Forensic Intelligence

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In this chapter, the term 'intelligence' is progressively integrated into the dominant conceptualizations that traditional forensic science laboratories implement in serving justice systems. Forensic intelligence thus expands the narrower scope of forensic science. The latter's frame of reference eventually changes when its contribution to security studies and proactive styles of policing is envisaged. A generic forensic intelligence process is presented, which provides forensic science with a global framework demonstrating the possible collaboration between many new professions and forensic scientists who are interested in crime intelligence.

Introduction

Forensic intelligence brings together two terms whose definitions are the object of many interpretations. Depending on the position adopted, forensic intelligence can even be considered an oxymoron, or, at least, as highlighting tensions inherent in the articulation of security and justice systems. Indeed, 'forensic', etymologically, designates the context of a court of law. Crime intelligence (the conjunction of criminal intelligence analysis and crime analysis, following Ratcliffe [2008]) covers a much broader scope. Beyond its role in investigative procedures, it is often related to security studies. This field has travelled some distance from the legalist approach to crime problems.

Nevertheless, there are many incentives for adopting the proposed articulation. The narrowness of traditional views on forensic science does not allow the structured, useful and comprehensive exploitation of all data whose treatment should fall under its purview. This is particularly evident in its allegiance to justice systems, which themselves struggle to adapt to increased human traceability and the harm caused by innovative crime systems. Consequently, a reform movement within forensic science is gaining greater recognition. It proceeds by progressively expanding the role of forensic science, from its narrower interpretation to its integration into proactive styles of policing and security studies. A logical framework that allows the gradual integration of ideas under the heading 'intelligence' supports this expansion.

A generic forensic intelligence process developed in the scientific literature will be described here (Morelato et al. 2014). It aims at:

(1) Facilitating the debate around the protection of civil liberties;

(2) Questioning efficiency as the primary, or sole, criterion in forensic work;

(3) Serving training and education purposes;

(4) Leading to more realistic computerizations; and

(5) Showing how forensic science can collaborate with a broad set of new professions related to security.

Defining Forensic Science: From a Structural to a Procedural View

Currently, the dominant practice in forensic science splits the treatments of data collected at scenes into specialized fields, called forensic disciplines. This division follows different dimensions: the types of forensic data (e.g., pattern evidence such as fingermarks, shoemarks or toolmarks; trace evidence; and DNA), the use of sophisticated techniques (e.g., separation methods in analytical chemistry or image acquisition and processing techniques) and limited fields of investigations where the analysis of the material collected has a particular legal relevancy (e.g., illicit drugs, fire and firearms investigations). This fragmented view has been called forensics (Roux *et al.* 2012) see Roux and Crispino's chapter) and is based on the following postulates:

- It clearly distinguishes police work from sciences serving justice purposes.
- It is implemented through an independent organization responding to specific demands from authorities, such as commissioned expertise. Such a structure is implemented under the form of the so-called traditional forensics laboratory.
- The sciences concerned are directly related to fundamental disciplines, such as chemistry, physics or computer science.
- Terms used in the literature such as 'client' or 'forensic science provider' emphasize the existence of a public/private management system delineating services and products

offered to various actors/figures, mostly belonging to justice systems (some laboratories also respond to private demands).

The basic tenet of these forensics structures is mandatory compliance with procedures and rules of justice systems. Since the publication in 2009 of the US National Academy of Sciences report criticizing flawed practices and unstandardized procedures across laboratories (NAS 2009), pressure on forensic laboratories has increased. Subsequently, the major trend in response to this criticism has been the implementation of quality systems. Fundamental sciences and practices developed in common industrial laboratories have served as a reference. Forensics has thus almost no epistemology of its own within this frame of reference.

On this fragmented view of forensics, internal cohesive forces inevitably weaken until the question arises: is there any justification or advantage to maintaining a single forensic laboratory? The failure to provide a convincing answer to this elementary question is illustrated by the closure of many such laboratories around the world, or of some of their economically less viable components. In particular, trace evidence departments are in jeopardy, despite the richness of the information conveyed (Stoney and Stoney 2015). The most obvious gap in this conception, beyond lack of identity of a discipline, is its failure to consider crime scene investigations (Ludwig *et al.* 2012; Roux *et al.* 2012). This disregard creates a serious void in conceptualizing the whole treatment of forensic data.

A Procedural View of Forensic Science

The view privileged in this chapter is procedural; it considers how information is processed transversally, rather than focusing on the way forensic activities are organized (Williams 2007). For this purpose, we define in Figure 1 a global process for forensic science. It is inspired by Inman and Rudin (2001) and Roux et al. (2012). It outlines the logical treatment of information accessible from singular cases, toward their use in justice systems. This description is transversal and generic. This means it is independent from how the various figures/actors are organized, how their roles and functions are distributed, the type of material exchanged, as well as the techniques used to detect, observe and measure it.

