

How to share and utilise expertise in a police forensic department through externalisation and mutualisation.

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Abstract

Fire investigation is a forensic domain in which expertise and analogy play a central role. We conducted an ethnographic study in a Swiss forensic police department, aiming at deciphering how fire investigators use analogy to support their work. We also evaluated knowledge conservation and sharing within the department in order to propose a suitable knowledge management strategy. Results highlighted that actionable knowledge is mainly registered in investigators memory and especially in a few, very experienced, individuals. Facing a lack of knowledge during fire incident investigation, an individual generally requires help of a more experienced colleague, who will then uses his memory and analogy to find a possible similar case that can contribute to the solution of the ongoing one. The research also established that knowledge exchanges occur orally during on-site investigation and that knowledge receivers are generally limited to investigators involved in case solving. Based on those findings we suggest building a case library to support the externalization and sharing of knowledge.

Key words: Fire investigation, knowledge management, case library, ethnographic study, computer-supported cooperative work, human factors

1. Introduction

Forensic science encompasses a wide range of activities and skills often starting with (crime) scene examination, and sometimes going as far as evidence presentation in court. In this paper, we take a look at the forensic activity of scene examination that, despite attracting little attention from the academic community, remains the core practice of the overwhelming majority of forensic practitioners. More specifically, we focus on one type of situations for which scene examination is undertaken: fire incidents. Due to the somehow peculiar aims of this type of investigation – elucidation of the origin and cause of the fire, of its propagation, and, when appropriate, of criminal responsibilities – it may be conducted by specialised units. But more often than not, it is carried out by police forensic units that are involved in all types of scene examinations. Yet, fire investigations differ from other types of scenes both by the context and the environment – more often than not very destroyed – in which they take place. Concretely, in Switzerland, fire investigations are mainly realised or supervised by investigators with huge experience in this domain. It highlights that fire investigations

are difficult to solve for individuals with less experience in the field and so the crucial role of experience. Consequently, fire investigation knowledge is highly bound to a restricted number of individuals and the risk of knowledge and competence loss due to retirement or departure is significant.

To avoid such deleterious situations, it is necessary to externalise the relevant knowledge, and to make it available and actionable to others. Several methods as case-based reasoning or case library may assist in this perspective, and the choice of the most suitable one is not straightforward. It should rely on a deep understanding of the interactions between the several individuals composing a unit, and the forms of knowledge exchanges that take place.

We therefore decided to conduct an ethnographic study in the forensic department of a state police (Commissariat d'Identification Judiciaire, Police Cantonale de Fribourg, Switzerland) in which the main author of this paper is employed at part-time. This study aimed in particular at deciphering how knowledge gained through fire investigation was maintained, used and shared. We also looked at unveiling and assessing the roles and mechanisms of using cases analogy in the investigation of a new fire incident.

1.1. Fire investigation as a knowledge-based activity

In police forensic unit context, fire scene investigation may appear largely as a case-to-case activity, each fire incident being the start of a new and isolated investigation, conditioned by the characteristics of the incident. But in fact, the investigation process is strongly embedded within a continuum of practice of a unit and of the individuals composing it. Past investigations provide valuable knowledge that investigators can utilise – more or less implicitly – by analogy to help solve the new situation: the fire under investigation is scrutinised as a possible “reoccurrence” of a past incident(s). Past solutions or successful strategies are re-applied to current fire incident. This approach refers to a concept of *recurrence* or *repetition* that plays a pivotal role in many applications in forensic science, in particular for intelligence purposes. Physical traces (DNA profile, shoe marks, etc.) are commonly used to link offences, revealing the repetitive actions of perpetrators (Ribaux 2014). Other dimensions of repetitions are also taken into account in fire investigation, revealing possible problematic situations or informing decision-making: detection of serial arsons can influence the operational strategy of investigation (Bruenisholz et al. 2017), evaluating the predominant “modus operandi” of accidental fire can usefully impact prevention strategies (Waser 2010).

Currently, the repetitive dimension of fire incidents is mainly considered for the identification of a serial arsonist and for the mitigation of risk situations. But as previously mentioned, the recurrence of similarity between fire incidents is already a pillar of the actual practice of fire scene investigation. Facing a new incident, investigators rely on the lessons learnt from past cases that could share some degree of analogy with the current incident: similar environment, materials or heat sources involved, etc. Findings or successful strategies arising from these past cases are then integrated as actionable knowledge in the investigation process of the actual case. This kind of repetition between cases is central in the investigation process: analogy is the core of cognition (Hofstader et Sander 2013), and recognition of common pattern between two cases is an essential skill for an experienced individual independently from his domain of speciality (Chi, Feltovich, et Glaser 1981; Marchant et al. 1991; Johnson 1988; Schmidt, Norman, et Boshuizen 1990). Context of fire investigations may vary a

lot in terms of place, appliances involved or potential criminal dimension. Moreover damages could hide some clues. This imply the impossibility to use a predefined procedure to guide all investigations. Context analysis and adaptation is essential in this type of case. Consequently pattern recognition is the main tool of fire investigator and stay mainly bind to individual experience.

