The role of argumentation in the resolution of ambiguous situations: an exploratory study in the field of supervision in the nuclear industry

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ABSTRACT

This exploratory study is part of the evaluation, using a full-scale simulator, of a new organisation for a nuclear plant operating team. The purpose of the study is to test the possibility of there being a link between the characteristics of the operating activity and the argumentative activity of the teams when managing ambiguous situations. A comparative analysis of the operating activity, the "decision pathway" and the argumentative discourse of the three future operating teams was carried out during the resolution of an ambiguous situation. Results show that, according to the team, the "decision pathway" differs in terms of the aims set or prioritised by the team (alongside those required by the procedure). According to the types of aims, we will highlight the different argumentative patterns.

KEYWORDS

Decision-making; cooperation; argumentative process; supervision; ambiguous situations.

INTRODUCTION

This study is part of a process to design new operating methods for a next generation nuclear power plant control room. By "operating methods", we mean the procedures, human-machine interfaces and organisational requirements that operators must observe in order to supervise and manage the process. The new team organisation features four operators: an action operator (AOP), a strategic operator (SOP), an operations shift manager (OSM) who is in charge of the operating team and a safety engineer (SE). The goal is to ensure that "human-machine" and, more broadly speaking, "human-organisation-machine-interfaces-procedures" relations work properly and promote effective and safe emergency operation.

This study was carried out within the context of an evaluation process that has been implemented for over ten years, in relation with the designers of a new nuclear reactor (Labarthe, & De la Garza, 2011; De La Garza, Labarthe & Graglia, 2012). The specific feature of this study is that this *Human Factors* evaluation campaign was carried out by a multi-disciplinary EDF team (ergonomics, reliability and safety experts), using a full-scale simulator of the future control room. This study looks at one of the aspects of this evaluation, which concerns the processes of cooperation deployed within the operating team (Burke et al., 2000; Crichton et Flin, 2004; Hoc, 2001) in situations that appear to be "poorly defined" or "ambiguous" (Klein, 1997). In the case analysed, given the fact that we are in a design situation, the "poorly defined" or "ambiguous" situations are mainly linked to operating methods that have not been completely finalised and the teams not having completed their training programme which might, for example, result in a lack of understanding when faced with major technological changes. Feedback from plants in operation suggests that we can find similar situations that were not foreseen in the design phase and for which the operating methods are not optimised. The operating teams can therefore, in natural situations, be faced with "ambiguous" situations.

PURPOSE

The purpose of this exploratory study is to describe the underlying processes of cooperation involved in the resolution of ambiguous situations, in cognitive terms. To cooperate, team members needs to interact. It is even more necessary when team members have different roles and thus possess information appropriate to their own role. In emergency operation situation, team members are often engaged in an argumentative process in order to share their mental representation or to confront their point of view in order to make an effective and appropriate decision.

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Numerous studies were interested in these argumentative processes in the nuclear industry (Carvalho et al., 2005; Chung et al., 2009; De La Garza et Le Bot, 2008; Kim et al., 2010a,b; Lee et al., 2012; Park et al., 2012; Stachowski et al., 2009) but also in other domains such as the medical domain (Pelayo, 2007), the military aviation (Bourgeon, 2011) and manufacturing (Darses, 2006). The speech act coding schemes developed in these studies are based on various models of team cooperation (Hoc, 2001; Hélie et Loiselet, 2000; Hollnagel et Woods, 2005; Endsley, 1995), the choice of which depends partially on the object of study: to explore the link between interaction patterns and team performance (Stachowski et al., 2009; Kim et al., 2010b), to study the impact of a new technology (Chung et al., 2009) or a standard communication protocol on team processes and team performance (Kim et al., 2010a)...

This study seeks to determine whether the characteristics of the argumentative process developed by the operators can be correlated to the specific characteristics of operations and the decision pathway[10] involved when managing ambiguous situations. By looking at the involvement of the various roles in the argumentative process of the "decision pathway", this study seeks to establish the extent to which the new team organisation influences the generation of argumentative processes promoting safe and efficient operating activity or not. By analysing the argumentative process, we should, in addition to understanding the individual and collective aspects of argumentation, be able to identify areas where the design of the operating methods and the organisation can be improved, so as to make the system more robust when dealing with situations that were not anticipated or foreseen in the design phase.

