Enhancing Safety: The Challenge of Foresight

ESReDA Project Group *Foresight in Safety*

Chapter 4

Loss of Memory as a Cause of Failure of Foresight in Safety

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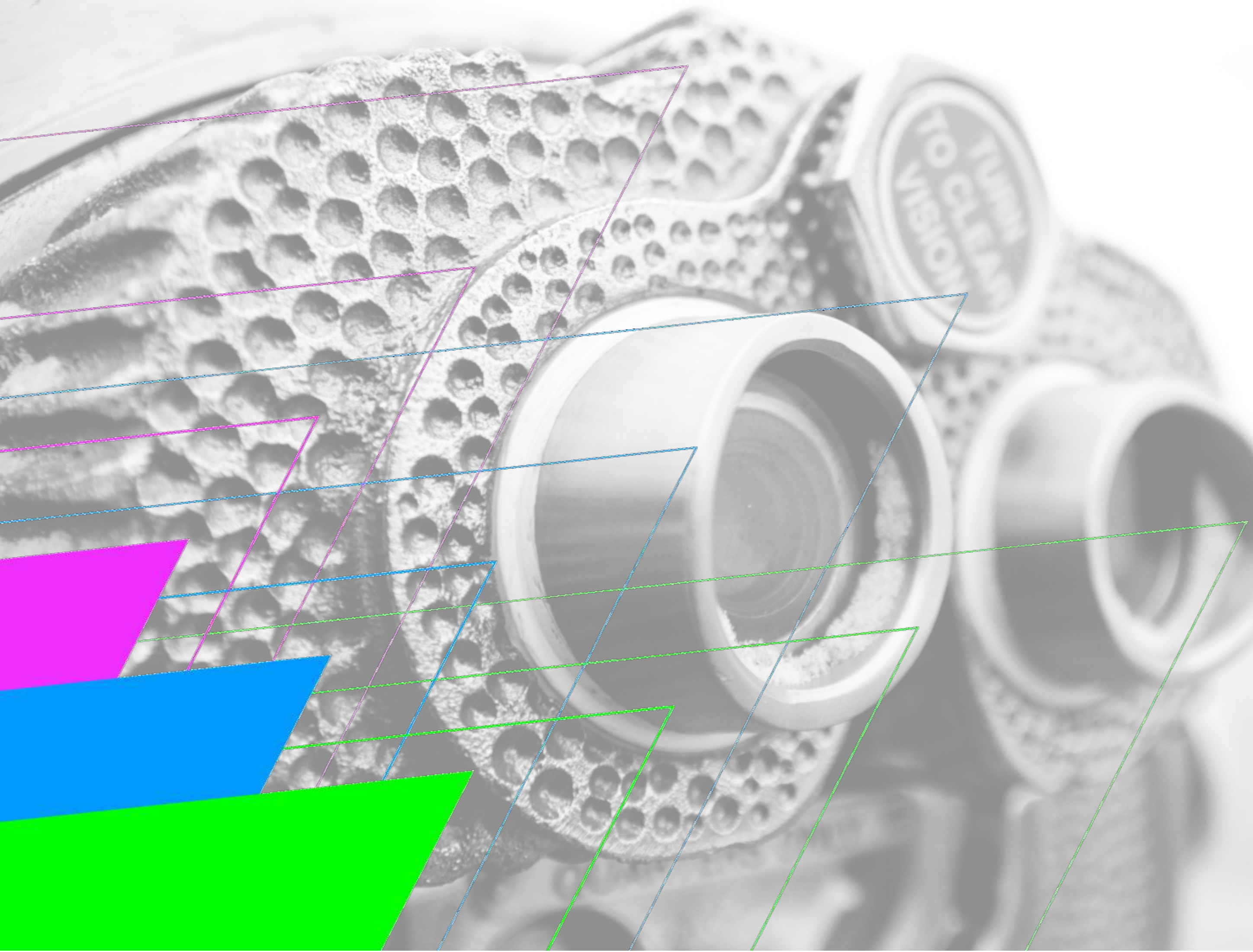

ESReDA
European Safety, Reliability & Data Association

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4 Loss of Memory as a Cause of Failure of Foresight in Safety

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4.1 Executive Summary

Loss of memory that degrades foresight in safety, especially implies a loss of knowledge of Early Warning Signs. With this focus, four aspects of memory playing a crucial role in foresight are identified which enable four different abilities (awareness for vigilance, recognition for sense-making, investigation for detection, and follow-up). They are associated with three faculties of human memorisation (encoding, storing, retrieving). Thus, difficulties for maintaining the memory useful for foresight fall into twelve categories of loss of memory. The individual aspects of memory important for foresight are distributed among different humans on different levels of hierarchy in socio-technical system. Organisational memory is a complex concept, phenomenon and system which relies on several aids, functions and artefacts (documents, procedures, processes, structures). Safety management measures can reduce some kinds of loss of memory without duplicating efforts but organisations should direct proactive specific measures against relevant categories of loss of memory.

4.2 Key Messages

- Loss of memory is a recurring root cause of disasters.
- Knowledge from the past, hindsight knowledge is still useful for insight and foresight.
- Part of the foresight is 'reproductive' based on past experiences while another part is more 'creative'.
- Loss of memory represents a loss of knowledge about early warning signs resulting from learning deficiencies.
- Four aspects of memory playing a crucial role in foresight have been identified and enable different abilities (awareness for vigilance, recognition for sense-making, investigation for detection, and follow-up).
- There are three key faculties of human memorisation (encoding, storing, retrieving).
- Loss of memory useful for foresight can fall into twelve categories defined by the combination of four aspects and three faculties of memory.
- This classification applies not only to human memory but also to organisational memory.
- Organisational memory is a complex process that integrates memories of all humans within the organisation and sustain collective memory, supporting safety management aids and functions, and all the artefacts (documents, procedures, structures, processes) that integrate the experience of designers, operators and managers.
- For each part of memory, contributing persons, aids and devices and supporting functions of the local safety management could be identified.
- Some of generic safety management measures may prevent loss of memory and there is no need to duplicate efforts. However, there is still an effort to convert the question of what increases or decreases loss of memory to the measures or specific functions in local safety management that sustain overall safety performance including the memorisation aspects and faculties.

4.3 Introduction

It may seem paradoxical to address foresight, while its perspective is towards the future, with an issue such as "loss of memory" which perspective is towards the past. Indeed, knowledge from the past, or hindsight knowledge is still useful for insight and foresight. To face risks in the future, we are convinced that history still matters even with the forthcoming era of big data and artificial intelligence which implies duties for establishing some safety history to remember.

First and as a reminder according to Stark (1961), part of the foresight is 'reproductive' based on past experiences while another part is more 'creative'. For Ricoeur analysing the relationship between history, memory and forgetting (2000), "the important is that the projection towards the future is now solidary to the retrospection on the past times". In summary (Kingston and Dien, 2017), foresight is about imagining the future possibilities based on knowledge of the past and present. In chapter No.°5 dedicated to the use of scenarios (Ferjencik et al, 2020), we have explained how the use of scenarios for foresight in safety is both prospective and retrospective.

Second, one should remind that our society that is currently driven by 'creative destruction' (Schumpeter, 1942) which puts an emphasis on innovation and adaptation and highlights how experience and knowledge can become obsolete in face of changes that accelerate. Indeed, in management science, Abernathy (1978) proposed a paradigm shift that considered that innovation and experience should be understood as rival forces and strategies for companies. This dilemma between the two rationales was later reformulated by March (1991) within organisational learning framework: one would relate to the exploration of new knowledge while the other would relate to the exploitation of the existing knowledge. However, one should acknowledge that not all changes are disruptive, some are incremental and some designs last for several years. We believe foresight in safety has to consider both dimensions as it is done in the whole book. In this chapter, we focus more on the failure to use existing safety knowledge.

Third, the quote 'Loss of Memory' (LoM) is a fairly common explanation of the reasons or the way an unwanted event recurred or occurred despite early warning signs.