This highlights the central and fundamental role held by repetition inside cases in fire incident investigation. Existing research suggests that analogy in an important means of knowledge conservation and sharing. But the nature and the extent of this reasoning by analogy through repetitions is not formalised, and its added value still needs to be understood. Despite the common use of analogy in fire investigation no study was conducted to better understand which elements are used to establish relations between cases, the level of abstraction of those relations and how they could differ or not between individuals.

This is precisely the purpose of this paper that reports the results of an ethnographic study conducted within a police forensic department. It studied the ways a forensic department manages fire investigation knowledge and similarities between cases. In consideration with relevant scientific research, these results lay down the foundations for the design of a knowledge management system that could support operational investigations and contribute to perpetuating relevant knowledge.

In general, we believe that such research can substantially contribute to understanding the role of expertise and the influence of analogies and repetitions in fire investigation either to solve new cases or to manage knowledge within a forensic department. It is a prerequisite to the improvement of fire investigation knowledge management through the use of those repetitions and analogies.

This research is part of an ongoing framework project aiming at understanding, structuring and mutualizing the knowledge generated within a forensic unit through the investigations conducted by each forensic investigator on fire incidents.

2. Literature review

Within the activity of fire investigation, it is widely acknowledged that experience – in terms of number and diversity of incidents investigated – is an essential component of proficiency. Experienced fire investigators are generally recognised as *experts* by other investigators due to their higher performance. They are seen as mentors for younger colleagues and are generally requested to provide support to ongoing investigations.

In this perspective, the standing of experienced fire investigators is very comparable as that encountered in many other domains, epitomised by the distinction between an *expert* and a *novice*. One of the main differences between experts and novices is their problem solving ability; experts will rapidly find the best solution and identify clues that others do not (Chi 2006; Johnson 1988; Shanteau 1992). This superiority in problem solving results from an improvement in reasoning and cognition gained from experience.

Novices rely mainly on formalised (or explicit) knowledge and are fully conscious of every steps made within the reflexive process (Köpsén et Nyström 2012). With the accumulation of experience and consequently of tacit knowledge, their reasoning becomes increasingly intuitive and unconscious (Eraut 2000). According to Collins and

Evans, novices possess ubiquitous knowledge (Collins et Evans 2008) as any other individuals. As far as they take part to practice they become investigator community member, listen to story from the field and acquire its codes and vocabulary (Van Maanen 1973; Waddington 1999; David Wyatt 2014; Innes 2003). This immersion in field work will allow them to develop specialist tacit knowledge and more precisely contributory expertise (Collins et Evans 2008). In parallel accumulation of knowledge and experience gained through practical work alters one's memory structure, allowing for easier establishment of relationship between cases (Hofstader et Sander 2013).

Each time a case is solved, the investigator will commit to memory its details by classifying it using one or many general concepts by which the case is representative of. With accumulation of expertise, those network of concepts will become wider, more complex and also distributed on many level of abstraction (Hofstader et Sander 2013). Consequently, analogies drawn between situations will be different for a novice or an expert (Ozkan et Dogan 2013). Generally novices will establish analogies at a lower level of abstraction. In contrast, the expert's complex network will allow them to establish many analogies at different levels of abstraction (Ozkan et Dogan 2013; Hofstader et Sander 2013). At this point they possess contributory expertise which allow them to do their activity with competence (Collins et Evans 2008). With such cognition system, experts are able, in almost any situation, to see many similarities between cases and to reuse elements of past cases to help solve the present situation. This also allows expert to make heuristics (Hofstader et Sander 2013).

Those elements help understand an expert's reflective superiority but also highlight the fact that such capacities require years of training and are highly bound to individuals.

As few researches presented in this literature review relate to the forensic domain, and none specifically to fire investigation, in a first step, we decided to evaluate if expertise induces cognitive and performance differences between investigators. Then we wanted to understand how fire investigation experts were using repetitions and analogies to solve fire incident.