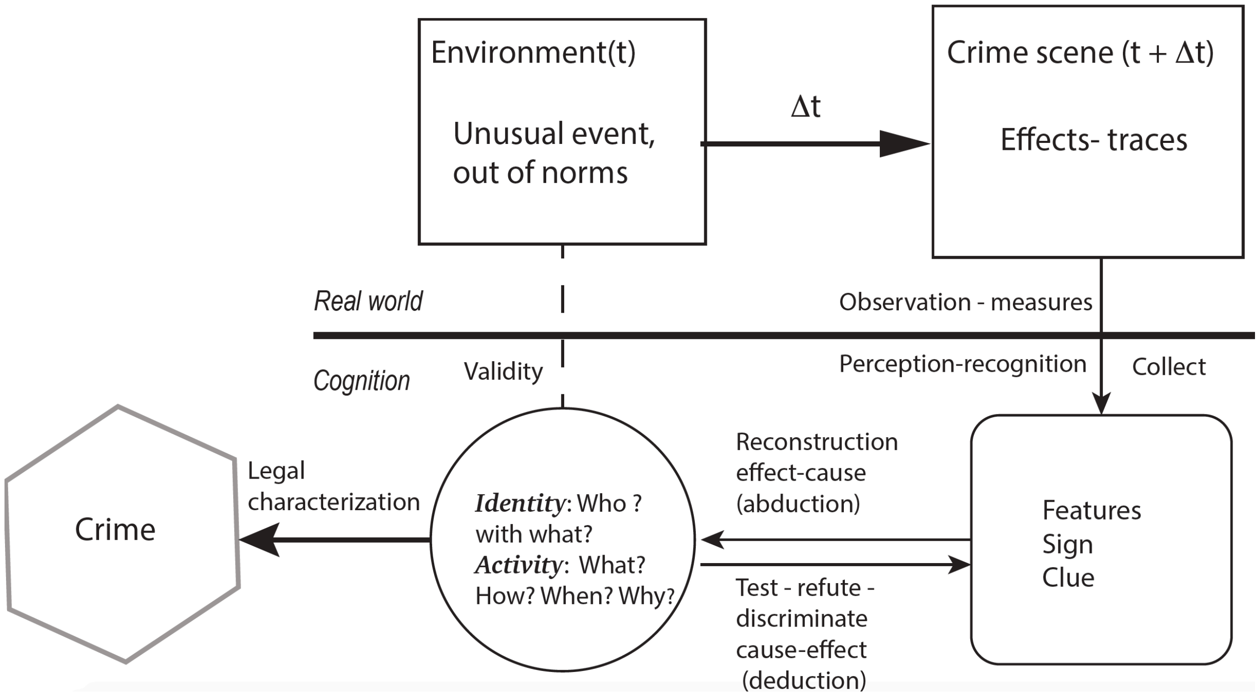

Figure 1 ***Global forensic process****. The activity perturbs the environment and causes exchanges of material (application of Locard's postulate). This material is dispersed and delineates the crime scene. Investigations lead to the detection of traces, which are observed, collected, measured and recognized as relevant. Results of observations and features extracted become signs that indicate aspects of the activity through reconstruction (logical abduction). More than one hypothesis may explain observations. Rival hypotheses and their logical consequences are tested through experiments. In function of their resistance, they are discriminated, reformulated and beliefs in their validity adapted. Hypotheses are eventually developed in regard to their relevancy for legally characterizing the case.*

The procedural view derives directly from the richer interpretation of Locard's postulate. Hence, it situates the trace as the common object of study (see Margot chapter). The trace is the effect, the vestige of an unusual activity perturbing the environment, whatever the nature and the size of the material exchanged. It is the elementary information on which the activity of interest is logically reconstructed. The trace follows a long path and may be used under many forms before eventually being presented at a court of law. We consider that it becomes evidence only when it supports a court's decision-making process (see Margot chapter), whatever its use in earlier phases of the logical process. This logical transformation from the trace to evidence aims at making actionable the information conveyed.

Of course, forensic science cannot be considered in isolation. Justice systems still mostly define the context, whatever the vision adopted. In a procedural view, however, forensic science demonstrates its own epistemology and benefits from a greater latitude for its development.

Scope of the Narrower View of Forensic Science

Bringing a transversal view into the fragmented practice of forensics is the principal merit of the so-called Bayesian community. It developed a rational model for assessing the strength of the information conveyed by a trace, and for integrating it into the global decision-making process of a court of law. Forensic science thus retakes the initiative in relation to the exploitation of its object of study.

