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OVERLOOKING CAUSES IN HEALTHCARE ACCIDENT INVESTIGATION. CHOOSING THE ANALYSIS IS CHOOSING THE RESULTS

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Abstract

This paper demonstrates the influence of one's assumptions and angle of analysis on the causes discovered during an accident investigation. The research investigates a real medical case where a physician diagnosed a dislocated shoulder and a pneumothorax on a patient who was subsequently found to only suffer an undisplaced fracture of the shoulder blade and contused ribs. The physician inserted a tube into the thoracic cavity in order to drain the suspected pneumothorax. In doing so, the patient's liver was punctured twice.

Three successive analyses of the case were performed: human-centred, organisation-centred, and joint (cognitive and organisation brought together). By comparing analyses, we tested the type of causes of the accident that can be overlooked, and the type of conclusions that can be drawn, depending on the type of analysis performed. We demonstrate the interest in carrying out a joint analysis: it highlights organisational conditions that influence individual behaviour, and therefore minimises the loss of information when looking for explanations.

We address the issue of the early decisions and assumptions made in the investigation process. We claim that these determine one's ability to discover complex causes, and have an impact on the capacity of an organisation to protect itself against re-occurrences. Our research discusses these assumptions and lists recommendations that are relevant to the field of accident investigation in the large. As such, our paper can support the work of safety practitioners in a wide range of industrial sectors.

1 INTRODUCTION

The main argument that we will defend in this paper is that analysing the human and organisational dimensions separately is detrimental to accident analysis. Indeed, after Reason (1990) and Bourrier (2007), we acknowledge that operators' failures (at the sharp end) find some of their roots in organisational factors and managerial decisions (the blunt end). In this view, the latter are seen as creating the conditions for the former to happen.

We will rely on the official report on a medical accident to detail the various conclusions and recommendations that can be produced, depending on the early analysis assumptions made and the discipline adopted. Our claim is that ideally, an accident should be analysed in an interdisciplinary manner, joining disciplines together. Despite not being new, this is still a worthwhile topic. Indeed, the largest portion of the industry (small and medium-sized entreprises) does not publish accident reports other than internally, and for the most part, these reports do not address the human or organisational dimensions.

From the above points, we claim it is still worth revisiting the issue of accident investigation and highlight the consequences of early assumptions and choices of disciplines on the results of the analysis. This exercise will be performed with a simple recursive analysis starting from the outcome of an accident, and tracing back to various levels of contributing factors. Many methods of accident analysis exist (see Sklet, 2002; Gall, 2008; Hollnagel & Speziali, 2008, for reviews) and could have been used. However, we will show that resorting to a simple, method-independent demonstration suffices to make our point.

1.1 Objective of the paper

This paper will analyse a real case of medical failure that took place in 2004 at a Canadian Health Authority. The unpublished official accident report was used as the basis for the following demonstration. From varying the adopted standpoints through three analyses of the case, we will show how different the results of an accident investigation (and related recommendations) might be.

Figure 1 graphically describes the successive hypotheses we will test in this paper, by highlighting the different types of investigations that will be conducted, and their respective limitations and strengths.

Each diagram in the figure reads from right to left since accident investigation is typically a backwards process, starting from an event and looking back for its causes. One will also note the similarities of assumptions, identified causes and recommendations expected from the human and organisational investigations. Conversely, from the joint analysis, we expect a different investigation process altogether. We expect an array of factors that, taken individually, cannot account for the accident. This explains why we talk about cognition-related contributing factors (not causes) and organisational enabling conditions (not causes). Last, one can notice that each investigation line carries expectations about the results. This is a central feature of this paper.

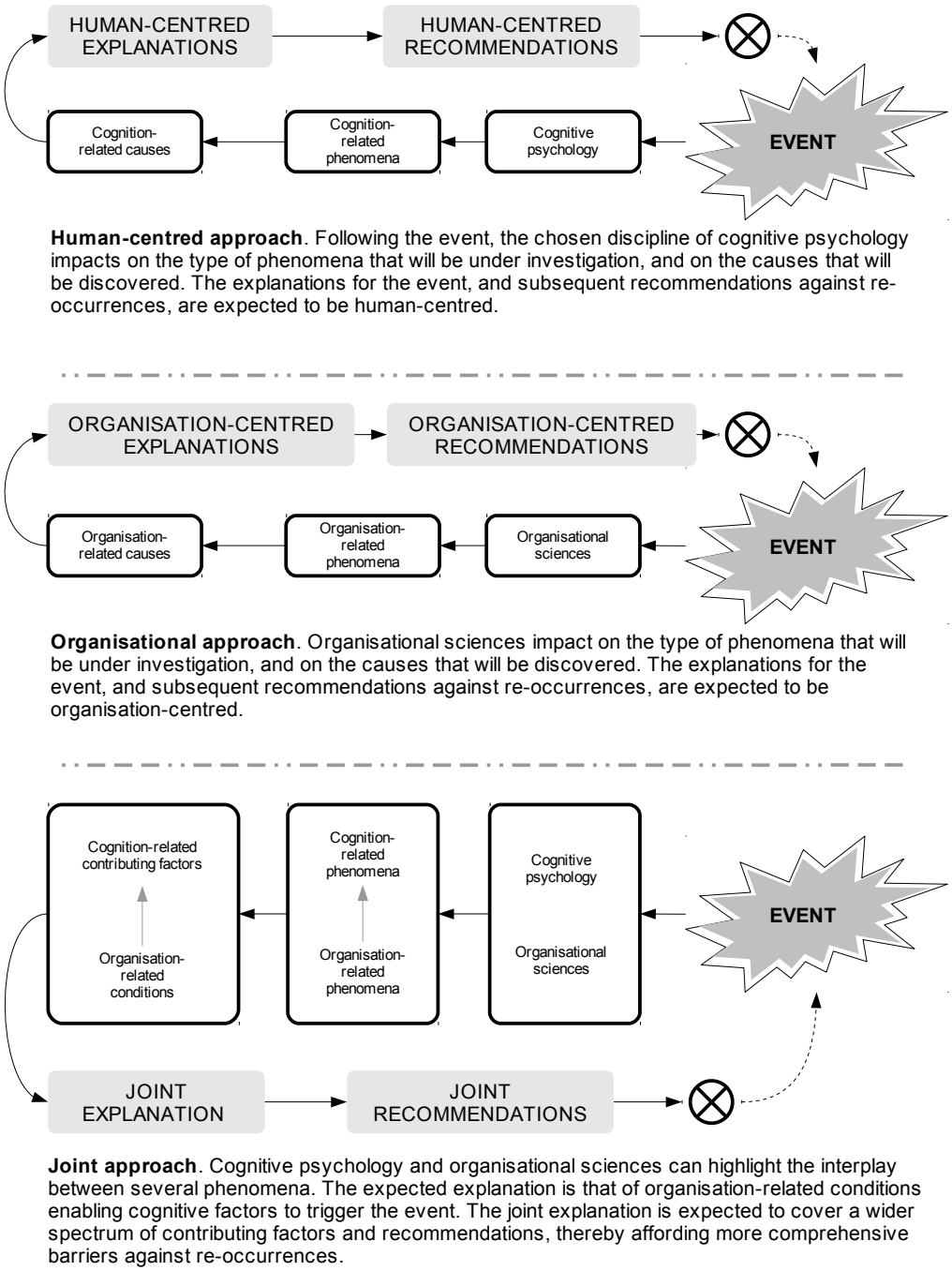

Figure 1: Graphical representation of the successive lines of arguments

1.2 Outline

In order to test the hypotheses laid out in Figure 1, we will run three analyses on the basis of the medical case mentioned earlier:

- *Human-centred*. This will provide a precise account of what the case at hand felt like from the doctor's point of view, how the various symptoms were interpreted, and how decisions were taken that could have killed the patient.