Once those elements fixed through results of an ethnographic study, we wanted to propose a suitable methodology to extract, conserve and share fire investigation knowledge. In consequences as environment is crucial to methodology implementation, we will first study how knowledge is actually managed in the forensic department. Then we will define the best knowledge management strategy that could be applied within this service. Those methodologies were currently mainly used to guarantee companies competitiveness (Gavrilova et Andreeva 2012) and could be diverse as supervision (Köpsén et Nyström 2012; 2015), community of practice (Ackerman et al. 2013; Chiem et al. 2014; Doak et Assimakopoulos 2007), Case-based reasoning (Casey 2013; Roldan Reyes et al. 2015; Hoffman 1987; Aamodt et Plaza 1994; Schank et Abelson 1977) or case library (Kolodner et al 2003; Kulasegaram et al. 2017; Tawfik et al. 2017; Tawfik 2017). Even if some kind of supervision and community of practice (exchange between more and less experienced investigators) is used within almost every forensic department through interaction between investigators they are not seen as a knowledge management tool and their use is rarely formalised. Case-based reasoning rely on the reuse of past cases and successful strategies to support the resolution of new case. Case-based reasoning system could be quite different in terms of automation of problem solving and interaction with the user (J.L. Kolodner 1993). One of the simplest form is case library in which similar past cases are proposed to the user to support his reasoning.

3. Methodology

An ethnographic study was conducted to get a clear understanding on investigators reasoning and on how fire incidents investigation and case knowledge were managed within a given forensic department. This approach was chosen because the main subject of this research is human. Understanding how human think running a fire investigation and how knowledge is managed within a particular forensic service requires studying individuals within their work environment. Ethnographic study is particular suitable in this perspective as it enables to study fieldwork of a particular group of individuals, in a particular environment, and for a long period of time (Beaud et Weber 2010). Recently, Wyatt and Wilson-Kovacs (D. Wyatt et Wilson-Kovacs 2019) used this approach to study crime scene examiners and better understand their role within the criminal justice system. One of their conclusions is that "... ethnographic lens has a lot to offer the academic and practitioner literature on crime scene examination" (p.9).

This study was undertaken through forensic investigators observations and semi-structured interviews. Those two data collection methods were chosen for their complementarity and compatibility with the daily work of forensic investigators. A similar approach was applied by Köpsén and Nyström (Köpsén et Nyström 2012; 2015) to study novice education through supervision by experts in a forensic laboratory. As duty constraints in such an operational unit requires high flexibility in time management, participant observation seemed as a very suitable approach for the ethnographic study (Beaud et Weber 2010). The unpredictability of fire incident occurrence and fact that one of the author is fire specialist in this department meant that participant observation was the best methodology to run an ethnographic study without having a negative impact on investigations. Observations were conducted both at scenes during fire investigations, and during working hours at the office. In some particular situations, a discussion was engaged with an investigator after a particular observation in order to better understand their reasoning relating to a particular action or to obtain further explanation about a specific statement. Data collected through participant observation was completed and corroborated by semi-structured interviews. An interview plan was prepared in order to get systematic and as exhaustive as possible data collection. It was based around 4 dimensions: 1) the professional situation (i.e. education, seniority, role within the service...), 2) the way knowledge gathered through case investigation was conserved by individuals and within the department, 3) the way this knowledge was shared, 4) how relations between cases were made and utilised. Investigators were asked to provide examples of relations between cases if they were able to remember any. Details about cases concerned, the type of relation and the aim of having established such connexion were also asked. Interviews were conducted in the investigator's office and recorded after agreement.

The ethnographic study was conducted between January and July 2017. During observations, a particular attention was paid to individuals involved, the environment, the different tools used and some particular reactions. Notes were sometimes taken during observations. As the main author has an active role in fire investigations, notes were mostly taken after the completion of the scene examination.

3.1 Validation

Results were presented to participants during a meeting in which they had the opportunity to make comments. All data were validated as presented which imply that the implication of the main author within this department has not induced bias on results interpretation.

3.2 Population

Observations were conducted on a daily basis depending on fire incidents and investigators involved in the case solving process. The total workforce of the police forensic department during the studied period was 17 investigators, 8 women and 9 men. 10 of them had an academic degree (MSc in Forensic science) and seniority was between 1 and 24 years. This department possess a fire investigation specialist team, which is composed of 3 people: an experienced investigator (Julien), a team manager and fire investigation specialist (the main author of this article).

Interviews were conducted with 8 of these 17 investigators. They were selected to be representative of the larger set of investigators in the forensic department. Interviews were planned by sessions of an hour, to have sufficient time at disposal and not to interfere with work of the investigator interviewed. Demographic details of the interviewees are presented in the table 1. There were 4 men and 4 women of different hierarchical level, having between 1 and 24 years of forensic experience (mean: 10.63 years). All have received a theoretical training in fire investigation (either at the university or during continuous education) and completed their education in the field under supervision of more skilled investigators. 6 of them had an academic degree, all in forensic science (MSc level). The two others got another professional education before entering the police academy, and also served for several years as police officers before joining the forensic department where they underwent a forensic training. All of them were investigators, specialists in scene investigation, but some had also specific roles within the department. In particular, one of them – Julien¹ – was considered as a fire investigation specialist due to his high expertise and the large number of fire incidents he investigated. The amount of fire investigations conducted by these different investigators during their career varied from 10 to about 500.

