the Court process. In the forensics model, crime scene is considered as a separate police technical activity.

In operational terms, forensics has recently faced significant challenges. For example, an influential report,[1] which is strongly based on this view of forensic science (ie 'forensics'),

* Professor Claude Roux, University of Technology, Sydney, Centre for Forensic Science, PO Box 123, Broadway, NSW, Australia, email: claude.roux@uts.edu.au; Professor Frank Crispino, Université du Québec à Trois-Rivières, 3351 Boulevard des Forges, CP 500, Trois-Rivières (QC) G9A 5H7, Canada, email: frank.crispino@uqtr.ca; Professor Olivier Ribaux, Université de Lausanne, Institut de Police Scientifique, Batochime, CH 1015 Lausanne, Switzerland, email: Olivier.Ribaux@unil.ch.

1 This report entitled *Strengthening Forensic Science in the United States: A Path Forward* was commissioned by the United States (US) Congress and publicly released by the US National Academies on 18 February 2009. According to its authors, it provides a plan for addressing the needs of the forensic science community and gives a full account of what is needed to advance the forensic science disciplines, including upgrading of systems and organisational structures, better training, widespread adoption of uniform and enforceable best practices, and mandatory certification and accreditation programs. The Report also recommends the creation of

pointed to flaws across US laboratories (National Academy of Sciences (NAS) 2009), including the absence of overall leadership, the fragmentation of the field, as well as the lack of accreditation, education, training and research in forensics. Accordingly, forensics occasionally leads to miscarriage of justice; and the main reasons suggested include the location of forensic practice within a law enforcement organisation, pressure from investigators and the lack of a research culture to validate methods and techniques used in casework. The recent announcement of the closure of the main forensic service provider in the United Kingdom (UK), the Forensic Science Service (FSS), is another salient event that promotes instability in the whole forensic community (House of Commons Science Committee 2011). In the current forensics model, these issues may be primarily identified as symptoms of deficient implementation systems. It is, therefore, often believed that current problems in forensics can be fixed by a series of normative recommendations. This assumption grounded the NAS (2009) recommendations and initiated a movement along this line across forensic stakeholders (Mnookin et al 2011).

However, as it will be shown below, the current situation may also mean that forensic science faces more fundamental issues. In other words, one may ask the question whether these issues are not simply the result of an unfit paradigm. If this is the case, current issues in forensics cannot be solely resolved by a traditional quality assurance response. According to Thomas Kuhn's social epistemology of science (Kuhn 1962), a dominant paradigm initially shows anomalies that precede a crisis. A new paradigm that results from a scientific revolution subsequently replaces the previous one. The kind of problems forensics meets today might, thus, also indicate anomalies and future significant changes. There are many contingencies that could lead forensic activities in many directions. We argue that there is no need for a forensic revolution in a Kuhnian sense. However, a positive future definitely requires rethinking the forensics paradigm and revisiting fundamental forensic science principles. From these elementary building blocks, a distinctive science can re-emerge through focusing on its object of study: the trace that is a remnant of unlawful activity.

Problems in forensics

Beyond specific failures (Office of the Inspector General 2006) and miscarriages of justice (Schiffer 2009) that justified audits, and eventually led to the NAS Report (NAS 2009), forensics is faced with a broader set of issues. The questions as to whether these issues constitute anomalies in the sense discussed by Kuhn or only flaws coming from improper applications of the current model ought to be discussed.

Organisational issues

Most governments are currently under financial pressures and, as a result, the transfer of forensics from the public sector to private enterprise has been seriously considered. This change already began years ago, mainly in the UK in the broader context of the development of 'New Public Management' (Lawless 2010, 2011). The recent decision to close the FSS in the UK, which was systematically losing money despite its dominant position, raised questions about the possibility of generating a viable market for forensics.

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a new government entity to establish and enforce standards within the forensic science community. It had a global impact on the forensic science community, at least in terms of strategic discussion and international benchmarking.

Looking beyond the specific UK situation, while not having made it the object of a systematic study, it is apparent that forensics is implemented differently in a large variety of organisational settings across the globe. In this scattered situation, mostly explained by the local history of the development of forensic science, it is difficult to define what the 'best' model is (Bedford 2011).