METHODOLOGY

Population

Three teams recruited for the operation of the future nuclear reactor took part in this evaluation campaign. All those involved have previous operating experience and the training program for future reactor is in progress. The teams were trained on the processes, HMI, imaging and the specific skills required for each position in the operating team for the purposes of the evaluation.

Technical configuration

The simulator features an exact replica of the future control room (spatial layout of the stations, HMI, procedures, etc.) and the dynamics of the future technical system are almost totally replicated. This enabled the operators to play out various ecological use scenarios defined by a team of experts for the requirements of the evaluation. The design of the entire socio-technical system (procedures, HMI…) is not yet finished.

An instructor workstation next to the control room was used to view the progress of the scenarios and the on-screen display on each of the four computer workstations in the control room. Headsets also enabled the various conversations between members of the team to be followed in real-time. The instructors simulated telephone calls with the various on-site specialist sectors. Each simulation, lasting around three hours, was followed by a group debriefing with the operating team, led by the evaluation team.

Collection of data

The study is focused on an emergency operation situation, carried out on a full scale simulator that should be handled in the right way in the future by the teams. The emergency operation procedures cover "nominal" emergency situations, where everything goes as expected. However, when a failure occurs (covered or not by operation procedures), situations could require operators to perform a considerable activity of diagnosis and even problem-solving. This may or may not be facilitated by the HMI (accessing information in the HMI could be easy or not), the procedures themselves (the action may be found in the sequence of the procedure or not) or by the knowledge of the operators. This study looks at this type of situation, in this case, the failure of a process controller that has not been clearly understood by the team.

The data collected are:

- Notes taken from the observations made by the evaluation team;
- Verbal exchanges and behaviour observed in video and audio recordings;
- Copies of on-screen displays and overviews of the control room.

Selection of the sequences analysed

Our study focussed on managing the cooling system following a partial cooling system process controller failure. In the scenario in question, when certain threshold parameters were reached, the partial failure of the cooling system process controller was quickly compensated by the automatic start-up of a diversified controller fulfilling the same function. While dealing with this failure, the teams had to continue to apply the procedures geared towards ensuring the complete cooling of the facility until such time as the required thresholds were reached.

[10] The decision pathway means all the discussions, consultations and deliberations, as well as the aims set and prioritised by the team, related to the resolution of a specific problem.

Processing of the data

For each team, the sequences featuring the topic of cooling were extracted from the verbal protocols. These sequences could be very short: very basic information (e.g. "it's 2°C cooler") or a longer discussion, designed to solve a problem. In this case, problem-solving related to: (i) A misunderstanding about the changes to the facility, (ii) the perception that what was proposed by the procedure was unsuitable for the changes to the facility, and (iii) the need to prioritise an action given the changes to the facility and/or available resources (human and technical).

Coding of the sequences

A coding system was defined with the aim of modelling the cognitive and collective processes involved in the decision pathway. The graphic representation of the coding includes a time line, where T_0 corresponds to the switch to emergency operation triggering initiation of a specific emergency procedure adapted to the degraded state of plant. This coding, an example of which is shown in Figure 1, enables the pathway of the decision-making process to be described exhaustively, specifying:

- The key events
- The required steps, and the steps actually taken
- The aims pursued, whether they are required by the procedure (in black) or set/prioritised by the team (in red in the coding)
- The human resources assigned to achieve each required aim or each aim set/prioritised by the team and any shift in the scope of the roles
- Communication activities (information sharing, approval requests and decision-making)
- Individual cognitive activities (anticipation of a step, detection of an event, etc.)

