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Statistical Approach to Identify Stress and Biases Impairing Decision-Making in High-Risk Industry

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***Abstract*—**Decision-making occurs several times an hour when working in high risk industry and an erroneous choice might have undesirable outcomes for people and the environment surrounding the industrial plant. Industrial decisions are very often made in a context of acute stress. Time pressure is a crucial stressor leading decision makers sometimes to boost up the decision-making process and if it is not possible then shift to the simplest strategy. We thus found it interesting to update the characterization of the stress factors impairing decision-making at Chinon Nuclear Power Plant (France) in order to optimize decision making contexts and/or associated processes. The investigation was based on the analysis of reports addressing safety events over the last 3 years. Among 93 reports, those explicitly addressing decision-making issues were identified. Characterization of each event was undertaken in terms of three criteria: stressors, biases impairing decision making and weaknesses of the decision-making process. The statistical analysis showed that biases were distributed over 10 possibilities among which the hypothesis confirmation bias was clearly salient. No significant correlation was found between criteria. The analysis indicated that the main stressor was time pressure and highlights an unexpected form of stressor: the trust asymmetry principle of the expert. The analysis led to the conclusion that this stressor impaired decision-making from a psychological angle rather than from a physiological angle: it induces defensive bias of self-esteem, self-protection associated with a bias of confirmation. This leads to the hypothesis that this stressor can intervene in some cases without being detected, and to the hypothesis that other stressors of the same kind might occur without being detected too. Further investigations addressing these hypotheses are considered. The analysis also led to the conclusion that dealing with these issues implied i) decision-making methods being well known to the workers and automated and ii) the decision-making tools being well known and strictly applied. Training was thus adjusted.

***Keywords*—**Bias, expert, high risk industry, stress.

I. Introduction

DECISIONS occur several times an hour when working in high risk industry, among which a lot are concerned by crucial safety stakes. The erroneous choice that would lead to an industrial accident might have undesirable outcomes for people and the environment surrounding the industrial plant. This is why the contexts of decision-making in high risk industry, usually occurring within a group of specialists, must be optimized to lead to an appropriate decision. Unfortunately, most of the time, industrial decision-making contexts are submitted to acute stress, often induced by the safety stakes (e.g. potential accident risks, responsibility) or due to a combination of stressors such as work load, role ambiguity, freedom of expression, organizational problems, interruptions, time pressure (e.g. [1], [2]). The literature reports combinations that impair decision making in groups: for example, under acute stress, members of the group may create and increase an internal cohesiveness, the leadership support and the pressure for uniformity leading to a restriction of information search while divergences are overlooked; conversely, in case of internal threat (perception by the members of a lack of performance within the group), then cohesiveness and consensus decrease. This generates a decrease of the group dynamic and of information seeking. Time pressure is also a crucial stressor characterized by three factors: decision time, sensitivity, and problem intensity [3]. Time pressure reduces interactions among the decision-making units which are subsequently less coordinated; under time pressure, decision makers prefer considering options perceived as lower risk choices and focus on negative dimensions of the options; they also try to boost up the decision-making process or move towards a simple solution if it is not possible (see the review in [4]). If the literature is profuse regarding bias due to stress in decision-making process, and if this has been used to objectify how a socio-technical system may be concerned by such issues and elaborate appropriate remedial solutions, re-questioning the objectification and the related solutions is not often undertaken. We thus found it interesting to update the characterization of the stress factors currently impairing decision-making at Chinon Nuclear Power Plant (NPP) in order to optimize decision-making contexts through reinforcement of existing remedials or elaboration of new solutions.