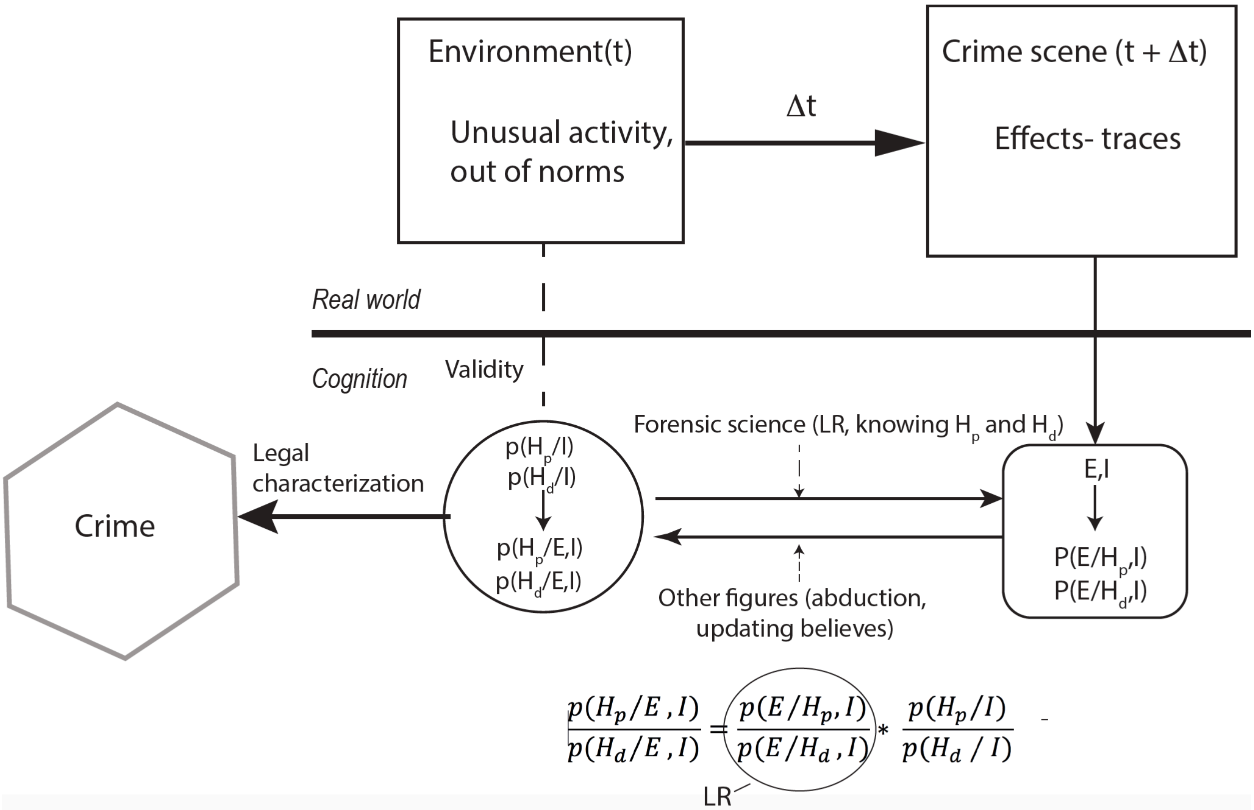

Figure 2 ***How probabilistic inferences situate narrower visions of forensic science****. H_p and H_d are the hypotheses remaining after investigations. At this stage, they are preferably termed 'propositions', rather than 'hypotheses'. A formula derived from Bayes' theorem expresses how relative beliefs in these hypotheses, interpreted within specific circumstances (I), change with new observations (E). The likelihood ratio (LR) delineates the territory of forensic science. It demands an evaluation of the observations extracted from a trace, supposing that H_p and H_d are true. It is thus deductive in nature. The other terms are the province of other figures of the court process. One of the advantages of this conception is the universality of the model. It applies whatever the type of traces under consideration and across justice systems.*

The model's contribution can be situated within our forensic science framework (Figure 2). The Bayesian model clarifies the respective positions of actors/figures when an expertise is commissioned. The so-called Likelihood Ratio (LR), derived from Bayes' theorem, is defined as the province of the scientist, while the client, it is assumed, deals with other terms of the formula. The clients here are mostly a court of law or an authority that commissions an expertise. This approach postulates that the core of the forensic expertise resides in the capacity to evaluate uncertain information through subjectively stated probabilities, and to combine them coherently. Hence, the rationalization efforts focus on intensively 'probabilizing' the process, but keeping in its own hands a very limited part of it (Biedermann 2015). The LR is deductive in nature: propositions are assumed to be given.

Occasionally, a broader contribution of forensic science to the whole process is recognized. Forensic science goes beyond the LR by providing opinions on other terms of the formula. However, such contributions are allowed under very restrictive conditions: 'another situation where scientists may legitimately formulate probabilities is when they intervene at the investigative phase and express, for example, an opinion about a matter that can reasonably be confined to technical and scientific considerations only (e.g., the cause of a technical failure, cause of a fire, etc.)' (Biedermann 2015, 146). This opening remains very narrow. Support provided to a client for formulating propositions is also only reluctantly admitted. Inman and Rudin (2001) recognize that this is where the experience of the scientist is the most useful—and the least recognized!

Delineation of an Area for Forensic Intelligence

There is a growing consensus that recognizes other poorly formalized forms of forensic work scattered across justice systems and the police (e.g., crime scene investigation). They concern the abductive part of the forensic process (reconstructing the activity, developing hypotheses) rather than evaluating already stated propositions. Some within the academic community, however, judge this logic to be insufficiently mature, and scientists operating in forensic laboratories by and large concur. Abduction is not sufficiently mathematized, while forensic science at a court of law must provide protagonists with transparency and robustness in how conclusions are reached. The difficulties in expressing the logic consequently exceed the threshold for a science dedicated to justice systems.

This is exactly the postulate forensic intelligence does not take as granted. Etymologically, investigation contains the Latin root *vestigium*, which means the vestige or the trace. Investigation expresses the central role of detecting, collecting, recognizing and interpreting trace in the whole crime investigation process, not only in the evaluation of given propositions (LR). In comparison with the forensics view, forensic intelligence addresses a significant gap. The police already take the initiative in this area and create good practices, but with weak scientific grounding. This creates a context with great potential for missing information or misinterpreting data. Forensic intelligence considers participation in the structuring and implementation of these processes one of the responsibilities of forensic science.

In summary, the dominant view of a forensic expert's role within forensic science explicitly covers only a very small part of the global treatment of traces. This view masks the variety of uses of information conveyed by traces, the need for integration with other data and the missed opportunities for conducting investigations, particularly in the earlier phase of crime investigation. These gaps are already evident at the crime scene.

Forensic intelligence and crime investigation are about crime reconstruction. Such a logic can hardly be mechanized since it calls for imagination, drawing analogies and associating ideas. Some aspects can nevertheless be rationalized and structured, even if not readily mathematizable. Forensic intelligence postulates that these efforts bring greater efficiency and robustness to justice procedures globally than the proliferation of costly measures of control externally proposed in the traditional model. The scientific consolidation of these wider territories dramatically reduces risk of error and augments transparency in the conduct of crime investigations.

Differentiated Contexts for the Application of the Forensic Science Process

Kind (1994) provides a useful positioning of forensic activities within the whole criminal investigation process. He provides a first structure, and allows the progressive integration of the concept of intelligence (see also Delémont et al. 2014. At least four different contexts (Kind calls them chapters) can be postulated: they have differentiated implications for the way to logically apply the forensic process, prior to a court's final decision (see Figure 3).