Pseudo	Seniority (years)	Number of cases treated
Robin	1	10
André	3	13
Rachel	5	?
Cindy	8	23-30
Marco	14	50-100
Aurélie	15	50-100
Laura	15	50

¹ All names are fictitious to preserve anonymity.

Julien	24	400-500
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Table 1: Summary of the population characteristics

3.3 Research Location

The ethnographic study was conducted directly in the police station within the forensic department, and at the different fire scenes within the canton of Fribourg.

3.4 Information Systems in use in the forensic department

At the office, two databases are available to manage information related to fire incidents. The first one is the general police information system (Zephyr) and is accessible for every member of the police. It contains all information on cases and all documents produced during police activities, including pictures and reports.

The second one is the LIMS database specifically designed for the forensic department. It allows managing forensic evidences and data related to cases handled by the forensic department. It includes all the different traces and exhibits collected within a case, as well as the results of the analyses performed, providing a global overview of the case. The current architecture of database was implemented in January 2016. This tool was developed because Zephyr did not allow for the management of forensic related information. Concerning fire incidents investigation, it contains mainly the summary of the investigations with its findings, and the evidence collected at the scene for further analysis in laboratory. Pictures and reports are stored separately, but a direct access to all information needed is possible through direct links in the LIMS.

4. Results

4.1. Importance of expertise in the investigation process

During interviews, influence of expertise – either that of the interviewed individual or of others investigators – was discussed. It highlighted the central role of fire investigation specialists and how their expertise facilitated solving cases.

Four inspectors mentioned the fact that they did not feel confident in this type of investigations, and generally rely on more experienced investigators to support them. Aurélie said:

“Except for really simple cases such as kitchen fire, I generally need a second opinion on my cases.”²

Observations showed that almost every fire incident was discussed with Julien. Due to his expertise and knowledge, other investigators consider him as a reference for fire investigation.

² All citations were freely translated from French.

On another side, some of the interviewees mentioned the fact that people with huge expertise like Julien, possess a reasoning path that is difficult to follow. One of them explained that sometimes he was not able to follow Julien's reasoning on the field, and that he finally understood it later, after a detailed discussion with him at the office about the case. Some also reported that more experienced specialists seem to see clues that were not perceived by other investigators. For instance, Laura stated:

"When investigating a scene, a skilled investigator, has two or three possible causes for the fire in his mind and will go to see what is relevant for discriminating those causes. If I was alone, I think that I would not go to see those things because I would not be able to know where to search."

And Aurélie added:

"Julien often explains how things happened. [...] so we learn that it exists but I am not sure that I will be able to redetect such things on the scene because the picture that you saw is out of context and because sometimes things are tiny."

According to literature review, the difficulties expressed by Laura and Aurélie to be able to follow or recreate Julien's reasoning is probably the consequence of cognition differences. Experts think faster and use different features than novices to build their reasoning and conduct investigations.

Marco, despite having a wide experience in fire investigation, did not consider himself as a fire specialist (he was not formally a member of the fire investigation specialist team). Nevertheless, he pointed out the fact that other investigators had often required his help and knowledge when they had to solve a fire case. He explained:

"I do not consider myself as a fire specialist. People ask me questions [...] also because I investigated many fire incidents and maybe because I can give some information about building materials or help understanding how things happened."

This illustrates that actual expertise is perceived as central, and that it does not necessarily cope with the belonging to a formal group of specialists. As in other domains, experts in fire investigation are individuals who possess an expert ability in problem solving. This characteristic is recognised by the other investigators and valuable for them.

4.2. The use of analogy and case repetitions

During this study, it was observed that case plays a significant role in the investigation of fire incidents as a reflexion support. Facing a new case to solve, investigators generally compare that case to situations they've previously investigated, either already during the scene examination or later during discussions at the office.

This was particularly visible with Marco and Julien, two of the most skilled investigators, who regularly and explicitly refer to old cases to explain their reasoning about ongoing investigations. They explain what is similar or different between cases and the way it supports or not their hypotheses of fire origin and cause. If the discussion stands at the office, they sometimes rely on pictures from old cases to illustrate their reasoning and show how things are similar or not. At the scene, as those pictures are not accessible, they describe how traces or elements of old cases look like or differ from what is currently observed. During the interview, Robin (the least experienced investigator) mentioned a case in which Bernard (another experienced member of the fire investigation specialist

team) gave him support. He was facing a fire possibly caused by hay self-heating. Robin said:

“Concerning this fire incident, it was my first situation of hay self-heating but we did not see the typical burn patterns of this phenomenon. As it was my first time, I was not sure of the cause but Bernard directly said that it was this cause due to the typical smell.”