In the context of this ESReDA book on the issue of Foresight in Safety, we limit our scope to situations where LoM is used to explain some failures of foresight (Turner, 1976; Kletz, 1993; Llory, 1996; Vaughan, 1996; Reason, 1997; CAIB; 2003; Woods, 2009, Dechy et al, 2011, Ferjencik and Dechy, 2016). These are situations where LoM represented a failure of foresight, or memory loss has caused some 'Early Warning Signs[16]' (EWS), 'weak-signals', 'latent flaw', 'precursors of accidents', 'near-misses', or 'alerts' to be omitted or unrecognised, during an 'incubation period' (Turner, 1978), which created an 'accident waiting to happen'.

In other words, loss of memory is a root cause of numerous disasters. Indeed, the situations we may encounter and should explain by the term LoM are diverse. Loss of Memory could actually be considered itself as a generic and transversal kind of EWS. However, it is a term that remains so vague and broad that different forms of LoM need to be analysed.

To address the challenge of making the concepts 'foresight in safety', 'EWS' and 'LoM' operational, we therefore attempt in this chapter to identify different forms of LoM and classify them. The resulting categorization can help to highlight a few specific LoM examples to better focus repetitive prevention efforts through safety management.

In this analysis of LoM forms or patterns, we assume first that LoM represents a loss of knowledge about EWS resulting from learning deficiencies (as described in Part 4.4). Accordingly, LoM forms can be divided into four groups which relate to several (in-)abilities (lack of awareness that leads to lack of attention or vigilance, lack of recognition or sense-making abilities, lack of investigation abilities for detecting EWS, and lack of follow-up after EWS). This will be explained in Part 4.4.3.The second step of the analysis (in Part 4.5) starts from the position that the term LoM tends to relate to human memory and can be approached as a process. Some definitions on human memory is provided. This leads to a distinction between three types of deficiencies in encoding, storing and retrieving information and knowledge; this represents the second dimension of the proposed classification scheme as later explained in Part 4.5.2. Combining these two dimensions together, it leads us to propose a framework of twelve categories of risks for LoM to manage (see Part 4.5.4).

In general, however, LoM does not only concern human and individual memory. For about the third generation we already live in a world where the term memory is commonly used outside the description of the human mind as a component of machines and systems and ultimately as a component of socio-technical systems (Rasmussen, 1997). Today we are not surprised to use the term loss of group memory, collective and also organisational memory - see Stemn et al. (2018). The legacy of Kletz (1993) "lessons from disasters: how organisations have no memory and accidents recur" was a triggering key message for this chapter and especially a more controversial warning that "organisations have no memory, only people

[16] EWS is the acronym for Early Warning Sign. "EWS are discriminated from all information and signs faced every day; EWS are those where a link towards risk identification and management has been made by a field actor, a manager, an analyst…. The relevance of the link, either intuitive or formal (e.g. data correlation), has to be assessed by experts. It can become a signal of danger when it is signalled by someone in the system. Not all EWS are signalled by somebody. Weak or strong signals of danger can be either amplified (change of risk models and actions taken strengthen risk management measures) or weakened (no action to reassess risk assessment assumptions or to take provisions for risk management). See Part 4.4.2 for further developments and relationships between concepts.

have". This statement is therefore discussed towards foresight in safety challenges. An analysis of this 'organisational memory' term will lead us to explain the paradoxical statements about LoM that we may come across (in Part 4.6). This will complement our knowledge of LoM forms.

At the end of the chapter (in Part 4.7), we consider what can counter LoM. A few approaches and tools within safety management are shown that could be used to prevent different categories of LoM.

Though we will provide insights from different scientific literatures, our goal was still to propose to safety practitioners (analysts, managers) some guidance to tackle this challenge and to make some links with management of safety. Some industrial and day-to-day examples will be used for the purpose as well.

4.4 Loss of Memory Relates to Learning and Knowledge

4.4.1 Failures of foresight in safety due to a loss of memory

Several disasters occurred or recurred and highlighted various kinds of loss of memory. Former astronaut Dr. Sally Ride who was a member of both NASA space shuttle accident investigation teams observed that there were "echoes" of Challenger accident (in 1986) in Columbia accident (in 2003). Indeed, the CAIB noticed (2003) that "The foam debris hit was not the single cause of the Columbia accident, just as the failure of the joint seal that permitted O-ring erosion was not the single cause of Challenger. Both Columbia and Challenger were lost also because of the failure of NASA's organisational system" (CAIB, 2003, p. 195). These deficiencies to learn and to correct organisational failures have been pointed out by the CAIB: "First, despite all the post-Challenger changes at NASA and the agency's notable achievements since, the causes of the institutional failure responsible for Challenger have not been fixed. Second, the Board strongly believes that if these persistent, systemic flaws are not resolved, the scene is set for another accident. Therefore, the recommendations for change are not only for fixing the Shuttle's technical system, but also for fixing each part of the organisational system that produced Columbia's failure" (CAIB, 2003, p. 195).

Moreover, we can also mention the premonitory conclusion in 1996 of her book about the study of the Challenger accident by the sociologist Vaughan: "After the Challenger disaster, both official investigations decried the competitive pressures and economic scarcity that had politicized the space agency, asserting that goals and resources must be brought into alignment. Steps were taken to assure that this happened. But at this writing, that supportive political environment has changed. NASA is again experiencing the economic strain that prevailed at the time of the disaster. Few of the people in top NASA administrative positions exposed to the lessons of the Challenger tragedy are still there. The new leaders stress safety, but they are fighting for dollars and making budget cuts. History repeats, as economy and production are again priorities" (Vaughan, 1996, p. 422).

Unfortunately, NASA is not the only organisation that was responsible for recurring accidents. BP had several accidents with "striking similarities" in their organisational root causes (CSB, 2007; Merritt, 2007): fires and explosions in Grangemouth refinery in Scotland (in 2000), explosion and fires in Texas City refinery in USA (in 2005), pipelines leaks in Prudhoe Bay in Alaska (in 2006), Deepwater Horizon oil rig blow-out at Macondo in Gulf of Mexico (in 2010). They were preceded by several early warning signs, some of them were recognised and signalled by some workers and managers but also within internal audits, but the follow-up was poor leading to "too little, too late" reactions (Merritt, 2007).

This phenomenon of loss of memory in relationship with failures to learn (Hopkins, 2010) and limits in enhancing organisational learning (Dechy et al, 2011; ESReDA, 2015) should not be restricted to one organisation or one worldwide company with many sites. It should be addressed transversally across countries and across sectors as well.

The ammonium nitrate industry faced a long history of accidents since the beginning of 20th century (Gyenes and Dechy, 2016) and the recent tragedy in Beyruth these last days is recalling that some lessons of the most recent ones (e.g. Toulouse disaster in 2001 in France (Dechy et al, 2004) and West major accident in Texas in 2013 (CSB, 2016)) are still not learned by different stakeholders (regulator, government, judicial department, operator, subcontractor). They all showed a low awareness of explosion danger and inherent risks of ammonium nitrate fertilizers but also some lack of follow-up after EWS or alerts. Similarly, within the explosive manufacturing industry in Europe, the analysis of three accidents showed some missed opportunities for improvement after near-misses, external accidents in other countries and regulation changes, but also a loss of designers' intentions throughout the lifetime of operation of the plant, especially on critical incident scenarios (Ferjencik and Dechy, 2016). Similar observations about losses of awareness and follow-up of previous lessons from accidents have been made on Buncefield disaster (in 2005), as similar explosions occurred in history prior to Buncefield and even recurred after (Paltrinieri et al, 2012) (see the list of accidents in chapter 3).

4.4.2 Early warning signs and foresight in safety

Early warning sign (EWS) is an event or more generally a condition that if it is not detected and acted upon can lead or contribute to an incident. EWS is a broad term that covers several others such as weak signals (Vaughan, 1996, Llory, 1996), precursors of accidents (Carroll, 2004), near-misses, latent flaw (Reason, 1990) and extends to alerts made by operators, safety analysts, managers, inspectors or whistle-blowers.

The word 'early' means that it can be early detected, prior a more severe accident, during an 'incubation period' (Turner, 1978). If EWS are correctly recognised, they can inform of 'time-bombs' in the system (Reason, 1997). Early warning signs should be detected as early as possible in order to take proper actions in due time to prevent or mitigate incident. This is one of the main purpose of foresight in safety.