This fact by itself illustrates the absence of consensus on how and where to locate forensic services within the whole criminal justice system. Forensics is shaped differently in each jurisdiction (Welsh and Hannis 2011) and scattered across police, justice, or even health and other hosting organisations. Employees with very diverse backgrounds operate in these structures: managers, sworn police officers and a cross-section of scientists and technical staff coming from various disciplines. It was acknowledged by the NAS Report that this badly fragmented forensics system needs overhaul in the US (NAS 2009). However, it is fair to say that the same problem exists elsewhere (Bedford 2011; Margot 2011a).

At this stage, it is interesting to note a common observation across this very variable spectrum of administrative organisations: the role and scope of the scientist in the criminal justice system are poorly identified and almost never clearly articulated regardless of the forensic service organisational setting (Margot 2011b).

Education and research

Other problems occur in the competitive education and research sector (Roux and Robertson 2009). The demand for university programs in most enabling sciences has been decreasing over the last 20 years (RAC Royal Australian Chemical Institute 2005), while at the same time funding models for tertiary education have been increasingly linked to student numbers. As a result, many university programs often try to attract more students by opportunistically revamping their offers through the addition of the term 'forensic' to their program names. In this context, the forensic 'anything' flourishes. This confused situation has generated significant concerns about the quality of these programs in the UK (Forrest 2004; Science, Engineering Manufacturing Technologies Alliance (SEMTA) 2004; Mennell 2006). In particular, potential employers have criticised the lack of consistency and clarity in the vast range of forensic programs on offer, thus leading to difficulties in determining what skills a graduate might have (SEMTA 2004). More recently, skill deficits about basic forensic science theory and professional attitudes have also been highlighted by principal forensic employers (Welsh and Hannis 2011). These concerns have led to significant reviews of forensic science education and training in the UK (SEMTA 2004), US (National Institute of Justice 2004) and Australia (National Institute of Forensic Science 2005). In parallel, formal accreditation systems for forensic science academic programs were developed in the US (Forensic Science Education Programs Accreditation Commission (FEPAC) 2003/2011) and in the UK (Forensic Science Society 2008).

These developments are, overall, positive and enable a constructive debate around how to devise forensic science programs (Welsh and Hannis 2011). However, it is also fair to say that forensic science in academia by and large accepts the traditional forensics model, and forensic science is generally taught as an application of techniques, tools and enabling sciences, rather than as a scientific discipline on its own right with its distinctive object of study (Margot 1994; Crispino 2006, 2010; Crispino et al 2011; Margot 2011a, 2011b). With the pace of technical changes, there is no guarantee that when students have completed their program based on short-term technical requirements and needs of the employers, the skills they have developed will still be useful. For example, Mennell (2006) described the need for

universities in the UK to be influenced by the FSS in the design of academic programs largely on the ground that the FSS was one of the biggest employers in forensic science. But, by the time the students who had entered university at this time completed their program, the FSS was closed.

While distinctive tertiary education in forensic science was first called for more than 100 hundred years ago (Reiss 1909 cited in Mathyer 2001:71), for the reasons expressed above, we could argue that, with a few notable exceptions, most forensic programs today remain glorified chemistry or biology degrees.

Serious issues also exist with respect to research (Robertson 2011). From an academic standpoint, a research program is not sustainable and does not attract the respect from academic peers and major research funding bodies until it offers doctoral degrees (Roux and Robertson 2009). Such degrees are not common in forensic science across the world. Further, the capacity to carry out high-level research requires the ability to attract major funding, which in turn allows universities to employ experienced professional researchers such as post-doctoral fellows, research assistants and the like (Roux and Robertson 2009). Unfortunately, in most countries, it is still difficult to attract major funding for forensic science research through traditional research funding bodies while the 'forensic science industry' is cash deficient in being able to invest in R&D (Robertson 2011). In addition, traditional quantitative measurements of research quality, including number of citations, H index[2] and Journal Impact Factors[3], increasingly drive the allocation of resources; and it is fair to say that these indicators tend to underestimate the true usefulness of a person's or a group's contributions to forensic science innovation (Jones 2003). Overall, there seems to be little strategic encouragement for academics to elect forensic science as their main research endeavour.