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II. Material & Method

The investigation was based on the analysis of safety event analysis reports: at Electricité de France (EDF), every safety event gives rise to an in-depth analysis in order to well understand which were the causes and the real and potential consequences of the event and to provide remedial solutions. A safety event must be understood as a deviation of what has been done in regards of what was expected in the field of nuclear safety. The analysis covered the last three years from 2016 to 2018. This duration was chosen in accordance with the International Atomic Energy Agency recommendations for statistical analyses in nuclear industry [5]. The statistical data were thus based on the identification and history of safety event reports relating to a decision-making issue. Safety event

reports explicitly addressing such issue were identified. In addition, we sought safety event reports which content contained the word "decision" (except the previously identified reports) then read the reports to check if any decision-making issue would have been forgotten. The characterization of each event was undertaken in terms of stressors, biases impairing decision-making and weaknesses of the decision-making process.

Additionally, for 1 case identified as "non-classical" stressor, workers (N = 16) who had been involved in the occurrence of the safety event were met during a 1-hour interview for an in-depth characterization of the event context.

III. Results

Over 2016-2018, 93 safety event reports were analyzed. Among them, 8 reports explicitly identified issues related to decision-making but only 6 were selected after analysis (for the others, the relationship with decision-making was found abusive) and 3 additional new reports detected through the keyword "decision" among which 2 actually addressed such issues.

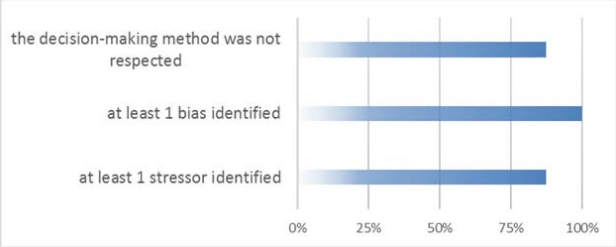

Fig. 1 Among the safety events identified as concerned with a decision-making issue, distribution (%) of the characteristics

The analysis of the selected reports (Fig. 1) showed that 87.5% of the events were associated with at least one stressor. Three classic stressors were reported: safety stakes, time pressure and workload; a fourth stressor was identified as non-classical because never discussed in the literature as a key-factor influencing decision-making: the trust asymmetry principle of the expert, detected through a double analysis of the safety event undertaken by analysts on the NPP. This principle depicts how an expert may be influenced in decision-making by preserving his/her reputation knowing that it is difficult to gain a reputation and very easy to lose it [6], [7]. Among the stressors, time pressure was clearly salient (6 contributions over 9).

The selected reports showed that 100% of the events were related to at least one bias. Biases influencing decision-making identified in the reports were distributed over 10 possibilities (Table I): biases of conformity, social desirability, overconfidence effect, attentional focus, excessive confidence in expert, collective rationalization, confirmation, self-protection, defense of self-esteem and interpretive bias. Major contribution was confirmation bias (3 contributions over 14), attentional focus bias and bias due to excessive confidence in expert. In addition, 87.5% of the events were associated with an issue regarding the decision-making method not applied as expected.

There was no significant correlation for the pairs bias/bias or bias/stressor or stressor/stressor.

The reports were anonymous (no name mentioned regarding the people involved in the event), it was impossible to undertake an analysis addressing the influence of the gender.

Half of the events were associated with a lack of technical skills specific to the activity performed and all these events were associated with a context of stress.

IV. Discussion

Three findings are worth to be combined: 87.5% of events are associated with an issue regarding the decision-making method not applied as expected; 18% of events were not identified as related to decision-making issues whereas they actually were; 18% of events were inappropriately associated with decision-making issues. This combination shows that there is an actual lack of knowledge within the NPP staff regarding what is decision and what must be an efficient decision-making process. These data demonstrate that all levels of the staff are concerned: Most of the time, those who contribute to a safety event are technicians or engineers (these who touch the machine) and those who undertake the event analysis are managers. Training the staff on this topic is a need. In addition, the literature shows that inexperienced workers are more sensitive to the negative effects of stress during decision-making process [8]-[10]. This might lead to the conclusion that a training focus is needed for novices; nevertheless, our results showed that one case over two involved novices, suggesting that novices as well as experienced workers are concerned by training or re-training.