In this article, we will focus exclusively on analysing exchanges between operators which correspond to:

- *Arguments aimed at evaluating and understanding the situation* (answering the question, "what?") which are symbolised by a circle in the graphic coding. Here is an example of this type of argumentbetween the Operations Shift Manager (OSM) and the Strategic Operator (SOP): OSM - "It doesn't look like the partial cooling is running... SOP - "Yes, hang on, I'm just getting a message, Auxiliary Steam Distribution System (ASDS) restore request. "
- *arguments about procedures* that the operators are going to implement to solve the problem (answering the question "how? ") which are symbolised by a triangle. Here is an example of a argument about procedures: SOP - "Now he's working on isolating it fully from the Steam Generator (SG). I'll let him finish that and before he (NB: the other operator, the AOP) moves onto something else, I'll get him to change module." OSM - "But the SG level won't go up as long we haven't lowered the pressure, will it... unless you do it." SOP - "If you like." … OSM - "There's no point interrupting him, there are two things to do: the isolation and the partial cooling." … SOP - "OK, that's fine. ...”.

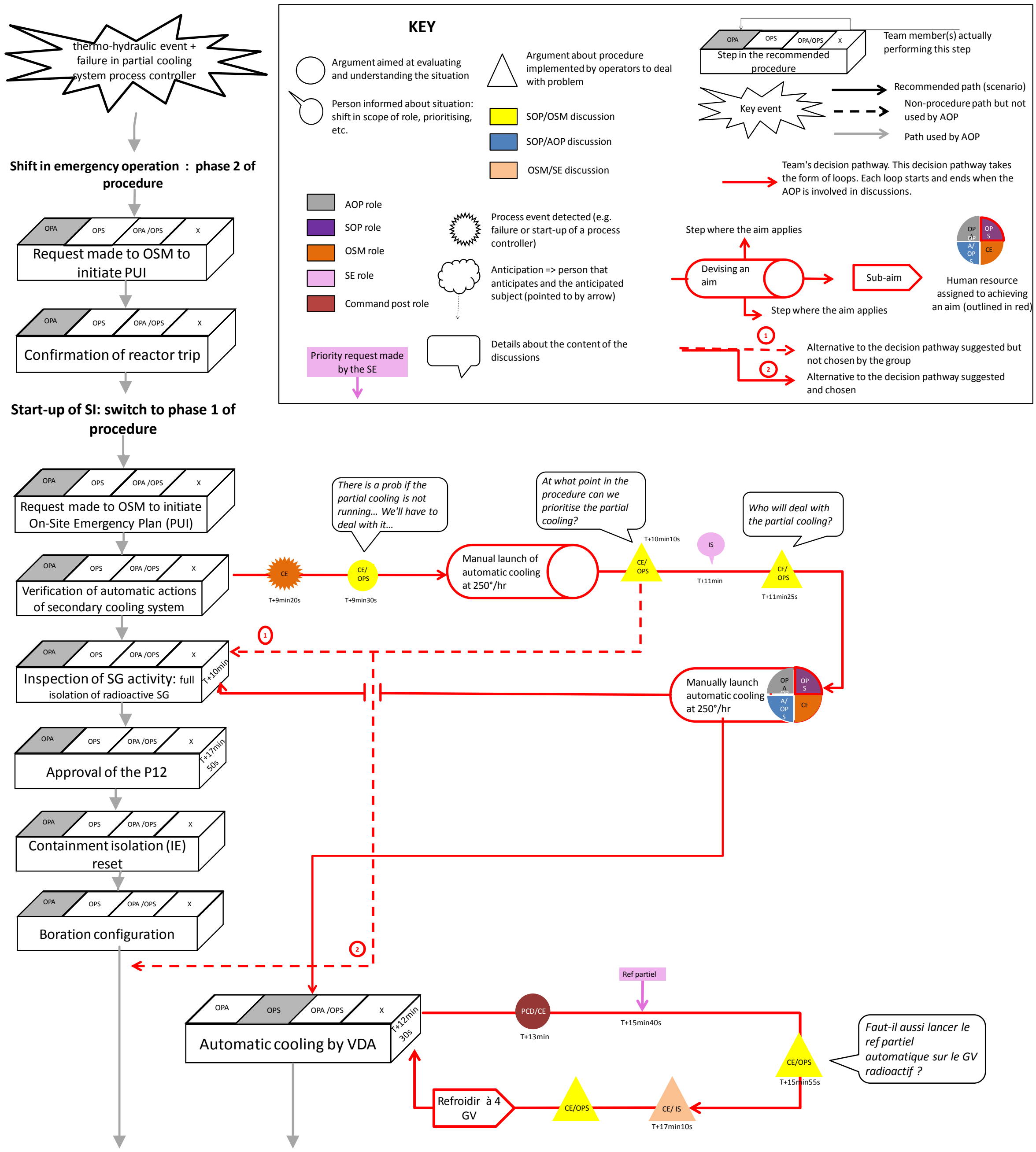

Figure 13. extract from the coding of a team A sequence

Indicators of the teams' operating activity

The operating activity of the operators was characterised according to the following indicators:

- *Correct evaluation of states E1* (the facility is not cooling) *and E2* (the facility is cooling)
- *Correct diagnoses D1* (partial cooling system process controller failure) *and D2* (start-up of the diversified cooling system process controller), corresponding to the states E1 and E2 respectively.
- *Time (in minutes and seconds) elapsed between E1and D1, and time elapsed between E2 and D2*
- *Number of attempts required to achieve the aim*
- *Time (in minutes and seconds) elapsed between T0 and the first attempt to achieve the aim*
- *Efficiency of the aim (yes/partial/no): effective and optimum achievement of the aim* (e.g. the facility cools correctly and sufficiently quickly until it reaches the required threshold)
- *Relevance of the aim (yes/no): given the changes in the state of the facility, the aim set remains relevant* (e.g. cooling is no longer relevant because it was implemented too late);
- *Safety of the aim (yes/no): the aim is achieved without there being any risks for personnel, the local population and the environment.*

RESULTS

Characteristics of the teams' operating activity

The three teams correctly and quickly diagnosed (D1) the facility as being in state E1: the malfunction of the process controller (partial cooling). In the studied scenario, they didn't immediately have the means to diagnose the starting up of the diversified automatism (D2), even if they had identified the E2 installation state: a cooling in spite of the automatism failure. From the operation point of view, impacts on the general goal achievement are different, i.e. in the cooling of the installation. The cognitive analysis of the argumentation and decision-making process is thus relevant to be able to understand some of the difficulties met by the teams.

Role of argumentation in the activity of the teams

In this section, we will describe the *argumentative loops* developed by the three teams as they tried to resolve the problem. We will analyse the differences and similarities by team.

Regarding the first argumentative loop

As regards the first *argumentative loop*, which follows detection of the malfunction (partial cooling system process controller failure) and is shown in figure 2 for each team, we can make the following points:

- There are no *arguments about procedures* for teams B and C
- In contrast, team A has several *arguments about procedures*. This can be explained by the fact that, given that the facility was identified as being in state E1 (not cooling), this team quickly set itself an aim (compensate for the malfunction by manually triggering the cooling system process controller), at the same time as the actions of the AOP. From this point on, the arguments of team A, in the first loop (and the next one), were more arguments about procedures than arguments aimed at evaluating and understanding the situation and its consequences (two of the three discussions are arguments about procedures).