Center for Chemical Process Safety (CCPS, 2012) writes about incident warning signs which are subtle indicators of a problem that could lead to an incident. Warning signs precede incidents or contribute to them as a condition.

While some EWS are weak, subtle, ambiguous, and may raise some uncertainties and are difficult to hear and filter from the background noise, some are strong signals such as near-misses, incidents, deviations which are normalised (Vaughan, 1996) or weakened (Guillaume, 2011), or external accidents lessons that should be learned. Some strong signals can be weakened and can lead to issues in the follow-up of actions, which are sometimes 'too little, too late' as remarked by US CSB former Chair C. Merritt (2007) about Texas City refinery accident in 2005 (CSB, 2007).

In conventional risk terminology, early warning sign can be understood as an indicator of hazard strengthening or of weakening of a safety measure (control) or of an increase of the vulnerability of the targets, which can result in an increase of likelihood of occurrence or in an increase of potential severity of consequences of scenarios causing damage. Simply said, we can consider that an early warning sign is an indicator of increase of risk.

The relationship between data, information and risk is sometimes not easy to establish at all. To recognise some EWS, investigation and data collection are necessary to produce pieces of information. However, all data, information and signs cannot be called EWS. An interpretation effort is required and implies to filter from the background noise, select some signs (Lesca, 2001; Rouibah and Ould-ali, 2002) and link several pieces of information "such as in a puzzle"[17] to discover a hidden form or pattern. This pattern that links several information to a risk is considered as a safety signal. This sense-making can be performed by a worker 'close to the valves' (CSB, 2007) or a manager or an analyst at different position in the sociotechnical system. This interpretation is then challenged towards its links to the risk or even to a scenario (Jouniaux et al, 2014). This process involves individual and collective expertise, which relies on knowledge (e.g. models, theories and studies of risk but also on frameworks, stories and patterns) that are learned and memorised.

4.4.3 Four aspects of memory useful for foresight in safety

Such a way, foresight in safety means capability to indicate increase of risk with the help of EWSs. In order to be able to implement foresight in safety, this capability has to be conscious and it has to be acted accordingly.

Speaking about the ability to indicate EWSs, four conditions related to memory have to be maintained that are shown in Table 1.

The four conditions from Table 1 describe four aspects of memory considered to be a necessary instrument for foresight in safety. In our view, memory plays a crucial role in foresight in safety as much as imagination addressed in other chapters of the ESReDA book. In our definition or proposal, 'loss of memory' in any of above aspects of memory corrupts foresight in safety.

[17] Metaphor of puzzle for recognizing EWS in strategic management is attributed to several researchers (Rouibah and Ould-ali, 2002). Those authors propose to consider the concept of early warning sign rather than weak signal.

Table 1. Four aspects of loss of memory related to foresight in safety.

N°	Aspect of memory to be maintained	Ability
1	Remember that such indicators of safety problems (EWSs) can arise	Awareness, attention, vigilance
2	Remember what forms of EWSs are possible (in order to be able to identify them)	Sense making, recognise
3	Remember how presence of EWSs can be detected	Method to detect
4	Remember EWSs that were detected until they are reasonably responded (in order to be able to respond)	Follow-up

Indeed, memory useful for foresight in safety means knowledge of EWSs that can be activated with abilities to be vigilant, to make sense, to investigate and to follow-up EWS. It does not matter how the knowledge of EWSs has been acquired. In any case, knowledge of EWSs is a result of lessons learning. Such a way, loss of memory relates to unlearning and forgetting. Lessons learning may be based on use of scenarios (including stories), both retrospective and prospective (see in Chapter 6 dedicated to the use of scenarios, Ferjencik et al, 2020).

4.4.4 Applied example: the kitchen dangers

To explain our proposal and related definitions, the four aspects mentioned in Table 1 can be easily illustrated using the example of Kate and William in the kitchen (Kate and William are married; they have sometimes slightly different views on what is dangerous in their kitchen; see Chapter 6 (Ferjencik et al, 2020)).

The first aspect is related to a situation when both Kate and William do not recognise their kitchen to be a dangerous place where EWSs may warn against possible incidents. They do not remember (they have not learned) that EWS can arise in their kitchen. If a person in the kitchen is not 'aware' that frying oil is combustible and frying can cause a fire, then it is natural that this person is not 'vigilant', and does not 'pay attention', because he or she does not understand that leaving the frying pan on a hot ceramic hob unattended is an early warning sign. This person probably suffered a loss of the first aspect of memory.

The second aspect can be illustrated by a situation when they both understand a possibility of fire but do not recognise that a bottle of oil standing at the hob may be a problem. A person in the kitchen who realizes that the oil is combustible and hence the pan cannot be left unattended during frying, but does not realize that also the presence of a plastic bottle with the oil in the vicinity of hob can contribute to the fire, suffered a loss of the second aspect of memory.

The third aspect can be described as a situation when both William and Kate understand that a decreased capacity of safety valve on pressure cooker is an EWS but they do not know that or how the presence of this EWS can be detected. In this case, they suffered a loss of the third aspect of memory.

The fourth aspect means that they know about the above bottle of oil or about degraded pressure cooker safety valve but have given up all the attempts to improve the situation. A situation where a person recognizes that the presence of plastic bottle with the oil in the vicinity of hob is an EWS, but then places the bottle on the same place again, can be related to the loss of the fourth aspect of memory.

4.4.5 Other examples from industry

The first aspect of memory means that people who are important to the system are aware of facing a hazard, etc., and that, therefore, some EWSs exist at all. It seems trivial, but this triviality is sometimes forgotten in industry. It can be illustrated by the case of West in Texas in 2013 described by CSB (2016). People who are important to the behaviour of the system have not realized that their storage of ammonium nitrate represents a hazard. Therefore, it is understandable that even repeated warnings about electrical installation faults were not considered to be EWSs related to this hazard.

We can imagine examples very similar to those from kitchen in a chemical laboratory. For instance a situation in a lab where a flammable liquid is used that is volatile and has a specific odour. Odour in the lab however is not considered to be an EWS.

Other examples have been briefly described in Part 4.4.1 and cover the four aspects of loss of memory.

4.4.6 The four aspects of LoM: description related to hazards

As we earlier defined, an early warning sign is the result of an interpretation process. An EWS can be recognised as a sign of the strengthening of a hazard or the weakening of a control over the hazard or an increase of vulnerability in the targets exposed to hazards. As such, if proper studies are conducted, it can be determined as a cause of causal event (explanation see Chapter 6, Ferjencik et al, 2020) or as an indicator of causal event or of a cause of causal event.

Differences in four aspects of memory can be well explained when we realize that EWSs are associated with the existence of hazards, controls of hazards and environmental conditions that affect hazards within the system and the exposed targets. EWSs can be recognised as signals of adverse changes in hazards, controls of hazards or environmental conditions affecting hazards or of vulnerability of targets.

1. Loss of the first aspect of memory means loss of knowledge that certain hazards and relevant controls and environmental conditions are present in the system. If one is not aware, then it's natural not to know, not to pay attention and to become vigilant about EWSs that can signal their unfavourable changes.
2. The second aspect of memory can be degraded in situation where hazards, controls, and environmental conditions are known, but there is a lack of knowledge of some EWSs that may signal their degradation. The sense making abilities are poor enough and do not allow a proper recognition of the EWS.
3. Loss of the third aspect of memory would be identified if EWSs signalling adverse changes in hazards, controls of hazards or environmental conditions affecting hazards are known but means enabling their detection are not known (improper data collection, measurement of wrong indicators).
4. The fourth aspect of memory is damaged e.g. in a situation where hazards, controls, and environmental conditions are known, and the occurrence of some EWSs indicating their degradation has been identified, but the existence of these EWSs had been routinized, normalised and forgotten before they could be responded.

It is visible from the above explanations that the loss of the first aspect of memory is close to what is described as a loss of *sense of vulnerability* (see e.g. CCPS, 2007). Reason (1997) recall that sometimes, especially after success or when preoccupation with production goals is too high, actors can lose sight of dangers and forget to be afraid. Similarly, the loss of the fourth aspect of memory is close to the *normalisation of deviance* (Vaughan, 1996) or *standardization of deviance* (see e.g. Rosen, 2015).