The importance to consider similar past situations to gather valuable information for the investigation of a fire incident appears through observations. When an investigator requires someone else’s assistance, the request “Have you ever investigated a similar case?” often appeared in the discussion.

Through participant observations, we noticed that the trend to consider previous cases was also significant for less experienced investigators. For example, at the scene of a burned barn where hay self-heating was considered, Aurélie said that the smell of the hay was the same that she had smelt on other cases, and hold it as typical of hay self-heating. She stated:

“This smell is so typical that even the first time you will recognise it and then you will never forget it”.

Another example occurred when Robin was investigating a vehicle fire. He made a search in the LIMS database in order to retrieve several vehicle fire cases and compare traces between those cases and the ongoing one. He used this knowledge to evaluate and balance several hypotheses of fire cause. He simply made the research using the “type of crime” and “type of place” fields of LIMS to obtain all fire vehicles previously investigated. It retrieved 4 cases (the database was only at its very early stage). The comparison with previous investigations allowed him to confirm that the visible burn pattern visible in this case was similar to those where the fire started at the front of the vehicle.

Those results show that analogy and case repetitions are central when reasoning about a fire investigation. Table 2 summarises results obtained after asking investigators if they remember situations in which they established relations between two cases.

Insp	New case	Old case	Relation	Aim of the relation
Rachel	Fire in an annex building of a piggery	Fire in a farm	Cases with more than one non-excluded hypothesis	Report writing guidance
Robin	Fire under a hay tunnel	Fire in a farm which contained hay	Hay	Traces and chronology comparison
Robin	Vehicle fire	Vehicle fire	Vehicle	Traces comparison in relation with the cause of the fire
Robin	Vehicle fire in a garage	Vehicle arson	Vehicle	Traces comparison depending of the origin of the fire
Julien	Fire of a small building on the public	Many fires on the public path	Geographical situation and type	Research of cases that could be part of

	path		of building	a serial phenomenon
Julien	Wooden bridge fire	Wooden bridge fire	Bridge and same heat source (fire starter blocs)	Possibility of a common arsonist

Table 2: summary of relations established between different cases

The first relation concerned two cases for which more than one possible cause remained plausible after the investigation. Having to write her report, Rachel used this similar previous case as inspiration and guidance to write the report for this case.

Concerning the second relation, the old case was the one where Bernard helped Robin to establish the cause of the fire as hay self-heating. After having investigated this new fire where hay was involved Robin said:

“When this new case occurred, links were rapidly established, we tried to see if the same signs were present and if the time difference between the fire starting and the day the hay was put in the barn was similar.”

In this situation the presence of the hay was the element that enabled the investigator to draw an analogy between the two cases.

The two other cases reported by Robin were vehicle fires. The first one has been already discussed above. The second established a link between an old case in which the fire was set in a trunk and the new case where it was hypothesised that the origin of the fire was situated in the engine zone. Here the relations between the two fire incidents were used in order to exclude a hypothesis. Robin explained:

“Concerning those two cases, you can really see the difference in the burn pattern intensity in the engine zone and it helps to situate the zone where the fire started.”

During the whole interview Robin was really clear about which analogies were made, how they were made and how he used the information. In contrary, the discussion with Julien was a bit harder. First he said that he did not remember situations in which he established analogies between cases and after a few seconds he cited the two examples presented in Table 2. The first one concerned the geographical proximity between many fires of small public buildings. The second involved two wooden bridges where fire was set with similar fire starter blocks. Julien stated:

“It was the same fire starter blocks so I immediately put the two cases together.”

The examples given by Julien are interesting because they are really far from observations. In almost every fire investigated, he used to refer to previous cases to support his reasoning. Those relations between cases were mainly used to identify fire origin and cause, and pertained to the type of appliance, type of defect or the physico-chemical phenomenon involved. In contrary, the examples he mentioned during the interview related to the possibility of a common arsonist for many fire incidents. This step of reflexion generally occurs after the determination of the origin and the cause of the fire. Those results highlight the fact that most steps of Julien’s reasoning are automatic and unconscious. He only remembers analogies established at the final steps of the fire investigation where relations are formalised and used to produce classical intelligence.

The observations and interviews highlighted the fact that analogy was a central reasoning scheme for every investigator. But expertise induced great differences in the intuitive part of this reasoning.

4.3. Knowledge conservation

The ethnographic study showed that different methods still coexist within the forensic department to conserve knowledge gained by case investigation: some are institutional and other individual. The department manager sets institutional strategies whilst investigators themselves set individual strategies.