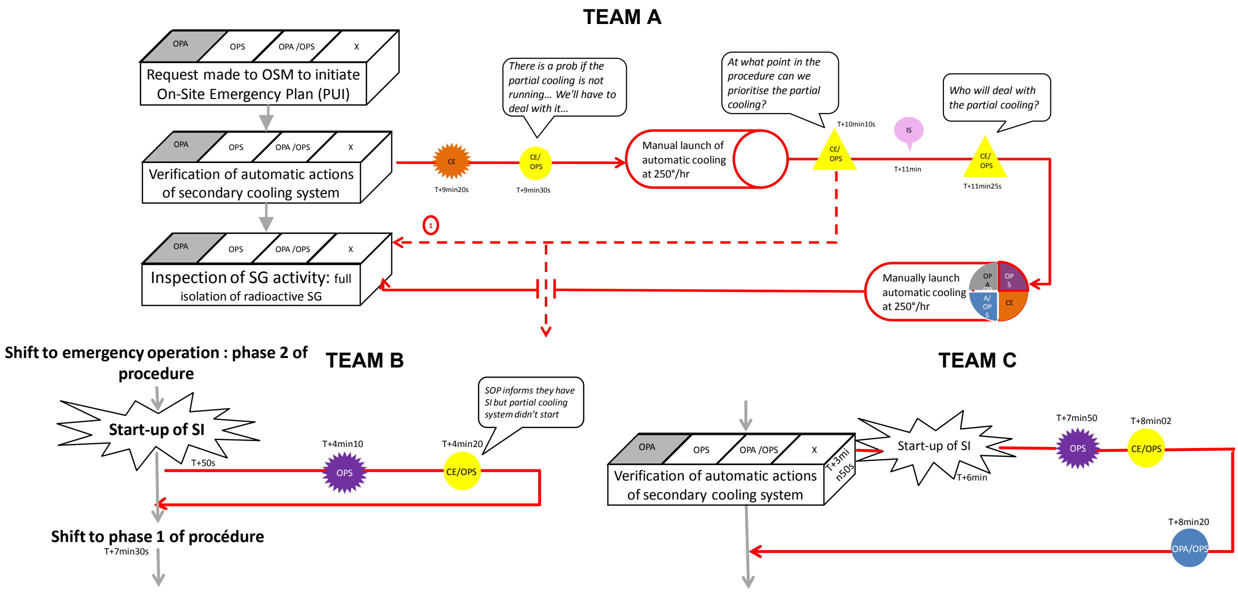

Figure 2. Comparing the teams' first argumentative loop

Regarding all of the argumentative loops developed during the scenario

Analysis of the argumentative process in each team — Team A held twice as many arguments (there are 32 in total) to deal with the cooling system malfunction than team B (18 arguments) and team C (16 arguments). Each argumentative loop developed by team A includes the formulation of one or more aims. Team B, which in the simulated situation achieved the aim too late to be efficient, only set itself one aim at the same time as applying the procedure (delegation of the monitoring of an action to the AOP). Team C devised or prioritised two aims, only one of which was implemented.

Number of arguments and prioritising of the teams — For all three teams, arguments about cooling were principally held between the SOP and the OSM. There were nonetheless ten times fewer SOP/OSM discussions in team B than in the other teams. Team B did not prioritise achieving this aim at any point. During the debriefings, the SOP and OSM confirmed their intention "not to focus on that and slow down operations, given that we knew the instructions indicated that we would have to do it later (cooling to compensate for the malfunction of the process controller)". Achieving this aim (cooling) was therefore not their main concern. Indeed, at the same time as managing the malfunction, we can see that team B held several discussions about resolving another problem: the rising water level in the radioactive steam generator. Solving this second problem was given priority over the rest of the operations by assigning this task to the SOP.

Roles of team members involved in arguments about aims set or prioritised by the team — During the scenarios, all of the teams devised or prioritised aims, at the same time as addressing the aims required by the procedure. Depending on the situation, this consisted of:

- A totally separate aim or sub-aim (for example, the aim of implementing cooling or the sub-aim of cooling with the four SGs). This was the case for teams A and C;

Or evaluating whether the targeted state had been properly attained, especially when the facility's response time was longer. This was the case for teams B and C. Typically, this involved monitoring the outcome of actions such as cooling or even depressurisation. This evaluation sometimes involved performing adjustments when the state of the facility did not totally match the targeted state.

The aims consisting of evaluating whether the targeted state had been properly attained systematically followed argument between the AOP and the SOP, not involving the OSM, whereas devising a totally separate aim or sub-aim followed argument between the SOP and the OSM. This pattern of behaviour, which may be described as defining a totally separate aim or sub-aim following a SOP-OSM discussion and deciding whether the targeted state has been properly attained following a AOP-SOP discussion, was also seen in other cases of problem-solving not covered in this study (rapid rise in the pressuriser level and rapid rise in the water level of the radioactive steam generator).

DISCUSSION AND CONCLUSION

The description of the "decision pathway" relating to a specific malfunction, in terms of the operating activity and the argumentative loops developed by the teams, can be used to shed light on the way in which a team takes decisions when faced with an ambiguous or poorly defined situation.