Further, the lack of a research culture (Mnookin et al 2011; Margot 2011a) in forensics has been singled out as a major flaw in the system. Indeed, researchers see forensics as an opportunity to test generic methods generated for their core discipline using unusual or interesting data sets. This situation creates additional confusion by introducing highly specific and complex methods and technologies that are not specifically devised for forensic science, are sometimes not necessary and whose integration into forensic science practice is far from clear. In line with Margot (2011a) we argue that, while the need for more research is obvious, it has become crucial to seriously think about the nature of this research and ask questions about what actually constitutes fundamental forensic science research and who dictates the research agenda. Ultimately, forensic science research outcomes should assist in answering security, policing and justice questions in a tangible manner.

Laboratory backlogs and the undetermined effectiveness of forensic science

Laboratory backlogs have been pointed out as very damaging to the criminal justice system (Audit Office of New South Wales 2010; Strom and Hickman 2010). Traces often remain unexploited or test results are provided too late with respect to the evolution of cases. For example, it is not uncommon to wait for up to six months for a result (Strom and

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2 A scientist has index H if H of his or her number of papers (NP) have at least H citations each and the other (NP – H) papers have fewer than H citations each (Hirsch 2005); eg the H index of someone with 25 papers, but 10 papers that have been cited at least 10 times, is 10.

3 Journal Impact Factors are calculated on a yearly basis by the Journal Citation Reports (JCR) database. The Impact Factor of a journal is the average number of times that articles published in that journal in a two-year period have been cited in the following 'JCR year'.

Hickman 2010). Asking for more resources or improving the efficiency of analytical techniques are possible responses to the intractable number of exhibits transmitted to the laboratories. However, we ought to ask the questions: isn't there a risk that the demand for forensic testing will further increase following the laboratory's upgrade? And isn't the laboratory backlog issue also dependent on the selection of exhibits at the crime scene? One can, therefore, wonder whether a clear holistic strategy exists, not only based on economics, but also on how to use forensic resources appropriately and efficiently.

For example, triage efforts have been initiated in order to address backlogs (Raymond et al 2011). Triaging is directly related to the effectiveness of forensic science because information potentially conveyed by a profile may have a differentiated impact according to stated goals of the use of DNA: solving a single case, reducing crime, preventing crime or looking after other social interests (Bieber 2006; Robertson 2012). However, when goals are stated, they rarely go beyond solving specific cases (Burrows and Tarling 2004; Bieber 2006; McCartney 2006; Walsh 2009; Ribaux et al 2010a). Thus, the decision to submit a specimen is generally restricted by the type of offence for which the sample has been collected or the type of object submitted (Raymond et al 2011). This absence of systematic consideration on what DNA information brings to policing when triaging, is compounded by evidence that DNA laboratories tend to be unable to respond to basic questions about the follow-up of their work through their data management systems (Raymond et al 2011).

But how can a triage process be efficient? And what is efficiency? Does efficiency relate to the ratio of the number of specimens received/number of profiles extracted successfully by the laboratory? Or to the more global contribution of forensics to justice in regards to the resources engaged? Or to policing? But what kind of policing?

In the first instance, we may be satisfied with the impact on specific cases (success stories) or with the number of identifications obtained by the use of databases (mainly AFIS and DNA). After all, generating and interpreting relations between a crime stain (trace) and a source (person/object) may be what is expected from forensics, and some would argue that it is up to the broader system to elaborate a strategy to make sense of this service. However, more often than not, the question of efficiency is directly addressed to the forensics community and not to the broader system! In this context, it is acknowledged that very few empirical research studies are available that scientifically evaluate the value of forensics, especially when we consider the many processes where forensic information is or can be used (Wilson, McClure and Weisburd 2010; Julian et al 2011). As a result, forensics does not really know what the nature of its contribution is, because such a contribution is often drawn into broader policing activities, while laboratories are mainly concerned about complying with the quality of the service they have implemented, and not with efficiency in the broader criminal justice/security system.

Problems or anomalies?

According to Lawless (2010, 2011), the movement towards the privatisation of laboratories has also generated positive outcomes for forensics. At the very least, it stimulated the formalisation of interpretation models of forensic case data as a result of the necessity to clearly define the client/customer relationship — although, it remains unclear if such formalisation is welcomed by end-customers (ie investigators, the justice system and the trier of fact). This model gives some unity to forensics as a discipline

(Cook et al 1998, 1999). Thus, the current forensics model should not be prematurely rejected. It may be under attack only because it is not applied in a proper way. This is the tacit hypothesis that grounds dominant movements in forensics. The NAS Report, as well as the recently adopted Polish initiative in Europe (Council of the European Union 2011), follow this logic and propose directions to be taken to fix problems or mitigate risks. This strategy is mainly driven by specific failures and miscarriages of justice. Importantly, however, when a failure is apparent, the organisation generally acts at the individual level (ie an employee may be dismissed), while, externally, there is mounting pressure for a system overhaul.