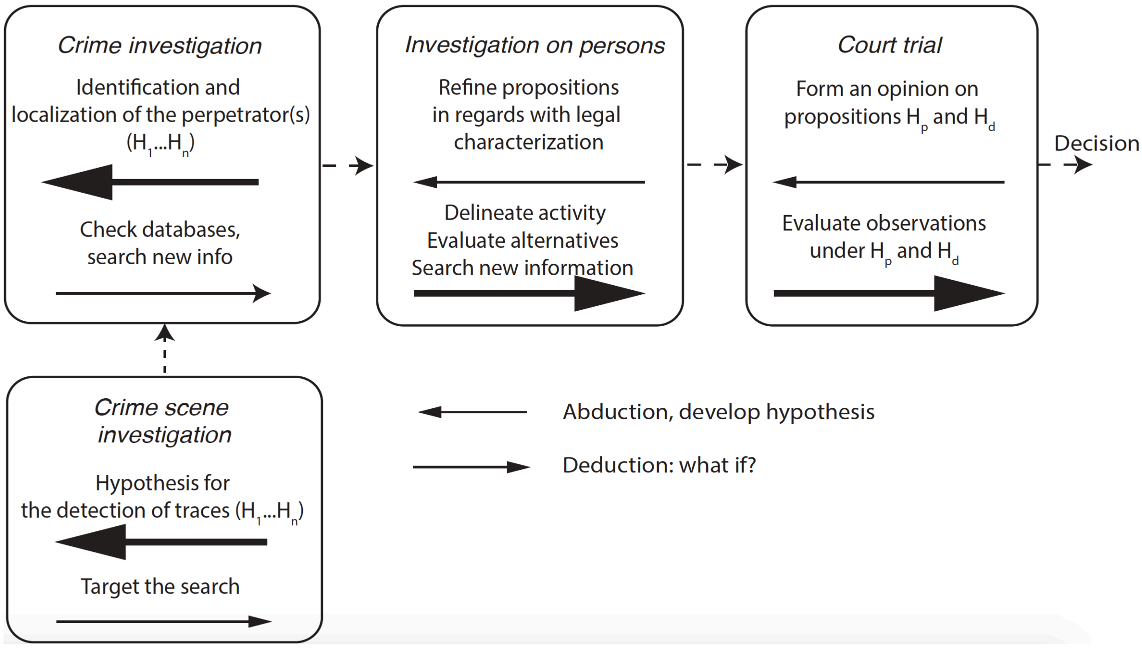

Figure 3 ***The criminal investigation process as four chapters inspired by Kind*** *(Kind 1994). Crime scene investigation requires the intensive development of hypotheses about what occurred with the intent of collecting relevant traces of the activity or noticing their astonishing absence. They are relevant in the sense of being related to the case, as well as adding value for the variety of tasks distributed over the chapters (Bitzer et al. 2015). Those traces will first find their utility in supporting the identification and localization of potential perpetrators. But they also serve to legally characterize the crime. The next step means that persons are under investigation. New scope for the activities can be delineated, for instance, through operations such as the search of the home of the person. Legal characterization is now crucial. It demands adaption of hypotheses until they reach the form of propositions (both the defence and the prosecutors proceed) relevant for informing the court's judgments. The court trial itself, then, is the place for debating propositions (and occasionally raising new ones) to reach a verdict. The sequence is not perfect. When a person is stopped in the street wearing a gun without authorization or carrying an unknown suspect substance, this may lead directly to the initiation of an investigation of that person to search for possible illegal activities. When informants point to persons, investigations of these (networked) persons also start immediately in order to delineate their activities.*

In the first two chapters of the investigation (see Figure 3), the main question is to link activities to persons, while the next two chapters deal with connecting persons to activities. At this point the logic is reversed, from being more abductive in the early phase to becoming more deductive leading to the court trial. This progression is compounded by the increased stability of hypotheses along the whole process. In the early phase, there are incentives for imagining a broad range of possibilities for explaining all the information available. At the other end, propositions have been refined and stabilized.

Forensic Intelligence as Interpreted Traces Supporting Decision Making

Figure 3 describes the many treatments the trace follows until it reaches a court of law, where it becomes evidence. The framework suggested by Bitzer et al. (2015) helps structure further the process.

A detected trace is first found factually relevant, i.e., linked to the event under consideration. It is useful, i.e., helps in the resolution of the task. It is usable, i.e., understandable for its users. Such a gradual interpretation allows a first link to be drawn with the term intelligence.

Indeed, in its broader interpretation, intelligence is the accurate, timely and useful product of logically processing information (Ribaux et al. 2003). It influences decision making. On this interpretation, evidence is a particular form of intelligence obtained from a trace, as it has been evaluated with the objective of supporting a court's decision-making process. Judging by the amount of attention the trace attracts, it is probably the most visible and studied form of evidence. Yet, it has been demonstrated that only a tiny part of existing traces are detected, analysed and eventually used by a court of law (Bradbury and Feist 2005). Moreover, the resolution of only few cases can be attributed to traces (Brodeur 2010). Thus, the focus on the court trial calls into question the effectiveness and efficiency of forensic science (Roux et al. 2014). Why engage so many resources if forensic science's influence on the outcome of justice systems is negligible?

In response, forensic intelligence argues that many opportunities to use the informative potential of traces are missed and that a systematic identification of the variety of its actual contributions is needed (Delémont et al. 2014).

Such decisions already come up in crime scene investigation (see Delémont chapter). For instance, a sequence of shoemarks is found at the scene of a burglary. This sequence may lead to the assumption that the perpetrator moved toward an object that has potentially been touched (contact point). A fingermark found on the object may, in turn, lead to the burglar. In this situation, the sequence of shoemarks was assumed relevant, useful and usable in making a decision relative to the task (collecting traces). This reasoning is independent of whether the shoemarks will subsequently also play a role at a court of law. These shoemarks have acquired the status of intelligence because they have provided support in guiding actions that help resolve the task. There is no evaluative model of the efficiency of forensic science that integrates such determinant contributions.