This "decision pathway" differs from one team to another. For example, when faced with an unexpected event, in this case the malfunction of the partial cooling system, a team may decide to act quickly by devising new aims, by reassigning its resources to implement these aims. The members of team A therefore hold arguments more frequently and set themselves aims to deal with the malfunction quickly. On the other hand, in terms of safety, the first attempt to achieve the aim does not subsequently appear to be the most suitable even though it resulted from a discussion between the SOP, OSM and SE.

Team B, however, preferred to wait and see if time and/or the procedure would resolve the problem before acting. For this team, the attempt to achieve the aim ended up being no longer relevant (not useful) given the state of the facility. We can draw an analogy here with the conclusions of Amalberti (2001) regarding the behaviour of operators faced with errors in dynamic and complex situations, even though in our case, we are not concerned with errors but rather with the specific state of the facility: many detected errors are not dealt with by operators because they can resolve themselves over time, as the situation changes. It it therefore necessary to weigh up the risks incurred by the specific state of the facility, possible changes to the situation and the resources involved (physical and cognitive) if action is to be taken. Team B did not weigh up the situation correctly.

More specific analysis of the roles taking part in discussion of the aims set or prioritised by the team also enables us to formulate hypotheses about the degree of abstraction and distance from the action that the various roles are likely to have, in ambiguous situations. Therefore, when devising aims close to operational tasks, in this case delegating monitoring of the outcome of an action that the AOP has just performed, it would appear that cooperation between the involved parties occurs more through horizontal controls (De La Garza & Weill-Fassina, 2000) between the AOP and the SOP and through "task-oriented cooperation" as described in Hoc's model (2001). The hypothesis that a degree of "task-oriented cooperation" seems to make sense given the nature of the functions of the AOP (completion of operating tasks) and the SOP (checking that operating tasks have been completed properly). As far as devising the aim is concerned, vertical controls (De La Garza & Weill-Fassina, op.cit.) between the SOP and the OSM would enable them to coordinate themselves with a greater degree of abstraction, similar to the level of "planning-oriented cooperation" (Hoc, 2001). In the sequences analysed, the AOP was not involved at this second level of cooperation at any point. Meanwhile, the SOP was actively involved at both levels of cooperation.

In all of the scenarios, we noted that discussions predominantly involved two member. Just one discussion involved three member (each operator exchanging information) and there were no discussions involving four operators. The AOP appeared to be unable to be a resource involved in decision-making discussions because he seemed to busy with his operating activities. However, studies in the nuclear industry, as in other sectors, have shown how collective decision-making can make a socio-technical system more robust. In the rest of the study it will be necessary to specify the organisational characteristics that promote or handicap collective discussion, and which therefore lead to more safe and efficient operation.

The "decision pathway" is dependent on the individual mental representation of the situation and on what their colleagues know and do. It is therefore essential to take an in-depth look at the types of arguments put forward by the various roles. Analysis of these arguments will enable the dynamics of the roles in this new team organisation to be described more effectively in the process of cooperation, and in situations where requirements and technical support systems are not always enough to guide operators (in "unconsidered situations"). However, taking into account the fact that some of the operating methods are still in the process of being designed, the situations identified as "ambiguous" or poorly "defined" will be reviewed beforehand in order to identify any points that may be improved and therefore contribute to the reliability of the socio-technical system.

GLOSSARY

AOP: Action Operator
ASDS: Auxiliary Steam Distribution System
HMI: Human-Machine Interface
IE: containment isolation
OSM: Operations Shift Manager
P12: permissive 12
PAF: switch to cold shutdown
PCD: command post
PUI: On-Site Emergency Plan
SE: Safety Engineer
SG: Steam Generator
SI: Safety Injection
SOP: Strategic Operator
TBS: Turbine Bypass System
VDA: atmospheric steam dump system

REFERENCES

Amalberti, R. (2001). La maîtrise des situations dynamiques. *Psychologie Française,* 46 (2), 105-117.

Bourgeon, L. (2011). *Mécanismes cognitifs et rôle du collectif dans la persévération : gestion des évènements imprévus dans l'activité de pilotage militaire*. Thèse de Psychologie Ergonomie, Université Toulouse 2 Le Mirail, Toulouse.

Burke, C.S., Cannon-Bowers, J.A., & Salas, E. (2000). Teamwork: emerging principles, *International Journal of Management Review,* 2(4), 339-356.