However, forensic science plays many roles in a complex set of interrelated processes that support policing and the courts. If we analyse the dominant lines of action in forensics that also reflect the NAS recommendations (NAS 2009; Mnookin et al 2011) in regards to this broader perspective, it becomes apparent that the recommendations may also impact negatively on other processes. In the following section, we identify and critically discuss three such recommendations and/or strategies that have been proposed as ways to 'fix' the current problems in forensics.

(1) Contextual biases should be controlled by the implementation of various mechanisms, but an immediate measure would be to separate forensics structures from law enforcement

The context influences, positively or negatively, the treatment of forensic case data in many ways. Whatever the type of organisation, some fragmentation of information processes occurs. Thus, an organisational measure devised to mitigate a specific type of bias can potentially cause damage to other processes by fragmenting them in another way and slowing down, if not stopping the circulation of information. The holistic effect of commonly proposed measures has essentially never been studied.

The suggested lines of action may even be in contradiction with other strategies covering security issues. The report of the 9/11 Commission (National Commission on Terrorist Attacks Upon the United States 2004), recommends more sharing and integration of data in order to connect the dots, which is in direct contradiction to some of the NAS recommendations! According to the 9/11 Report, which acknowledges the potential of forensic case data to link information, forensics should participate actively in these efforts to cut across organisational silos. This is definitely not where the debate focuses today.

(2) More standard procedures should be developed; formal certification should be increased and quality assurance systems have to be tightened up; accreditation should be mandatory

These normative measures are desirable in separated laboratories with a restrictive use of instruments and roles, such as the routine analysis of samples and their interpretation for the court. However, it becomes significantly more problematic as soon as we consider the integration of forensic case data with all the other sources of information used across intelligence or investigative processes. Conceptually, shouldn't forensic case data be primarily viewed as information feeding processes in policing? Consequently, isn't it strange that we overly regulate and monitor forensic activities and not the rest of policing activities to the same extent?

(3) As a priority, the validity of methods is the focus of research, together with the reliability thresholds (statistical inferences) for different types of evidence through the collection of population data

Notwithstanding the fact that these topics are valuable areas of research, should they constitute the main focus of forensic research? What is lacking in this line of action is that no measure is suggested around how forensics supports not only the court process, but also problem-solving in policing (Goldstein 1990). In other words, this line of action suggests that in forensics we learn how to properly use instruments in routine processes, with little or no attention given to the purpose of these same processes in broader policing. Essentially, it is considered that the objectives that these processes serve are not the scientist's business. We consider this proposition to be absurd. For example, agonising about the statistical relationship between a trace and its source, when probabilities themselves are so high that they become meaningless, is irrelevant in most cases and especially in common situations when there is no dispute on the source of a trace. The defendant is more likely to contest aspects around the activity that eventually determines the court's decision. This is also true for cases when the uncertainties reside in the specific situation, and how it is handled, rather than in error rates of a scientific instrument (which appear negligible in the order of magnitude).

As a result, by considering the broader picture, it becomes apparent that many of the commonly suggested solutions to problems in forensics may not solve the fundamental problem. The following questions ought to be asked:

- Do we really improve the system by focusing on methods and error rates of instruments, while most uncertainties are the result of the situation and the trace generated by the situation?
- Do we really improve the system by increasing its complexity through additional monitoring and auditing processes essentially applied in laboratory settings?
- Are there antagonisms between commercial, scientific, and police activities?

In fact, the fundamental problem may be more global. Does forensics really address the right questions? While evaluation studies of the efficiency of forensic science concentrate on crime-solving on a case-by-case basis, policing is concerned with much broader questions: reducing crime, at least disrupting crime activities, and reducing the fear of crime. By reinstating these questions, the contribution of the existing patchwork of identification technologies and databases used without a clear strategy in relation to policing can be reasonably questioned (Ribaux and Hicks 2012). In this context, published research provides an unclear picture of the value of forensics, even occasionally contradictory, and this situation clearly necessitates further work (Julian et al 2011).