- *Organisation-centred*. This will provide a view of the configuration of the healthcare system and the hospital concerned. We will see how staff shortage, limitations in the certification process, and leadership issues could explain the event.
- *Joint*. This will blend the human-centred and organisational approaches, thereby building the functional links between the hospital settings and the doctor's activity. In doing so, we will highlight the organisational factors that created the conditions for the human failure to happen.

By running this three-way comparison of approaches, we will attempt to identify the different causes of the accident that can be found, compare assumptions, the information lost, and derive the type of recommendations they allow for safety management. This approach is very much a practical test of the concept of WYLFIWYF (What You Look For Is What You Find; Lundberg *et al.*, 2009) whereby assumptions used in the analysis preselect *de facto* the results that will be discovered.

The paper will end with a discussion of the implications of accident investigation on safety, and how the shortcomings of the former can affect the latter. We will also point out our contributions to the original report and draw recommendations based on our findings.

2 FACTUAL PRESENTATION OF THE CASE

The following account is based on a confidential report from a Canadian Health Authority[1]. The patient was a 45 year-old man who was admitted in a public Canadian hospital in the summer of 2004 for a fall from an 8-feet height[2]. He was taken to an emergency room where he complained about painful ribs on the right-hand side of his chest, intense pain in his right shoulder and shortness of breath. The patient was taken care of by Dr Smith, a 35 year-old female physician, who X-rayed the patient's chest. She saw a dislocated shoulder, hairline fractures on the ribs and a vertical line dividing the right lung lengthwise. Beyond this line outwards, the right lung appeared to have a different colour.

Aside from the dislocated shoulder, the shortness of breath, the dividing line across the chest and the light-shaded right lung on the X-ray led her to suspect a pneumothorax. The latter is an air pocket that compresses the lung towards the inside of the chest, thereby diminishing the pulmonary capacity and altering breathing. In order to treat the suspected dislocation, Dr Smith sedated the patient (who remained conscious) and reduced the shoulder. Also, to treat the diagnosed pneumothorax, she inserted a chest tube inside the rib cage of the patient; a common practice.

1 In order to preserve the anonymity of all people involved, dates, names and ages have been altered.
2 The time of the accident and the time of admission are not documented in the report.

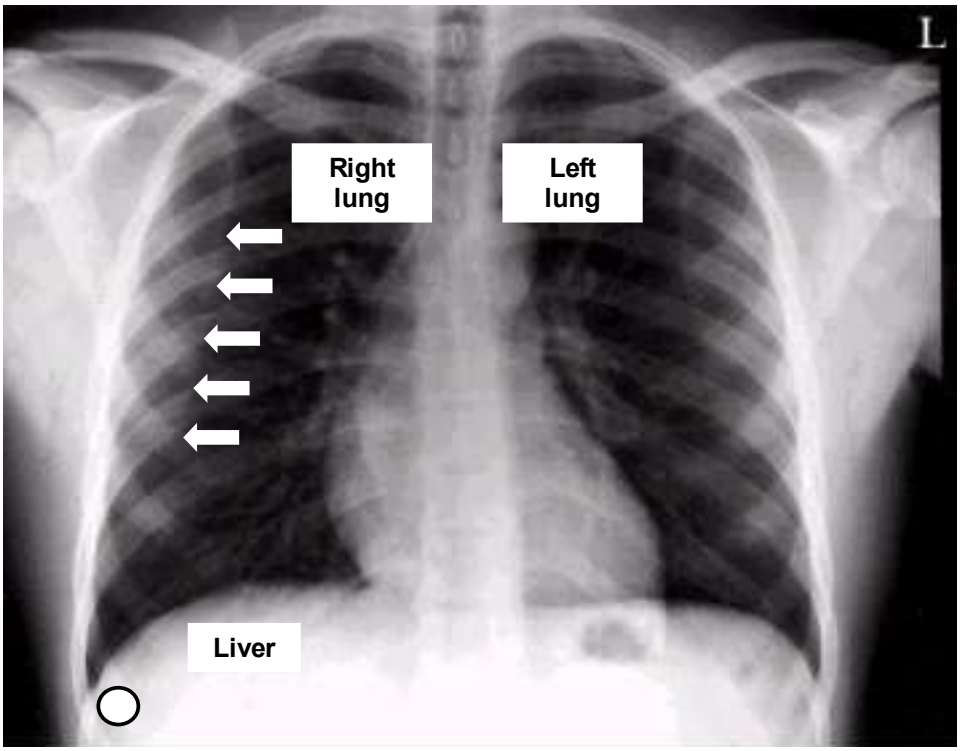

Figure 2: A normal X-ray of the chest showing the vertical inner edge of the right scapula and the liver (adapted from Dick, 2000 ; © BMJ).

Figure 2 is an X-ray of a normal chest[3]. It shows the location of the organs that are relevant to the case and provide a view of the material Dr Smith might have been working from. The white dot at the bottom left corner of the figure plots the body area that the tubing reached. The white arrows show the dividing line across the right lung.

The expected effect of inserting the tube into the patient's chest was the air venting out and immediate relief of shortness of breath. Instead, some blood came out of the tube. Dr Smith then suspected a hæmothorax (a blood pocket compressing the lung inwards). She then inserted a second tube (with the first one still in place), for a reason that the investigation report does not document. Again, after inserting the second tube, some blood came out. After each tubing, the report states that the patient said he "felt a lot better".

The report determined that the blood that was expelled from the chest tube did not come from the lung but from the liver, an organ that the physician punctured twice when inserting the two tubes. In hindsight, we also know that Dr Smith did not detect that the patient actually had an undisplaced fractured shoulder blade and contused ribs. Therefore, she unnecessarily reduced the shoulder. Finally, she mistook the dividing line on the X-ray for a sign of a compressed lung. Instead, this line was the vertical inner edge of the right scapula that was showing through the lung (see the white arrows in Figure 2). We know from the investigation report that a radiologist was present in the hospital at the time of the accident. However, no formal reading of the X-ray of Dr Smith's patient was given by the specialist because other cases were given priority.

3 The actual patient's X-ray was not included in the report, and could not be obtained.

3 HUMAN-CENTRED INVESTIGATION OF THE CASE

In this section, cognitive limitations will be briefly addressed. This will allow to better understand the particular situation in which Dr Smith found herself. The analysis of the case will be summarised in a graph showing the links between the various factors at play. The section will end with a summary of the assumptions made in this analysis, the conclusions that can be reached, and the recommendations that can be drawn.