Two methods considered as institutional are the information management systems (Zephyr and LIMS) that are used to archive cases. A third element contributes to knowledge conservation at the institutional level: written and illustrated synopses of interesting fire incidents that were investigated. These synopses are periodically prepared by a member of the fire investigation specialist team and distributed by e-mail to all investigators of the department.

At the individual level, each investigator conserves and structures his own knowledge, mainly in his memory. Explicitly, Julien said:

“In fire investigation I remember all cases very well. I do not know why but they stay in my mind”.

Besides, some investigators created physical and/or digital repositories of cases they investigated. For example, Marco and Aurélie constituted a paper repository that contains all the reports of the fire incidents they investigated, and use it as a support for future report writing. Marco explained:

“I like the option to have my folder behind me, with the reports that I wrote, and having the possibility to read them and to turn pages without jumping from a computer screen to another”

Those results illustrate the need of investigators to constitute personal repository outside of institutional tools at disposal to have a rapid access to particular information. Marco indicated a preference for paper support but it seems that the impossibility to easily have access to all the report an investigator wrote with Zephyr or LIMS is also playing a role. The design of these databases requires accessing each case separately to access the reports.

Julien, who was part of the fire investigation specialist team, made a paper repository that he calls the “Fire Bible”. This “Fire Bible” contained diverse information accumulated through years of practice, and considered by Julien as potentially useful for future fire investigations. He said:

“Most elements of this Fire Bible are things that I use for some cases. But when you perform searches, you find things that you think could potentially be useful for a future case. I have also a lot of books about fire investigations or topics like electricity.”

Information contained in this “Fire Bible” have multiple origins: cases, fire investigation education, conferences, Internet etc. Consequently most of that knowledge is only conserved in the “Fire Bible” and used almost exclusively by Julien even if it is freely available to anyone within the department.

4.4. Knowledge acquisition and sharing

On the institutional level, two strategies were identified. The first one is the presentation of investigated case that occurs during the daily department meeting, every morning. Each investigator on duty has to attend the meeting during which all cases investigated the previous day are exposed with the support of pictures, and eventually discussed. The second strategy is the synopses of cases previously mentioned, that is distributed to all investigators.

Interviews revealed that most investigators firstly considered that no institutional strategy was set in order to acquire new knowledge. Nevertheless, after having mentioned the two observed strategies, they admit that indeed these allow them to acquire and share knowledge. Laura realized that the morning meeting was indeed a relevant way for continuous education for all investigators. She stated:

“The morning meeting is a good way to proceed to continuous education. Concerning myself, I take as much information as possible and if something is not clear I discuss it with the investigators afterwards.”

Nevertheless, one of them raised the problem of lack of attention during the meeting; André said:

“My memory is essentially photographic and not oral. So if someone is only speaking, I will not acquire and remember the knowledge as well as if it is presented in pictures.”

Another highlighted the problem of individuals that are not present at the meeting due to day off, part time work or emergencies on the field.

Concerning the synopses of cases, all interviewed investigators appreciate it and some mentioned the advantage that it could be read whenever they have time. Laura stated:

“I think that it is always interesting and that it gives a good summary of the case.”

But those summary only concerns about 15 cases a year and there is the possibility that not all investigators read them.

Regarding individual strategies deployed to acquire knowledge, two different situations were identified. The first one occurred during a fire investigation and was directly related to the case. The second appeared when an investigator wanted to enrich his knowledge independently from a case.

When facing a gap in knowledge during cases, investigators relied on their colleague's knowledge. They mainly seek the help of some more experienced investigators, or of colleagues holding knowledge in a particular field due to their previous education or previous cases. For instance, it was observed that when a case involved a possible electrical fault, investigators often discussed the case with Florian as he was an electrician before becoming police officer. Laura confirmed this trend to use skills at disposal in the department:

“A lot of people have technical knowledge here, I will ask them to explain the situation”.

It is interesting to note that even the most experienced investigator, Julien, relied on other's knowledge, either within the forensic department, or within the Swiss fire investigators community. He stated:

"I have good contact with some members of the Swiss fire investigation group who have a lot of technical knowledge. I can call them or send them an email and they will answer me. It's a network that is functioning really well".

It was observed that knowledge was mainly transmitted orally and directly through discussions. Knowledge exchange could occur directly on the field, as many cases were investigated by more than one person (generally the investigator in charge of the case and a member of the fire investigation specialist team). It also happened at the office, with investigators discussing the case. Aurélie explained:

"If I have questions, I go to Julien's office to see if it is possible to determine the cause of the fire based on pictures".

And Marco added:

"I share my office with Julien and people come to ask him questions, so we discuss these together".

This illustrates that design of office space is also playing a role in terms of knowledge sharing and dissemination.