In summary, we argue that current problems in forensics may be anomalies that result from an overly restricted conception of the discipline as a single and simplified process serving court purposes. The forensics model itself reinforces this limited view, and, ultimately these anomalies may also illustrate the limitations of this conception of forensic science.

Anomalies and the risk of spiralling out of control

In the current context as presented here, one may speculate that forensics is engaged in an out of control spiral that forces it to reduce its scope to the point that it ends up as a series of service laboratories with limited strict analytical functions, rather than a set of interrelated processes that meet the needs of the criminal justice system in a holistic way.

The problem stems from the single process view. Rather than evaluating forensic activity in a broader security framework, forensics (as currently organised) concentrates all its effort on the mitigation of risks of inaccuracies in presenting information in court. There is evidence that forensic case data can deliver more value by feeding intelligence processes and supporting investigation in its early phases (Tilley and Ford 1996; Barclay 2009; Crispino, Brault and Burgueyre 2009). However, in the forensics view, this service is seen as secondary, and sometimes even undesirable. It is our experience that forensic scientists often hesitate, if not refuse to deliver information for intelligence purposes, because this kind of service does not belong to the core business of a laboratory developed with the current forensics mindset. And when the police receive such information they rarely see its real potential. This means that when the laboratory is making an effort to go beyond producing outputs for the traditional court purpose, there is often an impression that valuable work is being produced without really generating significant interest from the police. In other words, the absence of models for integrating forensic case data creates an apparent paradox where more well-meaning efforts from the laboratory generate more problems for the scientist and for the laboratory — with little, if any, reward.

Indeed, inaccuracies in interpretation have become so unacceptable that forensics find refuge in laboratories that content themselves with accepting a sample as input, and giving a neutral result as output leading to a significant waste of information. The problem is compounded by the absence of models of integration. Moreover, structures of control are added to mitigate risks that very rarely materialise. Ultimately, this overhead leads to increased costs for the service, while customers (primarily police) concurrently see their budget cut. As a consequence, it is foreseeable that forensics organisations will strictly focus on fixing specific commercial issues and will overlook the development of their discipline. Because of this, it is not surprising that scientists become frustrated as they may feel they are able to contribute more in specific situations, although structures and procedures rarely allow this nor do they reward commitment that goes beyond routine tasks. If this diagnosis is proven right, isn't there a risk of initiating or even increasing and reinforcing a foreseeable spiralling (and narrowing) process through a loss of motivation? With a lack of broad valuable goals to which the scientist is committed and the loss of a distinctive mindset, would a forensic career still remain attractive? Wouldn't this situation ultimately leave the space to pure technical staff? Eventually, wouldn't such a trend lead to limited technical services whose overall efficiency is difficult to assess? Forensics would have difficulties in justifying its existence in this context: would a tiny service for a high cost be acceptable?

This sequence is probably too pessimistic for most of us. Faced with perceptible net loss of information with the forensics model, some organisations have refocused on the crime problem. They may show a path forward in breaking this vicious circle. For instance, the French gendarmerie has created the role of crime scene coordinator[4] (Schuliar 2009). Ironically, this action was partly inspired by the coordination structure that was in place in the UK before the demise of the FSS (House of Commons Science Committee 2011). The integration of forensic case data in investigations has also been rediscovered in some organisations (Barclay 2009). Finally, the idea of devising a position of case manager (Thompson 2011) in the laboratory as an interface with the police is another illustration of some emerging initiatives. But forensics shows a series of anomalies that are far from being

[4] The crime scene coordinator in the French gendarmerie is claimed to be a new actor in charge of supporting decision-making related to forensic operations, from the crime scene along the whole process, for an intelligence, investigative or evaluative purpose.

easily addressed without embracing the possibility of alternative or complementary views of the discipline. This is not obvious in a context where the traditional division of the sciences is institutionalised and hampers the emergence of a new model. There is, thus, a need to look back at the first part of the 20th century in order to understand how the fundamental principles of forensic science have been ignored by forensics. More importantly, a modern conception of forensic science that serves problem-solving in policing can emerge from these fundamental principles.

Forensic science instead of forensics

The two basic principles that constitute the pillars of forensic science have been attributed to Paul L Kirk and Edmond Locard. Indeed, Kirk's principle can easily fit the forensics model, while Locard's principle provides opportunities for an extension of this model.