3.1 The limitations of human cognition in diagnosis

Medical diagnosis is not as logical as it seems. The picture according to which diagnostic reasoning is an exhaustive, rational, step-by-step reasoning process from symptoms to causes does not fully reflect the actual human activity. Human cognition is limited in various ways (memory, information processing, etc.). Also, it always operates under a number of conditions (time, resources, skills, etc.; see Swain & Guttman, 1983; Hollnagel, 1998) that directly affect performance. For these reasons at least, exhaustiveness is not an option for human reasoning, even when lives are at stake. Instead, humans attempt to achieve their objectives via a bounded rationality : they satisfice (Simon, 1957). In the case of medical diagnosis, cognitive constraints shape human reasoning into an imperfect, heuristic, pattern-matching process. This means that diagnostic reasoning seeks a good enough answer to a problem that is recognised as belonging to a known category, for which solutions are ready to be deployed. This view is consistent with Rasmussen's (1986) ladder model. More detailed information on psychological processes in diagnosis can be found in Besnard and Bastien-Toniazzo (1999).

3.2 Sensible decisions leading to failure

Dr Smith saw a pneumothorax where there was none. However, the symptoms (the patient feedback and the X-ray) were misleading. Each of them could have several alternative explanations but once combined, a pneumothorax made sense. The vertical line the physician saw across the patient's right lung was the inner edge of the right scapula. What is more, from this line outwards, the colour of this side of the rib cage looked different from the other side. These symptoms, along shortness of breath, were the those extracted by Dr Smith and interpreted as a pneumothorax. From a cognitive point of view, the explanation ties back to a well-known decision-making process: pattern-matching (see Klein, 1999). Applied to diagnosis, this mental process identifies symptoms as a set. Then, the diagnosis process looks into memory for the explanation and corresponding actions that have appeared correct most of the time in the practitioner's past experience. By being inherently subjective, pattern matching can operate on the basis of an incomplete set of symptoms. The outcome is then a mental model (a mental picture of how the various cues explain the case at hand) that is potentially and unknowingly flawed but that still makes perfect sense.

The insertion of a chest tube is sensible given the mental model held by Dr Smith. However, blood came out through the tube (not air). This was the unexpected consequence of the treatment of the physician who happened to have punctured the patient's liver. The presence of blood probably led her to change her diagnosis of a pneumothorax for that of a hæmothorax (a blood pocket compressing the lung inwards). From a diagnostic point of view, this makes sense: finding coherence in symptoms is more a process of selection and aggregation than rejection. It is known today that the blood found in the tube came from the liver. But for the physician, given her initial diagnosis, a hæmothorax was a reasonable alternative diagnosis.

It takes more contrary evidence to revise a mental model than logic would predict. Dr Smith was caught into a confirmation bias (Wason & Shapiro, 1966). This is an unconscious reasoning process whereby working hypotheses tend to be tested by using confirming (instead of contradictory) evidence. In Dr Smith's case, as new symptoms appeared, they were "forced" into the practitioner's current mental model, instead of being used to consider alternative explanations.

The physician inserted a second tube into the patient's chest while the first one was still in place. This can be interpreted as a fixation error. The latter is the process by which a mental model is maintained despite opportunities to revise it (De Keyser & Woods, 1990). The fixation error can then become part of a loop where the same action is repeated without any new information being gained (Besnard & Bastien-Toniazzo, 1999). In the case of Dr Smith's treatment, an objection could be that she was simply hoping to drain more blood out of the hæmothorax by inserting a second tube. However, one must remember that the patient had no hæmothorax. Therefore, Dr Smith exhibited precisely the type of behaviour that a fixation error triggers: keeping the same line of reasoning and corresponding actions, towards solving a misperceived problem.

3.3 Graphical representation of the human-centred analysis

In the above analysis of the human dimension of this case, we have referred to three psychological phenomena: pattern-matching, confirmation bias and fixation. Moving to understanding how these can explain the accidental occurrence, one needs to introduce a granularity in the various contributing factors. This is what Figure 3 shows.

The figure is a diagrammatic representation of the case, looking at the human dimension. The outcome is the patient being injured. The explanation of the event relies on a recursive decomposition of causes into three orders, accounting for three different levels of depth of causality. This recursive decomposition is consistent with the notion of antecedents found in the CREAM[4] method (Hollnagel, 1998). The three orders are arranged from the coarser to the finer, from right to left. This is the sequence in which they are going to be discussed.