TABLE I
Distribution of Cognitive Biases among Safety Events

Bias	Percentage of occurrence (%)
conformity	7.1
social desirability	7.1
overconfidence effect	7.1
attentional focus	14.3
excessive confidence in expert	14.3
collective rationalization	7.1
confirmation	21.4
self-protection	7.1
defense of self-esteem	7.1
interpretive bias	7.1

The fact that 87.5% of the events were associated with at least one stressor confirmed how stress is an important component of decision-making issues in high risk industry. Knowing how stress may physiologically and psychologically impair cognitive capacities and therefore may contribute to favor expression of cognitive bias [8]-[10], this confirms that reducing stress in such contexts may help to reduce the influence of cognitive biases in decision-making. However, if stress favors expression of cognitive biases, results showed that even without stressor, biases in decision-making occur

anyway for the cases related to safety events: 100% of the events were related to at least one bias.

Stressors as well as biases yield cognitive limitations to subjects and reduce performance whilst performing the activity. The question is thus how to reduce these limitations when the work context remains stressful and/or conducive to the expression of biases. The solution might be found in the design of automatic decision-making processes. Indeed, the literature demonstrates that i) automatic processing (i.e. when there is a strong link between the stimulus and the expected response) is little sensitive to attentional limitations [11], and ii) repetitive training leading to automatic process improves resistance to stressors [12]-[15]. This concerns simple mental tasks as well as complex activities depending on subjects' training in terms of content and frequency: training must aim at building a strong link between the stimulus and the expected response [12]. However, the issue is different for the non-classical stressor highlighted in the present analysis: the trust asymmetry principle of the expert. The trust asymmetry principle of the expert designates the fact that it is difficult for the expert to gain a reputation while it is very easy for the expert to lose it, especially because the negative facts are more prominent and have a greater emotional burden than the positive ones. The reputation is asymmetrically revised. The problem associated with this stressor is that its detection and the detection of its effects are difficult because, as we shall argue, it is part of a psychological process that subjects try to keep invisible. In our case, it was detected because it combined two problems: i) the duration – the expert's judgment regarding a technical problem remained unchanged (a kind of "frozen expertise") for several days in spite of incoming divergent new information, ii) the impact – the "frozen expertise" had a consecutive impact on safety and production.

Characterizing what made the expertise frozen and how this happened appeared crucial to deal with it. From the testimonials of the colleagues met in interviews (N = 15), it was concluded that the expert adopted a behavior marked by the conservatism bias (he revised his belief insufficiently even when presented with new divergent information) and the confirmation bias (he always focused and interpreted information in the way that confirmed his first expertise). However, when met in interview, the expert (N = 1) never acknowledged the "frozen" nature of his expertise and did not mentioned explicitly any difficulty associated with the trust asymmetry principal, demonstrating a posture of denial regarding these concepts. These facts, and especially the posture of denial, are typical of what psychodynamics identifies as defensive mechanisms developed by workers to preserve their mental health when facing threats or after experiencing fears in the work context [16]. These strategies are intentional (intended by the subjects), unconscious, structured in a system (this system associates different behaviors), with the aim of anesthetizing the fear or the perception of the threat [17]. As demonstrated in the in-depth review of Sylvers et al. [18], this kind of avoidance behaviors are characteristic of fear. However, Davies [19] highlighted that fear response tended to be short while a long-lived response related to anxiety and McNaughton & Corr [20] showed that fear and anxiety were associated with two distinct defensive systems. The question is thus to know whether the trust asymmetry principle of the expert is a matter of fear or anxiety. Again, Sylvers et al.'s review [18] brings parts of the answer. First, they match the definition of the American Psychiatric Association [21] which clearly defines the difference between anxiety and fear: fear is a response to a well-identified threat, real or perceived whereas anxiety involves the expectation of future threat often not clearly defined. Second, they emphasize that "internal fear cues can generate human fear reactions" [21, p.127]. Third, quoting the work of Ruiz-Padial & Vila [22], they note: "the acquisition of fear may occur as part of implicit (unconscious) processing" (p.127). Forth, they conclude that fear results in an underactive extinction circuit whereas anxiety result from a hypersensitive appraisal circuit [22, p.128]. And fifth, when summarizing several tens of studies calculating correlation coefficients between phobic fear, harm avoidance and anxiety, they demonstrate that while phobic fear is well correlated with anxiety, harm avoidance is uncorrelated to anxiety. From these findings, the trust asymmetry principle of the expert cannot be considered in terms of anxiety but is more similar to fear and harm avoidance. In this case, it comes back to stress if we consider that "fear arousal, initiated by an environmental threat, leads to activation of the stress response, a state of alarm that promotes an array of autonomic and endocrine changes designed to aid self-preservation" [23], but this proposal refers to physiological changes that, if existing in the case of the trust asymmetry principle of the expert, have an intensity and a dynamic which are low enough or widely distributed over time not to be observable easily. At the same time, it induces a psychological process based on the trigger of defense mechanisms: the aforementioned biases of conservatism or confirmation, the posture of denial, are related to defense of self-esteem and to self-protection. This leads for example to a decision-making process biased by the expert's judgment that remains frozen in its first expression despite new information would make it change. In other words, the trust asymmetry principle of the expert may induce fear generating stress that impairs decision making from a psychological angle rather than from a physiological angle. Furthermore, this expertise cannot be counterbalanced by another expert' view as usually, on industrial plant, the expert is unique.