Paul L Kirk and the individuality principle

Paul L Kirk's (1902–1970) individuality principle is the building block for forensic science (Kirk 1963). On the assumption that 'every object in the Universe is unique', he claimed that the main aim of forensic science is to focus on the source of two items (questioned and known, or mark and print) supposed to have originated from a single source, or to approach it as closely as the present state of science allows. Together with Kwan (1977), he pointed out that the identity of properties measured from a trace and its putative source (eg a fingermark found at the scene and a fingerprint taken from a person) did not necessarily mean the identity of the source. A deterministic statement about the latter is only a subjective position of the expert. In particular, Kwan (1977) who was Kirk's PhD student, provided the methodological basis for the identification process, including a statistical approach that is debated today under the term 'Bayesian approach' (*R v T*; Berger et al 2011). Indeed, this principle provides the grounding for the only significant recent movement that gives unity in forensics (Cook et al 1998, 1999).

Edmond Locard's exchange principle

Edmond Locard (1877–1966) built his laboratory in Lyon in 1910. He claimed that there is a broad variety of traces that are remnant of activities. And these traces, if properly interpreted, are the most valuable information that can be used to explain what occurred:

> The truth is that none can act with the intensity induced by criminal activities without leaving multiple traces of his path. [...] The clues I want to speak of here are of two kinds: Sometimes the perpetrator leaves traces at a scene by their actions; sometimes, alternatively, he/she picked up on their clothes or their body traces of their location or presence. (Locard 1920)

Locard insisted that the discipline not be restricted to consider one single trace. During his time, he was arguing against those who wanted to rely only on fingerprints. The discipline should consider all the traces available, depending on the activity, and its information potential. It is hypothetical, but we cannot resist the temptation to wonder how Locard would have considered the current forensics focus on DNA.

Locard's principle was embraced in North America in the 1930s. However, its traditional English translation, 'every contact leaves a trace', is a good example of how the understanding of the purpose of forensic science was tightened up and prefigured the forensics view. Indeed, in this formulation, the nature of the activity is removed. This is

unfortunate, as the original statement in French not only satisfies the philosophy of science according to Popper (2002), but its scientificity can also be accepted under a modern epistemological conception of science (Crispino et al 2011).

Understanding crime and criminals was a real concern for Locard who never hesitated to immerse himself in the milieu. While this attitude has to be understood in the context of its time, it illustrates how the connection of forensic science to the nature of criminal activity has been almost entirely removed from forensics since that time. This creates an obvious gap between those who analyse traces and those who are concerned with the study of crime. After all, Paul L Kirk was a professor in the prestigious criminology school of University of California (UC) Berkeley, first developed by August Vollmer (1876–1955), who introduced significant reforms in bridging scientific approaches with policing (Vollmer 1930). Together with Locard, who kept himself very informed about criminology, they embody the whole territory that forensics has moved away from, up to the point where it has now lost its object of study.

Several roles for forensic science in the criminal justice system

Forensic science can rely upon its historical roots in order to find the path that can be used to reclaim its lost territory.

> Forensic science has an object: the study of crime and its traces. These are silent witnesses that need to be detected, seen, and understood to make reasonable inferences about criminal phenomena, investigation or demonstration for intelligence, investigation and court purposes. After all, traces are the most elementary information that result from crime (Margot 2011b:100).

Traces are the remnant of a presence or an action. The trace, sometimes latent, becomes a sign (pattern, signal, or object) that can tell at least part of the story.