4.5 The Process of Loss of Memory

Foresight in safety is to be realized in socio-technical systems by people. In a first step (in this part), the memory of humans working in socio-technical system is considered to be crucial for foresight in safety. In a second step (next part), the collective and organisational dimension of memory will be addressed.

4.5.1 Memory and forgetting

Memory work is directed against the forgetting. Forgetting is linked to memory, by being its negative side and it is its condition (Ricoeur, 2000). Todorov (1995) recalls that the integral restitution or reproduction of the past is impossible. Memory implies inevitably a choice (some traits of the events will be stored while others are immediately excluded or later eliminated and forgotten). However, though accessibility of the past is a requisite, past should not rule present, which questions the adequate re-use in the new context.

"To forget is sublime" was popularised by Tom Peters a management guru (in Forbes, 1994). Indeed, in intensive innovation capitalism (Le Masson et al, 2006), the value of experience over time decreases, with forms of quick obsolescence (e.g. in computer and electronic industries). “Unlearning theory” in management (e.g. Hedberg, 1981) studied the need to intentionally get rid of outdated experience, habits and routines in order to be able to innovate.

Knowledge is partly and directly acquired by learned-by-doing and repetition which materialise by a learning curve (Argote et al, 1990). Other kind of learning is indirect through learning from others, from failures and good practices.

Some risks of unintentionally forgetting, can imply a decay in the knowledge ‘commodity or assets’ and ‘practices’. These risks were recognised as well (Easterby-Smith and Lyles, 2011) and may imply the loss of important technical knowledge and competence, the loss of identity and personal networks, the ability to learn from errors and to remain accountable from mistakes.

This can lead to knowledge losses or crash (Ermine, 2010) and costly crisis of relearning (Garcias, 2014). This phenomenon was encountered by nuclear engineering after years of downsizing in the aftermath of Three Mile Island and Chernobyl accidents.

4.5.2 The process of memorising: three key faculties

According to Sherwood (2015), memorising process is the faculty of the human mind by which information is encoded, stored, and retrieved:

- *Encoding* or registration: receiving, processing and combining of received information
- *Storage*: creation of a permanent record of the encoded information in short term or long term memory
- *Retrieval*, recall or recollection: calling back the stored information in response to some cue for use in a process or activity.

In our view, 'information' is a very broad term than encompasses data, information and knowledge learned (patterns, stories, models).

4.5.3 The process of loss of memory useful for foresight in safety

According to the above-mentioned definition that relies on a human perspective, loss of memory represents a failure in one of the three key faculties of the memorising process, for the individuals involved in the risk prevention process.

For the case of foresight in safety in a socio-technical system, according to the proposal made in the previous part, loss of memory means that information and knowledge cover four aspects mentioned in Table 1.

Therefore, for the four aspects of memory, the danger is that they are not encoded, stored, or retrieved properly by humans who can influence the design, structure and behaviour of the sociotechnical system.

This description of loss of memory is very general (more general than descriptions from ESReDA (2015)) since it encompasses not only information that was present and later was forgotten, but also the information and knowledge that should have been present but was not present.

Visibly a large variety of causes can contribute to the loss of memory. Typical causes of loss of memory represent insufficient knowledge, training or support of four aspects of memory. For instance, the refreshment of some training needed to maintain a skill is very dependent from the frequency of use in the daily practices, differentiating rescue skills from daily health and safety skills for operating (Lawani et al, 2018).

Frequently, such problems become highly visible when turnover of workers bring a loss of experience, transfers of obligations to new people, outsourcing, subcontracting, or ageing of personnel especially when the generation of 'baby-boomers' is retiring. Within the presented approach also all these problems point to the insufficient knowledge, training or support of four aspects of memory. For example, the subcontracting issue was raised for Toulouse disaster about the likely lack of awareness about the danger of chemical incompatibility between ammonium nitrate based wastes and chlorinated compounds. In addition, LoM happens between groups of workers and phases of operations, especially when modifications are made by operators forgetting the designers' intentions and limits of the system (Ferjencik and Dechy, 2016). LoM can occur as a consequence of changes and transitions (e.g. technological, regulatory, cultural and societal) (Mangeon et al, 2020), which are especially at work these years.

Such a way, not only situations when a specific knowledge or ability has been forgotten (i.e. it was not possible to be retrieved) are covered by these four aspects of loss of memory. In addition, situations are covered when this knowledge or ability has never been present (encoded and stored) in memory or has been present (and retrieved) but the ability and will to use it has not been observed.

4.5.4 Twelve categories of loss of memory

The three human faculties of memorising – encoding, storing and retrieving – allow to distinguish three kinds of failures leading to LoM. Failures of individual faculties can occur in each of four aspects of memory mentioned in Table 1 (awareness for vigilance, recognition for sense-making, investigation for detection, and follow-up). Thus, this leads to consider a two-dimensional scheme that is depicted in Table 2 that classifies LoM into twelve options, each representing a failure of one faculty in one aspect. E.g. LoM marked L2C3 represents failure of faculty #3 in aspect #2 or information is not retrieved on what forms of EWSs are possible. This division of LoM forms may help to sort various difficulties for maintaining the memory and possible safety management actions against the loss of memory.

Table 2. Twelve categories of loss of memory.

		Memorising faculties		
	Memory of information/knowledge	is not encoded	is not stored	is not retrieved
Aspects of memory related to foresight in safety	that Early Warning Signals can arise (awareness)	L1C1	L1C2	L1C3
	what forms of Early Warning Signals are possible (recognition and make sense)	L2C1	L2C2	L2C3
	that and how presence of Early Warning Signals can be detected (method)	L3C1	L3C2	L3C3
	about EWSs that were detected until they are reasonably responded (follow-up)	L4C1	L4C2	L4C3

4.5.5 Applied example: loss of memory in the kitchen

As long as Kate or William are alone in the kitchen, it may seem that all the LoMs that may occur are truly connected to their individual memories, of their individual experiences. Even with Kate and William both in the kitchen, we can only associate memory with the brains of these two people. Notice that they can develop a collective memory of their experiences in this kitchen or previous ones, with their parents or as students, and make it a topic of discussion. In the end, several hazards and practices to manage risks become implicit and do not need an explicit communication and analysis of the risks in the kitchen and on how to handle them. But this approach becomes unsustainable, especially when Kate and William want to involve their teenagers in the kitchen. The process of learning and memorising has to start all over again.

It cannot be assumed that from the very first moment they enter the kitchen, George, Charlotte or Louis will have the same information about EWSs as their parents. William and Kate will teach and train their children, on the relevant information to consider and the knowledge to learn that is important for managing risks and foresight in safety. And they may use some tools to do this - for example, a list of EWSs detectable in preparing the pressure cooker for use. What if William and Kate fail to put an item on the list and Charlotte or Louis get an unwanted event? In this case, it was probably the loss of human memory classified in Table 2 as L3C1. But what if the critical item was originally listed but ceased to be readable, for example due to the effects of kitchen fumes? In this case, it could be an L3C2 LoM, but only on condition that we accept the list of EWSs as part of the memory.

This example shows that in organisations (even a couple and a family can be considered as a group or as sub-unit of an organisation) it makes sense to extend the term memory beyond the human mind to address the aiding mechanisms that support and/or replace human memory (especially considering turnover risk and retirement perspective). The existence of such aids is a normal situation. Memory support is one of the tasks of safety management systems. Management system and culture should support memory of personnel. Hardware and software of socio-technical system may contain tools that help memory of humans (e.g. proper databases and/or procedures for identification of EWSs). We will address some features of organisational memory in the next chapter and some functions of the safety management system to support it (in Part 4.7).

4.6 Loss of Memory and Organisational Memory

4.6.1 Extension from human to organisational memory

The previous daily-experience example of the kitchen can serve as an explanation for the need to extend the perimeter of memory of risks that is to be managed and applied to an organisation. Obviously, organisational memory includes memories of all humans and groups within the organisation, who contribute to make the information and knowledge on all four aspects of EWSs encoded, stored and retrieved as described in Table 2. It includes the collective memory of some experiences and tacit rules of groups of workers related to danger (or within the family for the kitchen example). But in addition to human minds, it is also necessary to consider in organisational memory all the safety management aids and functions implemented by an organisation in relation to the aspects and faculties of Table 2. Indeed, the memory of many kitchens risks faced over decades and centuries should be somehow treated by the designers of kitchen, and they should implement man-machine interface to secure some processes (e.g. confirmation request when programing, alarm, fail-safe,…). To us, this is a rather radical extension.