4 Cognitive Reliability and Error Analysis Method

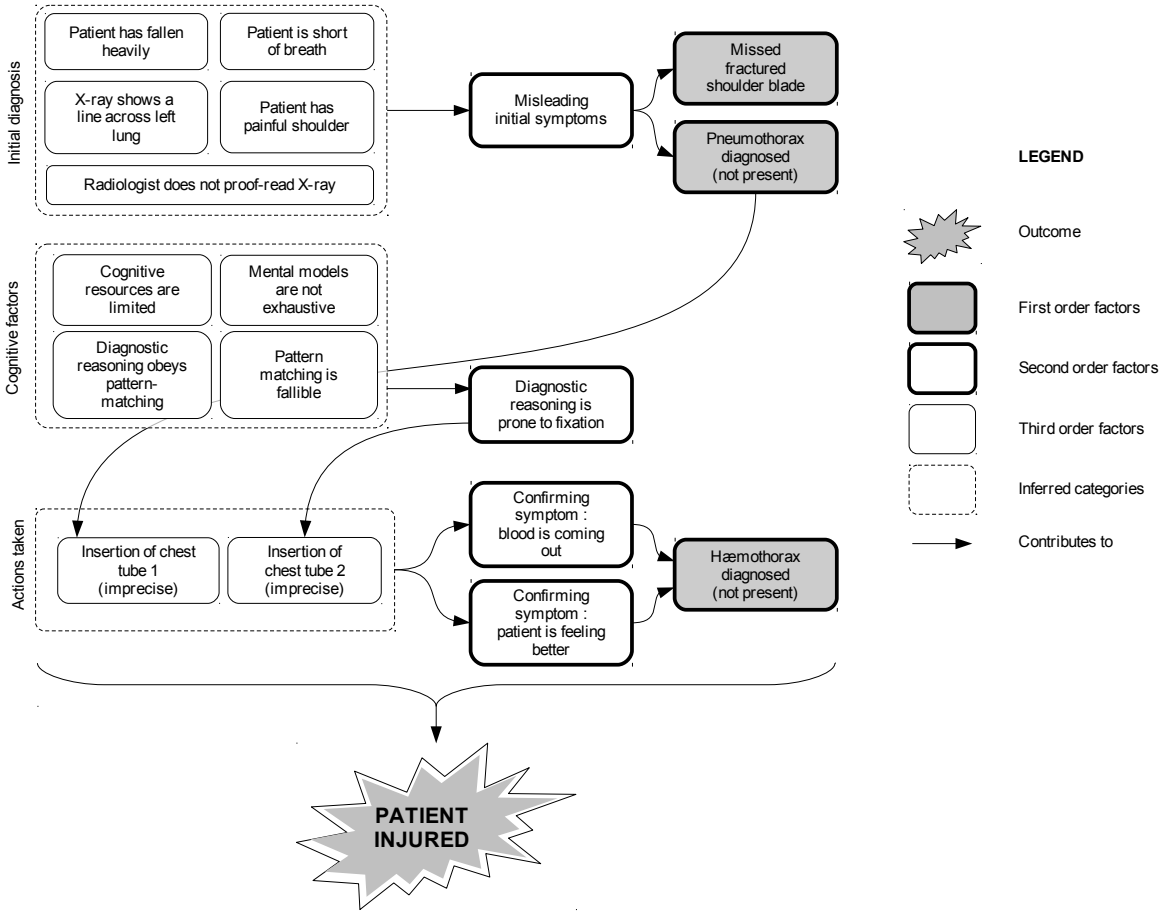

Figure 3: Descriptive diagram of the analysis of the human dimension

Some first order factors have been identified (*Pneumothorax diagnosed*; *hæmothorax diagnosed*). These are noted in Figure 3 and can be taken as failures. However, they only are phenomena, not the causes of the accident. To discover the causes, we need to ask the simple recursive question: why? Why did Dr Smith miss the fractured shoulder blade, diagnose a pneumothorax, and then a hæmothorax? This question leads to the actual practitioner's activity, the cognitive processes at play, and the symptoms recognised. These belong to a finer level of granularity: second order factors (*Misleading initial symptoms; Diagnostic reasoning is prone to fixation; Confirming symptoms*); they are noted . Again, we can wonder why these second-order factors were at play in this case. This leads to the identification of third order factors (noted) that provide the deepest level of detail (e.g. *Pattern-matching is fallible*) or indisputable factual data (e.g. *Patient has a painful shoulder*). Finally, third-order factors have been arranged into categories (*Initial diagnosis; Cognitive factors*; *Actions taken*) noted . However, these categories only aim at structuring the diagram and will not be used for analysis purposes. For the rest of this article, we will consider that second-order factors provide the best compromise between identifying sensible causes and avoiding over-simplification[5]. However, the horizontal bracket at the bottom of Figure 3 shows that in reality, it is the combination of all factors at all levels of depth that truly account for the accidental scenario.

5 We are explicitly choosing the criteria that qualify a fact as a cause for the accident. This is a critical choice that any investigation has to make, and is an issue we will return to.

To sum up the human-centred analysis, Dr Smith was dealing with a somewhat misleading case, got caught in a fixation error initiated by misleading symptoms, and maintained by confirming evidence. In principle, this combination can be given some credit since it has also triggered errors in troubleshooting tasks (Besnard & Toniazzo, 1999; Besnard, 2000; Besnard, Greathead & Baxter, 2004); an activity that shares many similarities with medical diagnosis.

3.4 Conclusions to, and limits of the human-centred analysis

From this individual analysis, the explanation for the diagnosis delivered by Dr Smith lies in a rather complex combination of cognitive processes, coupled with the patient's misleading symptoms. However, such a conclusion overemphasises individual explanations. Table 1 therefore summarises some key data about the human-centred analysis and addresses the shortcomings of this approach.

Table 1: Summary of the key data from the human-centred analysis

Contents	Cognitive psychology
Assumption	The main causes of the event belong to the cognitive domain. Therefore, cognitive psychology can reveal sufficient causes to explain the accident
Main causes identified	Misleading initial symptoms; Fixation; Confirming symptoms
Possible recommendations	- Based on training personnel on self-control of activity: improving symptoms recognition, detecting fixation errors by avoiding mere repetition of actions, better knowledge of diagnostic reasoning, awareness of shortcomings of human reasoning - Based on training personnel on cross-control of activity: sharing diagnoses
Information loss	The organisational conditions that enabled the psychological processes to trigger the accident are unaddressed.
Impact on safety	The organisational conditions not being taken into account, the latter might lead later individual failures to trigger more accidents.

By using concepts from cognitive psychology, it comes as little surprise that the identified causes are typical of what cognitive psychology can explain (nature of symptoms and related psychological phenomena). The obvious limitation to this angle of analysis is that it overlooks the possible role of organisational contributing factors, and therefore does not capture all other sources of re-occurrence.

The fact that we left organisational factors out of our analysis is a serious limitation since it is impossible to know whether latent conditions were present. Also, we do not know the institutional context in which Dr Smith worked, what her status was, what her level of experience was, and so on. So far, the conclusion is that such facets of the accident cannot be addressed by a sole analysis of the human dimension. Looking into the organisation is needed; this is the topic of the next section.

4 ORGANISATIONAL INVESTIGATION OF THE CASE

Following the human-centred analysis from Section 3, we are now going to shift our standpoint and look into the organisational factors that might have played a role in the accident. The factual data contained in the original report will be presented according to three

main categories: the local Health Authority, working in an emergency department, and the effects of cultural issues. These categories will be discussed in order.

4.1 The Local Health Authority

In the specific Canadian Health Authority we are concerned with here, the main steps of the certification procedure for external medical doctors (MDs) are as follows. MDs submit their application for a vacant position to the Health Authority credentialing process, and background curriculum checks are performed. In the next stage, a committee inspects the application with regard to its implications for the target specialty. For MDs applying to the Emergency Department, a checklist is completed. The application then goes to an appointment committee to ensure that all recruitment criteria are met. If approved, the application is then sent back to the Health Authority who notifies the recruiting hospital. If the Chief Medical Officer has no objection, the applicant MD then receives one-year temporary privileges. Following this period, the MD receives a performance appraisal and is then confirmed in the position.

As stated by the accident report, the Local Health Authority where the accident happened experienced a significant staff shortage of emergency physicians. The Health Authority's response to the situation was to relax the assessment criteria for candidate MDs' privileges. This was the situation when Dr Smith applied. Her privileges, although clearly not optimal for being a practitioner in the Emergency Department (she was trained in another specialty than emergency medicine), were not taken as an impediment to her recruitment; she was then accepted as an MD in the Local Health Authority.

4.2 Working in the Emergency Department

The hospital where the accident took place is a community hospital in Canada. At the time of the accident, the Emergency Department (ED) was busy. The workload increased substantially when five to seven ambulances arrived after Dr Smith started work that day. Staffing levels in the ED were considered adequate in terms of the number of nurses but low in terms of their years of professional experience. Last, it should also be pointed out that an ED is a place where MDs can be exposed to high levels of stress due to a high working tempo and patients being in pain. As suggested by classifications of performance conditions such as the Performance Shaping Factors (Swain & Guttman, 1983) or the Common Performance Conditions (Hollnagel, 1998), the prevailing working conditions in the ED were clearly not optimal.