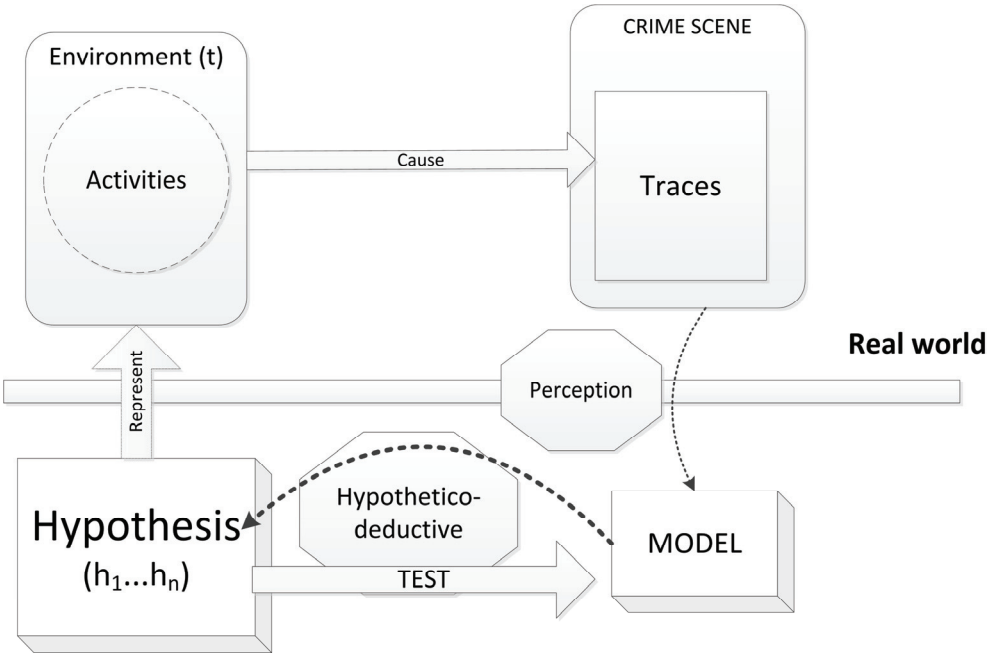
According to this definition, the focus moves back on the unlawful activity, on the crime itself and on the nature of physical exchanges that result from it. From this perspective, forensic science concentrates on how this knowledge can support the large variety of processes of the criminal justice system. The formalisation of this full potential still requires significant work, although models have been recently proposed (Delémont et al 2012).

Forensic investigation

Extending the use of forensic science beyond the court for supporting decision-making in the course of crime investigation is generally felt necessary. But what is the nature of these decisions? Brodeur (2010) helps in this perspective by distinguishing three types of investigations: the identification problem (who is the author?), the localisation problem (where is the author?), and the problem of structuring evidence (what happened?). In forensic science, Kind (1994) presented crime investigation very similarly as three ‘chapters’: the problem to find; the decision to charge; and the court process itself. From a more fundamental point of view, this approach calls for a distinction between the inferential approaches adopted within each ‘chapter’. Crime investigation starts from traces in order to establish the activity and its criminal nature, and then find the offender. According to Kind, this relies mostly on an inductive approach that starts from traces and leads to suspects. It can be stated better in a Peirce abductive form; that is, the reasoning process that tries to reconstruct what occurred (the case) from the result of the activity (the traces) with the

support of general rules (Eco and Sebeok 1988). Once a suspect is under scrutiny, the logical process changes to become more deductive: what are the consequences if 'this' scenario is true. This is why the global process of crime investigation can be modelled as a hypothetico-deductive mechanism (Figure 1).

Figure 1: The hypothetico-deductive cycle as a model of reasoning.



Material is exchanged during an activity in an environment at a certain time. Traces are collected later and characteristics are extracted from them. A set of hypotheses that may explain the presence of the traces are abducted from the resulting model. Then hypotheses are (experimentally) tested with respect to all the information available. This process may lead to refutation or lead to the collection of new information. Hypotheses are then iteratively updated as a function of the new information available.

These logical foundations are the basis for the development of methodologies for a more systematic integration of forensic case data into crime investigation. In forensic science, there are already some instances of such applications. A typical example would be when relatives of the source of a biological trace are searched for in a database, rather than the source itself (Bieber, Brenner and Lazer 2006; Curran and Buckleton 2008; Hicks et al 2010). Drug profiling suggests other examples where crime investigation can be supported by forensic analysis (Esseiva et al 2008). In all these examples, a salient point is how forensic case data is integrated with other elements of the investigation. Forensic case data only tell part of the story. Thus, keeping a holistic view of the case is of great importance, and there is a need to develop models for this purpose (Fraser 2007; Barclay 2009; Schuliar 2009). It is recognised that this framework is generally broadly applied in the investigation

of serious cases (Chisum and Turvey 2007). However, there is still a lack of a published model, beyond police manuals, of how this integration should proceed more generally.