Indeed, Kletz (1993) already warned that if organisations had no memory, accidents would recur. ESReDA (2015) underlined that the loss of knowledge is one of symptoms of the numerous barriers and failures to learn listed in that report: "There is a natural tendency that memory fades over time. People forget things. Organisations forget things. The lessons learned from incidents and accidents are slowly lost if no measures are taken to make them alive." This quote already associated LoM with the organisation. Not only people, but organisations lose information from classes L1C1 to L4C3 as shown in Table 2.

In addition, ESReDA (2015) stressed the importance of keeping memory: "Keeping memory of past events, lessons to be learned or not forgotten, and changes made is a key learning function”. Expanding ESReDA (2015) and other proposals (Ferjencik and Dechy, 2016), organisations must therefore set-up a dedicated process to remember important safety issues and struggle actively against natural tendency to loss of memory that increases with time (erosion of memory, turnover of people, loss of designer intentions…). The management of LoM require some functions that we associate, with concerns of synergy and limited resources in real world context, with safety management as well as functions that support the retention of information from classes L1C1 to L4C3.

4.6.2 Nature of organisational memory

Organisational memory is not a simple concept. The human memory metaphor with its three faculties is often used, but it is criticised for the anthropomorphism risks it generates when addressing organisational memory. Organisational memory is defined (Walsh and Ungson, 1991) as “stored information from an organisation’s history that can be brought to bear on present decisions”. Another author insisted more on knowledge than information (Stein, 1995) “Organisational memory is the means by which knowledge from the past is brought to bear on present activities, thus resulting in higher or lower levels of organisational effectiveness”. Often seen as internal, some researchers (De Cuffa et al, 2018) proposed to widen its scope as practitioners mobilise other means such as social networks outside the organisation’s control and responsibility.

Knowledge is also a much debated concept that can be seen in three different ways according to scientific disciplines. Some scholars in knowledge management (combining cognitive and economic resources based approaches) consider knowledge as a commodity with a “stock” of knowledge and often focus on the codification of the information content and the flow of its dissemination. Organisations can be seen as collections of knowledge assets (Wenger, 1998). But this approach is criticised for the reification of knowledge and inadequate understanding of ‘situated action” and impact of context. A few scholars in organisational learning approach it as a capability for organising (Carroll, 2004). While scholars in theories of action study practices and approach knowledge rather as a process embedded in practices of learning and doing, called knowing, that is acquired by doing. It is also acquired by sharing experience and appropriating knowledge in context of use with community members (Cook and Brown, 1999; Gherardi, 2006)). Knowledge is dynamic, is a process and an outcome. “Knowledge is a flux mix of framed experiences, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisation routines, processes, practices and norms” (Davenport and Prusak, 1998).

Polanyi (1975) insisted on the personal character of knowledge “all knowing is personal knowing”, especially in relationship to the concept of tacit skill. Bell (1999) considers that “knowledge is the capacity to exercise judgment”, especially “to make competent use of categories and distinctions constituting that domain of action” (Wenger, 1998). But the judgment and competent use are influenced by a collective and organisational dimension that provides shared understandings, heuristics, knowledge repertoires and rules of action, which then relates to organisational memory. These ideas enabled Tsoukas and Vladimirou (2001) to propose that: “knowledge is the individual capability to draw distinctions, within a domain of action, bases on an appreciation of context, or theory or both. Organisational knowledge is the capability members of an organisation have developed to draw distinctions in the process of carrying their work, in particular concrete contexts, by enacting sets of generalisations whose application depends on historically evolved collective understandings”. Within similar focus on knowledge for action, Gherardi (2006) addresses safety (in the construction industry) as an object of knowledge, the result of a practical activity of knowing, and the context in which that activity is performed and institutionalised as ‘organisational practice’.

Knowledge categories often distinguished (Nonaka and Takeuchi, 1995) are explicit, tacit but also declarative and procedural, and even judgmental (Girod-Séville, 1996). In the famous SECI model (Nonaka and Takeuchi, 1995), they require four different process for being extracted, transferred and used (e.g. socialisation, externalisation, internalisation and combination).

The organisational memory systems are "sets of knowledge retention devices, such as people and documents, that collect, store, and provide access to organisation's experience" (Olivera, 2000). Some means are tangible artefacts (intranets, databases, smartphones, procedures, products, people, social networks) and less tangible (culture). They are more or less dispersed and centralised. Three levels can be distinguished: individual, groups dispersed, centralised (Girod-Séville, 1996).

However, when conceived as a passive depository of data, knowledge and information is doomed to remain of little use (Bannon and Kuuti, 1996). The key issue is that the use relies on an interpretative process that takes into account the context of use. Codification removes context and the challenge to codify without knowing the context of use is not obvious (Koornneef and Hale, 2004). While use of organisational memory highlights processes of memorising and remembering that should compensate loss of context, but should also co-produce complementary knowledge adequate to the new context, implying that is not just an application of knowledge. In other words, there will always be some improvisation in context.

Their accessibility (retrieval in our labelling) is a key variable for their use. Indeed, some research show that people were considered as the most effective memory system, especially for easy access, specific filtering of content (Olivera, 2000) and for experiential knowledge (Arasaki et al. 2017). While dependence to technological means has increased, the reliance on "who knows what" is still a key (Jackson and Klobas, 2008). The speed in access to information and the nature of activity shape a distinction between administrative jobs which rely more on centralised technological systems of explicit organisational memory while operational jobs prefer access means with tacit content (De Cuffa et al, 2018). External social network means are more used than expected blurring the frontier between internal and external organisational memory means. While French nuclear power plants started to invest in the nineties (Girod-Séville, 1996) some resources in official memory (made of centralised memories of declared, procedural and judgmental), the research showed that in daily activities, the organisational memory was rather coming from the unofficial underground individual and collective memory (declarative, procedural and judgmental). This parallel and redundant system remains a key but is under-invested by management. It relies on key experts (Girod-Séville, 1996), and pillars of experience (Llory, 1996) that have a lot of judgmental experience, especially about networks of people and incidents. It is vulnerable to turnover. The official memory is rather used for legitimising the management choices towards the control authorities. Both systems interacts.

According to Lévy (1990), the new technologies of information and communication are creating a third pole "computer and medias" that follows the writing and oral poles. From integration and incarnation by humans in oral mode, it shifted to written archives, losing its connection to individuals and context, being objectivised in technical provisions and artefacts. To counter the danger of forgetting, among the combination [individual-writing-computer], companies invest too much in technology. While doing so, they promote an official memory that is not so used in daily practice. In this sense, Tsoukas and Vladimirou (2001) warn that in knowledge management, digitalisation cannot be a substitute for socialisation.

An effective memory relies on interactions and a good combinations of the three modes (oral, written, computer and medias). It also relies on the connexions between people, units that build the meta-memory on the location of its memory resources. Expert-systems (popular in nineties) failed to capture the know-how of experts. A better reliance on key individuals, old and pillars of experience, or "filters" that compensate loss of context (Koornneef, 2005) remains an important strategy. Also, investing on formalisation of organisational history, on stories which are valuable and convey culture, beliefs, values and help decision-making (Girod-Séville, 1996; Hayes and Maslen, 2014; Duffield and Whitty, 2015). Communities of practice with focus groups are also a key to develop knowledge sharing about skills and know-how. The role of facilitators, mentors is a key (Duffield and Whitty, 2014).

4.6.3 Extension accords with nature of organisational memory

The foregoing overview of the nature of organisational knowledge and memory has accumulated a number of perspectives that would require further explanation and commentary. For example, differences in memory versus knowledge, relationships between the human mind, written documents and computerized media, or the boundaries between external and internal.