The trust asymmetry principle of the expert is difficult to detect, it raises the hypothesis that this stressor can intervene more often that what can be analyzed (because not being detected), and to the hypothesis that other stressors of the same kind might occur without being detected too. During quick exchanges, some engineers and managers at the NPP have already suggested other forms of such stressors; for example, the impact of the manager's decision making on the manager' career. Moreover, the defense mechanisms might concern more than an individual and be elaborated as a collective defense strategies, thus concerning a collective of

peers [16], [17]. Further investigations addressing these hypotheses are currently under consideration at the NPP.

In order to deal with the impairment of decision-making due to stress, some authors suggested working on stress resilience through training (e.g. [24]); others noted that female subjects are more resilient than male subjects (e.g. [25]). However this solution is subject-dependent. The literature review of Raaijmakers et al. [11] emphasized that automatic processing of information (which is only possible if there is a strong link between the stimulus and the expected response) was less sensitive to the limitations of attention, while the controlled treatment was. Raaijmakers et al. [11] reported that "consistent training (leading to automatic processing) not only makes task performance more reliable but also makes it resistant to the effects of stressors such as alcohol, heat and mental workload [12]-[15]" (p.8). Fisk and Scerbo [12] showed that the nature of information processing was not determined by the complexity of the task but by the training of the subjects.

In summary, reducing the impact of stress on decision-making is possible by generating automatic processes, which is possible through training, even for complex tasks, provided that there is a strong link between the stimulus and the expected response. Thus, regarding decision-making under stress for tasks other than a technical choice versus a simple failure, the only processes that can be automated relates to the method applied and the process structure of problem-solving and decision-making. It was thus decided to reinforce training with a special focus on the identified biases, integrating a simulation training in order to illustrate the negative consequences of these biases on decision-making and to promote associated remedial techniques, complemented with a follow-up of the trainees and the implementation of a refresher training program. Using resilience capacities is considered as a future perspective. The question remains regarding stressors of the type identified as "non-classical" such as the trust asymmetry principle of the expert. Future observations will help us to state whether automated method or process may deal with this sort of stressor in decision-making or not.

V. Conclusion

A statistical analysis of safety event reports on the NPP over three years allowed us to update the focus of the training related to decision-making by focusing on the major biases involved in such processes and by insisting on the retraining and follow-up of staff training. In particular, one of the goals is to automate the application of the decision-making process and the associated methods to enhance their robustness to the effects of stress and decision biases. Beyond these considerations, special attention will be paid to a newly identified and little studied stressor in the literature: the trust asymmetry principle of the expert. This stressor is difficult to detect because most of the time people deny it; therefore, it could occur more frequently than it is detected and leads to the hypothesis that other stressors of this type might exist. Investigations are underway to progress in this field.

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