Types of inference	Example of intelligence provided	Usefulness/possible actions taken
Suggesting a possible frame (possible sources for the trace)	A fingermark found at the scene is compared to fingerprints of known persons stored in a database. The interpretation of this comparison may point to the source of the trace.	An investigation against the person begins.
	A partial DNA profile extracted from a biological trace collected at a scene is compared with a database, providing a frame of possible sources.	Focus the search to a limited set of persons (frame).
Identifying a substance	A powder found on a person is identified as an illicit substance.	Decide to keep the person in jail for further investigations.
	A red substance found on the floor is identified as human blood.	Envisage the hypothesis of a homicide, and take measures accordingly.
Suggesting the description of an object or a person	A red paint fragment is recovered at a car accident. The make and model of the car at its source is determined.	Police call the public for assistance and check databases of car's owners according to this information.
	DNA has been extracted from biological traces. It provides the gender of the person, as well as indications about the human appearance of the source.	Police target their search according to the physical profile determined.
Reconstructing the modus operandi	Debris found at the scene is compared to images taken by witnesses, allowing the development of possible scenarios for the origin and cause of the fire, and establishing its criminal nature.	Start an investigation for arson.
Assembling pieces of same origin	Pieces of a single body are found at different places.	Link investigations that may have started independently.

Situating trace in time (Weyermann and Ribaux 2012)	Time since the person died has been evaluated by the examination of the body and the use of forensic entomology.	Test scenario and adapt actions in function of chronologies.
Localization of trace	The signal of a mobile phone belonging to a missing person is localized.	Orient the search for the missing person.
	Specific plants, soil and fibres are found on an abandoned body	Reorient the investigations. If a place is determined, search for possible source for the fibres.
Linking individuals	Fibres are exchanged between shirts of persons.	Orient the investigation by supposing a link between the two individuals.
Linking persons to objects	DNA profile of a person is found on the screen of a computer.	Evaluate consequences that the person is a possible user of the computer.
Linking objects	A list of calls to/from a mobile phone collected from an arrested person is made.	Search for accomplices or detect/consolidate knowledge on the structure of a criminal network.

Table 1 Examples of forensic intelligence related to investigations

Some typologies illustrating the variety of the kinds of intelligence provided by traces have been proposed (e.g., Ribaux et al. 2006) (see Table 1). They provide elementary building blocks. Looking for decision-making points where traces are used in practice, as well as evaluating this contribution, is, however, at the top of forensic intelligence's research agenda.

One important characteristic of crime has still not been taken into account: forensic science work has been considered as a response to events, on a case-by-case basis, while certain forms of criminality are highly concentrated and repetitive. What role can traces play in this perspective?

Forensic Intelligence, Repetitive Crimes and Crime Analysis

The repetitive nature of certain forms of crimes has long been recognized (Ratcliffe 2008): crime concentrates in place and time; it often reaches the same (type of) victims; and some offenders are known to be ‘prolific’.

The elementary inferences described above can thus be linked to form a chain in many practical situations. When a DNA profile allows the identification of a suspect, police can take actions against this person—for example, interviews or a search at his or her home. When shoes are collected in the course of these operations, sole patterns are systematically compared with those collected previously at different scenes. Similarities found extend the scope of the investigation to other cases. The person’s mobile phone may, in turn, indicate connection with criminal networks. These kinds of inference structures are frequently used for uncovering part of the broader activity of a person under arrest.

The information conveyed by traces is also used for detecting crime repetitions prior to an arrest. When used systematically, traces are extremely powerful for this purpose. A typology for structuring the contribution can be defined (Table 2). Of importance in terms of intelligence is the evaluation of the impact of linking activities on investigations. The variety of forms this intelligence (usefulness) can take increases dramatically.

Types of inference	Example of intelligence provided	Usefulness/possible action taken
The same source – person	DNA profile found at a scene is the same as a DNA profile found at another scene.	Investigations are linked together and information joined. This synthesis allows a better description of the profile of the perpetrator.
The same source – object	A bullet found at one scene is assumed to have been fired by the same gun as another bullet found at another scene.	Investigations are linked together, and information joined. The synthesis reorients investigations.
The same type of source – object/substance	An illicit substance found on an individual is linked with (comes from the same batch as) the illicit substance found on another person.	The substance comes from the same network, and investigations can be linked.

	From images and paint specimens found at the scene, robbers have used the same make and model of car in break and enter of jewellery store.	Envisage the possibility that perpetrators belong to the same group. Recent stolen cars of this make and model are searched for in order to extend investigations and anticipate next cases.
	An increase in the use of guns of a certain make and model is observed from bullets and cartridge found at scenes (Hannam 2010).	Possibility of a new organized crime network and its consequences has to be envisaged.

Table 2 Examples of forensic intelligence related to crime repetitions

Forensic Intelligence and Intelligence-Led Policing

The contribution of forensic intelligence seems, at this point, related only to crime investigations. Its contribution is, however, far broader. Linking activities and persons is part of the understanding of crime systems and mechanisms. This knowledge, in turn, allows the design of proactive actions aimed at disrupting those activities. From investigating the past, forensic intelligence turns to anticipating the future.

For instance, traces can support the detection of the activity of a serial offender through the comparison of DNA profiles collected at different scenes. Then the synthesis of all the information collected on each case in the series may cause a pattern to emerge. This pattern shows regularities in the behaviour of the offender that can be used to anticipate his or her further activities. Intelligence partly provided by traces thus indicates how preventive/repressive measures can be envisaged and planned to mitigate an activity causing harm.