4.3 Effects of cultural issues

At the time of the accident, Dr Smith was one of the two physicians on duty. As described earlier, she was female, was trained in another specialty than emergency medicine, and belonged to an ethnic group. The other physician was male, experienced in emergency medicine, and Caucasian. At first sight, these might not be taken as relevant dimensions to the accident. However, hospitals have a very vertical power structure, where senior doctors have extended authority and are extremely well-respected. Although part of the medical culture, double-checking one's diagnosis with a senior member of staff might expose areas of lesser competence. In the case of Dr Smith, other factors such as ethnicity and gender might have also combined with temporary credentials to put her (a new recruit) in a very difficult situation.

4.4 Organisational analysis of the case

In Figure 4, only organisational factors are taken into account. This simulates a situation where the investigation places a heavy focus on organisational factors. This approach emphasises the role of such categories as *Working in ED*, the *Health Authority*, as well as *Cultural issues*. The diagram obeys the same three-fold granularity and the same semantics as the one used in the previous section.

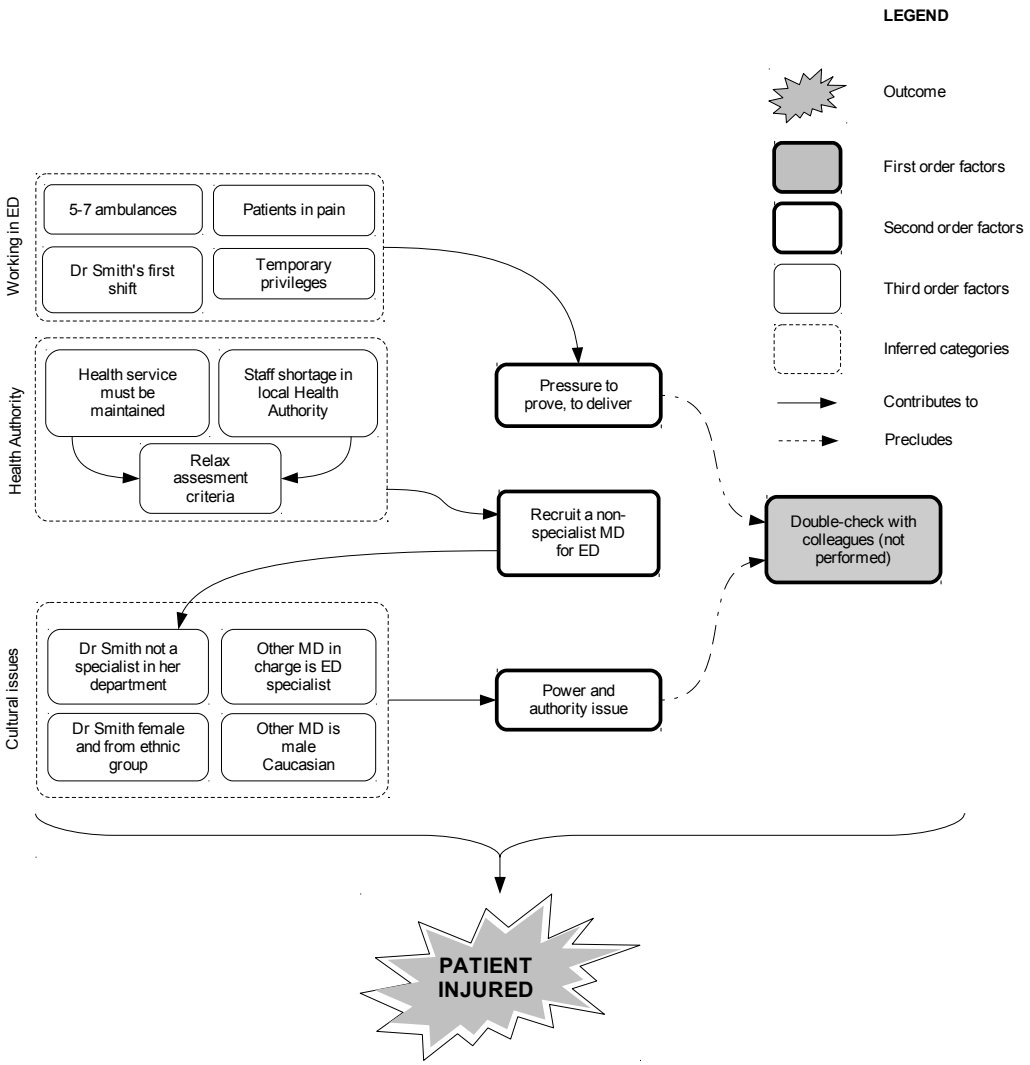

Figure 4: Descriptive diagram of an organisational analysis

The accident report states that Dr Smith did not double-check her diagnoses with colleagues. This is an important contributor to the accident but its origin was not given a lot of attention in the official report. The senior physician who was on the same shift as Dr Smith could have helped to bring a different light to the case. However, as stated previously, a high *Pressure to deliver*, and *Power and authority issues* placed Dr Smith in an unfavourable context.

Another second-order factor played a role in the accident: the Health Authority recruited a non ED-specialist. This lead back to a historical condition whereby staff were difficult to find for some parts of Canada, thereby forcing the Health Authority into a trade-off between staff qualifications and patient safety. In hindsight, the consequences of these trade-offs seem

obvious. However, the recruiting pressure might have made these trade-offs drift insidiously into normal practice, thereby making them difficult to notice.

This opens the issue of normalisation of deviance (Vaughan, 1996) . Indeed, it is striking to note that the diagnostic failure happened over the course of some hours[6] whereas the organisational factors that contributed to this occurrence are rooted in almost invisible decisions that happened over a long history of decaying ED staff levels in the Health Authority. Also, the practitioner's failure happened at the sharp-end where evidence is easy to collect, whereas facts about the drifts in the recruitment at the Local health Authority are much harder to establish. This fundamental difference partly explains why individual failures are so often emphasised as opposed to their organisational origins.

4.5 Conclusions to, and limits of the organisational analysis

Despite the organisation-centred analysis revealing new contributors to the accident, a serious limitation appears: we have lost the results from the analysis of the individual dimension. Namely, one can no longer capture and understand the fine psychological causes of Dr Smith missing the fractured shoulder blade, then diagnosing a pneumothorax, and a hæmothorax. A summary of the key data about the organisational analysis shows the shortcomings of this approach. This is what is shown in Table 2.

By using an organisational standpoint, the investigation had to assume that this level of analysis would reveal the main contributing factors to the accident. Therefore, it is almost unavoidable that the ones that were discovered are typical of what an organisational analysis can explain: pressure, recruitment and power issues. The limitation to this approach is that the individual contributing factors to the fine mental processes involved in the accident are totally unaddressed. Like the human-centred analysis limitations, a one-sided organisational analysis overlooks important data and therefore becomes detrimental to safety. Indeed, the recommendations from the above analysis will only touch the organisation and the authorities. This overlooks the possible role of the cognitive contributing factors identified in the previous section, and therefore does not control all sources of re-occurrence.

6 Only some hours elapsed between the admission of the patient in the ED and the injury. However, the patient needed subsequent medical care after the accident and was only discharged four days later.