All this scientific knowledge informs us how complicated is the field we enter when considering loss of memory in socio-technical systems. However, they do not suggest that the description of the organisational memory that we have proposed here in a safety practitioner perspective is fundamentally incorrect.

In summary, we consider that organisational memory includes:

- memories (that are encoded, stored and retrieved) of all humans within the organisation, who contribute to make and communicate the information and mobilise their knowledge on all four aspects of EWSs,
- the collective memory of experiences and tacit rules of groups of workers related to danger,
- the safety management and safety culture aids and functions implemented by an organisation in relation to the twelve categories of loss of memory,
- all artefacts that directly support human actions (documents, databases,…) or indirectly influence activities and interactions where organisational memory has been embedded into the equipment design, organisational structures and processes.

In this chapter, we assume that the decisive role in this description is played by the description of the safety management system, its tools and functions. To refine and use this description it is necessary to use a modern and up-to-date description of the safety management system (see Parts 4.7.5 and 4.7.6).

4.6.4 Paradox of organisational memory

An important starting point of this ESReDA book chapter, is to discuss the legacy of Trevor Kletz and its provocative statement: indeed, Kletz (1993) has warned that 'organisations have no memory, only people have'."

To our interpretation, Kletz did not want the notion of memory to be exclusively associated with the human brain, but at the same time realised the needs for organisations to work actively on their memory. In addition to the above strongly critical statement about organisations that have no memory Kletz (1993) also stated: "the leitmotiv of this book: the need for organisations to learn and remember the lessons of the past", which is coherent with our findings and research (Ferjencik and Dechy, 2016; Dechy et al, 2016). So Kletz (1993) was warning us about the paradox that is also mentioned in ESReDA (2015): organisations do not strictly have human memory and at the same time need to remember.

4.6.5 Complexity and fundamental difficulty for maintaining the memory

The extended description of organisational memory clearly shows how complicated the organisation's memory is and exposes how fundamentally difficult it is to maintain the memory. It will likely remain a root cause of accidents if this issue is not address by a strong program and without specific management actions.

The fundamental difficulty for maintaining the memory is that the individual aspects of memory important for foresight in safety are distributed among different humans and groups on different levels of hierarchy in socio-technical system.

In addition to people and groups, other devices and tools (databases, documents…) may be involved and help to centralise and sustain part of the official memory. Machines can also play a supporting role in foresight. In a simpler case they help the humans to remember, identify, by providing aids and cognitive prosthesis like databases, etc. Basically, any aspect of memory (be aware - identify - detect – respond) can nowadays be accomplished by or with machines, and men-machine interfaces.

But we should consider that all system meta-components such as machines, equipment, procedures, processes and structures of organisations, are all embedding some of the memory of their designers, their operators, their managers and some of the organisational memory. Some memory is internal while other is external; some is formal while other is informal (e.g. kept within a group oral culture, such as a story on an incident), and their accessibility varies according to the work situations where it could be used. In summary, any organisational artefact integrates some organisational memory and by interacting with other meta-components of the sociotechnical system is more or less making alive the organisational memory.

The interactions of meta-components are permanently formed and influenced by formal and informal organisational interactions, rules and approaches (management system and culture). Hence all actors (operators closest to the valves (e.g. in Texas City), safety analysts such as auditors, managers) are concerned by the four aspects of memory (awareness, making sense, investigating, follow-up) and may be exposed to difficulties in the three faculties of memorisation process.

The role of all is important towards treatment of EWS for foresight in safety. However, we want to insist on the point that the knowledge on the highest levels of hierarchy where local safety culture is promoted, is regulated, is scrutinized for the alignment it implies, is of extraordinary importance. As it is suggested above: humans on the highest levels of hierarchy need the knowledge about the EWS that can arise in order to motivate their vigilance and their commitment to identify EWSs, detect EWSs and respond to EWSs. Indeed, the notion of weak signals in safety has been inspired by one of its origin in strategic management (Ansoff, 1975; Ansoff and McDonnell, 1990) and military management ('intelligence' in Turner, 1978), especially when uncertainty is high and to avoid strategic surprises. Loss of this knowledge and commitment would represent a fundamental loss of memory in the system.

4.7 Activities against the Loss of Memory

4.7.1 Use of extended description of memory

Though we previously understood that taking care of human, group and organisational memory useful for foresight is quite complicated, we assume that in many ways it merges with general care of good safety culture and safety management.

However, to avoid the danger of dilution and lack of will if one considers that LoM is already addressed by existing provisions in safety management, the foregoing text also offers one aid that may be useful in identifying more specific measures that may decrease LoM. Using the scheme in Table 2, local organisational memory can be divided into twelve categories. The scheme can be applied to any activity within the organisation.

For each Table 2 category separately, the following questions can be asked:

- What is the memory of important hazards according to the different actors?
- Who are the pillars of experience holding critical knowledge and memory about risks and EWS?
- Are there some processes to formalise some of this knowledge and to train newcomers on an informal basis within day-to-day practice?
- Is the continuity and stability of groups and communities of practice considered?
- Are the lessons from other plants, units, competitors, countries, sectors learned?
- What are the threats in the near and longer term to human, group and organisational memory owned by the organisation?
- Are some persons from the local hierarchy involved in actions to maintain organisational memory?
- Which aids and devices contribute to make available this memory?
- How much organisational and human memory is embedded in the designs, structures, and processes and how is it known to daily users?
- Which functions of the local management system do support it?
- Are the operators and managers trained to methods to detect EWS?
- Is the follow-up of critical risk reduction actions adequate?
- …

Of course, the list of questions remains open and can be further developed. Such an analysis could help detect, for example, under-covered parts of local organisational memory.

As an illustration, example of cooking in the pressure cooker can be used (see Parts 4.4.4 and 4.5.5). If we focus on detection categories L3C1 and L3C2, then the above question can draw our attention to the fact that there is a threat that newcomers will not realize that detection of safety valve throughput is necessary before cooking. An aid reminding this act as inherently as possible should be incorporated.

4.7.2 Against the loss of first aspect of memory

Examples of approaches that can help against the loss of individual aspects of memory are given in this and next sections.

Kletz (1993) already suggested some ways of improving the organisational memory. Starting from the belief that organisations had no memory, he tried to promote the memory of insiders especially with regard to safety in design and production. Writing about memory, he concentrated on the need to remember the lessons learned from the past undesirable events. He already recommended to processing the lessons learned into the form of short messages (stories) which are spread, discussed and taught. These lessons should be referenced anytime they caused a change of a code, standard or operating instructions. Old messages should be made permanently accessible.

The CAIB (2003) compared NASA practices with US submarines. Indeed, the US Navy submarine had two major submarine loss in 1963 (the Thresher) and 1969 (the Scorpion) which resulted in renewed efforts to prevent accidents. Some of them are redirected towards loss of memory (pp183-184). CAIB noticed: “The submarine Navy has a strong safety culture that emphasizes understanding and learning from past failures. NASA emphasizes safety as well, but training programs are not robust and methods of learning from past failures are informal” and “The Navy implements extensive safety training based on the Thresher and Scorpion accidents. NASA has not focused on any of its past accidents as a means of mentoring new engineers or those destined for management positions”.

All these ideas seem to be perfectly right if the first aspect of loss of memory - missing knowledge, awareness and therefore vigilance about EWS that can arise in the system - is to be prevented. Such messages can vividly and convincingly remind the existence of EWSs, support this knowledge and motivate the will and commitment to identify EWSs and respond to EWSs.

Nevertheless, such activities cannot be considered as sufficient with regards to prevention of other aspects of loss of memory. Activities recommended by Kletz (1993) provide examples of EWSs arising in the system but do not warrant that any possible EWS will be identified and responded during the learning from undesirable events, both internal, and external. Completeness of identification is not warranted.

4.7.3 Against the loss of second aspect of memory

Woods (2009) states that the safety field still lacks the ability to identify EWSs. He also recommends the alternative way to desired indicators – adaptive stance –, but this is not the main issue here, except if some EWS invite to set-up an adequate and adaptive response to prevent further safety degradation. Contrary to this opinion, CCPS (2011) means that warning sign surveys are feasible and offers a tool to identify EWSs – a list of catastrophic incident warning signs that flows from the description of safety management system in book (CCPS, 2007) and which is supplemented by a list of physical warning signs. Based on this list classes of EWSs that can be distinguished and most probable classes of EWSs may be identified for a specific socio-technical system. This list seems to represent a tool that may help to identify EWS in a socio-technical system when it arises. Such a way it gives a strategy on how to identify EWSs during learning from experience and at the same time the ability to prevent second aspect of loss of memory.