During the interview, André mentioned the problem raised by the absence of someone whose knowledge is required:

"This human sharing of knowledge is clearly determined by individuals that are present".

In addition to that, five investigators indicated during their interviews that within a few years, most of the experienced investigators would retire. They notified their concern of not having such knowledge at disposal their anymore, as they do not feel confident enough to complete the investigation of some cases by themselves. Aurélie stated:

"Julien will retire in few years. It will be a problem for me if no one replaces him because I need someone to help me with fire investigations."

Even if Aurélie has a seniority of 15 years and already investigated between 50 and 100 cases with support of an expert, she felt that she was not skilled enough to investigate future cases by herself.

Apart from oral transmission of knowledge, a few inspectors indicated they sometimes use books or the internet to fill gaps in their knowledge.

When the subject of personal education appeared in the discussion, all the investigators indicated that the best way to acquire new knowledge was to attend the scene of fire incidents and actively participate in their investigations. Aurélie stated:

"My feeling is that the only way to acquire expertise is to go to the scene. At the office cases can be shown to you but it is never the same as at the scene. Pictures are oriented and it is different from when you stand in the middle of the scene and everything is destroyed all around you. At the office, everything is prepared in order for you to understand the situation."

Due to operational constraints, generally only the investigator in charge of the case and one or two members of the fire investigation specialist team attended fire scenes. Consequently, some individuals will investigate only one or two fire scene in a year, which drastically limits their opportunity to acquire knowledge in this manner.

Four investigators also mentioned the use of the LIMS in order to gain knowledge. They examined pictures and information of new cases added to the database, learning from fire incident investigations they were not directly involved in. Robin explained:

“Sometimes, information is given during the daily report, then I have a look at the case in more detail, especially in domain in which I have limited knowledge or that are more specific like electricity or explosions”.

Through participant observations, it was also noted that Julien and Marco systematically studied the pictures of every new fire incident that was investigated by the forensic department. In many cases, their interest was not solely related to case consultation in the database, but it was completed by a discussion with the investigator who was in charge of the case. As details were often difficult to see on picture of burn elements, this discussion allowed Julien and Marco to complete and nuance their opinion about the case and also advise the investigator for future fire incident. This attitude contributed to reinforce their knowledge gained through fire investigation, and to share with others the experience they have accumulated.

5. Discussion

The findings of the ethnographic study support the hypothesis that, from a cognitive point of view, expertise in fire investigation has the same impact on individuals than in other domain.

Results obtain during interviews and observations showed that investigators consider individuals within their department with a huge expertise as expert in fire investigation. This status is independent from the internal organisation of the forensic department, particularly concerning the composition of the fire investigation specialist team. Many investigators require recurrent help from these experts, this showed that expertise was held as a central element in fire investigation case solving.

Cognitive differences were also highlighted by the ethnographic study. Robin (a novice investigator) was able to remember all situations where he applied analogy, and to explain precisely his reasoning. In contrast, Julien (the fire investigation specialist) had trouble remembering such situations and was just unable to cite the multiple examples highlighted by observations, which prove that he really understood and fully used relationships between cases. According to literature review, this difference results from expertise variance and the consequent change to memory structure and cognition. The automatic and unconscious reflexion done by Julien is probably due to a combination of a complex and highly organised memory structure and the use of analogy at different level of abstraction (Hofstader et Sander 2013). This finding confirms the need to externalise the knowledge that is rooted in the individuals to make it available to others.

The ethnographic study highlighted the pivotal role of analogy with past situations in the reasoning scheme that is applied for the investigations of fire incidents. In almost every case investigated during the time of this study, analogy was used by the main investigator or by someone with more experience to support case solving. This analogy occurred mainly by connecting the fire incident under investigation with past solved cases in order to gather useful information.

This role of analogy is fundamental: the finding of relevant past cases is a good predictor of the chance to solve a fire incident. Although rather schematic, this assertion highlights the primer necessity to have access to a large repository of cases to find the most suitable one.

As we have seen, the memory of past cases is distributed and inherent in the investigators of the department. There is a plurality of individual and internalised memories. The ethnographic study brought to light some initiatives aiming at externalising this knowledge, for instance through the constitution of physical repositories. But these initiatives are neither systematic, nor uniformed in their structure, so that they remain bound to the individuals that created them. The information management systems that exist are mainly oriented towards the classification and storage of administrative information or forensic data. They are of limited utility in structuring, preserving and sharing knowledge arising from the problem solving approaches of underlying investigation and reconstruction processes.