Forensic intelligence

Even if the area of investigation has been the object of some attention, the potential of forensic science is much broader. The police are moving towards models of policing where intelligence and crime analysis are central in order to elaborate strategies that disrupt crime activities (Ratcliffe 2008). It is obvious that forensic science has a great role to play in feeding crime analysis functions. After all, forensic case data constitute the most elementary pieces of information that allow an understanding of the mechanisms underlying many forms of criminality. According to Locard, traces have the information potential to indicate what occurred. Forensic intelligence can, thus, be inscribed within intelligence-led policing frameworks. Further, crime intelligence is pivotal in these frameworks to provide reliable, accurate and timely information for making decisions at a tactical, operational and strategic level in terms of how to respond to crime problems (Ratcliffe 2008). However, the use of forensic case data in these more proactive models of policing is very rarely mentioned, and models for this integration are still limited (Tilley and Ford 1996; Braga and Pierce 2004; Tilley and Townsley 2009; Ribaux et al 2010a; Aepli, Ribaux and Summerfield 2011; Gagliardi 2012).

However, the linking capacity of forensic case data has the potential to dramatically consolidate crime intelligence at all levels. DNA links, comparison of striae on bullets collected on different scenes (Braga and Pierce 2004), drug profiling (Esseiva et al 2003) or other drugs seized (Roggo, Degardin and Margot 2010), as well as counterfeited documents (Baechler et al 2011) or high volume crimes (Milne 2001; Napier 2002; Ribaux, Walsh and Margot 2006) provide solid building blocks for crime analysis. This contribution is not restricted to traditional police activities, but may also concern other types of risk analysis such as in public health (illicit and counterfeited substances) or for intelligence agencies (terrorist modus operandi on the run). In this view, crime scene examination is a core activity, because it feeds all these processes (Crispino 2008; Ribaux et al 2010b). This contrasts with how the forensics model currently considers crime scene examination.

How intelligence-led forensic activities will develop directly depends on how intelligence-led policing will be embraced by police organisations (Ratcliffe 2008). Without the implementation of such a strategic framework, the efficiency and relevance of forensic activities will always be difficult to assess.

Other contributions to policing

Outside the laboratory, when the frontline is considered (eg crime scene examination, identity checks, identification of a suspected substance by customs or during house-search and crack-down operations, decoy, search for explosives at the airport), there is a demand for forensic science to provide rapid information. The development of transportable technologies (eg Lab-on-a-Chip, spot tests) driven by the concept of 'bringing the laboratory to the scene', thus, belong to the many challenges of forensic science. Once again, the use of these technologies should inform the security, policing and justice context in which they are deployed. It becomes crucial to reflect on the proper application of these technologies and the best use of the results in terms of the problem being addressed and considering the intelligence available. This situation compels the scientist to leave the traditional laboratory, to be directly engaged in the field and integrated with the other actors in the security system.

Conclusions

Forensic science primarily deals with explaining what occurred. Forensic science should, therefore, contribute much more to the study of crimes.

Rather than focusing on techniques and instruments by taking the point of view of traditional disciplines of science, a modern forensic science concentrates on the problem to be solved and calls for appropriate specific instruments and techniques.

This conception brings crime scene examination to the forefront of the whole picture. Traces are not only collected from the perspective of their presentation in court, but also to feed the variety of information processes running in parallel in the law enforcement system. Traces also bring information that is crucial to intelligence-led policing management or for informing other disciplines that study crime. This perspective might be occasionally tacitly applied, but it generally does not belong to the agenda of current organisations. The NAS Report itself refused to address this issue in its introductory part, reinforcing the partition of the various forensic disciplines at the laboratory level (NAS 2009).

We argue that the current forensics conception of forensic science is in crisis, or at least shows a series of anomalies and serious limitations that has led the forensic scientist to retreat into the laboratory:

> As for reasons that continue to elude us (which means they must be administrative or fiscal), the system continues to try to force square pegs into round holes, placing the onus of all-important evidence collection on those least trained to recognize it, and sequestering the criminalist in the laboratory with the expensive equipment. (Inman and Rudin 2001:64)

Along with others (Berger et al 2011; Margot 2011a), we claim that the forensic science community itself urgently needs to revive the original forensic science perspective from its historical roots. Developing and fostering a strong forensic science culture is crucial, and this implies changes in the way forensic scientists should be educated and trained. For instance, notwithstanding the fact that accreditations of academic forensic programs in the US and the UK are valuable contributions to ensure some quality and provide some coherence, they broadly accept the traditional forensics model and still do not require a single unit on policing or criminology (Forensic Science Society 2008; FEPAC 2003/2011). This revival also involves the development of holistic models to provide a strategy to integrate technologies, and to help scientists develop their potential to engage in a more significant way in policing, crime investigation and, more generally, in criminology, instead of further compartmentalising the various forensic fields.

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