This switch from reactive to proactive policing changes the reference for forensic science and also connects to the global field of security and policing, in particular to problem solving (see Cusson in this volume) or, broadly, to the so-called intelligence-led style of policing. Since the late 1980s, intelligence-led policing models have developed, principally in the UK (Ratcliffe 2008). As early as 1996, Tilley and Ford (1996) regretted that forensic science was not sufficiently connected to the new developments in policing high-volume crimes. This was confirmed by subsequent audits (Blakey 2002), as well as when globally evaluating the variety of contribution of forensic science (Bradbury and Feist 2005).

This recognized potential needed to be further investigated and expounded. A definition of a forensic intelligence process has been proposed for this purpose (Morelato et al. 2014; Baechler et al. 2015) (see Figure 4). The SARA (scanning, analysing, response, assessment) methodology developed for supporting problem-oriented and community policing (see Cusson, this handbook) has inspired the description of this process. The forensic intelligence process, however, focuses on the use of traces. It is generic since it does not depend on the type of traces under consideration. It is iterative in the sense that it ensures the continuous follow up of problems. And it relates to intelligence since the main objective is to lead to recommendations on how to deploy measures for responding to problems.

It can be adapted for monitoring high-volume crimes (Ribaux et al. 2006), the systematic linkage of false ID documents (Baechler et al. 2013), illicit markets on the Internet or any other types of repetitive problems (Morelato et al. 2014). Of course, each adaptation demands the integration of specificities associated with the problem under scrutiny or the nature of the traces treated.

It is not easy to discern which elements of the architecture of the process—and at which level of detail— are generic transversally. Such discernment is related to a subtle modelling activity. Many aspects of its elementary functions have, however, been identified with some genericity (Morelato et al. 2014). For example,

- methodology for linking cases can be based on measure of similarities, i.e., the definition of 'distances' calculated between vectors of features extracted from traces (Esseiva *et al.* 2003) Baechler et al. 2013);
- analysis can be oriented by the detection of tendencies in the data, such as the increase or drop in the appearance of a specific characteristic of a certain type of trace collected in a time series. For instance, an increase in the appearance of a certain type of sole pattern in the traces collected during a certain period in a specific region may indicate the activity of a single perpetrator (Albertetti et al. 2016);
- clusters in the data are detected, for instance, the grouping of characteristics of the chemical profile of illicit seized substances (Esseiva et al. 2003).

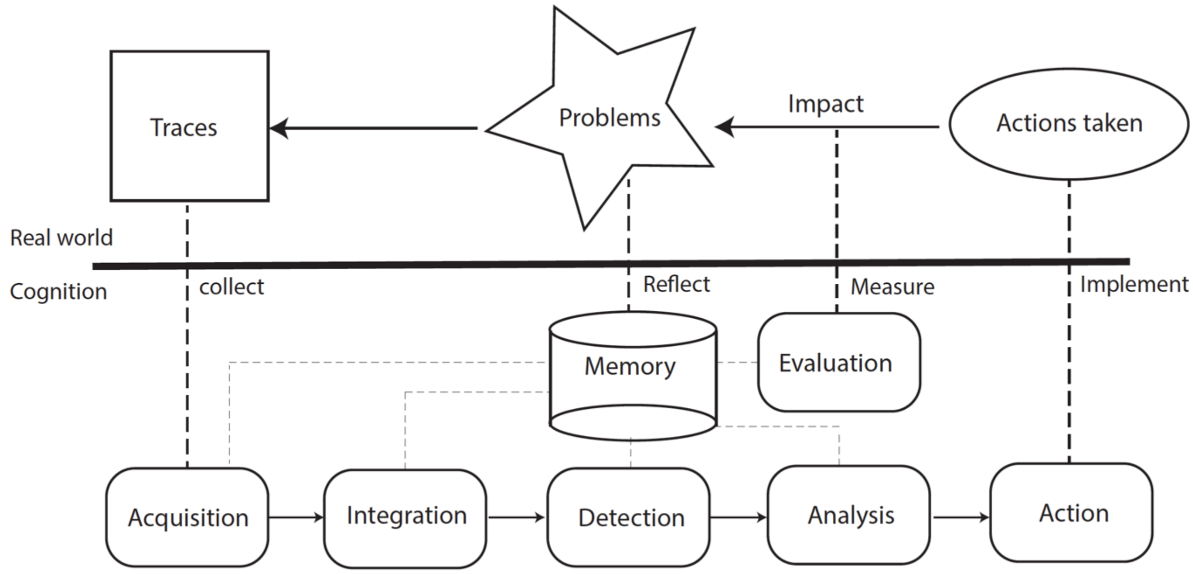

Figure 4 ***Forensic intelligence process, inspired by Ribaux*** *(2014). Repeated activities cause problems. They generate traces that have to be detected and collected. Features are extracted from traces (acquisition). This data is entered into a memory and linked to the knowledge already available on certain problems (integration). Repetitions are detected, for instance, through the search of tendencies, clusters or elementary links, and grouped into new problems (detection). Problems detected are analysed in order to determine their cause (analysis). This analysis allows the design and the choice of a response to the problem (action). Actions are eventually deployed, and their impact on the problem has to be systematically evaluated.*

The whole articulation of forensic intelligence can now be formulated in Figure 5.