Strategies are set to transfer knowledge and so broaden an individual's expertise. The morning report, consisting in an oral presentation of each new case, is a good strategy but the absence of some investigators due to operational constraints and the lack of attention create inequality in knowledge transmission. Even if all cases are presented all investigators do not acquire their knowledge as receiver motivation in the main limitation to this knowledge transfer (Schafermeyer et Hoffman 2016). Statements of interviewed investigators allow to realise that the added value of case presentation is highly variable between individuals. A synopsis of case is distributed to every member of the department but it only concerns a minority of cases (about 15 per years). Contrary to morning report all investigators receive the same information but the amount of knowledge transferred is very low. Consequently, institutional strategies are insufficient to transfer knowledge as their efficiency is limited either by the number of cases concerned or by the number of investigator who beneficiate of this transfer. In parallel, those two strategies are mainly based on the transfer of explicit knowledge. As the acquisition of tacit knowledge is the main condition to develop expertise in a domain (Köpsén et Nyström 2012; Eraut 2000; Collins et Evans 2008) the lack of efficiency of those strategies is easily understandable. Some inspectors developed individual strategies to accumulate more knowledge but not all of them. The main methodology used is to study cases investigated by others within the department, either through the consultation of these cases in LIMS or discussions with the investigators. By doing so, the individuals gain knowledge regarding the case that can be used in the future. Such process is really valuable as the investigator proceeds to a "second investigation" and so acquires practical expertise and so tacit knowledge but it is time consuming and requires motivation. This is probably why only some investigators of the forensic department use this strategy.

Another method discussed to gain expertise is to go on the field when investigators are not in charge of the case. For the questioned investigators, it is the only way to acquire "real" expertise, as they have to realise the entire reflexion process without facilitation. This is obviously one of the best strategies as they acquire direct experience and can reason by themselves (Waddington 1999; David Wyatt 2014). Moreover this strategy will allow investigator do develop their skills through practice and gain tacit knowledge as far as contributory expertise (Collins et Evans 2008; Köpsén et Nyström 2012). But the operational constraints and sometime the size of the scene will not allow for many

extra investigators on the scene, rendering accumulation of experience difficult. Generally, only two investigators go on a fire scene.

All those elements contribute to knowledge transfer; however, due to the limitations discussed in this article, those elements do not overcome the long training required to accumulate the amount of knowledge or expertise required for investigators to investigate fire scenes by themselves. The worries exposed by some investigators with 15 years of experience regarding the upcoming retirement of a colleague are symptomatic of this problem.

Those facts lead to conclude that trying to enlarge concretely each investigator personal expertise in order to transfer fire investigation knowledge to prevent loss in case of an individual's departure is not a suitable solution. Management strategies like supervision and community of practice will not be the answer to this problem as their result is the enrichment of each individual's expertise. Moreover they are still informally used - through the support of experts and discussions between colleagues - in this department and did not give sufficient results. This is why we propose to use a strategy, which will allow the use each individual's expertise without requiring their previous personal acquisition. This is precisely what Case-based reasoning permit. It simulates expert reasoning using a collection of past cases that could be retrieved through analogies in order to support case solving. This means that another's expertise could be used without a previous acquisition of this knowledge and at any time. It is a way to extend artificially each one expertise. As previously said the degree of automation an interaction with the user may vary (J.L. Kolodner 1993). Fire investigation is a domain in which much information as testimony burns pattern analysis and images analysis has to be combined and value judgment made to solve a case. They are ill-structured cases as defined by Jonassen (Jonassen 1997). At this step of the research, those observations lead to define that the best knowledge management strategy is a low automation one. We then propose to use case library as fire investigation knowledge management strategy. The construction of a case library will create a collective knowledge memory by externalising, preserving and sharing each and everyone's knowledge. Each investigator could then use expertise by searching for useful cases in the memory using analogy. The ethnographic study highlighted the fact that comparison of related cases is the basic strategies used by everyone in the forensic department. But difficulties lie in the accessibility to those cases. In our opinion, the use of a case library could greatly facilitate access to cases. This could tremendously impair the critical human factor currently ruling fire investigation in the forensic department and guarantee a long-term conservation and sharing of knowledge.

As the core of such strategies is to reproduce, at least partially, what was previously done, if a mistake is not identified the risk of perpetuate this mistake occurs. This is why such system is devoted to be a support for case solving and not to replace expert knowledge and critical thinking.

In general, we think that our study highlights notable benefits that can be derived from a reflective and critical approach, carried out in the form of an ethnographic study. The fact that the main author of this study was part of the forensic department under investigation is definitely a strength to prevent misinterpretation of the observations. On the other hand, it may hinder an attitude of detachment and of critical reflection. It is clear to us that the results of the ethnographic study, although useful for the specific forensic department that was considered, may not prevail in other services, and that generalization would be inappropriate. We therefore call for similar studies being

carried out in other institutions, in order to corroborate or amend findings from our study.

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