Table 2: Summary of the key data from the organisational analysis

Contents	Organisational data
Assumption	The main causes of the event belong to the organisational domain. Therefore, an organisational analysis can reveal sufficient causes to explain the accident
Main causes identified	Recruit a non-specialist MD for ED; Pressure to prove, to deliver; Power and authority issue
Possible recommendations	- Based on a better control of the recruitment decisions and staff allocation: identify constraints on recruitment process, identify ways of mitigating these constraints at the government and Authority levels; optimise trade-off between shortage of staff and public health (e.g. enticement measures to work in understaffed geographical areas) - Based on understanding the pressure to deliver and power issues: identify the motivational effects of temporary credentials, the need from practitioners to demonstrate their value, dampening the effects of the hospital power structure on individual work
Information loss	The fine mental processes are left unaddressed. The role of the misleading initial symptoms, the fixation error and the subsequent confirming symptoms are not known.
Impact on safety	A better understanding of the recruitment trade-offs and staff allocation will not, just by itself, prevent human failures on misleading cases to occur again.

So far, we hope we have demonstrated that accident analysts cannot rely on cognitive, or organisational sciences alone to fully discover the contributing factors to an event. Since any discipline will only help understand the facets of an accident that its concepts cover, the choice of a discipline to analyse a case is in itself a selection of the causes that will be identified. One needs multiple angles of analysis to discover multiple types of contributing factors to an event. This will be addressed in the next section where we will combine the human-centred and organisational analyses. This will simulate an investigation that would have combined disciplines in the analysis of the accident, starting with the assumption that contributing factors are spread over a number of dimensions.

5 JOINT INVESTIGATION OF THE CASE

From the limitations of the previous two angles of analysis, we wish to highlight the need to take into account both the sharp end (individual factors) and the blunt end (organisational factors) in accident analysis (see Hollnagel, 2004, p. 62-63). Doing so will bring more than the sum of the parts; the added value being the understanding of the emergent interactions between the human and organisational dimensions. This is what we will discuss in this section.

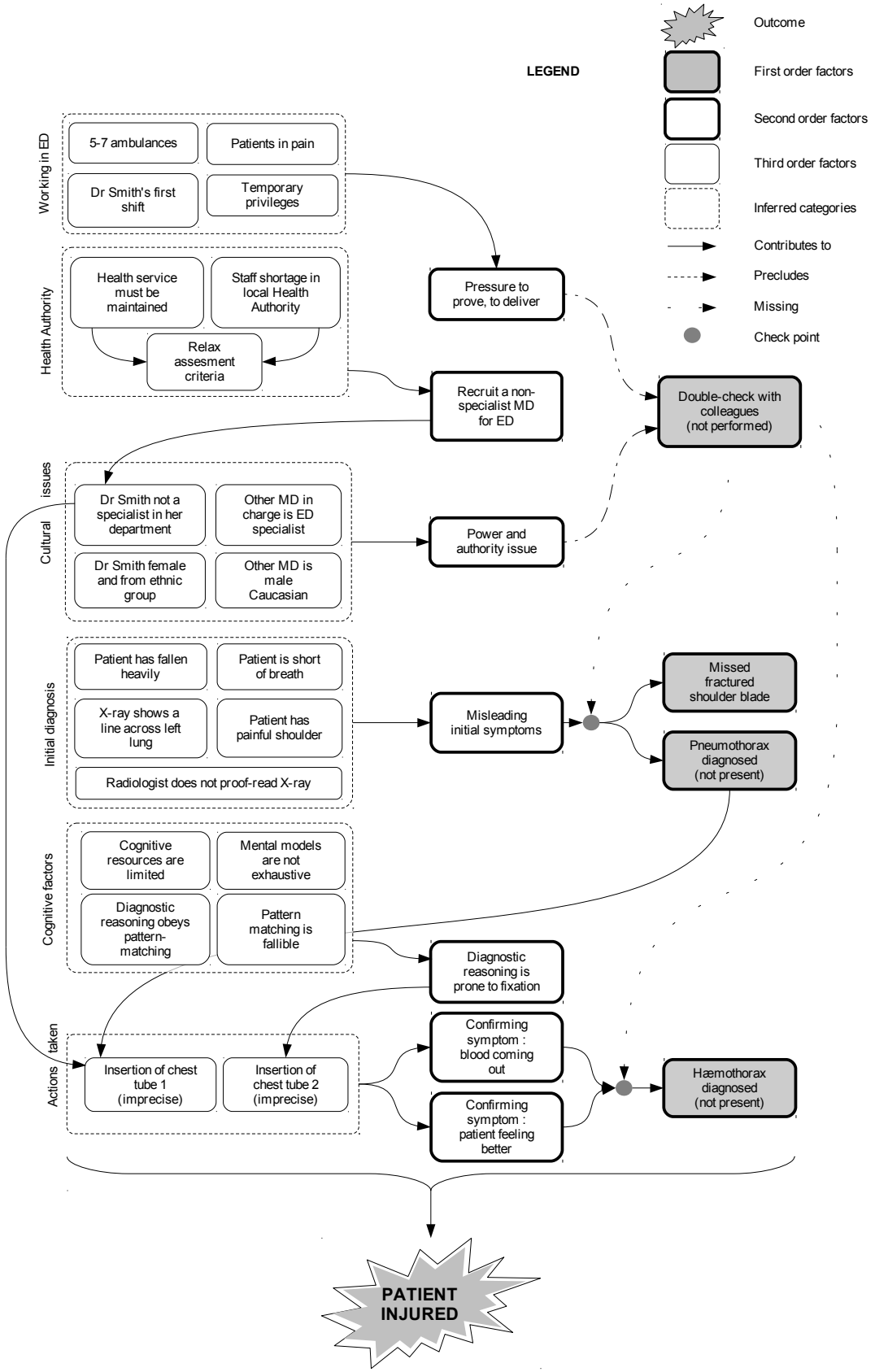

Figure 5: Descriptive diagram of a joint analysis

By merging the human-centred and organisational analyses from the previous sections, Figure 5 provides a fuller account of the contributing factors to the accident. We are of the opinion that this last level of analysis is the richest of the three presented in this paper, and the one that best describes the interplay of the various contributing factors.

First, one gets the full picture of the scale of the factors at play. All the data gained from the analysis of the human and organisational dimensions are present; no information is lost, nor is any level of depth. Reading Figure 5 from right to left, one can notice the small number of first order factors at play, compared to second and third order factors. This supports a claim made earlier in this article: the phenomena that are immediately accessible (first order factors) cannot be treated as causes since this overlooks the more numerous and deeper conditions that enabled them (second and third order factors). This is a critical issue since deep factors are where sources of re-occurrences lie, and therefore offer the best leverage against re-occurrences.

An interesting side-effect of the growing complexity of our analysis is the progressive expansion of the legend through Figure 3, 4 and 5. Progressively, the notions of *preclusion*, *miss* and *check point* had to be introduced. In itself, this accounts for the increasing variety of relationships that appear between contributing factors, a typical feature of complex socio-technical systems.