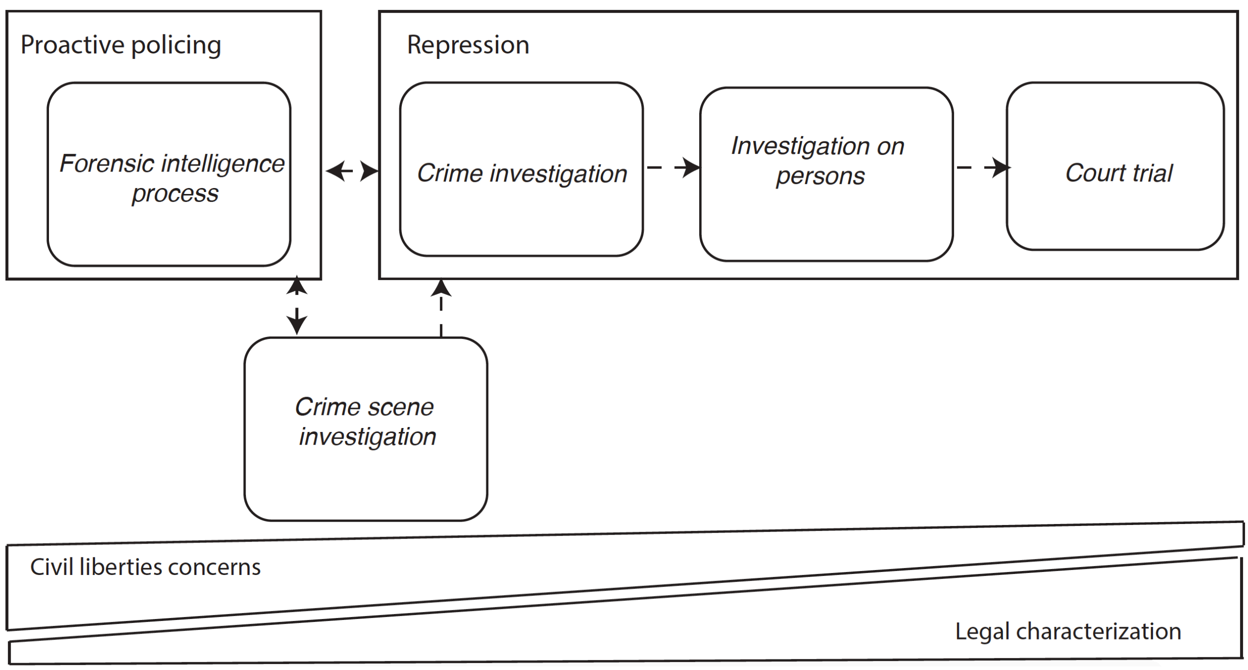

Figure 5 ***The use of forensic science in proactive policing*** *The use of forensic intelligence in proactive policing may orient crime investigation and crime scene investigation (see Delémont chapter). Conversely, lessons learned from investigations feed knowledge on crime systems and mechanisms. The legal context in which those activities are carried out changes*

dramatically, as proactive policing needs the collection of data and may be closely related to surveillance. Concerns about civil liberties are thus a priority, while the analytical activity take distance from a too legalist approach of criminal behaviour. When the investigation of the case progresses, legal characterization is a priority, and the judge orders intrusive measures for this purpose.

Building Capacities for Articulations with Other Types of Data

Forensic intelligence proposes that traces left by the activity of interest receive much more attention as elementary building blocks producing intelligence for guiding investigations and orienting policing. In recent times, investigators have relied principally on interviews of witnesses, victims or suspects. This activity has not been abandoned, but few investigations are conducted now without numerical traces extracted from electronic devices. The volume and variety of information accessible in the early phase of an investigation has thus dramatically increased, necessitating new frameworks for their integration with more traditional types of data. The formalized model for accessing scientific expertise through an external laboratory in a formal and punctual manner cannot work in these conditions. Investigations thus become naturally much more collective and interdisciplinary. On a serious case, interdisciplinary teams are now ready to intervene rapidly in certain countries (Barclay 2009), while laboratories tend to define new roles for coordinating scientific information and ensuring more fluidity in the process (Schuliar and Crispino 2013). The future will demand much more work for formalizing such a collective process in order to favour hypothesis development and management, which are at the core of crime investigation.

Traces have rarely been considered as central in crime linkage systems and crime analysis. Such processes are founded to a greater extent on modus operandi or other behavioural aspects related to the activity of the perpetrator. They therefore leave very implicit the reconstruction phase at the core of the forensic process: the activity took place in the past, and modus operandi can be assumed only on the basis of the interpretation of relics of the event. This hole in the reasoning process may lead to missing essential points. Modus operandi is systematically the result of a reconstruction, even when the action has been filmed (images are definitely traces of the activity). How many homicides, for example, are lacking in the data because the investigative process failed to analyse sufficiently deeply suicides or accidents? The systematic use of traces in comparing crimes is far from effective. Structures for this purpose must still be defined by starting from the generic process presented.

Conclusion

This chapter contributes to articulating the pervasive message in this handbook: the study of crime cannot totally abstract from understanding the disturbances caused by unusual specific activities occurring on a physical/digital substrate. This is not only a technical problem; this is much more an information-processing problem calling for solid logical foundations—the proper use of information conveyed by traces.

By filling an alarming gap in crime investigation and broader policing, forensic intelligence contributes to restoring a broader position for forensic science. It demands the more offensive and explicit integration of information conveyed by traces. A solid framework is urgently needed since the increase in human traceability demands changes in the way investigations are conducted and proactive policing envisaged.

Traditional physical traces often come late in the investigative process, more often under the form of a commissioned expertise carried out by an independent laboratory and dedicated to a court of law. Conversely, numerical traces are used very early in crime investigations, even before crimes are perpetrated, through communication monitoring. Numerical traces are *voluminous*, of great *variety* and demand *velocity* in their treatments. Their *validity* is often questionable. They have a great informational *value*. These 5 Vs are well-known signs that investigation and intelligence has entered into big data space. Methodologies for exploring those spaces are only in their infancy.

The view of forensic intelligence presented in this chapter shows how the richness of the concept of trace can be used for this purpose.