4.7.4 Learning acts against the loss of memory

Since LoM related to foresight in safety is a matter of forgetting the safety lessons learned by people and organisations, suitable recommendations can be found in texts about learning (e.g. ESReDA, 2015). For example, if we share the empirical statement that learning is quite often not satisfactorily efficient (ESReDA, 2015 ; Dechy et al, 2011) and is among the major recurring root cause (Hopkins, 2010, Dechy et al, 2018), For the sake of completeness, it should be noted at this point that Marsden (2017) suggests other possible root causes of LoM in addition to ineffective learning. He summarizes them as short-termism, loss aversion, regret aversion, ambiguity-driven indecisiveness, and dilution of responsibility.

The paper by Lawani et al. (2018), on the other hand, makes recommendations on how to make people's training more successful with a better memorisation if the frequency of use of the knowledge and skill is low (e.g. contrasting daily safety practices and emergency and rescue practices only performed during refreshing exercises).

Stemn et al. (2018), in a retrospective analysis of a fairly large set of articles, tried to describe how and why failure to learn from safety incidents do occur. To understand where breakdowns in learning from incidents are occurring, a bowtie analysis was used to organise the literature on failure to learn from safety incidents in a way that informs researchers and practitioners of priority areas. Stemn et al. confirmed in their retrospective analysis the importance of safety management functions for learning and memory.

In our analysis of three accidents in a very particular type of industry in Europe (Ferjencik and Dechy, 2016), we have seen the importance to learn the “hard lessons” “from others”, especially from accidents that occurred abroad. This is not a new idea but still there remains huge margins for progress. This remark is to be extended to generalizable lessons coming from accidents in other industrial sectors (e.g. Can we learn and transfer the lessons learned from Columbia space shuttle loss to others sectors in Dien and Llory, 2004). Again, the knowledge basis to consider for memorisation should integrate the history and knowledge of recurring patterns of accidents (Dien et al, 2004; Dechy et al, 2016). We are convinced that this knowledge and the stories of accidents are useful for the four aspects of memory described in Table 1. The CAIB (2003) noticed "Recurring Training and Learning From Mistakes: […] For example, since 1996, Naval Reactors has educated more than 5,000 Naval Nuclear Propulsion Program personnel on the lessons learned from the Challenger accident."

In addition, lessons from good, reliable and safe practices or new requests from regulations appear from time to time as well and challenge the status quo of the knowledge base. If they are not seized as opportunities for improving safety management and preventing next accidents, they can be considered as a flawed process of management of actions and to some extent of memorisation.

Last but not least, the importance to keep memory of designers' intentions (Ferjencik and Dechy, 2016), while taking care of the danger of loss of information, knowledge and memory at every step of the life-cycle of the sociotechnical system (Stoop, 1996; Leveson, 2004) remains a key issue. In this perspective, CAIB (2003) observed that "Both Naval Reactors and the SUBSAFE have "institutionalized" their "lessons learned" approaches to ensure that knowledge gained from both good and bad experience is maintained in corporate memory. This has been accomplished by designating a central technical authority responsible for establishing and maintaining functional technical requirements as well as providing an organisational and institutional focus for capturing, documenting, and using operational lessons to improve future designs. NASA has an impressive history of scientific discovery, but can learn much from the application of lessons learned, especially those that relate to future vehicle design and training for contingencies. NASA has a broad Lessons Learned Information System that is strictly voluntary for program/project managers and management teams. Ideally, the Lessons Learned Information System should support overall program management and engineering functions and provide a historical experience base to aid conceptual developments and preliminary design".

The importance to formalise stories of incidents and accidents in order to facilitate the lessons sharing and remembering has especially been invited by Kletz (1993). Incidents databases have been established and the development of computers (and in the future with big data) has provided many new possibilities for better storing and retrieving data lessons (ESReDA project group in the nineties focused on the databases issue, produced several deliverables and organised a few ESReDA seminars). More recent work has highlighted the role played by stories in the daily decision-making processes (Hayes, 2013) but also in the mentoring of younger colleagues (Hayes and Maslen, 2014; Maslen, 2014). Beyond the formal training, and the databases, stories are particularly efficient from the memorisation standpoint and for transferring skills and values. As we recalled, US Navy implemented this lever and NASA did not (CAIB, 2003).

A last aspect deals with human resources management, to retain knowledge from critical competence (Ermine, 2010) by codifying, but also socialised 'pillars of experience' (Llory, 1996) with novices, or build through career paths management and other provisions. CAIB (2003) highlighted some provisions to retaining knowledge within US submarines: "Naval Reactors uses many mechanisms to ensure knowledge is retained. The Director serves a minimum eight-year term, and the program documents the history of the rationale for every technical requirement. Key personnel in Headquarters routinely rotate into field positions to remain familiar with every aspect of operations, training, maintenance, development and the workforce. Current and past issues are discussed in open forum with the Director and immediate staff at "all-hands" informational meetings under an in-house professional development program."

Among all these knowledge sources, some may be enough as they are to raise awareness, to be used as cognitive resource to recognise EWS, to investigate and to maintain rigour on the follow-up. However, with the goal of enhancing foresight in safety and proactivity in safety management, we believe that some dedicated efforts to extracts from this knowledge, the frameworks useful for awareness, interpretation of EWS are still necessary, as well as socialisation processes with pillars of experience and management of communities of practices.

In addition, not all EWS will be predefined. Some detection, investigation, sense-making processes will require imagination, further investigations to collect additional data and discussions with peers, analysts and managers to converge towards new type of dangers and EWS. To some extent, discussion with whistleblowers will provide an opportunity to revise beliefs, existing dangers and EWS lists. (see. Chapter 12, Dien et al, 2020).

4.7.5 Role of safety management system functions

Two ideas emerged in the previous parts:

1) Loss of memory can be divided into four aspects (awareness for vigilance, recognition for sense-making, investigation for detection, and follow-up) and three faculties (encoding, storing, and retrieving). Combination of both results in division of loss of memory into twelve categories.

2) Speaking about memory, not only human memory but also a group and organisational memory have to be considered; in operational perspective, they combine a careful resource management of human brains and bodies (skills) with aids from safety management system including safety culture.

The above ideas will be further developed in this and following parts. The close relationship between categories of loss of memory and functions of safety management system will be made visible. To be operational and synergistic with resources constraints, we will show that the question on what decreases certain category of loss of memory can be converted into the question of what improves the performance of specific functions in local safety management. Beware that a complementary strategy is however needed to address tacit skills and personal knowledge and knowing (Polanyi, 1975). It would require long term human resource management that includes socialisation processes (Nonaka and Takeuchi, 1995), invest in key experts (Girod-Séville, 1996) that can share judgmental experience within communities of practices (Wenger, 1998).

Safety management has many definitions as well. Harms-Ringdhal (2004) formulates probably the simplest one: 'Safety management is a way of managing the hazards (safety risks) of a company.' Number of more detailed descriptions of safety management can be found in literature. They differ from a brief information in Meyer and Reniers (2013), formal description in BSI (2007) to very detailed explanation in CCPS (2007). Their recommendations can be considered valid despite the fact that completeness of even the most detailed description is not warranted. For example, Broadribb (2018) shows that CCPS (2007) may lack recommendations for "Sharing and Learning Lessons".

For purposes of this chapter, we need a systematic and detailed description of safety management system that is generally respected. Suitable safety management system has to cover much broader range of functions than mere risk management (see Meyer and Reniers, 2013). It has to include even functions considered usually to be a part of safety culture.

Risk Based Process Safety (RBPS) model of safety management system by CCPS (2007) is used in this chapter. Article by Frank (2007) can be recommended for the introduction to this model. RBPS model consists of twenty elements. The elements are grouped into four main themes that is to say four safety management pillars: Commit to Process Safety, Understand Hazards and Risk, Manage Risk, and Learn from Experience. Relations between pillars can be illustrated by Figure 1.