Carvalho, P.V.R., dos Santos, I.L., & Vidal, M.C.R. (2005). Nuclear power plant shift supervisor's decision making during microincidents. *International journal of industrial ergonomics, 35, 619-644.*

Chung, Y.H., Yoon, W.C., Min, D. (2009). A model-based framework for the analysis of team communication in nuclear power plants. *Reliability Engineering and System Safety*, 94, 1030-1040.

Crichton, M.T., & Flin, R. (2004). Identifying and training non–technical skills of nuclear emergency response teams. *Annals of Nuclear Energy*, 31, 1317-1330.

Darses, F. (2006). Analyse du processus d'argumentation dans une situation de reconception collective d'outillages*. Le Travail Humain*, 69 (4), 317-347.

De la Garza, C., Labarthe, J-P., & Graglia, L. (2012). The contribution of ergonomics to risk analysis in the design process: the case of a future control room. *Work: A Journal of Prevention, Assessment and Rehabilitation*, 41, 730-736.

De la Garza C., Le Bot P. (2008). *Emergency operation in nuclear power plants : proposition of analysis protocol to highlight collective team performance in simulation situations*. International conference on Probabilistic Safety Assessment and Management, Proceedings of the PSAM9, Hong Kong, China.

De la Garza, C., Weill-Fassina, A. (2000). Régulations horizontales et verticales du risque. In T.H. Benchekroun, & A. Weill-Fassina (Eds.), *Le travail collectif. Perspectives actuelles en ergonomie* (pp. 217-234). Toulouse, France : Octarès.

Endsley, M.R. (1995b). Toward a theory of situation awareness in dynamic systems. Human Factors 37(1), 32–64.

Hélie, P. & Loiselet, A. (2000). *Human-human cooperation in airborne combat system: Designing CSCW assistances*. Paper presented at *6th S.E. Ergonomics Society Conference and 4th Asia Pacific Conference on Computer Human Interaction*. Singapore, Nov.

Hoc, J-M. (2001). Towards a cognitive approach to human-machine cooperation in dynamic situations. *Int. J. Human-Computer Studies,* 54, 509-540.

Hollnagel, E., & Woods, D.D. (2005). Joint cognitive systems: Foundations of cognitive systems engineering. Broken Sound Parkway : CRC press Taylor and Francis Group.

Kim, M.C., Park, J., Jung, W., Kim, H., & Kim, Y.J. (2010a). Development of a standard communication protocol for an emergency situation management in nuclear power plants. *Annals of Nuclear Energy, 37, 888-893.*

Kim, S., Park, J., Han, S., & Kim, H. (2010b). Development of an extended speech act coding scheme to observe communication characteristics of human operators of nuclear power plants under abnormal conditions. *Journal of loss prevention in the process industries, 23, 539-548.*

Klein, G. & Zsambok, C.E. (1997). Naturalistic Decision Making. New Jersey: Lawrence Erlbaum Associates.

Labarthe, J-P., & De La Garza, C. (2011). The human factors evaluation program of a control room: The French EPR approach. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 21, 331-349.

Lee, S. W., Park, J., Kim, A. ryum, & Seong, P. H. (2012). Measuring situation awareness of operation teams in NPPs using a verbal protocol analysis. *Annals of Nuclear Energy*, *43*, 167–175.

Park, J., Jung, W., & Yang, J-E. (2012). Investigating the effect of communication characteristics on crew performance under the simulated emergency condition of nuclear power plants. *Reliability Engineering and System Safety, 101, 1-13.*

Pelayo, S. (2007). *D'une coopération verticale à une planification coopérative des actions : le cas de la gestion des prescriptions thérapeutiques hospitalières*. Thèse de Psychologie, Lille : Université de Lille 2.

Rasmussen, J., Pejtersen, A.M., & Schmidt, K. (1990). Taxonomy for cognitive work analysis. Roskilde, Denmark: Risø National Laboratory. (Risø report M-2871).

Stachowski, A.A., Kaplan, S.A., & Waller, M.J. (2009). The benefits of flexible team interaction during crises. *Journal of Psychology, 94 (6), 1536-1543.*