References

Albertetti, F., L. Grossrieder, O. Ribaux and K. Stoffel. 2016. 'Change Points Detection in Crime-Related Time Series: An On-line Fuzzy Approach Based on a Shape Space Representation'. Applied Soft Computing. http://dx.doi.org/10.1016/j.asoc.2015.12.004.

Baechler, S., M. Morelato, O. Ribaux, A. Beavis, M. Tahtouh, P. Kirkbride, P. Esseiva, P. Margot and C. Roux (2015) 'Forensic intelligence framework. Part II: Study of the main generic building blocks and challenges through the examples of illicit drugs and false identity documents monitoring', *Forensic Science International* Vol 250, 44-52, 10.1016/j.forsciint.2015.02.021

Baechler, S., V. Terrasse, T. Fritz, J.-P. Pujol, O. Ribaux and P. Margot (2013) 'The Systematic Profiling of False Identity Documents: Method Validation and Performance Evaluation Using Seizures Known To Originate from Common and Different Sources', *Forensic Science International* Vol 232 no 1-3, 180-190, 10.1016/j.forsciint.2013.07.022

Barclay, D. (2009) 'Using Forensic Science in Major Crime Inquiries' in J. Fraser and R. Williams (eds), *Handbook of Forensic Science*, Willan, Cullompton**,** 337-358

Bitzer, S., N. Albertini, E. Lock, O. Ribaux and O. Del�emont (2015) 'Utility of the Clue - From Measuring the Investigative Contribution of Forensic Science to Supporting the Decision to Use Traces', *In press*, 10.1016/j.scijus.2015.05.005

Blakey, D. (2002) *Under the Microscope Refocused. A Revisit to the Thematic Inspection. Report on Scientific and Technical Support*, Her Majesty's Inspectorate of Constabulary, Ditching

Bradbury, S.-A. and A. Feist (2005) *The Use of Forensic Science in Volume Crime Investigations: a Review of the Research Literature*, Online Report, Home Office, Londres

Brodeur, J.-P. (2010) *The Policing Web*, Oxford University Press, New York

Delémont, O., O. Ribaux and E. Lock (2014) 'Forensic Science and Criminal Inquiry' in G. J. N. Bruinsma and D. L. Weisburd (eds), *Encyclopedia of Criminology and Criminal Justice*, Springer, Berlin**,** 1754-1762

Esseiva, P., L. Dujourdy, F. Anglada, F. Taroni and P. Margot (2003) 'A Methodology for Illicit Heroin Seizures Comparison in a Drug Intelligence Perspective Using Large Databases', *Forensic Science International* Vol 132, 139-152

Hannam, A. G. (2010) 'Trends in Converted Firearms in England & Wales as Identified by the National Firearms Forensic Intelligence Database (NFFID) Between September 2003 and September 2008', *Journal of Forensic Sciences* Vol 55 no 3, 757-766, 10.1111/j.1556-4029.2009.01293.x

Kind, S. S. (1994) 'Crime Investigation and the Criminal Trial: a Three Chapter Paradigm of Evidence', *Journal of the Forensic Science Society* Vol 34 no 3, 155-164

Ludwig, A., J. Fraser and R. Williams (2012) 'Crime Scene Examiners and Volume Crime Investigations: An Empirical Study of Perception and Practice', *Forensic Science Policy & Management: An International Journal of Police Science and Management* Vol 3 no 2, 53-61

Morelato, M., S. Baechler, O. Ribaux, A. Beavis, M. Tahtouh, P. Kirkbride, C. Roux and P. Margot (2014) 'Forensic Intelligence Framework. Part I: Induction of A Transversal Model by Comparing Illicit Drugs and False Identity Documents Monitoring', *Forensic science international* Vol 236, 181-190

NAS (2009) *Strengthening Forensic Science in the United States: a Path Forward*, National Research Council of the National Academies, National Academies Press, Washington D.C.

Ratcliffe, J. (2008) *Intelligence-Led Policing*, Willan, Cullompton, UK

Ribaux, O., A. Girod, S. Walsh, P. Margot, S. Mizrahi and V. Clivaz (2003) 'Forensic Intelligence and Crime Analysis', *Probability, Law and Risk* Vol 2 no 2, 47-60

Ribaux, O., S. J. Walsh and P. Margot (2006) 'The Contribution of Forensic Science to Crime Analysis and Investigation: Forensic Intelligence', *Forensic Science International* Vol 156, 171-181

Roux, C., F. Crispino and O. Ribaux (2012) 'From Forensics To Forensic Science', *Current Issues in Criminal Justice* Vol 24 no 1, 7-24

Roux, C., R. Julian, S. Kelty and O. Ribaux (2014) 'Forensic Science Effectiveness' in G. Bruinsma and D. Weisburd (eds), *Encyclopedia of Criminology & Criminal Justice* Springer, Berlin**,** 1795-1804

Schuliar, Y. and F. Crispino (2013) 'Semiotics, Heuristics, and Inferences Used by Forensic Scientists' in M. Houck and J. A. Siegel (eds), *Encyclopedia of Forensic Science*, Academic Press, 2nd edition, Waltham**,** 310-313

Stoney, D. A. and P. L. Stoney (2015) 'Critical review of forensic trace evidence analysis and the need for a new approach', *Forensic science international* Vol 251, 159-170, 10.1016/j.forsciint.2015.03.022

Weyermann, C. and O. Ribaux (2012) 'Situating Trace in Time', *Science and Justice* Vol 52, 68-75, 10.1016/j.scijus.2011.09.003

Williams, R. (2007) 'Policing and forensic science' in T. Newburn (eds), *Handbook of Policing*, Willan, Cullompton**,** 760-793