Among the added values of the joint analysis is the visibility of the impact of organisational factors on individual decisions. The most obvious of these links is related to the recruitment decision. This led to a non ED specialist to work in ED; a decision which contributed to the misdiagnosis of the patient condition and subsequent imprecise insertion of the chest tubes. Another element linking organisational factors to individual behaviour is the failure to perform the double-check with colleagues. The joint analysis now captures the fact that Dr Smith could have double-checked her diagnosis twice, at two distinct check-points: the diagnosis of a pneumothorax, and the subsequent diagnosis of a hæmothorax. But as explained before, these checks did not happen because of a pressure to deliver and a power issue. On this specific point, it is interesting to note that the very same people who would promote the practice of double-checking diagnoses (senior physicians) are likely to have unknowingly contributed to it not happening.

Table 3 summarises the key data from the joint analysis and highlights the contribution of a multidisciplinary angle of analysis. Using both cognitive and organisational data, it became possible to reveal the interplay of the cognitive and organisational factors (*Misleading initial symptoms*; *Fixation error*; *Confirming symptoms*; *Pressure to prove, to deliver*; *Recruit a non-specialist MD for ED*; *Power and authority issue*). This allowed the development of recommendations targeted at the fine cognitive failures, as well as the organisational background that enabled such failures to trigger the accident.

Table 3: Summary of the key data from the joint analysis

Contents	Cognitive psychology and organisational data
Assumption	Once joined together, cognitive psychology and organisational data can reveal the main contributing factors to the accident
Main contributing factors identified	Misleading initial symptoms; Fixation; Confirming symptoms; Pressure to prove, to deliver; Recruit a non-specialist MD for ED; Power and authority issue
Possible recommendations	- Based on training personnel on self-control of activity: improving symptoms recognition, detecting fixation errors by avoiding repetition of actions, better knowledge of diagnostic reasoning, awareness of shortcomings of human reasoning - Based on training personnel on cross-control of activity: sharing diagnoses and identifying the constraints related to this practice - Based on a better control of the recruitment decisions and staff allocation: identify constraints on recruitment process, identify ways of mitigating these constraints at the government and Authority levels; optimise trade-off between shortage of staff and public health (e.g. enticement measures to work in understaffed geographical areas), identify consequences of recruitment decisions on staff skills - Based on understanding the pressure to deliver and power issues: identify the motivational effects of temporary credentials, the need for practitioners to demonstrate their value, dampening the effects of the hospital power structure on individual work
Information loss	Reduced (the individual and organisational contributing factors to the accident are known)
Impact on safety	The fine mental processes involved in the diagnostic failure, as well as their organisational enabling conditions are known, thereby allowing a more comprehensive control of possible re-occurrences.

More elements for discussion will be provided in Section 6, along with related implications for accident investigation.

5.1 Conclusions to, assets and limits of a joint analysis

Opting for a human-centred or organisation-centred analysis overlooks a vast quantity of information, and introduces important biases in the discovery of the factors contributing to an accident. Instead, we wish to promote the idea that a joint analysis of human-related and organisational factors is needed when carrying out accident investigation. That said, a joint analysis has the following weaknesses:

- *Cost*. It is more costly (although only in the short term) than a "human error" attitude or a simpler analysis;
- *Technical difficulty*. It requires more skills and implies integration of these skills;
- *Acceptability*. It will uncover contributing factors that not all parties involved (especially management and regulators) might be ready to fully accept;

Conversely, a joint analysis also has strengths:

- *Scale*. It gives an account of all the individual and organisational factors at play;

- *Depth*. It allows one to pinpoint, and understand the role of, latent conditions;
- *Comprehensiveness*. It links together organisational and human-related factors;
- *Departs from "human error"*. The investigation can get away from the simplistic notion of individual cause, and instead look into the enabling conditions for operators' failures;
- *Safety management*. It allows the identification of the diversity of factors and offers the best leverage for preventing re-occurrences.

6 DISCUSSION

This section zooms out from the results of our analyses. Beyond the technical aspects of this article, it addresses the consequences of some investigation practices and assumptions on safety.

6.1 Main findings

As explained earlier, we have decided to retain the combination of the second-order factors identified in Figure 5 as a reasonable source of explanation for the accident. From such a choice of depth, we can reach the following explanation of the accident (second-order factors are italicised).

> Due to chronic shortage of medical staff, the Local Health Authority took the decision to *recruit a non-specialist MD for ED*. Partly because of temporary privileges, Dr Smith (the recruited practitioner) found herself under *pressure to prove, to deliver*, in order to demonstrate her value to the rest of the staff. This combined with a *power and authority issue* and led her to disregard double-checking her diagnosis with colleagues. Because Dr Smith was treating a patient showing *misleading initial symptoms*, the missing double-check of her diagnosis was not without consequences (fractured shoulder blade not treated and undue tubing of the patient's chest). A *fixation error* contributed to Dr Smith diagnosing a pneumothorax and a hæmothorax. This fixation was maintained by *confirming symptoms*: blood coming out of chest tubes and the *patient feeling better*.

6.2 Human error: confusing blame and science

Investigations sometimes take place within a judicial process or under a blame culture, where the discovery of responsibilities is the main deliverable. From this point of view, human error is a convenient concept since a) it creates an early stop point to investigations, b) eases the discovery of so-called causes and c) is itself a sufficient explanation of mishaps in the eyes of the layman. However, as Hollnagel (1993) put it: *To err is human; to understand the reasons why humans err is science*. In this view, that an operator failed does not inform on what caused the failure. Instead, any sensible investigation will have the prevention of re-occurrences as a raison d'être: *"Simply attributing incidents/accidents to human error is not adequate; human factors aspects should be investigated such that lessons are learned to prevent recurrence"* (Gall, 2008). Now, going back to Dr Smith, why did she puncture the patient's liver twice? A constructive standpoint for safety is to acknowledge that some organisational conditions were at play, that extend well beyond human activity or work at the ED.

6.3 Accident investigation is a matter of choice

Accident investigation is not a rational process by which causes to events are exhaustively found and subsequently protected against. Instead, it is an extremely constrained task where investigators implicitly select what is going to be analysed, operate under many constraints, and unconsciously pre-determine the causes they will be able to identify. For instance, Dekker & Hollnagel (2004) make the point that in the attempt to explain human performance, one can only account for what their explanatory model allows them to: *The model constrains what can be measured by describing what is essential performance, and the model parameters thereby become the basis for specifying the measurements* (p. 82). The biases listed here are only a few among a very long list (see Johnson, 2003); not to mention other dimensions such as the person carrying the investigation, the relation of this person to possible victims, the social and political nature of the accident, etc. (Sklet, 2002; Kouabenan, 2009). Because these constraints cannot be just eliminated, accident investigation turns out to be a constant trade-off that implicitly determines the variety and depth of causes discovered for a given event.