For each of twenty elements, the RBPS model identifies key principles associated with the implementation of the element. Further, essential features required to support each key principle are identified. Such a way, a four-level hierarchical description of functions of safety management system is created that identifies several hundreds of safety management system functions.

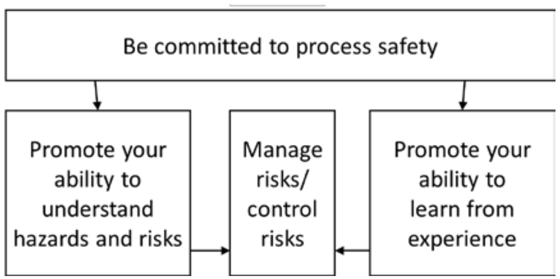

Figure 1. Relations among four safety management pillars from the Risk Based Process Safety model (CCPS, 2007).

Failures of safety management system functions are often considered to be among the underlying causes of undesirable events. Since EWS can be determined as a cause (including root cause) of causal event, links between safety management system and loss of memory start to be visible: early warning signs may be interpreted as failures of safety management system functions. This idea complements the two from the start of this part such a way that decrease of LoM can be converted to the improvement of the performance of specific functions in local safety management.

4.7.6 Safety management against the loss of memory

RBPS model of safety management system systematically describes functions and tools that may be applied as a protection against incident scenarios. Scenarios are always connected to hazards.

In previous Part 4.4.6 we explained how EWSs are associated with the existence of hazards, controls of hazards and environmental conditions that affect hazards. EWS represent causes or indications of failures in these hazards, controls of hazards and environmental conditions that affect hazards.

Altogether, we have strong arguments that the improvement of specific safety management system functions decreases specific categories of loss of memory. The practical problem that remains is to identify those particular relationships between functions and categories. These relationships provide an opportunity to convert a problem from the area of loss of memory to the area of safety management. In addition, if both the loss of memory category identification and the safety management system function identification are satisfactorily detailed, these relationships will provide useful support against the loss of memory.

The RBPS model is so detailed that for a particular activity it enables to precisely target safety management system measures against a particular category of loss of memory.

We will illustrate this with an example of a specific activity from our kitchen example, which was already used in sections 4.4.4 and 4.5.5. As shown in Table 3, we focus on detection categories L3C1 to L3C3 during preparation of pressure cooker for use.

In our example, we consider three possible findings of loss of memory, which we denote a) to c). We assume that we have found that information about what can detect a failure of the safety valve that protects against a specific hazard (overpressure during cooking in a pressure cooker) was not a) encoded, b) stored, c) retrieved. Each individual function of safety management system is described as a chain composed of a pillar, an element, a key principle, and an essential feature from the RBPS model.

Table 3. Conversions of categories of LoM to functions of safety management.

Failed activity	Kitchen example: Preparation of pressure cooker for use		
Category of Loss of Memory	Memory of information/knowledge that and how presence of Early Warning Signs can be detected is not		
	a) encoded: L3C1	b) stored: L3C2	c) retrieved: L3C3
Functions of safety management system described in Risk Based Process Safety model	Three alternatives: (i) in case that parents ignored to prepare the information: Commit to Process Safety - Process Safety Competency - Maintain a dependable practice - Develop a learning plan; (ii) in case that parents did not encode due to poor understanding: Understand Hazards and Risks - Process Knowledge Management - Protect and update process knowledge - Ensure accuracy; (iii) in case that parents forgot an item: Manage Risk - Asset Integrity and Reliability - Address equipment failures and deficiencies - Promptly address conditions that can lead to failure	Understand Hazards and Risks - Process Knowledge Management - Catalog process knowledge in a manner that facilitates retrieval - Protect knowledge from inadvertent loss	Two alternatives: (i) in case that children were not able to retrieve: Understand Hazards and Risks - Process Knowledge Management - Catalog process knowledge in a manner that facilitates retrieval - Document information in a user-friendly manner; (ii) in case that children did not try to retrieve: Manage Risk - Asset Integrity and Reliability - Develop and maintain knowledge, skills, procedures, and tools - Train employees and contractors.

4.8 Conclusions

Foresight is not only about imagination and exploration, but it also relies on reproduction and exploitation of existing knowledge; prospective views remains linked to retrospective views.

In an era that shows an acceleration of innovations and changes (technological such digitalisation trend, industry 4.0, but also societal, such as with short and potential long term impacts of COVID-19 pandemics), the value of experience in the time dimension is threatened and may become obsolete. However, history and memory still matters for expert knowledge at the age of big data and artificial intelligence, especially in systems governed by incremental changes.

If we take the current disaster of Beyruth, some authorities lost awareness and follow-up capabilities after alerts received. If we look at the major scale crisis of COVID-19, we forgot some lessons even from the 1918-1919 Spanish-flu, the worst pandemic on 20th century which killed 50 to 100 millions of people, 2 to 5% of population, much more than the world war one (Vinet, 2018). And we repeated patterns of minimising threats, late reactions to EWS, normalised health system vulnerabilities.

At the end of this journey, we are more than ever convinced that conducting generic and specific actions integrated in management of safety against loss of memory is a strategic investment to prevent accidents. One should remain humble in front of the complexity of "managing" human and organisational memories, and in front of the huge and everlasting tasks that require a dedicated dynamic and recurring program. The difficulty is not so much in the imagination, but it is rather in the complexity of the distributed meta-components of the system that should be used to lever organisational memory. In addition, it requires a dedicated commitment and constant attention. We believe that top management can provide organisational resources to pay attention to key safety issues, such as EWS, but also they can lever the practices if they are committed as exemplary leadership.

The accidents we referred in the dynamite and ammonium nitrate industries, the case of NASA and US Navy, and the pandemics are tragic stories but perfect reminders of how these issues matters. They also provide an alert to remain proactive towards the external lessons to learn and extend the perimeter of 'organisational memory' to other industries and countries. The everyday practice in your kitchen can be also the reminder of hidden and embedded aspects of individual, group and organisational memory and trigger your thoughts on how to make the EWS alive in daily practices with family and friends and on how to transfer those practices at work.

We are conscious that a strategy that would use the synergy with safety management actions for preventing loss of memory is necessary but not enough. There is also a general tendency to emphasize the knowledge management tools especially at the time of digitalisation, big data and artificial intelligence. One should accept that not all context can be captured in formal tools of knowledge management when codifying and storing information. In addition, the re-use will always imply a critical distance and adaptation to the context of use, within local practices that require a form of creativity. Indeed, "all knowing is personal knowing" (Polanyi, 1975) which invites to consider individual memories related to tacit skills and abilities to make judgment, which are coupled to socialisation mechanisms. This is done by the people who filter, who are the pillars of experience, within groups or communities of practice. So, on the one hand, a greater care and respect to worker expertise should be acknowledged, especially in face of particular turnover and skills losses with retirement waves. And on the other hand, organisational learning and making alive memory of others 'hard lessons' from failures is not trivial as well.

4.9 Acknowledgments

To our reviewers, Miodrag Strucic, Ana Lisa Vetere Arellano, Franck Anner, Alexandre Largier, Bernard Chaumont.

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This chapter is extracted from the final technical report of the ESReDA Project Group *Foresight in Safety*. The full report is freely downloadable from the ESReDA web site and from the EU Joint Research Centre publications repository.

Bibliographic identifiers for the full report are indicated below.

PDF	ISBN 978-92-76-25189-7	ISSN 1831-9424	doi: 10.2760/814452	KJ-NA-30441-EN-N
Print	ISBN 978-92-76-25188-0	ISSN 1018-5593	doi: 10.2760/382517	KJ-NA-30441-EN-C

"Enhancing Safety: The Challenge of Foresight"

Edited by the ESReDA Project Group *Foresight in Safety*.

How to **cite this report**: ESReDA Project Group Foresight in Safety, *Enhancing Safety: The Challenge of Foresight*, EUR 30441 EN, Publications Office of the European Union, Luxembourg, 2020. ISBN 978-92-76-25189-7, doi: 10.2760/814452, JRC122252.

ESReDA
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