6.4 Contribution to the original report

This section does not aim at pinpointing the shortcomings of the official inquiry. Instead, we wish to highlight the interest of blending disciplines and making reasoning systematic:

- *Deeper and wider coverage of both human and organisational issues*. These dimensions are covered in the report but in a rather non-exhaustive way. Our analysis reveals seven (second-order) factors that contributed to the case, each linked backwards to their antecedents.
- *Detailed analysis of the psychological processes involved in diagnosis*. The human dimension is the one that most lacks precision in the report. Very little detail is given about the possible reasoning processes and their role in the diagnostic failure.
- *The insertion of the second tube in the patient's chest can now be (at least partly) explained*. In our interpretation, the MD worked under the influence of a fixation error which triggered the same action twice.
- *The lack of double-check can be explained*. In our interpretation, this is due to a combination of factors that put Dr Smith under pressure to prove and deliver, as well as submitted her to power and authority issues.
- *Recommendations are more comprehensive and more precise*. These are summarised in Table 3 and cover the seven second-order factors discovered in our joint analysis. In comparison, the official report issued two recommendations about a performance appraisal process, and a review of the credentialing process, respectively. A third recommendation suggested the referral of the case to a special committee for review.

7 ACCIDENT INVESTIGATION: KEY MESSAGES

At the end of this paper, we wish to summarise the various messages that we have conveyed though our research. For the most part, they extend beyond the specific case we investigated here, and address some high-level dimensions of accident investigation.

- *Choosing how to analyse an event carries assumptions*. It implicitly pre-selects the causes that will be identified by the investigation . A more insidious effect is that this choice cannot help identify the causes that will be overlooked.

- *Blending competencies* (e.g. psychologists, management scientists and field experts) is instrumental in covering the variety of causes to an event.
- *Advanced accident investigation methods are not always needed* to understand the main causes of an event. More than the method, it is the assumptions held by the investigation team that will determine the outcome of the analysis, the subsequent recommendations, and the changes implemented.
- *Not all contributing factors belong to the same level of granularity*. The first-order factors (phenomena) are available to the layman. Specialists are needed to discover deeper factors, understand the general system's behaviour, and contribute to safety.
- *Not all contributing factors are of the same nature*, but they all contribute to the same event. Some factors have a direct influence on individual behaviour whereas others are organisational enabling conditions that allow such behaviour to occur.
- *Almost any event has human and organisational facets.* Safety has much to gain from enriching a detailed investigation of individual actions with organisational factors.
- *Accident investigation usually sets a focus* on the facts to be analysed, whereas there is not one single, ideal level of analysis.
- *Accident analysis cannot be perfect.* It is a constant trade-off between a better understanding of contributing factors and tangible limits of resources (e.g. budget, skills and time).

8 CONCLUSION

In this article, via a three-way comparison of possible accident investigations, we assessed the various contributing factors that can be discovered and missed, depending on the approach to an event, the deriving assumptions, and the disciplines selected for its analysis. Through this research, we used a recursive approach. This allowed us to address, with a relative simplicity, the complex aetiology of an accident in a socio-technical system. Also, this allowed us to revisit a classical tendency in traditional accident investigations: that of considering external, visible phenomena (first-order factors) as acceptable causes. We hope we have demonstrated that this approach is detrimental to safety.

The joint approach that we have promoted here allows one to establish links between local, individual actions, and their organisational enabling antecedents. Such links are missing from an organisational-only or human-only approach, and are a true added value to a joint analysis.

The investigation of several dimensions (e.g. human and organisational) of an event has implications on the type of causes identified, and on the barriers deployed to prevent re-occurrences. It follows that safety management as a whole is heavily dependent on the disciplines and depth of analysis chosen at the very early stages of an accident investigation, and impacts the causes identified. As Dekker (2005, p. 51) put it: *"Was this an error? It depends on who you ask"*.

9 REFERENCES

Besnard, D. & Bastien-Toniazzo, M. (1999). Expert error in trouble-shooting: an exploratory study in electronics. *International Journal of Human-Computer Studies*, 50, 391-405.

Besnard, D. (2000). Expert error. The case of trouble-shooting in electronics. Paper given at

the *SafeComp 2000* conference, Rotterdam (pp.74-85).

Besnard, D. & Greathead, D. & Baxter, G. (2004). When mental models go wrong. Co-occurrences in dynamic, critical systems. *International Journal of Human-Computer Studies*, 60, 117-128

Bourrier, M. (2007). Risques et organisations. In C. Burton-Jeangros, V. November & C. Grosse: *Face au risque.* Genève, Georg Editeur (pp. 159-182).

De Keyser, V. & Woods D. D. (1990). Fixation errors: failures to revise situation assessment in dynamic and risky systems. In A. G. Colombo & A. Saiz de Bustamante (Eds). *Systems reliability assessment*. Dordrecht, The Netherlands, Kluwer (pp. 231-251).

Dekker, S. & Hollnagel, E. (2004). Human factors and folk models. *Cognition, Technology & Work*, 6, 79-86.

Dekker, S. (2005). *Ten questions about human error*. Mahwah, NJ, Lawrence Erlbaum Associates.

Dick, E. (2000). Chest X rays made easy. *Student BMJ*, 08, 303-346.

Gall, B. (2008). *Guidance on investigating and analysing human and organisational factors aspects of incidents and accidents*. London, Energy Institute.

Hollnagel, E. (1993). The phenotype of erononeous actions. *International Journal of Man-Machine Studies*, 39, 1-32.

Hollnagel, E. (1998). *Cognitive Reliability and Error Analysis Method*. Oxford, Elsevier.

Hollnagel, E. (2004). *Barriers and accident prevention*. Aldershot, Ashgate.

Hollnagel, E. & Speziali, J. (2008). *Study on Developments in Accident Investigation Methods: A Survey of the "State-of-the-Art"*. SKI report 2008:50.

Johnson, C. (2003). *Failure in Safety-Critical Systems: A Handbook of Accident and Incident Reporting.* Glasgow, University of Glasgow Press. Available on-line at: http://www.dcs.gla.ac.uk/~johnson/book (last access on Feb 5th, 2010).

Klein, G. A. (1999). *Sources of Power: How People Make Decisions*. Cambridge, MIT Press.

Kouabenan, D. R. (2009). Role of beliefs in accident and risk analysis and prevention. *Safety Science*, 47, 767-776.

Lundberg, J., Rollenhagen, C. & Hollnagel, E. (2009). What-You-Look-For-Is-What-You-Find - The consequences of underlying accident models in eight accident investigation manuals. *Safety Science*, 47, 1297-1311.

Rasmussen, J. (1986). *Information processing and human-machine interaction*. North Holland, Elsevier Science.

Reason, J. (1990). *Human error*. Cambridge, Cambridge University Press.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, Ashgate.

Simon, H. A. (1957). *Models of man*. New York: Wiley.

Sklet, S. (2002). *Methods for accident investigation*. Norwegian University of Science and Technology, Report ROSS (NTNU) 200208.

Swain, A. D., & Guttman, H. E. (1983). *Handbook of human reliability analysis with emphasis on nuclear power plant applications*. Washington D.C., NUREG/CR-1278.

Vaughan, D. (1996). *The Challenger launch decision. Risky technology, culture and deviance at NASA*. University of Chicago Press.

Wason, P. C. & Shapiro, D. (1966). Natural and contrived experience in a reasoning problem.

In B. M. Foss (Ed): *New horizons in psychology*, Penguin, Harmondsworth.

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